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LEVEL II

DEFORMOGRAPHICS: HIGH-RESOLUTION PROJECTION DISPLAY DEVELOPMENT FOR AIR TRAFFIC CONTROL PURPOSES

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16. Abstract

This report describes the study of a unique display device and technology called Deformographics to determine its practical value for the presentation of large quantities (e.g., 30,000 characters) of air traffic control data. The report covers the engineering, development, human factors, and test and evaluation phases and provides the technical performance data and applications concepts. Deformographics is a technology that produces a high-resolution, projection, storage, digitally controlled, random access, up to 1-meter diagonal, low power consumption, monochromatic or multicolor alphanumeric/graphic display. The project determined the viability of the technology, established the basis for further operational concept studies, and assessed the reproducibility of devices and performance based on the technology. The conclusions indicate a wide use of the technology for Federal Aviation Administration air traffic control data and information presentation, as well as other similar applications, and indicate a significant superiority of performance over other conventional and emerging display technologies.

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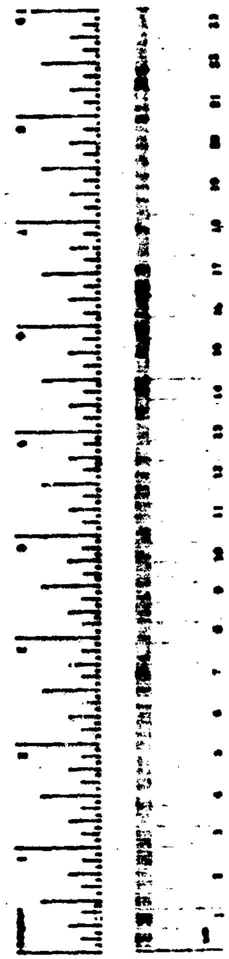
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

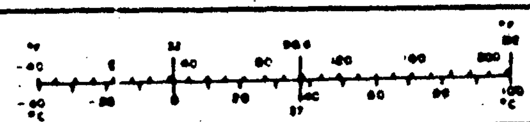
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

This technical report describes activities performed to determine the feasibility of applying a unique technology for the presentation of large quantities of information to the viewers. The efforts were part of a larger program to assure the availability of feasible and reproducible displays for the accomplishment of the Federal Aviation Administration's mission of air traffic control.

The author recognizes the technical contributions of Mr. F. Baldwin, Mr. W. Dunn, Mr. E. Alzner, Mr. R. Lucas, and Mr. J. Ertel at the National Aviation Facilities Experimental Center, Atlantic City, New Jersey, and members of the technical staff of the Federal Systems Division, Electronics Systems Center, IBM Corp., Owego, New York.

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I ANA-1 Letter to ARD-1, Demonstration of IBM Deformographics Storage Tube, Dated September 17, 1975

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FIGURE 1. DEFORMOGRAPHICS STORAGE DISPLAY

INTRODUCTION

PURPOSE

This report describes the development of a unique display device (see figure 1) for the presentation of large quantities of information to the viewer. The report covers the engineering and development phase, the operational/human factors phase, and the test and evaluation phase, and provides the technical performance data and applications concepts.

BACKGROUND

The Federal Aviation Administration (FAA) is the largest user of graphics and tabular displays in the world, most of which are cathode-ray tube (CRT) displays of real-time, dynamic, air traffic geographic position and flight planning information. Some 5,000 of these displays, located in en route air route traffic control centers (ARTCC's), terminal radar control facilities, airport tower cabs, airport instrument flight rules (IFR) rooms, flight service stations (FSS's), and other special service facilities, are the electronic machine-to-human link for the flow of massive amounts of air traffic related information which must be interpreted, monitored, and acted upon by the appropriate specialists.

The nonelectric link which supports, or is supported by, the display is the flight strip--a strip of paper which, depending on the type of facility, can be a flight progress strip or an arrival or departure strip which contains typewritten and handwritten information on the subject aircraft and flight. The physical movement and the handwritten updating of these strips comprise the basic long-term mechanism for keeping track of the effectiveness of the voice commands and the accuracy of the planned flight schedule.

The use of paper flight strips has resulted in the evolution of procedures, techniques, resource commitments, and logistic problems that have not permitted the full utilization of trained personnel, have resulted in system performance limitations, and have impeded the application of other human-machine technology improvements in the operating facilities.

A joint government/MITRE Corp. team, charged with the development of more efficient controller sector configurations, has indicated in an FAA report (reference 1) that:

"A major improvement in the productivity and efficiency of the en route sector may be attained if the "D" (Data) controller can be freed of the manual handling of paper strips. If this is done, his console can be redesigned to permit him to assist the "R" (Radar) controller to a greater extent. Achieving this greater support of the "R" controller would reduce the need for a "third man," variously called a tracker or handoff assistant, squeezed between the "R" and "D" controllers. Space is too tight for comfortable operations with three persons in the 6 feet provided by the two 3-foot consoles. Also, it will be noted that two controllers assisting the "R" controller get considerably less than twice as much productive work accomplished as would one assistant because of the added coordination. If we were dealing with a simple production task in which each person could work independently, the more people, the more work would be accomplished. A sector does not function that way, however. Here we have the R controller on the radio-frequency passing control decisions to the pilot. The more persons who have to process that same information or related information, the more the processing workload. Hence, the leverage for improving sector functions seems to exist in the potential work-saving in handling flight progress strips. If an automatic display can be introduced, this manual labor can be reduced, while a more legible reading surface is provided. This is the basic reason for priority study of an electronic tabular display as a replacement for the traditional arrangement of flight data."

Comparable observations were made of the Terminal Radar Approach Control (TRACON), tower cab, and FSS operations. Although these controller position configurations differ somewhat from en route, paper flight progress strips are the primary mode for displaying flight plan and control data, and the preparation and updating of these strips constitutes a significant controller workload.

The operating services of the FAA recognized that the replacement of these paper flight progress strips, associated strip-printing devices, and related procedures for use of the data in that form was a necessary evolution of the automated air traffic control systems.

OPERATIONAL REQUIREMENTS.

In early 1973, under the auspices of the Office of Engineering and Development Subprogram 161-111, the Data Entry and Display Technology Group formulated an Engineering Requirement (ER) for an electronic tabular display following an extensive survey of state-of-the-art developments and future research technologies in the display field.

This ER was predicated upon (1) operational needs as could be extrapolated from agency documentation relating to future Air Traffic Control (ATC) systems designs and (2) requirements as postulated by the Technology Group and subsequently confirmed by operating services and Systems Research and Development Service (SRDS) program personnel.

The combined items comprised a set of Operational Requirements which were used to direct the attention, planning, comparisons, and evaluation by the Technology Group of display techniques and technologies believed to have potential, as follows:

Item 1: The minimum usable display area must be that presently available on an enroute Manual Posting Console (22" high x 32" wide) with a minimum character size of 1/8 inch.

Considerations: Information to be electronically displayed--flight plan data, planning and control instructions, meteorological and pilot information--would not significantly change in content, format, or quantity from that presently displayed through use of flight progress strips, the Computer Readout Device, or other ancillary display devices. An additional hypothesis influencing the definition of display size was that future ATC concepts which entailed computer-generated advisories (flow control, conflict detection, data link pilot instructions, etc.) would produce additional information for the controllers' purview. Therefore, the space presently allocated for flight plan and control data would, in the future, probably be increased rather than decreased.

Item 2: The display should be capable of coping with major system failures:

Considerations: In event of flight data processor failure, the last displayed information must remain on the display for at least 30 minutes. In event of radar plan view display (PVD) failure, the electronic tabular display should have the capability of functioning as a standby PVD in addition to displaying sufficient flight plan and control data to maintain traffic control integrity.

Item 3: The display should provide a glare-free presentation in a wide range of ambient light levels and conditions.

Considerations: Ambient light levels in field facilities range from 1 foot-candle (fc) or less in en route centers to more than 6,000 fc (direct sunlight) in tower cabs. Although the major thrust of the effort described herein is the development of an en route electronic tabular display, it would be of economic benefit to the agency if the technique were applicable to other traffic control functions.

Item 4: The display should have the capability of providing at least two distinguishable color shades, a character blink mode, and varying character intensity.

Considerations: Previous experiments with the application of color to ATC (reference 2) indicate a significant controller preference for data color coding; however, an economic benefit versus cost could not be established when considering the cost of the color generation technique (penetron CRT) employed (reference 2). Therefore, a tabular display candidate which can provide "free" color would be of considerable operational benefit to the agency. The character blink and varying intensity is required as an "attention" function to permit more rapid controller identification of modified or time-critical data.

Item 5: The display should be capable of interfacing with the En Route Model 3d-2 system with a minimum of change to either the hardware or software subsystems of the en route system.

Considerations: The electronic tabular display replaces the sector strip printer and the computer readout device. When receiving initial or modified flight plan data, the display should function as a flight strip printer without levying additional refresh requirements upon the Central Computer Complex (CCC) or Computer Display Channel (CDC).

PROJECT DESCRIPTION

The project efforts included the following activities:

1. ER Preparation
2. Technology Survey
3. Contract monitoring, development review, and approval
4. Acceptance testing and acceptance
5. Performance evaluation, technical
6. Postcontract development and modification; test and evaluation
7. Operational testing and evaluation
8. Implementation plan and proposals.

ENGINEERING REQUIREMENT PREPARATION.

Engineering requirements were assembled and organized into an ER in early 1973. This ER, No. EA3323 (appendix A), formed the basis for the Technology Survey scope and ultimately for the specification used for procurement.

TECHNOLOGY SURVEY.

As a result of evaluation and analysis undertaken in the Technology Survey in 1973/74, a Technology Note (appendix B) was formally published in March 1975. Based on early drafts of the survey, the major efforts and resources were directed towards the most promising technological approach, projection display from a stored image.

CONTRACT DEVELOPMENT.

A contract, DOT-FA-74-NA-1103, June 24, 1974, was awarded to International Business Machines (IBM), Inc., Owego, New York. The actual statement of work as accepted is found in appendix C. In brief, the contract called for a 9-month program to design a storage projection display system based on an IBM "Deformographic" storage tube, to package such a system into a government furnished M-1 (flight strip posting) console, to develop an interface to permit the display to be driven from a Digital Equipment Corp. PDP-8i computer, and to provide test programs and test equipment to support the system. In certain categories of performance related to display parameters, improvements over initial indicated performance levels were required. Such improvements were to be achieved under close supervision and monitoring by FAA engineers to insure that they were repeatable and measureable.

The technical performance claimed for the Deformographic Storage Display Tube (DSDT) as of the latter part of 1973 resulted from measurements made at IBM, Federal Systems Division, Owego, New York under an Office of Naval Research contract No. N00014-71-0270, NR 213-103. The report of this contract which provides extensive graphs and performance details, some of which were verified by the FAA, "described the investigation into the feasibility of using the DSDT as a real time annotation device for an airborne moving map projection system.... The results of the investigation were favorable. Annotation from the DSDT was visible against a background consisting of a 4,300-footlambert (fL) map brightness and the reflected screen brightness from a 10,000-fc ambient light. Use of the DSDT could extend the use of the map projection surface for other aircraft display functions, thus creating a favorable cost effectiveness tradeoff for the additional equipment." (Abstract of subject report)

The major areas of interest in performance improvement were:(a) line width (resolution), (b) brightness uniformity, (c) display size/packaging.

Resolution was offered in terms of 11.8 to 13.8 line pairs per millimeter (lp/mm) on the storage tube target. This was satisfactory provided that it could yield 2.5-millimeter-high characters on a 1.0-meter-diameter display (300-350 lp/inch, 1/8-inch characters on a 39-inch-diameter display).

Brightness uniformity approaching acceptable center-to-edge variations found in other ATC displays was the goal. This ranged from 25 to 75 percent.

The initial projection efforts were directed to either small displays, 5 to 6 inches in diameter, or very large ones, 48 to 96 inches. The contract efforts would seek a display diameter range of 24 to 40 inches. Figure 1 is a photograph of the delivered Deformographic Storage Display (DSD) in operation with flight strip information displayed.

SYSTEM DESCRIPTION

For purposes of completeness, the following section of this report describes the tube itself, as well as the optical system it is coupled with. An understanding of the two basic elements of the display, namely a nearly-conventional CRT and a 100-year old design for an optical system, is essential to assessing the value of the technology.

The DSDT is a CRT in which the phosphor surface has been replaced by a flexible reflective membrane. A conventional CRT uses a phosphor coating on its faceplate to convert electron beam energy into light. In the DSDT, the electron beam controls a deformable mirror so that light from an external source is selectively reflected to an otherwise dark viewing screen.

In most other respects the DSDT operates like an ordinary CRT. It uses an off-the-shelf electron gun, a conventional deflection coil, and operates with the same type of deflection and video inputs as a conventional CRT. The DSDT electronics are derived from standard display circuit modules.

LIGHT VALVE.

Because of the difficulties of generating sufficient light from a phosphor to illuminate a large viewing screen, many large-screen display concepts are based on the use of a light source external to the CRT. This type of CRT controls the light reaching the display surface, but does not generate any light itself--hence the term "light valve."

The DSD, the unit name for the opto-electric system that contains as its "heart" the DSDT, is a light valve display. In comparison to other group displays, it is the only display of its type that requires none of the following elements: a vacuum pump; oil films; rotating disks within the CRT envelope; voltages of 25-49 kilovolts (kV) or more; photosensitive materials; a complex energy conversion mechanism external to the CRT; temperature control ovens; materials or components that must be changed every few days, or even hours of use.

The only active element in a DSD system is the reflective membrane inside the CRT. There are several characteristics of this elastic mirror that need to be emphasized (see figure 2).

a. The mirror consists of three simple layers. Starting from the side facing the electron gun, there is an insulating substrate about 0.0005-inch thick, then an elastic layer which is about 0.0001-inch thick, and finally, a conductive reflecting surface that is only about a millionth of an inch in thickness. No fluids or photoconductors are involved.

b. The deformations of the flexible mirror surface are extremely minute; a few millionths of an inch deep. Since this is only about a thousandth of the width of the depression, it puts no appreciable stress on the metal layer. The mirror surface has been tested through millions of write/erase cycles with no sign of metal fatigue.

c. Since the mirror is sealed inside the CRT, it is permanently protected from the effects of dust, moisture, handling, etc.

d. The DSDT is not sensitive to the temperature, shock, and vibration levels specified in MIL-E-5400 and MIL-E-16400. No infrared or ultraviolet energy is used in the operation of the DSD, nor does it emit any harmful radiation.

e. The DSDT light valve is highly efficient. All the illumination required to view the 22- by 32-inch display under normal room lighting can be obtained from a single 150-watt xenon lamp.

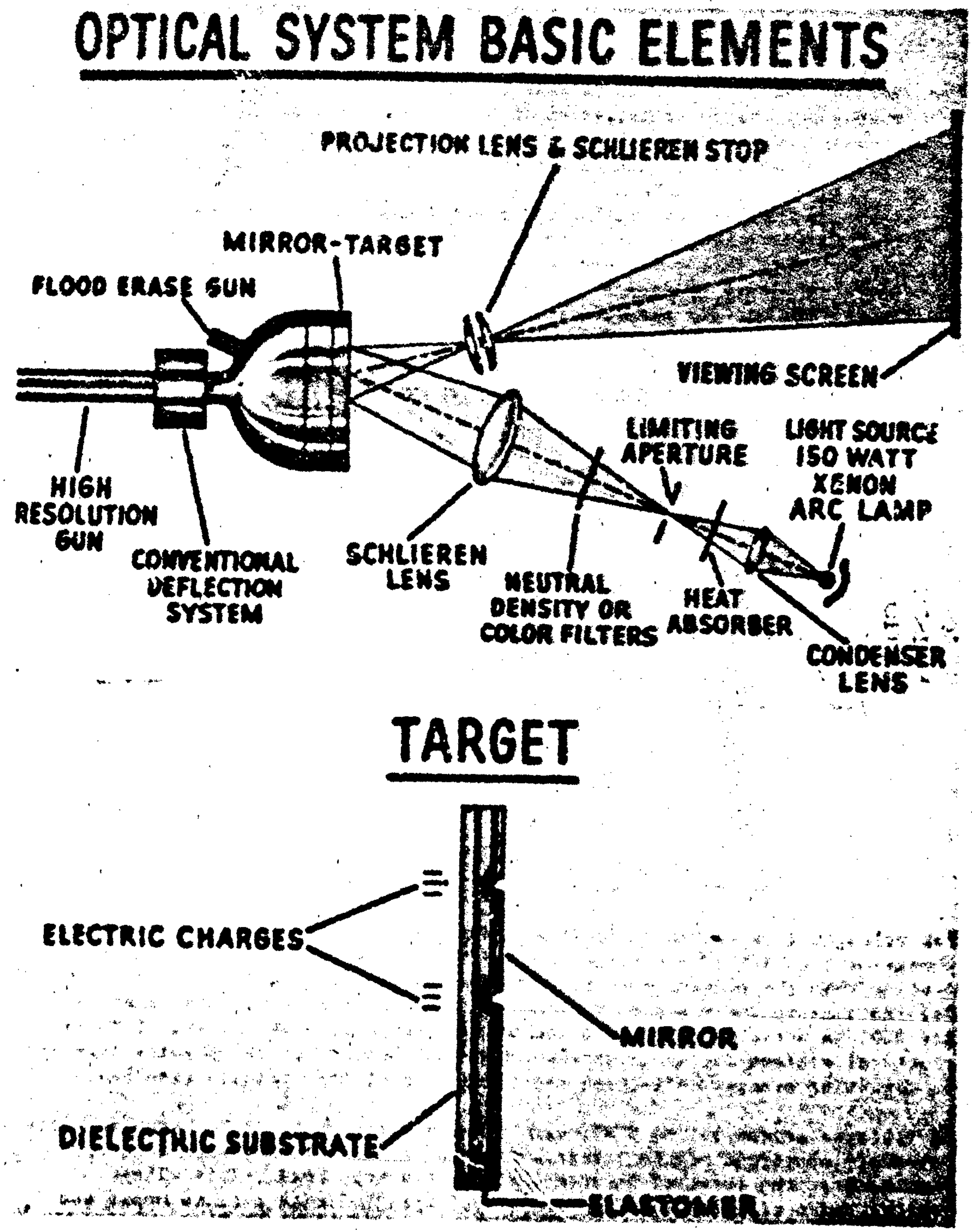

FIGURE 2. OPTICAL SYSTEM BASIC ELEMENTS AND TARGET

STORAGE.

The DSDT has inherent storage because the back of its mirror is an insulator that stores any charge deposited on it by the electron gun. Images can and have been stored for days without refresh--even without power, yet writing takes place at normal CRT speeds and erasure occurs in milliseconds.

The phenomena involved in writing and erasure are best understood by referring to the secondary emission curve of the substrate material (figure 3). What this curve indicates is that the average number of electrons that leave the surface (secondary emission) for every electron that strikes the surface (primary electrons) is a function of the CRT accelerating voltage.

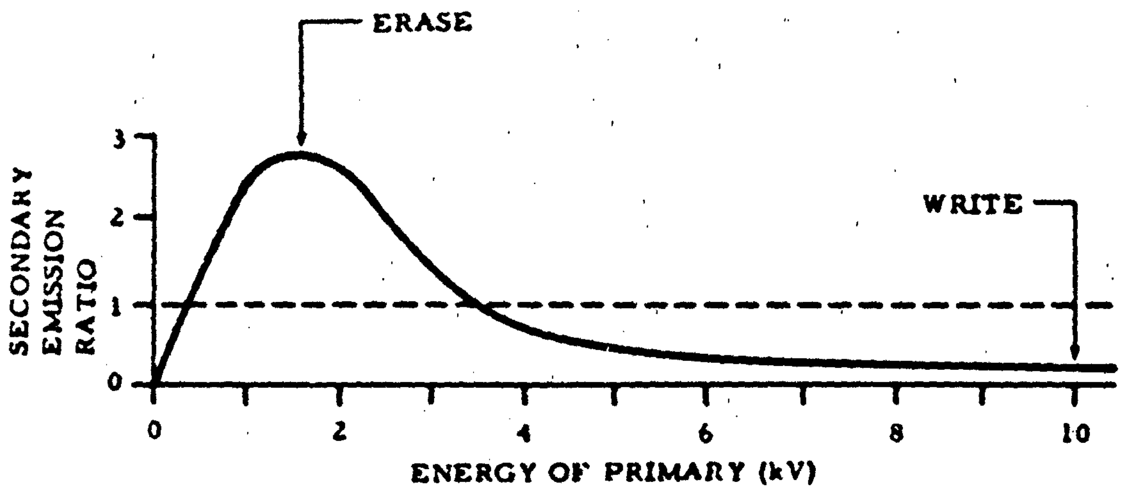

FIGURE 3. SECONDARY EMISSION CURVE OF TARGET

For voltages greater than about 4 kV, the DSDT electron beam builds up a charge on the back of the mirror because there are fewer secondary electrons leaving than the primary electrons arriving. These charged areas cause the deformations in the mirrored surface which create the light-valve action. The DSDT is normally operated at an anode voltage of about 10 kV. This is a practical minimum for any high-resolution CRT because of the physics involved in obtaining precise deflection and focus control over the electron beam.

At voltages around 1.5 to 2 kV, each primary electron tends to knock multiple secondary electrons off the surface as long as there is any excess charge remaining at the point of incidence of the electron beam. This allows various modes of erasure. The DSDT's evaluated included a flood erase gun designed to cover the entire target (i.e., mirror) with electrons at an erase potential of about 2 kV. At full current, a flood gun can totally erase the entire screen in milliseconds.

At lower erase currents, the persistence of the image can be controlled over a wide range. In this case, erasure takes the form of a continuous fading of any data written on the tube--much like a long-persistence phosphor. Any decay period, from a fraction of a second to many minutes, can be selected by controlling the amount of erase current.

In applications where time between data updates is typically several seconds or longer, displayed information need only be written once each time any information is updated. It will automatically be retained without refresh until erased and rewritten upon the next update of the input data. There is no perceptible decay in either brightness or focus over a period of several minutes. Furthermore, no power is required to retain the image.

This means that the displayed image will survive losses of either input data or power without degradation. The only power required to view the image once it has been written is the power required by the light source. It also means that the displayed image is very constant and steady. There is no flicker, jitter, strobing or other annoying instability in the displayed data.

In addition to storage, instant erasure, and controlled persistence, there is another important erase feature of the DSDT, selective erase. By biasing the main electron gun, normally used for writing data, to the 2-kV erase potential, a steerable, focused erase beam becomes available. This erase beam can be focused into a spot size considerably smaller than a character and can be directed to any point on the screen in the same manner as the writing beam. This makes it possible to erase a single area or block of data without affecting any other data stored on the screen. Selective erase is most advantageous in tabular formats where the data are systematically arranged in words and/or nonoverlapping blocks of data.

DISPLAY SCREEN SIZE AND OPTICS.

The DSD is a projection display. The size of the display area is a function only of the focal length of the projection lens and the distance to the viewing screen, both of which are adjustable. The images generated from a DSDT for various applications have ranged from 5 inches to 10 feet diagonal. The only performance parameters that vary with screen size are brightness, contrast, and optical line width.

A 150-watt xenon lamp provides sufficient display brightness for a 5-foot rear-projection screen to be viewed with ease under normal conference room ambient lighting. The projection distance required is approximately 1.6 times the diameter of the display area. This optical path can be folded through the use of one or more mirrors to significantly reduce the space required behind a rear-projection screen.

A very simple schlieren optical system is used to convert DSDT mirror deformations into a visible image on the screen. Referring to figure 2, the major elements of the optical system are:

1. An initial condensing lens and input aperture.
2. The schlieren lens.
3. The two-piece projection lens with an opaque metal stop at its center.

Light from the xenon lamp is trimmed into a well defined point source by the small condenser and the input aperture. This point is then imaged on the opaque schlieren stop by the large condenser (the schlieren lens). With a completely flat mirror surface in the DSDT, all light is blocked by the opaque stop, thus providing a dark background on the screen.

Any deformation in the DSDT's mirror deflects the light rays so that they bypass the schlieren stop and are focused onto the viewing screen by the projection lens. The image appearing on the screen is an exact replica of the data written on the DSDT mirror.

ACCEPTANCE TESTING

As part of the contract for the deformographic display system, a test plan was prepared and approved by the FAA which was designed to measure conformance with the specification in all the measureable performance areas and also to provide test data which would serve as a bench-mark for future performance improvements. Appendix D contains a copy of the Acceptance Test Plan document. The test of the DSD was done twice, once at the contractor's facility, and finally at the National Aviation Facilities Experimental Center (NAFEC) in the Controller-Computer Interface Laboratory.

The test plan defined the design parameters to be verified in the performance of the display system during an acceptance test procedure. In this manner, the critical parameters and characteristics were agreed upon prior to any determination of the values to be achieved.

The acceptance test procedure established the procedure required to demonstrate proper performance. Such a procedure is included as appendix E to indicate the degree of detail and completeness prevalent in the testing.

Certain critical parameter acceptance test results from the first engineering model/prototype are listed below to indicate the level of performance. These results convey the technical, high quality of the device; but more importantly, the degree of technical achievement is indicative of the soundness of the optical/electronic technology applied.

a. Deviation of a projected reflective mirror (non-CRT) grid pattern from a grid overlay at nine points in the horizontal and vertical direction: (in inches on a 22-inch by 32-inch screen):

	TOP LEFT	TOP CENTER	TOP RIGHT
Horizontal	+0.025	0.000	-0.090
Vertical	-0.025	-0.100	-0.080

	CENTER LEFT	CENTER	CENTER RIGHT
Horizontal	+0.040	0.000	-0.100
Vertical	+0.020	0.000	+0.020

	BOTTOM LEFT	BOTTOM CENTER	BOTTOM RIGHT
Horizontal	+0.065	0.000	-0.090
Vertical	+0.035	+0.085	+0.100

1% corresponds to 0.220 or 0.320 inches.

b. "Open Gate" background brightness uniformity, in footlamberts:

TOP LEFT	TOP CENTER	TOP RIGHT
43	59	36

CENTER LEFT	CENTER	CENTER RIGHT
56	76	41.5

BOTTOM LEFT	BOTTOM CENTER	BOTTOM RIGHT
48.5	60	31.5

c. Deviation of a projected, CRT-image grid pattern from a grid overlay at nine points in the horizontal and vertical direction: (in inches on a 22-inch by 32-inch screen)

	TOP LEFT	TOP CENTER	TOP RIGHT
Horizontal	-0.065	0.000	+0.120
Vertical	+0.100	0.000	0.230

	CENTER LEFT	CENTER	CENTER RIGHT
Horizontal	0.010	0.020	-0.005
Vertical	+0.035	+0.015	+0.035

	BOTTOM LEFT	BOTTOM CENTER	BOTTOM RIGHT
Horizontal	-0.010	-0.005	+0.120
Vertical	-0.050	+0.025	-0.090

d. Largest line width on a 22- by 32-inch screen (39 inches diagonal) = 0.034 inch; smallest = 0.021 inch.

e. Worst brightness variation in a 3-inch vector section:

Max = 46 fL　　　Min = 22 fL
Variation = 51.25%.

f. Contract Ratio at time of test measurements = 44:1.

g. Line spacing--worst case on display screen was 0.031 inch with worst case modulation of 71.3 percent.

h. Storage time to 1/3 of original brightness--15 minutes, to 1/8 of original brightness--30 minutes.

i. Rewrite accuracy after an erasure--less than 0.010 inch.

j. Overwrite accuracy--less than 0.005 inch.

Acceptance testing was completed and the unit accepted at NAFEC in May 1975, with one temporary waiver. The high-voltage switching power supply was not switching fast enough to meet the specification. The supply provided was not the final deliverable unit, and difficulties with delivery of an AMP, Inc., unit resulted in the waiver. The proper unit was subsequently delivered in June 1975.

Concurrent with FAA acceptance of the first unit, Dr. Carlo Broglio, Staff Systems Analyst with the Office of Systems Engineering Management, FAA, directed an official inquiry to the Controller, Avionics Systems, IBM, Federal Systems Division, concerning detailed estimates of the production costs of the DSD based on the first unit technology, for application in en route ATC centers to replace the flight strip printers and paper strip tabular bays.

Appendix F is the complete response from IBM. Excerpts of special note are:

"...In the absence of detailed specific definition of the consoles to be priced, we have made engineering estimates based on the following assumptions:

1. The consoles would be functionally identical to the unit we recently delivered to NAFEC except that they would interface with the CCC in the en route centers rather than the laboratory computer at NAFEC. The internal packaging and circuit technology would be completely redone to provide maximum cost advantage for a large volume production run.

2. The recurring and nonrecurring costs are based on a 1,000-unit buy with 100 units delivered during the second year and 25 units per month in the 25th through 60th months.

3. These estimates assume that the CCC provides the display data in a format reasonably compatible with the DSDT: i.e., more or less in accordance with the approach followed with the NAFEC unit. Within these ground rules, this console would be able to provide the functions presently incorporated in the flight strip printer, the flight strip posting console, and the computer readout and update display. In addition, this console has the graphics capability for the plan view display (PVD) with the information being periodically updated from the CCC rather than refreshed many times a second as with the PVD. The display surface can also be zoned off to present other types of data simultaneously with flight strips, such as weather, NOTAMS (Notices to Airmen) and other tabular or graphical data.

4. An IBM-modified GFE (Government Furnished Equipment) cabinet was assumed. However, there would not be a major cost impact if the cabinet were fabricated by IBM rather than modifying a GFE structure.

5. The unit would be designed and built to good commercial practice with the 2100 series of specs as a general guide. This same type of approach was very successfully used on the CCC and provides significant cost advantages without any loss of reliability or performance.

6. The nonrecurring estimate does include all the normal non-recurring design and startup activities we thought would be applicable, such as tooling, test equipment, conversion on packaging and technology, maintainability and reliability analysis, quality engineering, manuals, and other documentation, interface design, human factors analysis, etc.

7. The recurring price estimates are also complete figures including, in addition to direct hardware costs, testing, program management, engineering support to manufacturing, general and administrative expense, and all other elements that normally go into a unit selling price.

8. Two configurations have been estimated: a console with a single DSDT and a console with two DSDT's projecting on a single viewing screen. In the dual-DSDT unit, the CRT; light source; lens system; deflection, video, and erase circuits; and all associated power supplies have been duplicated. In all other respects, the two configurations are identical; i.e., only one set of electronics, power supplies, etc., have been assumed for such functions as interface, display generation, and overall unit control. In addition, there is very little difference in the cabinet, mirrors, and viewing screen whether one DSDT or two is assumed. Since the second DSDT projector is essentially a duplicate of the first, there is no significant difference in nonrecurring costs.

On the basis of these assumptions, our engineering estimates are as follows:

Single-head console:	$28,000 each
Dual-head console:	$41,000 each
Nonrecurring expense:	$4.6 million."

This proposal estimate was made prior to any of the developments and improvements which resulted from the FAA test and evaluation period which began in July 1975. Developments and experience with the system enabled many design areas to be simplified, and in some cases allowed a reduction in needed performance while still meeting FAA's needs. At that time, it appeared that each optical assembly or each electronic support assembly was estimated at approximately $14,000.

PERFORMANCE EVALUATION, TECHNICAL

Following installation, site acceptance, and software integration at NAFEC, the delivered system was subjected to a series of tests to determine its limitations, performance limits, and other technical benefits and deficiencies, strictly based on the unmodified delivered unit. A progress report (appendix G) describes the basic results at that time.

By optimizing the display for best overall performance routinely achievable on the prototype/engineering model, the following performance, with evaluation, was achieved, concurrently.

1. Brightness of alphanumeric and vector information on the 22-inch by 32-inch screen varied from 24 to 39 fL, which was very adequate for operational legibility in ambients at least as high as 30 fc. Because of the very low reflectivity of the plastic screen, these brightness levels result in extremely high contrast levels. Since screen filtering is not necessary to enhance contrast, the actual brightness levels of the data are, significantly, about the same as those on conventional CRT displays after passing through narrow band and/or neutral density filters. The superior antireflectivity and absorption properties of the etched plastic screen reduce the background brightness to extremely low levels, and there is no reflective layer equivalent to a white phosphor.

2. Line widths over the 1-meter (39-inch) diagonal display surface varied between 0.73-millimeter (mm) maximum to 0.58-mm minimum (0.029 to 0.023 inch). This corresponds to lines equal to approximately 0.06 percent of the display diameter, in any direction, which is comparable to or better than existing performance from CRT displays (example, 19.5-inch-diameter PVD has 0.015- to 0.020-inch line width, or 0.077 to 0.1 percent).

3. Because of the storage nature of this device, the line-to-line spacing is as important as the line width. For parallel vectors, the worst case center-to-center spacing was 0.84 mm (0.033 inch). While the best case

was about two thirds of that, the results indicated an effective worst case optical resolution of 1,182 lines per diameter. For the 22- by 32-inch display, this corresponds to 667 by 970 lines of resolution, an impressive figure considering the real display size.

4. The smallest usable character block on the 22- by 32-inch display was 0.142 inch high by 0.107 inch wide. Since a minimum of 20 percent is included in each dimension for space, this results dimensionally in a 0.125- by 0.07-inch character, corresponding to 0.645 percent of total display size vertically and 0.33 percent horizontally, regardless of final display size. In practice, the smallest usable character readable over the whole screen was 1/8-inch high, bottom centerline to top centerline, actually closer to 5/32's of an inch. By actual test, at least 33,000 readable characters could be placed on the screen, and, while the diagonal dimension corresponds to the diagonal of the useful storage target, the total area used is only 60 percent of the useful target surface.

5. The measured contrast ratios with 30-fc ambient light on the screen varied over the screen, with alphanumeric data, from a worst case of 25:1 to a best case of 39:1. Since brightness increases with the square of the display diagonal reduction, a display of 1/2 the diagonal, 19.5 inches, would have four times the brightness, with the same background brightness. Thus, contrast would be exceptional for smaller display sizes.

6. For the set of alignment conditions used, and with special care in test equipment calibration, the accuracy of rewriting information was found to be better than originally expected. With an erasure between the two writing sequences, the typical positional variation was 0.012 inch, about one-half a line width. Placed in perspective to the display diagonal, the error in placing a point on a line, after an erasure of the entire screen, is approximately 0.03 percent. An unexpected result of rewrite without an erasure was that positional accuracy was better than 0.001 inches, or 0.004 percent. This is what would be expected of a precision CRT yoke deflection system, but the manner in which charge on a storage target would affect final beam location was not clear.

7. For a single writeup of a pattern, as compared to a grid overlay, the worst deviation occurred at the top of the screen, as expected, due to the off-axis projection. This error was 0.8 percent and was due entirely to optical distortion resulting from the projection of a flat surface, the target, through a curved optical system. Since no x-y correction was applied through the deflection system to compensate for this error, this is purely an optical one and entirely correctable.

8. The optical magnification of the system remained at a nominal 13:1, 39 inches of diagonal final display for 3 inches of diagonal target. This was a necessity to compromise the available tube/target size to the desired tab bay size. It was subsequently determined in later tests (described in this report) that this magnification exceeded the "high-quality" optical limits of the optics provided and resulted in the line width and resolution

limits achieved. Magnifications of the order of 9-10 times significantly improved the objective and subjective quality of the display.

9. The capability of fast, total screen erasure was elusive throughout the early testing period. The measured times for a full screen of characters was as much as 1 second. An extensive beam energy analysis resulted in modifications to the pulse amplitudes and duty cycles, and the result was, first, a full erasure in 200 milliseconds (ms), and then finally in less than 100 ms. This significantly enhanced the appearance of the display, even though full (flood) erase would not normally be used in an operational system. The information gained was applied to the selective erase function.

10. The plastic screen used on the delivered system had a gain of 180 percent. A tradeoff exists between viewing angle and screen gain. The initial desire to get as much brightness as possible was compromised, satisfactorily, to achieve a much wider viewing angle. With a unity gain screen, the viewing angle is effectively 150° or more, and the use of the display by several people in a sector configuration would be enhanced. When tested with screens of 270-percent, 390-percent, and even 450-percent gains, considerably brighter displays resulted, and the viewing angle was reduced to as little as 60°, as expected.

11. With any storage display, the writing rate becomes one of the characteristics that is compromised in order to achieve better overall performance. The rates chosen during the design phase of the contract ranged from 500 inches per second to 2,000 inches per second. The use of 500 inches per second at that point in the evaluation permitted sufficient data to be written in adequately short time periods. Later in the program, through the use of novel timing cycles, higher rates were used as well as multiple rewrites at 2,000 inches per second.

The most efficient and effective manner to produce high-quality characters was to write one complete image at the 2,000-inches-per-second rate at a bias level above cutoff but below visual perception, immediately followed by a repeat of the image at a bias level above cutoff and above the visual level, but below the level needed to store the same image if a single-write image were used. In effect, a low drive followed by a moderate drive, at fast rates, produced a more superior image than a high drive at low rates.

12. The long-term stability of the display system was based on two aspects of the design, the mechanical integrity of the mi   's, mounts, frame, screen, etc., and the electronic stability of the deflection system, power supplies, etc. Over one 7-day period, using high-accuracy overlays, a fixed reference point on the project image drifted less than 0.001 inches, when console on-off power cycles and write-erase cycles were introduced over the time period. Character size and brightness differences over the time period were immeasurable using calibrated Gamma Scientific, Inc. scanning photometers.

13 Sixty-four digital video drive levels are available from the microprocessor that controls the display system. However, to the eye, six shades were discernible as logarithmic steps out of approximately 32 visible video outputs from the storage tube. This indicates the potential dynamic range, the gamma, from cutoff to saturation.

14. Selective erase action involved the switching of high voltage from approximately 10 kV to approximately 3 kV. The variations in deflection sensitivity resulting from such a change are and were able to be compensated for to the degree indicated by the erase and rewrite accuracies. However, there was no attempt made in the first model to correct for focus change during erase; hence, the erase beam is defocused to approximately 0.060 inches (1.5 mm). A "safe" area around any one character, or group of characters, was found to be about 0.075 inches (1.9 mm), or double that figure between adjacent data that could be selectively erased.

15. Each tube has a set of characteristics which are established by manufacturing processes and materials. At the start of the contract effort, storage time was determined to be a critical parameter that would significantly affect most other pertinent parameters. The storage characteristic was designed into the target material to produce a slow decay in image brightness over a long period of time. The initial specification was based on a 30-minute useful, readable life of the data. This resulted in the acceptance test results previously described, as well as a practical, daily verification that 10-percent brightness after 30 minutes was about the best for the particular chemistry chosen. It became clear, however, that the usefulness of the data after 5 or 10 minutes was marginal for most potential applications.

Furthermore, a technique called subliminal refresh was developed in the lab which permitted the rewrite of a complete display every 5 to 10 minutes at a video level just below visual perception. This action provided a perpetual high-quality display, and further development of such a refresh action would reduce the effects of the longer storage compromise on resolution, erase, and brightness.

16. The maximum time to erase a single character-sized block of video, excluding power supply switching times, was 100 microseconds (μs). As characters were made smaller on the target, less time was necessary to erase due to increased energy density in the erase raster; but as a practical figure, it takes as long to erase a single character as it takes to write it (worst case, 100 μs).

17. Over the months of testing and evaluation, the effects of dust, smoke, and building vibration were observed. Since the image is formed only at the display screen, dust particles do not defocus or modify the shape of the final image. Only at the schlieren stop (see figure 2) can dust particles affect the composition of the Fourier optical sum that produces the image. But the zeroeth order light is blocked by a "particle" almost 1/4 inch in diameter—the stop itself. Hence, dust cannot affect the opacity of

the stop anymore, since it is already impervious to light. On the mirrors, the effect of dust is to reduce light output, but no measureable differences were recorded.

Vibrations from an air-handling ventilator 30 feet away could be measured as 0.001-inch wobulations of the data, insignificantly small. A sharp knock on the console would cause a vibration of the image due to mirror movement, but the damping inherent in the mirror mass resulted in image damping of 0.5 seconds or less.

18. A capability for a limited number of colors, digitally selected, for displayed data, was studied and demonstrated. By the use of very simple composite color filters placed concentric with the schlieren stop, several modes of practical color generation were analyzed, and the application of such color capability, produced at such a low cost, was investigated. Figure 4 shows closeups of flight strip data with different colors as field backgrounds, as well as a monochromatic version. The colors were digitally changeable between red, green, yellow, blue, and, trivially, black. The smaller characters in the figure are approximately 4.75 mm (3/16 inch) high. The color capability was established but not pursued any further at the time.

DEVELOPMENTAL PERFORMANCE, MODIFIED

Three areas of modification were considered during the performance testing phase; two were related to improved display parameter performance, and the third was concerned with the enhancement of the operational use of the display as an interactive data terminal.

1. Dynamic focus was achieved in the delivered DSD by a multizone discrete step focus circuit that provided for concentric diamond-shaped areas centered about the display center. This resulted in focus compromises that were less than satisfactory, since it was obvious that equally good focus could be achieved everywhere on the display, but not at the same electrical focus (electrostatic) value. A more appropriate circuit was developed which utilizes the X-Y deflection position to calculate and generate a waveform that provides a true dynamic focus value. Significant overall improvement resulted, and alignment ease was enhanced.

2. As noted earlier, the magnification originally chosen resulted in an approximately 1:1 size substitute of electronic display for paper flight strips. Character size, number of rows, and characters per row closely matched the typewriter printing. The ambitious goal was to display 30,000 characters, each approximately 1/8-inch high, approximately 130 lines of 230 characters, all on a 22- by 32-inch display area. This was achieved, and all the characters were legible, but not as crisp as printed type. The 22- by 32-inch size resulted from a 1-meter diagonal image size "rectangled" to a flight strip tab bay size. As the diagonal was reduced in size, the characters became clearer, crisper, and more defined, and their mark-space

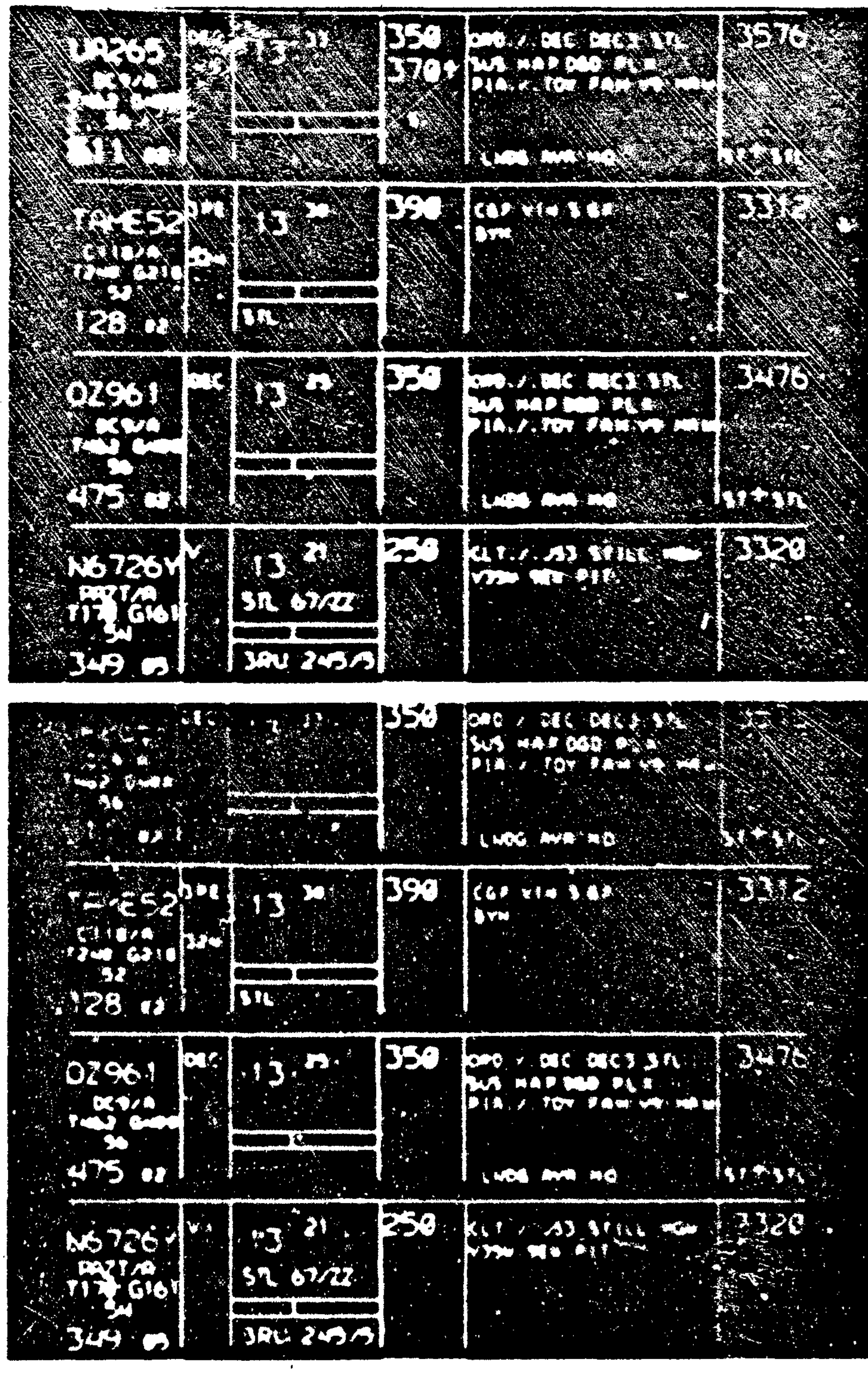

FIGURE 6. FLIGHT STRIP DATA WITH COLOR BACKGROUNDS (Sheet 1 of 2)

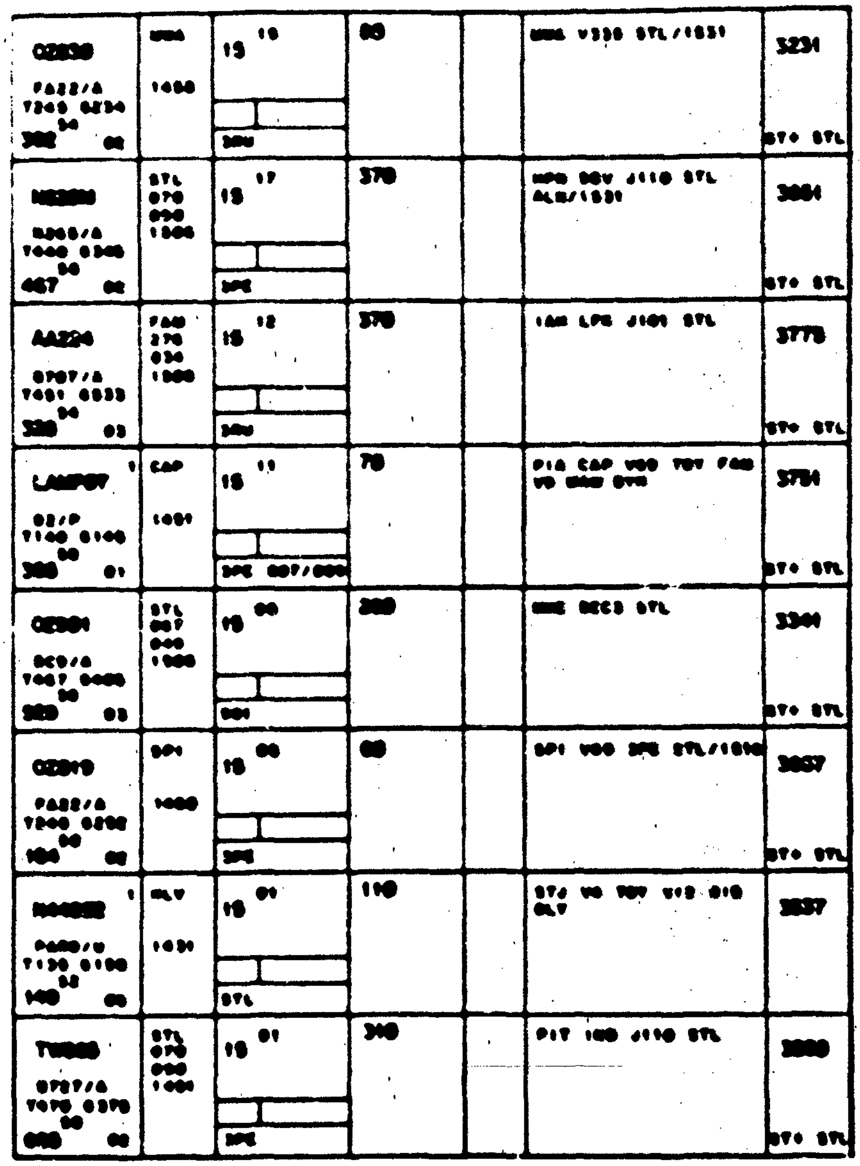

FIGURE 4. FLIGHT STRIP DATA WITH COLOR BACKGROUNDS (Sheet 2 of 2)

ratio improved. The smallest diagonal achieveable with the unit as configured was approximately 22 inches. While the characters shrunk to almost 1/16 inch, the display size became 15 by 15 inches, all too small for practical viewing at 24 inches. A reduced size of 26-inches diagonal resulted in a satisfactory display size, with considerable improvement in clarity. No loss of legibility occurred, and the display was more usable than before. Due to a smaller viewing angle, the apparent brightness uniformity improved. Also, as expected, any of the optically induced nonlinearities were reduced when the magnification was reduced.

This size was very compatible with tower cab display consoles, and provided encouragement for applications in this area. Brightness increased by the square of the size reduction; hence, the 67-percent size change caused more than twice as much image brightness.

An analysis of the cause of the character clarity improvement indicated that the optical system for projection was exceeding its limits of resolution with the 13 times magnification.

3. The use of such a large amount of display information, as is capable through the Deformographics display, depends on data entry techniques that are simple, reliable, and, as far as the FAA is concerned, amenable to ATC operations.

The display screen of the DSD is large enough to be considered as a fingertouch input device to be used to select a character, or a group of characters, or a position on the screen, and to make entries to a computer in this manner. Since the screen is plastic, it is safe to push on, and the etched surface is unaffected by finger prints; hence, it is very compatible with a finger-touch entry concept.

The development of such a system is not part of this report, but mention is made at this point because of the additional advantages of a touch input system coupled to a large-area, high-resolution display. The large screen permits spreading out of information on the display, dedicating the use of screen areas to menu selection lists providing programmable key cap legends for keyboard replication and mixing graphics data, tabular data, and fixed-image microfilm images.

Finger-touch input circuitry experimentation utilizing hardware matrix, electroacoustic and infrared optical have been designed and incorporated into the display console (see figure 5). A report has been written (reference 3), which describes the operational testing aspects.

The enhancement of the DSD, because of its inherent compatibility to certain finger-touch input systems, especially in high ambient illumination, was demonstrated during this phase of the project and established as fact.

FIGURE 5. FINGER TOUCH INPUT WITH DSD

IMPLEMENTATION PROPOSALS, SECTOR STUDY

The achieved technical performance of the DSD, coupled with the interest shown by all of the people who used the DSD in simulations of certain ATC tasks, provided an impetus to the DSD manufacturer, IBM Corporation, to consider a unique second step in the determination of the applicability of projection displays and the Deformographics in particular.

In conjunction with their own ATC-experienced personnel, and with their own highly experienced and knowledgeable National Airspace System (NAS) CCC engineers and systems analysts, they prepared a technical document describing a systems approach to replacing the flight strip printers and tab bays with electronic displays. They described how the NAS system already contained most of the hardware elements to accomplish the interface between the DSD and the CCC. The use of the microprocessor in the DSD as an emulator permitted the DSD to function and use the flight strip printer input data directly. As far as the CCC was concerned, it was talking to a printer. A summary of this proposal, written in 1976, is included in appendix H. It is very similar to the results expected from an ER for Electronic Tabular Display (E-TABS). A contract to procure such an E-TABS system was to have been released by the beginning of calendar year 1979.

The significant difference between the original 1976 proposal and the expected results from the 1979 contract is that the 1976 IBM proposal provided for a simulation capability to determine the tabular data requirements for an en route sector without imposing hardware limitations (display size, data format, etc.), without making assumptions about the sector requirements that would impair the objectivity and flexibility necessary to find out, in the first place, the role of such an electronic data system, without limiting the scope of operational investigations and evaluations, and without committing large sums of money to unproven systems concepts.

At such a critical point in the fulfilling of the long-term goals of ATC systems development programs, such an installation at the NAS System Support Facility at NAFEC was designed to:

1. "allow the direct evaluation of a very important new display technology," and

2. "be an unusually powerful display evaluation tool for use in a wide range of future concept development programs" (excerpt from summary).

The proposal was not acted upon, and the E-TABS contract effort was postponed until 1979.

DEVELOPMENTAL PERFORMANCE, CONCEPTS

Two entirely new concepts in display use and maintenance, continuous area display and noninterfering maintenance, emerged from the study and evaluation of Deformographics, both of which apply to projection displays of most types. They clearly indicate the potential for projection displays, in general, and were expanded upon only to the extent necessary to validate the concepts.

CONTINUOUS AREA DISPLAY.

The projection of complete area images alongside each other so as to produce a continuous display on a continuous display screen is a new concept unachievable by conventional display devices. The ability to provide a display surface perhaps 24 inches high and 10 to 20 feet wide, or more, with the positioning of information anywhere on the large screen under computer program control opens up new ideas for ATC operations. A series of projectors would be the information sources, as shown in figure 6. The test results show that under computer control, registration error between data of adjacent image areas can be less than 1 percent, corresponding to less than 0.3 inch, horizontally. In actual tests, linearity can be maximized at the image area boundaries by computer algorithm, and the resultant registration was less than 0.125 inch horizontally.

From an operational point of view, a continuous display surface of relatively unlimited horizontal dimension, free of bezels or CRT mounting hardware, capable of displaying any type of data, in any form or format, at any location on the viewing surface, under software control, would revolutionize the concepts of control sectors, sector size, reconfiguration, flight data utilization--in fact, entirely new, more effective and efficient concepts of data utilization could be applied.

In addition, this concept would accommodate any future concept which generates information for the controller. This would significantly reduce the need for implementing discrete displays as new data-generating functions are introduced into NAS.

NONINTERFERING MAINTENANCE.

The packaging design accomplished and verified in the DSD performance demonstrated the feasibility of separating a package called the "Head," containing the electronics, optics, and tube from the display viewing screen (see figure 6). The distance, in the case of the original deliverable, was approximately 7 feet. This permitted the "Heads" to be placed in an adjacent room or service area and to project the image through a window in the wall onto the display screen in the operational area. All service and maintenance, including "Head" substitution, would be accomplished outside of the ATC area, and with little or no interference in the ATC operations. In the case of a tower cab, the room below the cab would be the location of the

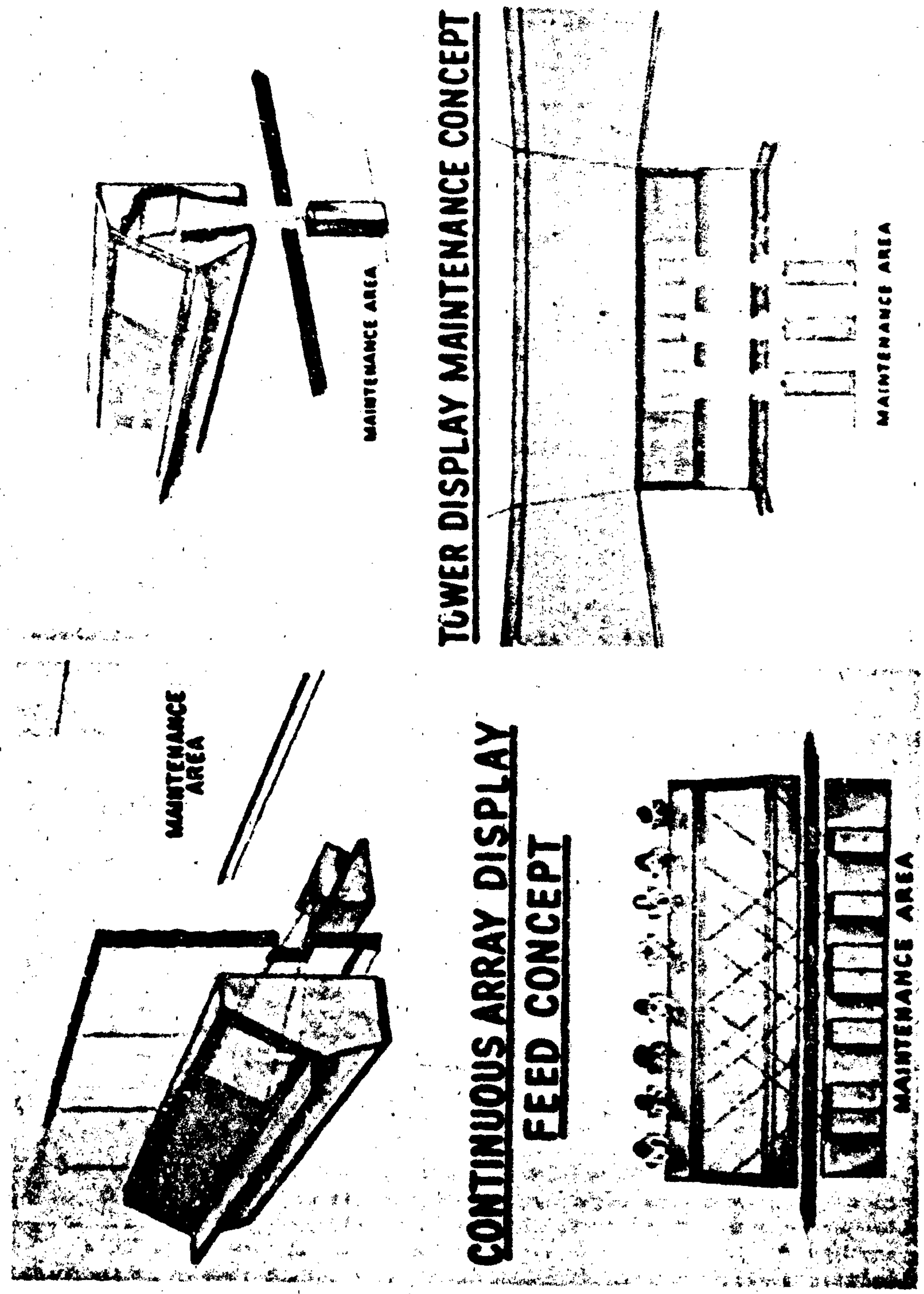

FIGURE 6. CONTINUOUS AREA (ARRAY) DISPLAY AND NONINTERFERING MAINTENANCE CONCEPT

"Heads," and projection to the console display surface would be through the floor.

The efficiencies of this more central and less interfering maintenance concept, including the aspect of staffing, are evident. (See letter dated 9/17/75, ANA-1 to ARD-1, appendix I.)

DSD CONTINUING ROLE

The DSD continues to play a vital role in a number of additional efforts beyond the original program intent.

1. The ER used in defining a specification for an E-TABS display (appendix A) was heavily based on the known performance capability of the DSD, and on the interactive capability of a touch input screen.

2. Advanced Tower Cab work station design underway at NAFEC is patterned after the consolidated display of information that is inherent in the projection concept. This effort is based upon inital requirements from a Request for RD&E Effort 9550-1, No. AT-100-29 (appendix J). As a baseline for future performance capabilities, the DSD performance has opened the limits of feasibility and firmly established display capabilities that have not yet been met by other technologies.

3. The ability to simulate most types of analog and digital displays (example, weather graphics, figure 7) has resulted in the use of the DSD as the prime display unit of the Controller-Computer Interface Laboratory (CCIL), a recently established human factors and technology development and evaluation facility at NAFEC. The DSD will enhance the lab's capability to deal with ATC display problems, designs, and developments for many years until technology can catch up with it. The CCIL, in the new building under construction at NAFEC, is being designed to take full advantage of the DSD flexibility.

4. The value of projection display as a serious approach to FAA's data presentation requirements has finally been accepted on a working level basis by the agency's research and development engineers.

CONCLUSIONS

This report records the development, testing, and evaluation of a new device application of a unique technology. The results of the technical testing evidence the actual performance of the first engineering model of this new technology in practical use. The performance was not measured on a production model; however, it is so exceptional as to encourage speculation on expected performance in production units.

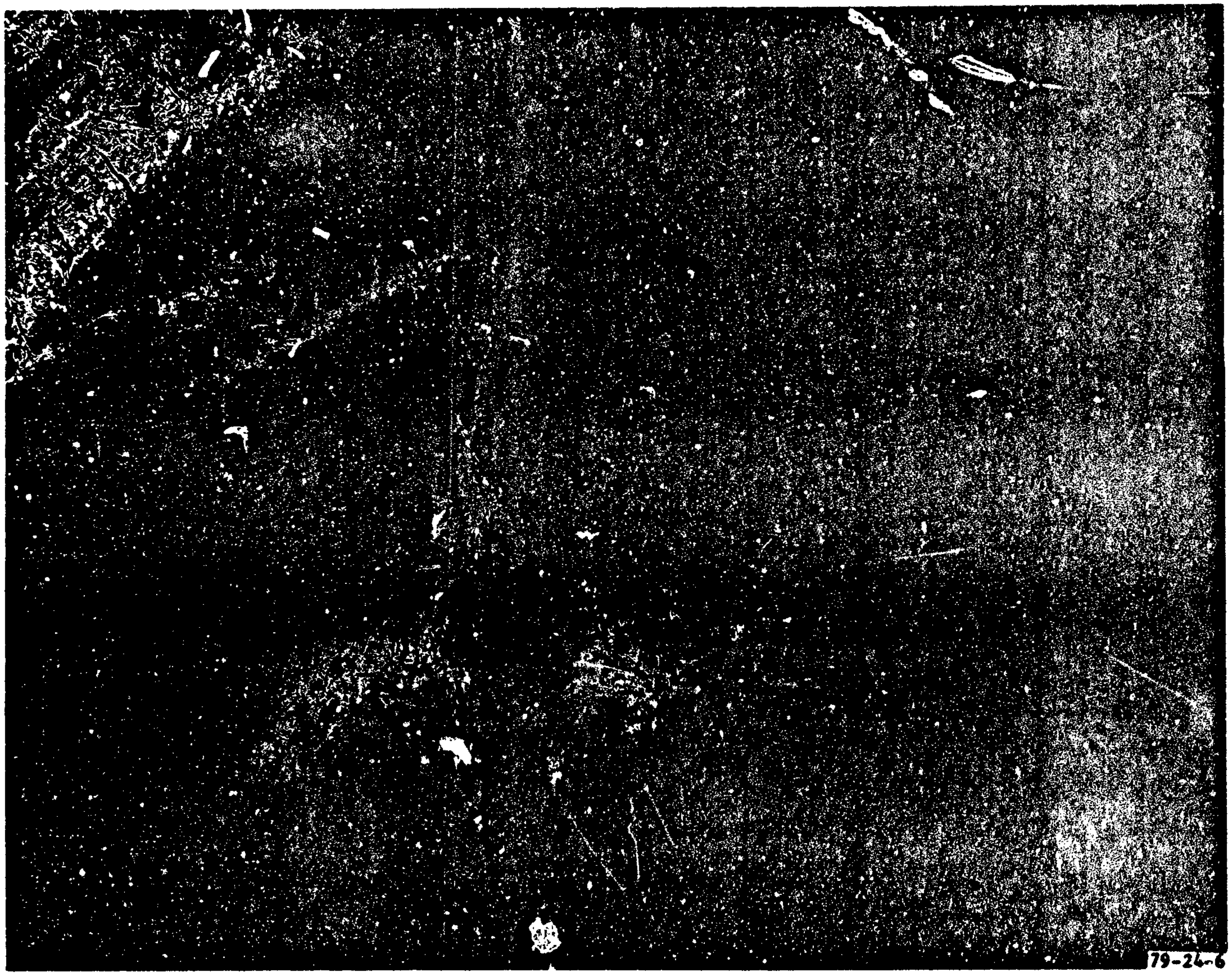

FIGURE 6. CONTINUOUS AREA (ARRAY) DISPLAY AND NININTERFERING MAINTENANCE CONCEPT

As is generally the case, peak performance is maintained on developmental equipment through special attention by experienced developmental engineers and technicians; expected nominal performance would be somewhat less than peak. The performance degradation with time in the DSD was comparable to that of a high-quality CRT.

However, it was very clear to program personnel that minor improvements in certain component and design areas would significantly raise certain performance levels. In most cases, applying the same kinds of state-of-the-art technologies that most commercial display manufacturers normally utilize is all that would be necessary to effect such performance increases as 600 line pairs per inch resolution, 10-percent brightness variations, 50-ms flood erase, and television writing rates of 15 to 30 μs per target inch.

Furthermore, in all the experiences of the technical project personnel with developmental display devices and systems, no other developmental display operated so consistently, so routinely, with so few "glitches," and with such little maintenance as did the DSD.

Specifically, it is concluded from all of the program efforts and results that:

1. Projection display from a stored image is the best method for achieving the performance necessary for ATC data display in the various environments encountered.

2. Devices exist today to provide the high-resolution, storage, safety, color, brightness, contrast, fail-safe capability, etc., already established as necessary or very desirable for ATC purposes.

3. The Deformographics technology and hardware are more than adequate for the FAA to begin larger scale studies of the use of such display capabilities to improve and enhance the ATC data display/handling functions.

4. The use of an integrated touch-input display surface provides significant capabilities in large data display systems and must be evaluated further.

5. The concept of separating the display support hardware from the operational viewing screen areas in facilities is viable and practical and is a direct advantage of projection display technology. This will save space in the ATC operation areas and will ease maintenance considerably.

6. The concept of a continuous array of projection displays to provide a work surface display that is equivalent to many work stations alongside each other is viable and easily achievable using projection techniques.

7. If the Deformographics were used to replace the PVD and other similar CRT displays, the following benefits would accrue:

a. The absence of a large evacuated PVD bottle would greatly reduce the risk of injury from implosion.

b. A dramatic reduction in power consumption would occur, and this would further reduce the air-conditioning load and capacity require for cooling the equipment, as well as lower the ambient noise levels from cooling fans and air moving through ducts.

8. As a result of the technical approach taken for the en route flight data tabular display development (E-TABS), the FAA is not pursuing nor has any plans to pursue the application of Deformographics and/or the technologies based upon it, and has not encouraged the advancement of this technology for tabular and graphic display. Instead of tabular and graphic data, stored in a fail-safe mode of display, in multicolor, on a safe, legible, flexible display device, the future en route flight data display system will be limited to a tabular-only, monochromatic, volatile display.

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2. Connolly, D., Spanier, G., and Champion, F., Applications of Color to ATC, DOT/FAA/NAFEC, Atlantic City, New Jersey 08405, Report Number FAA-RD-75-39, April 1975.

3. Lucas, R., Control Sector Redesign: Electronic Tabular Display Input Devices, DOT/FAA/NAFEC, Atlantic City, New Jersey 08405, Letter Report Number FAA-NA-77-32-LR, June 1977.

APPENDIX A

ENGINEERING REQUIREMENT, ER-3323

SCHEDULE

ENGINEERING REQUIREMENT NO. EA3323

FOR A

DEFORMOGRAPHIC STORAGE

DISPLAY SYSTEM

Revised

June 10, 1974

FOREWORD

The purpose of this preliminary engineering requirement is to provide a document which will support the Federal Aviation Administration (FAA) in the development of an engineering requirement containing the final requirements for the Deformographic Storage Display System.

The FAA intends to procure two versions of the Deformographic Storage Display System from the International Business Machines Corporation (IBM). One version will be configured for an En-Route environment, that is, in the form of a Radar and Manual Posting Console, Type M-1A. The second version will be configured for a tower cab. Both versions will be used at the National Aviation Facilities Experimental Center and at selected field sites to evaluate the potential of such storage display systems for use in the National Airspace System.

This engineering requirement therefore is designed to be used to procure a specific, one of a kind, development model of a display system which utilizes a Deformographic Storage Display Tube for evaluation by the FAA. It is not intended as a production specification to procure many display systems. Nor are the requirements specified herein intended to be the final requirements for procurement of the development model of the storage display system. This document is an interim step, to be followed by a document containing the final requirements for the storage display system. Background rationale required to understand the contents of this preliminary version of the engineering requirement is discussed in the following paragraphs.

a.) Since the intent of the FAA is to procure a specific system for evaluation purposes, the engineering requirement used for the procurement should define performance requirements which are within the capabilities of the contractor's system and are as close as possible to being within the range of acceptable performance parameters for FAA display systems.

b.) The IBM Deformographic system is still a development item, and therefore display performance characteristics are difficult to define. IBM has supplied their estimate of achievable performance parameters, and these estimates are used as the basis for this preliminary engineering requirement.

c.) Since in some areas the IBM estimates define a display system which might be unacceptable for use in the National Airspace

System, the FAA intends to use this document during technical discussions with IBM in an attempt to define a system which can both be achieved by IBM and is acceptable to the FAA. The result of these technical discussions should allow a final version of the engineering requirement to be prepared.

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1. SCOPE

1.1 Scope

This engineering requirement establishes the preliminary requirements for the design, development, fabrication, performance testing, delivery, installation, interfacing, and checkout of a Deformographic Storage Display System.

The intent of this engineering requirement is to obtain display systems from the International Business Machines Corporation (IBM) which utilize the Deformographic Storage Display Tube. These display systems will be used at the Federal Aviation Administration's (FAA) National Aviation Facilities Experimental Center (NAFEC) to evaluate the potential of such devices for use in the National Airspace System.

Since the systems are to be considered development items and will be used for evaluation purposes only, the use of "good commercial standards" in the construction of the equipment, documentation provided, etc. is specified in most cases. However, the documents which would apply to equipments selected for use in the National Airspace System are listed in Section 2. These documents should be used as a guide wherever feasible. System requirements are defined in Section 3. Quality assurance and delivery provisions are defined in Sections 4 and 5.

2. APPLICABLE DOCUMENTS

The following documents, including all parts, supplements, revisions, and amendments, of the issues specified, form a part of this engineering requirement and are applicable to the extent specified herein.

2.1 FAA Documents

FAA-G-2100 Electronic Equipment, General Requirements, including:

FAA-G-2100/1b - Electronic Equipment, General Requirements, Part 1, Basic Requirements for all Equipments, dated 10 July 1970.

FAA-G-2100/2a - Part 2 - Requirements for Equipments Employing Electron Tubes, dated 19 June 1968.

FAA-G-2100/3a - Part 3 - Requirements for Equipments Employing Semiconductor Devices, dated 19 June 1968.

FAA-G-2100/4b - Part 4 - Requirements for Equipments Employing Printed Wiring Techniques, dated 5 February 1969.

FAA-G-2100/5 - Part 5 - Requirements for Equipments Employing Microelectronics Devices, dated 24 March 1969.

FAA-G-2100/Supplement 4 - FAA List of Applicable Documents dated 10 July 1970.

Attachment to FAA-G-2100 - Attachment I, Non-Standard Part Approval Instructions.

NOTE: Specifications FAA-G-2100/1b, FAA-G-2100/2a, FAA-G-2100/3a, FAA-G-2100/4b, FAA-2100/5, FAA-G-2100/Supplement 4, and Attachment to FAA-G-2100-Attachment I are referred to, hereafter, as FAA-G-2100.

FAA-ER-650-003 - Connections, Electrical Solderless Wrapped, dated 25 September 1970.

FAA-D-638h - Instruction Books, Electronic Equipment, with Amendment 1, dated 13 December 1968.

FAA-STD-002 - Federal Aviation Agency Standard for Engineering Drawings, with Amendment 1, dated 6 October 1967.

FAA-STD-010a - Graphic Symbols for Digital Logic Diagrams, dated 2 February 1970.

FAA-E-2015C - Radar and Manual Posting Console, Type M-1A, with Amendment 1, dated 7 April 1970.

FAA-RD-72-111 - Evaluation of High-Activity Level Tower Cab, Final Report, dated October 1972.

2.2 Military Documents

MIL-STD-461a - Electromagnetic Interface Characteristics Requirement for Equipment with Notices 1 and 2, dated 20 March 1969.

2.3 Other Documents

2.3.1 NSA Standards

NSA 68-8S - Specification for Multilayer Printed Wiring Boards (Plated Through Hole), dated 15 November 1968.

2.3.2 Digital Equipment Corporation Documents

DEC-8I-HRIA-D - PDP-8/I Maintenance Manual, Volume 1, dated 1970.

F-85 - Programmed Data Processor-8, PDP-8, Users Handbook, dated July 1965.

2.3.3 MITRE Corporation Documents

MTR-1669, Rev. 1 - Evaluation Procedure for a Cathode-Ray-Tube Display Designed for the NAS En Route System, dated 29 March 1971.

(Copies of this engineering requirement, and copies of the applicable FAA specifications and drawings, may be obtained from Federal Aviation Administration, Washington, D.C. 20590, Attn: Contracting Officer. Requests should fully identify material desired; i.e., specification numbers, dates, amendment numbers, complete drawing numbers; also, requests should identify the invitation for bids, request for proposals, or the contract involved, or other use to be made of the requested material.)

(Single copies of Military specifications may be obtainable from Federal Aviation Administration, Washington, D.C., 20590, Attn: Contracting Officer; mail requests should cite the invitation for bids, request for proposals, or contract for which the specifications are needed; mail requests, if found acceptable, will be forwarded to a military supply depot for filling, hence ample time should be allowed.)

(Information on obtaining copies of Federal specifications and standards may be obtained from General Services Administration offices in Washington, D.C., Seattle, San Francisco, Denver, Kansas City, Missouri, Atlanta, Chicago, New York, Boston, Dallas, and Los Angeles.)

(Copies of other publications referenced may be obtained from Federal Aviation Administration, Washington, D.C., 20590, Attn: Contracting Officer. Request should fully identify material desired; i.e., publication numbers, dates, etc., and use to be made of the requested material.)

2.4 Precedence of Documents

When requirements of the contract, this engineering requirement, or subsidiary documents are in conflict, the following precedence shall apply:

a) Contract - The contract shall have precedence over all other documents.

b) Engineering Requirement - This engineering requirement shall have precedence over all subsidiary documents referenced herein.

3. REQUIREMENTS

3.1 Summary of Materials and Services to be Furnished

The contractor shall provide all necessary services and materials to design, develop, fabricate, test, deliver, install, interface, and check out the equipments required by this engineering requirement and the Contract, and shall supply the major deliverable items tabulated below in the quantities and at the times required by the Contract. Any feature or item necessary for proper operation in accordance with the requirements of the Contract shall be incorporated even though that item or feature may not be specifically described herein. In addition, the contractor shall provide all necessary services and material to prepare, reproduce, and provide reports and other documentation as specified herein.

The equipment shall accept the specified input signals and shall operate in accordance with all specified requirements. The contractor shall be responsible for the detailed design of the interface between the equipment developed to comply with this engineering requirement and the equipment with which it will be interconnected, subject to the requirements contained herein. Upon specific request from the contractor, the Government will furnish any technical information which it has or can reasonably obtain, and which is necessary for the contractor to meet the interface requirements. The contractor shall coordinate with the Contracting Officer's Technical Representative and other personnel (as designated by the Contracting Officer) its activities in meeting the associated equipment interface requirements.

3.1.1 Materials

3.1.1.1 Deformographic Storage Display System Equipment

a. En-Route Console Equipment

(1) Deformographic Storage Display Tube
(2) Light sources and Schlieren optical system
(3) Deflection drivers, video driver, and erase control for one tube.
(4) A single set of generator electronics consisting of PDP-8 interface, symbol/character/vector generators, and associated control and erase control logic. These electronics shall be capable of driving one or two tubes upon command.

(5) Viewing screen
(6) Power supplies

b. Tower-Cab Console Equipment

(1) Tower-Cab Console
(2) Deformographic Storage Disp' DELETE tube
(3) Light source and Schlier- .ptical system
(4) Deflection drivers, DELETE driver, and erase control
(5) A single set o DELETE .nerator electronics consisting of PDP-8 inte DELETE, symbol/character/vector generators, and associa control and erase control logic. These ele DELETE nics shall be capable of driving one or two tubes command.
DELETE viewing screen
(7) Power supplies

3.1.1.2 Support Equipment

(a) Special Tools and Test Equipment
(b) Spares

3.1.1.3 Documentation

(a) Management Reports
(b) Equipment Operation and Maintenance Instructions
(c) Acceptance Test Plan
(d) Equipment Acceptance Test Procedures
(e) Test Data Sheets
(f) Final Test Reports
(g) Site Prep.ration Specifications
(h) Installation Documents
(i) Spare Parts Lists

3.1.2 Services

3.1.2.1 Installation Materials and Services

3.1.2.2 Training Services

3.1.2.3 Facilities for Customer Representatives

3.1.2.4 Cooperation and Coordination

3.1.2.5 Quality Assurance Provisions

3.2 Definitions

The following are definitions of frequently used terms and abbreviations appearing in this engineering requirement.

CRR	Console Rack Rear
CTL	Console Turret Lower
CTU	Console Turret Upper
FAA	Federal Aviation Administration
IBM	International Business Machines Corp.
MDT	Mean Down Time
MUT	Mean Up Time
NAFEC	National Aviation Facilities Experimental Center
PDP-8	Programmed Data Processor-8 (computer)

3.3 Equipment Makeup and General Functional Requirements

3.3.1 Equipment Makeup

The Deformographic Storage Display System specified herein shall consist of:

- a.) En-Route console configurations as required by the Contract
- b.) Unassigned
- c.) Cables as required by the Contract
- d.) Support equipment as required by the Contract.

The Deformographic Storage Display System is configured in an En-Route configuration.

3.3.1.1 En-Route Console Configuration

In the En-Route console configuration the contractor shall modify a Radar and Manual Posting Console Type M-1A, which will be supplied by the FAA as Government Furnished Equipment at no cost to the contractor, and shall install the following in the modified console:

- a.) Deformographic Storage Display Tube
- b.) Light sources and Schlieren optical system
- c.) Deflection drivers, video driver, and erase control for one tube.
- d.) A single set of generator electronics consisting of PDP-8 interface, symbol/character/vector generators, and associat control and erase control logic. These electronics shall capable of driving one or two tubes upon command.

e.) Viewing screen
f.) Power supplies

3.3.1.2 Tower-Cab Console Configuration

In the Tower-Cab console configuration the contractor shall fabricate a typical Tower-Cab console and shall install the following in the console:

DELETE DELETE DELETE DELETE DELETE DELETE DELETE DELETE

a.) Deformographic Storage Display Tube
b.) Light source and Schlieren optical [illegible]
c.) Deflection drivers, video dri[illegible] erase control
d.) A single set of genera[illegible]ctronics consisting of PDP-8 interface, symbo[illegible]cter/vector generators, and associated control an[illegible] control logic. These electronics shall be capa[illegible] driving one or two tubes upon command.
e.) [illegible]ng screen
f.) Power supplies

3.3.2 General Functional Requirements

The Deformographic Storage Display System shall be capable of accepting signals from the Government-owned Programmed Data Processor-8 (PDP-8) and displaying this information on the viewing screen.

It shall be the responsibility of the contractor to determine and design the required interface between the PDP-8 and the Deformographic Storage Display System, using DEC-81-HRIA-D and F-85 as a guide. The Government will provide access to all documentation available at NAFEC on the PDP-8 (in addition to the documentation listed in Section 2.3.2), and to the PDP-8 equipment located at NAFEC if required by the contractor. (The PDP-8 is not available for use at the contractor's facilities due to other commitments for its use at NAFEC.) The contractor shall submit all such requests in writing to the Contracting Officer at least fifteen days prior to the requirement. If access to the PDP-8 equipment is requested the Government will allow such access on an as-available basis. If the contractor in any manner modifies the PDP-8 equipment, (that is, unplugs cards, disconnects wires, etc.), it shall be the responsibility of the contractor to return the PDP-8 to the condition which existed before such modification was made prior to the release of access by the contractor. The contractor is not required to take corrective action, except by proper action of the changes clause of the contract, to circumvent any discrepancy of the Government's PDP-8 or its interface from the descriptions contained in the referenced documents as provided to the contractor by the FAA.

3.4 Deformographic Storage Display System Physical Design Requirements

3.4.1 General

The Deformographic Storage Display System shall be configured in an En-Route console as required by the Contract.

3.4.2 En-Route Console Design

The FAA will provide one each of the following units of a Radar and Manual Posting Console, Type M-1A, to the contractor (Reference FAA-E-2015a). These units will be provided as Government-Furnished-Equipment, at no cost to the contractor, within thirty days after award of Contract.

Unit Name	Drawing Number
Console Turret Lower Assembly (CTL)	D-5647-3
Console Turret Upper Assembly (CTU)	D-5647-28
Console Rack Rear Assembly (CRR)	D-5647-103

The contractor shall modify the units as necessary to mount two Deformographic Storage Display Tubes and the other equipment defined in 3.3.1.1. These shall be mounted within the CTL (and CRR if additional space is required). The CTU shall not be used by the contractor to mount any part of the display equipment. The display equipment (tubes, light source, optical system and display electronics) shall be mounted in a removable frame which is capable of being removed from the console and operated as an independent unit for projection on other size screens.

The contractor shall mount a viewing screen in the space provided by removing the stripholder trays from the CTL. This screen shall completely fill the space provided (approximately 22 inches by 32 inches), and the optical system provided shall be capable of illuminating this entire area.

It shall be the responsibility of the contractor to coordinate the proposed console modifications and design with the Government Technical Representative prior to the start of modification to insure compatibility with intended use.

DELETE DELETE

3.4.3 Tower-Cab Console Design

The contractor shall fabricate a Tower-Cab console us DELETE FAA-RD-72-111, Figure C-2, Typical Console, as a guide DELETE ne plywood console shall be covered with Rosewood DELETE (64) matte-finish formica. The contractor may view sam DELETE of these consoles at NAFEC if it is required. It DELETE be the responsibility of the contractor to arrange to DELETE the consoles with the Government Technical Representat DELETE.

The contractor shall mount the DELETE ormographic Storage Display Tube(s), light source(s), S DELETE ren optical system(s), display electronics and power suppli DELETE a removable frame which is capable of being remov DELETE rom the console and operated as an independant unit f DELETE rojection on other size screens. The contractor DELETE mount a 12 inch by 24 inch viewing screen on the equipm DELETE mounting panel left side (when facing panel).

It shal DELETE the responsibility of the contractor to coordinate the DELETE sed console design with the Government Technical Re DELETE sentatives prior to the start of fabrication to insure DELETE patibility with intended use.

3.4.4 System Design

The Deformographic Storage Display Syst equipment specified herein shall be designed and constructed using good commercial standards, using the following as a guide:

(a) FAA-G-2100 - For the entire Deformographic Storage Display System

(b) FAA-G-2100/1b, Section 1-3.5.11 Condition B when measured at the highest noise level at a distance of 3 feet from the exterior surface of the equipment, for ambient noise using curve of Fig. 12.7, page 375 in <u>Acoustics</u> - For Audible Noise.

(c) FAA-ER-650-003 - For all wire wrapped connections.

(d) MIL-STD-461a, including Notices 1 and 2 - For conducted and radiated interference.

(e) NSA 68-8B - For multilayer printed wiring boards.

The contractor may use existing designs or design practices in this evaluation equipment which may differ from the referenced guidelines.

3.4.4.1 Personnel Safety Features

The Deformographic Storage Display System shall be designed to protect the safety of personnel operating and servicing the equipment, using FAA-G-2100 as a guide.

3.4.4.2 Conducted and Radiated Interference

The Deformographic Storage Display System shall be designed such as not to interfere with nearby equipment and as not to be adversely affected by external fields. The contractor shall use the requirements of MIL-STD-461a with Notices 1 and 2 as a guide.

3.4.4.3 System Grounding

The contractor shall specify any special grounding requirements and shall include in his design a grounding system so that there shall be no degradation of signals between equipment due to cross-coupling through the ground system. One ground for A. C. neutral, and a second, separate ground for signal, D.C. power, and chassis bond shall be maintained throughout.

3.4.4.4 Power Requirements

The standard design center value for voltage shall be 120 volts (Reference FAA-G-2100). The power consumption in either the En-Route or the Tower-Cab configuration shall not exceed 2.0 KW.

3.4.4.5 Maintenance Aids

The Deformographic Storage Display System shall contain maintenance aids (e.g., switches, test points, indicators) to allow detection, isolation, and repair of unit faults. The design shall emphasize the use of commercially available test equipment, tools, and fixtures for maintenance aids and minimize reliance upon special test equipment.

3.4.5 Special Tools and Test Equipment

If required by the Contract the contractor shall submit for Government review and approval a complete list of special tools and test equipment, the application of each, and the unit or component for which it is required. This shall be submitted prior to fabrication or procurement of any special tools and test equipment for use at Government facilities. The design of the equipment shall be such as to permit the use of standard tools and test equipment insofar as practicable.

3.4.6 Standard Test Equipment

The contractor shall provide a list of standard test equipment which will be required, as a minimum, to maintain the system.

3.4.7 Cables

3.4.7.1 Installation Cables

The Deformographic Storage Display System Installation Cables shall be supplied by the contractor. These cables shall include the cables needed to interconnect all units within the Deformographic Storage Display System, all cables required to interconnect the Deformographic Storage Display System with the PDP-8 computer and with the power sources at the site, and all other cables required to properly install the Deformographic Storage Display System at the site designated by the Contract.

3.4.7.2 Factory Test Cables

If cables are required in addition to the installation cables specified in Section 3.4.7.1 to factory test the Deformographic Storage Display System these cables ahll be furnished by the contractor.

3.4.8 Provisioning

A provisioning conference will be called by the Contracting Officer within thirty days after receipt of the recommended spare parts list specified in Section 3.6.10. At this conference, spare parts requirements shall be discussed in detail with FAA personnel. Within thirty days following the conference, the Government will specify the quantities of spare parts to be ordered. Delivery of the spare parts shall be as negotiated.

3.4.9 Mean Up Time and Mean Down Time

3.4.9.1 Mean Up Time and Mean Down Time Demonstrations

The Mean up time and Mean down time requirements are not subject to tests or demonstrations, but must be considered as design goals in the design approach and the quality of materials and workmanship required. They do not constitute a warranty of any kind.

3.4.9.2 Mean Up Time

Mean Up Time (MUT) is defined as the mean time to failure of the equipment, given that the equipment is operating in accordance with the requirements of this engineering requirement at time zero. The MUT for the equipment, excluding noncritical components such as indicator lamps, mechanical assemblies, etc., shall be at least 1500 hours. The cathode-ray-tube (Deformographic Storage Display Tube) replacement MUT for reasons of catastrophic failure or decrease in performance below that required to meet the requirements of this engineering requirement shall be at least 5000 hours. The projection lamp MUT shall be at least 500 hours.

3.4.9.3 Mean Down Time

Mean Down Time (MDT) is defined as the mean time to affect minimum repair sufficient to restore the equipment to operation in accordance with the requirements of this engineering requirement. The MDT of the equipment shall be one hour or less.

3.5 Deformographic Storage Display System Performance Requirements

3.5.1 General

The performance requirements specified herein shall apply to the Deformographic Storage Display System when displaying data written only once, measurements to be taken within 10 minutes, and measured under the following conditions:

1.) Input data is supplied from a PDP-8 computer over cables 50 feet in length.

2.) On a screen with a 30 inch by 30 inch usable display area.

3.) Using one Deformographic Storage Display Tube (DSDT) with its associated optics, light source and electronics on an individual basis.

4.) Using a specific black and white schilieren stop selected by the contractor.

5.) With all equipment--including filters, safety features, etc.--in normal operating positions.

6.) Measurements of brightness, line width and other related parameters shall be made in a direction parallel to the optical path at the center of the viewing screen using a Model 2020 Gamma Scientific Photometer with microscope, six mil aperture and 2.5X magnification, or equivalent. All such measurements shall be made with 6 foot candles of ambient illumination on the viewing screen as measured with the same instrumentation by using a suitable lambertian reflector held flat against the screen.

3.5.2 Measurement Techniques

The contractor shall provide a procedure defining the measurement techniques to be used to measure the display parameters specified herein. This procedure shall define the measurement equipment, test conditions, and test patterns to be used. MTR-1669, Rev. 1 shall be used as a guide in preparing this procedure. The procedure shall be submitted to the FAA for review and approval at least 120 days prior to acceptance test. The FAA will review and comment or approve within 30 days after receipt of the procedure.

In developing this procedure the contractor shall consider the use of Government owned measurement equipment at NAFEC. If information concerning this measurement equipment is required the contractor shall request such information in writing from the Contracting Officer. The Contracting Officer will arrange a meeting with Government technical representatives to supply the required information.

3.5.3 Brightness

3.5.3.1 Required Display Data Brightness

The Deformographic Storage Display System shall be capable of displaying data at a brightness of at least fifteen foot lamberts at the center of the screen.

3.5.3.2 Brightness Control

A brightness control(s) shall be provided to enable the brightness level to be adjusted from full brightness (Section 3.5.3.1) down to one-eighth or less of full brightness.

The control of brightness shall be uniform over the entire viewing screen for all settings of the control(s). That is, as brightness is lowered, all displayed data on the viewing screen shall be dimmed uniformly. Also, focus shall not change during small changes of brightness. Brightness levels shall not be affected by varying conditions of display data load. The brightness control may be implemented to provide discrete increments of brightness and, if so, there shall be at least four discrete levels.

3.5.3.3 Brightness Variations

Measured brightness variations over the entire viewing screen due to all causes shall not exceed 60 percent. Measured brightness variations shall be defined as:

$$\frac{B\ max - B\ min}{B\ max} \times 100 = \%\ \text{of brightness variation}$$

where: B max = Maximum brightness reading
B min = Minimum brightness reading

Measured brightness variations between and within characters and vectors shall not exceed 40 percent over a distance of three inches or less anywhere on the screen.

3.5.4 Contrast Ratio

Contrast ratio is the ratio os the brightness of an element of display data as compared to the brightness of an area adjacent to the display data, or:

$$\text{Contrast Ratio} = \frac{\text{Brightness of an element of display data}}{\text{Background brightness}}$$

The contrast ratio shall be sixteen to one or greater. The specular reflectivity of the viewing screen shall be less than 10%.

3.5.5 Display Color and Shades of Gray

3.5.5.1 Display Color

The following optical stops shall be provided for each Deformographic Storage Display Tube to permit display of the indicated colors:

a.) Black and white (shades of gray)
b.) Depth of modulation two-color: Red and Green - three sizes
c.) Spatially polarized four-color: Red, Green, Yellow, and Bluish White - two identical stops.

The optical stops shall be easily interchangeable.

3.5.5.2 Shades of Gray

When displaying data using the black and white optical stops the display shall be capable of producing six shades of gray on the viewing screen.

3.5.6 Line Width, Resolution and Spot Growth

3.5.6.1 Line Width

The width of a single line measured anywhere in the test pattern of 3.5.7.1 shall not exceed 0.040 inches at the 50 percent brightness points.

3.5.6.2 Resolution

A pair of lines on 0.035 inch centers shall be resolvable anywhere on the viewing screen with at least 20 percent modulation, where:

$$\% \text{ modulation} = \frac{B\ max - B\ min}{B\ max} \times 100.$$

and B max = maximum brightness reading
B min = minimum brightness reading.

3.5.6.3 Spot Growth

The ratio of the maximum to minimum line width measured anywhere in the test pattern of 3.5.7.1 shall not exceed 1.4.1, with 1.3.1 as a design goal.

3.5.7 Linearity and Registration Accuracy

3.5.7.1 Linearity

Linearity shall be measured using a cross hatch pattern consisting of nine vertical and nine horizontal lines which are intended to divide the full usable viewing area into 64 equal squares. The height and width of any square shall not vary by more than 0.15 inches from one-eighth of the height and width of the full usable area.

3.5.7.2 Rewrite Registration Accuracy

A block of data is defined to be a group of characters, symbols and/or vectors, contained within an area of 30 square inches or less, all of which are written and erased as a group. When the following three steps are completed, the data in step c) shall be within 0.030 inches of the positions of the data in step a):

a) A data block shall be written in any position on the screen not occupied by other data.

b) This data block shall be selectively erased without any other data being added or deleted from the screen.

c) The same data block shall be rewritten with the same commanded position as in step a).

3.5.7.3 Overwrite Registration Accuracy

When two identical data blocks are written at exactly the same commanded position with no other data being added or deleted from the screen during the interim, the rewritten data shall register to within 0.030 inches of the original data.

3.5.7.4 Selective Erase Accuracy

Referring to step b) in 3.5.7.2, the selective erase pattern shall be commanded to cover an area extending 0.15 inches beyond all sides of the data block in step a). It shall completely erase the data block without affecting any data that is outside the data block by 0.30 inches or more.

3.5.7.5 Registration of Two DSDT Images

DELETE DELETE DELETE DELETE

When identical test [illegible] DELETE DELETE [illegible] in 3.5.7.1 are written on both [illegible] DELETE DELETE [illegible] configuration, the two images shall coin- DELETE DELETE DELETE [illegible] within 0.30 inches at all points within the test pattern.

3.5.8 Display Magnification

The optical magnification of displayed data (diagonal of viewing screen display area divided by usable CRT diameter) shall be variable from 7.5X magnification to 18X magnification. Adjustable magnification for screen sizes other than the fixed screen built into the console shall apply only when the tube and its optics are removed from the console, and shall be accomplished by adjusting the projection lens and changing the optical path length from the DSDT to the viewing screen.

3.5.9 Jitter and Short Term Drift

Peak to peak short term drift or jitter of stored, displayed data shall not exceed 0.005 inches due to any internal source of vibration. Drift and jitter are defined as movement of the displayed data position within a 1-minute interval.

3.5.10 Stability

Equipment stability shall be such that the brightness, focusing, and other necessary controls shall not require adjustments more frequently than weekly to meet performance requirements.

3.5.11 Centering

Electrical horizontal and vertical centering controls shall be provided to center the display. These controls shall provide a range of adjustments sufficient to position the projected electron beam image to the center of the viewing screen when display center coordinates are addressed. Display center positioning shall not move more than one-quarter inch from the original point of adjustment over a one-week period.

3.5.12 Display Storage

The equipment shall be capable of displaying an image without refresh for thirty minutes minimum while retaining at least 50% of the original brightness. Degradation in display resolution shall not exceed 10%.

3.5.13 Character Repertoire

The equipment shall be capable of displaying the twenty-six capital letters of the alphabet, the digits 0 through 9, and the twenty-two special symbols shown in Figure 3-1.

3.5.13.1 Character Closure

Line segments of a character or symbol shall be closed or completed to within 0.015 inch from the idealized fonts.

3.5.13.2 Character Positioning

All alphanumeric characters shall be positioned so that the center of the character corresponds to the overall X, Y position command. The twenty-two special symbols shall be position such that the center of the box drawn around each symbol in Figure 3-1 corresponds to the overall X, Y position command.

3.5.13.3 Character Size

The nominal values of the character size shall be:

0.230 inches high
0.180 inches wide

Maintenance adjustments may be provided to permit setting character sizes to the nominal values. All characters shall have height and width (where applicable) within ±10% of the set value and shall not vary with time.

3.5.13.4 Character Spacing

Center to center spacing of characters shall be programmable in increments of 0.015 inches or less.

3.5.14 Writing and Erasing of Data

3.5.14.1 Writing Rate and Time

The system shall be capable of a writing rate of at least 20,000 inches/second at the viewing screen. The writing time per character shall not exceed 100 microseconds. The time required to cycle down, erase, cycle up, and write 100 characters located adjacent to each other shall not exceed 100 milliseconds.

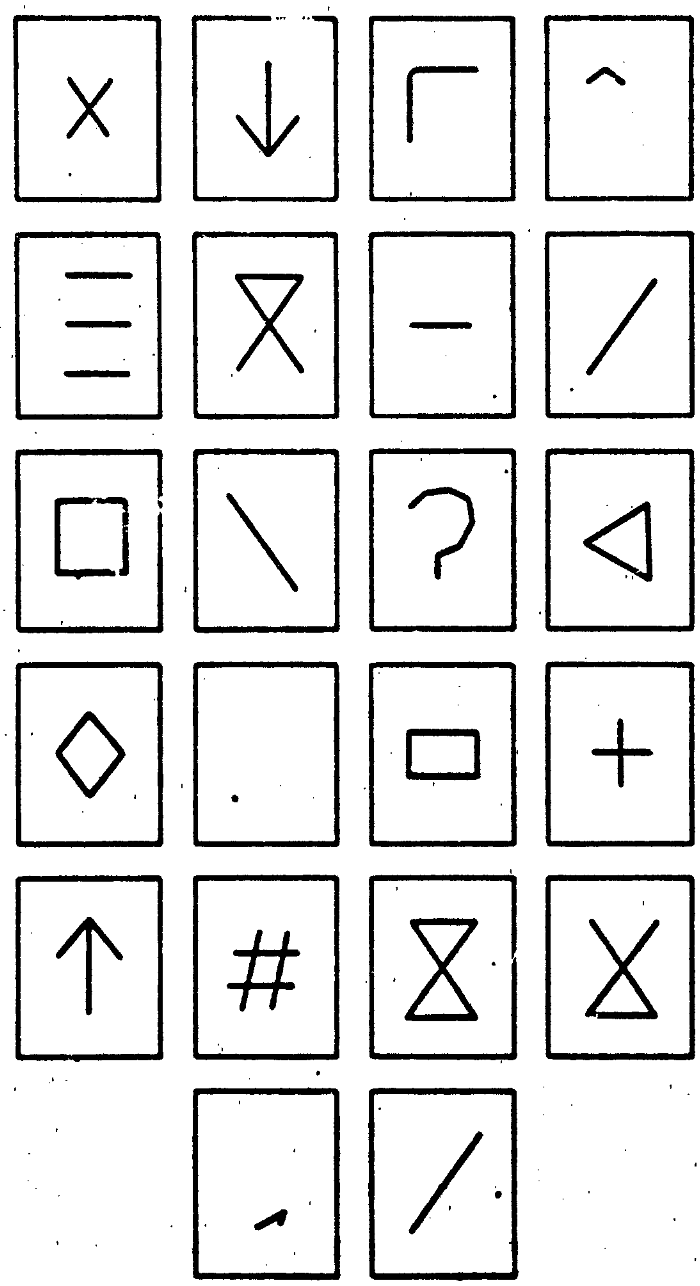

FIGURE 3-1
SPECIAL SYMBOL CHARACTER FONTS

3.5.14.2 Erase Time and Control

The erase time shall not exceed 10 milliseconds per square inch of display segment. Under electronic control, erase action, location, selection, and repetition shall be performed. Manual and electronic flood erase shall be provided.

3.5.15 Input Rate

The system shall be capable of accepting at least one character every 100 microseconds.

3.6 Documentation

3.6.1 General

The contractor shall provide all necessary services and materials to develop and deliver documentation in the quantities and at the time specified in the Contract.

All documentation produced or updated by the contractor shall show the contract number conspicuously displayed on each document, including drawings, to facilitate identification and association with the contract.

Documentation such as instruction books, maintenance manuals, etc. which are in existence or in use at the time of award of Contract will be accepted if so specified in the Contract. This documentation shall be updated if necessary to reflect the equipment design at delivery time. Documentation which is produced as a result of this Contract shall be produced to good commercial standards, using the following as a guide:

A. FAA-STD-010a
B. FAA-D-638h, with Amendment 1
C. FAA-STD-002, with Amendment 1

3.6.2 Management Reports

Monthly management reports in letter form consisting of the following two parts shall be submitted by the contractor during design, development, and fabrication of the equipment.

A. Part I, Program Status - A narrative of work progress during the reporting period

B. Part II, Problem Areas - A discussion and solution of progress toward solution of special problem areas.

3.6.3 Equipment Operation and Maintenance Instructions

The contractor shall provide operation and maintenance instructions containing sufficient detail to allow operation and maintenance of the system by skilled engineers and technicians.

These instructions shall include the basic theory of all unusual or uncommon circuitry used in the equipment, equipment limitations and warnings, schematic diagrams to the discrete component or packaged module level, digital interface details, a description of digital signals through logic levels, voltage and waveform information where appropriate, and sufficient detail to allow component replacement.

Documentation shall also include control requirements, special software sequences necessary to the performance of the DSDT system, wire listings as appropriate for signal/circuit tracing, circuit schematics and special instructions for power supplies, and other OEM assemblies not manufactured in-house.

Documentation shall also include maintenance procedures, maintenance aids and alignment procedures for the optical system.

These documents, in preliminary form, shall be provided to the FAA at least 30 days prior to planned or scheduled acceptance testing.

3.6.4 Acceptance Test Plan

The contractor shall submit a plan for FAA approval which outlines the acceptance testing program required to demonstrate compliance of the Storage Display System with all the requirements of this engineering requirement. The plan shall include but not be limited to the following:

A. The plan shall define the contractor's Quality Assurance Program required to meet the requirements of Section 4 of this specification. The FAA's role in the Quality Assurance Program shall be defined.

B. The plan shall provide an overview of all proposed test activities for all equipment. The overview shall clearly identify all test activities required to demonstrate compliance with the engineering requirement, list tentative start and completion dates, describe the objectives of each test activity, list the test documentation required, and define contractor and FAA participation in the test activities.

C. For each test activity identified in A and B above, the plan shall provide a checklist of test requirements. The approved checklists shall be used by the contractor to develop the equipment test procedures and data sheets.

3.6.5 Equipment Acceptance Test Procedures

The contractor shall submit test procedures for each test activity defined by the approved test plan of Section 3.6.4 to the FAA for review and approval. The test procedures shall include the measurement techniques procedure of Section 3.5.2, and include all details necessary to assure that the testing will satisfactorily demonstrate equipment compliance with the requirements as contained in this engineering requirement. Each test shall reference the specified requirement including the paragraph number and tolerance therein of the engineering requirement or other documentation for which the test is intended to demonstrate compliance. The contractor shall notify the FAA of proposed test dates for contractor conducted tests concurrent with submission of the test procedures. The contractor shall notify the FAA of final test dates at least seven days prior to conducting the test. The FAA reserves the prerogative to witness tests and to require additional testing as may be needed to show compliance with this engineering requirement.

3.6.6 Test Data Sheets

The contractor shall submit to the FAA Test Data Sheets with the test procedures defined in Section 3.6.5. The contractor shall submit the completed Test Data Sheets to the FAA after completion of each activity. Test Data Sheets shall be complete with respect to all tests specified in the test procedure.

3.6.7 - Unassigned

3.6.8 Site Preparation Specification

The contractor shall submit a Site Preparation Specification in letter form to the FAA, in advance of the proposed site installation. The Site Preparation Specification will be used by the Government to prepare the site for installation of the contractor's equipment and to perform necessary services not required of the contractor. The specification shall include but not be limited to the following:

A. Definition of power, physical space, and air conditioning requirements to be furnished by the Government.

B. Description of all required modifications to existing Government equipment.

C. Definition of cable and connector requirements for the complete installation.

D. Definition of contractor's office equipment and space requirements to be furnished by the Government during the installation and checkout period.

E. Identification of requirements for Government and other contractor's services and test equipment.

3.6.9 Installation Documents

The contractor shall submit installation documents to the FAA prior to delivery of the equipment. The documents shall contain all necessary information required by skilled technicians and engineers to correctly install the equipment and initiate its operation. The documents may be selected data prepared under other documentation requirements or previously prepared for installation of like equipment.

3.6.10 Spare Parts List and DSDT Spares Support

The contractor shall provide copies of an inital Spare Parts List containing those items the contractor deems necessary for the continuing support and maintenance of the equipment for a period of not less than one year. The contractor also shall provide for DSDT (C..) replacements.

3.7 Services

3.7.1 Installation Materials and Services

The Contractor shall install, debug, and test the system at the facility designated by the Government. Installation power wiring shall be in accordance with the requirements of the rules of local wiring codes and the National Electrical Safety Code. Installation materials furnished shall be Underwriters Laboratories, Inc. approved type.

3.7.2 Training Services

The contractor shall provide hands-on familiarization and informal training to a small number of FAA technical personnel prior to final acceptance testing. This shall be conducted at the contractor's facility for purposes of understanding the special, unique, non-standard operation, alignment, software control, set-up and maintenance requirements of the DSDT system.

3.7.3 Cooperation and Coordination

The contractor shall participate in meetings and conferences and exchange technical data relating to the equipment performance and design compatibility with others as directed by the Contracting Officer.

4. QUALITY ASSURANCE PROVISIONS

4.1 General

The Storage Display System shall be tested at the contractor's plant prior to shipment (factory acceptance tests) and after installation at the Government designated site (site acceptance tests) in accordance with the approved test procedures (Section 3.6.5), and compliance therewith shall be demonstrated. All acceptance tests shall be performed by the contractor and witnessed by the FAA. However, the FAA reserves the right to waive witnessing of the complete acceptance tests or any part thereof. If FAA witnessing of tests is waived, the contractor shall furnish certified test data showing the results of all such tests. In any case, factory acceptance by the FAA will not be made until test data, certified to be true and correct by a properly authorized official of the company, and notarized, has been submitted and approved by the FAA. Periodic design reviews shall be held at the contractor's facility beginning 30 days after contract award.

4.2 Acceptance Tests

4.2.1 General

The contractor shall perform factory acceptance tests and site acceptance tests to demonstrate that the equipment fully meets the requirements of this engineering requirement. The contractor shall furnish all equipment and test programs, if required, necessary to adequately test the Storage Display System. Government-furnished equipment will not be provided for factory acceptance tests unless so stated by the Contract.

4.2.2 Factory Acceptance Tests

Factory acceptance tests shall be conducted in accordance with the approved test procedures (Section 3.6.5).

4.2.2.1 Quality Control Inspection

This inspection shall include all checks and tests deemed necessary to ascertain that the equipment meets good commercial standards.

4.2.2.2 Factory Acceptance Exercise

The Storage Display System shall be exercised for a minimum period of 24 consecutive hours after completion of the Factory Acceptance Tests. Maintenance schedules for this factory acceptance exercise will be determined when the Factory Acceptance Tests (Section 4.2.2) are completed and Test Data Sheets are submitted.

4.2.3 Site Acceptance Tests

Site acceptance tests shall be conducted by the contractor after installation and shall consist of all tests specified by the approved test procedures (Section 3.6.5) or other tests as required to show compliance with specified requirements.

4.3 Maintenance Records

During system debugging prior to and during factory and site acceptance tests an informal maintenance log which lists malfunctions, their location in the system, and how they are repaired shall be kept. Odd situations, such as cases in which malfunctions disappear for reasons not clearly understood, shall also be recorded. Three copies of this record shall be furnished to the Contracting Officer at the completion of site acceptance tests if required, otherwise at the completion of factory acceptance tests.

4.4 Inspection of Design and Fabrication Status

Upon request from the FAA, the contractor shall make available for review at his facilities, at any stage of the Contract, all information regarding the design and fabrication status of the equipment being manufactured to this engineering requirement, except for proprietary data.

4.5 Notification of Readiness for Inspection

Notification of readiness for inspection shall be sent to the Contracting Officer at least seven days prior to the desired inspection start date.

4.6 Facilities for FAA Inspector

The contractor shall provide for the use of an FAA Inspector a desk (with lock), a typewriter, use of telephone (located at the desk) for official business in connection with the Contract (cost of long-distance calls made by the inspector to be borne by the FAA), and sufficient working space to permit him to perform his required duties adequately if required by the contract.

Appendix A
PDP-8/DSDT INTERFACE

A.1 DISPLAY COMMAND WORDS

The PDP-8 Computer controls the DSDT display by transmitting commands over its 12-bit interface to the display. The commands specify pertinent control information and define the symbols which are to be added to or deleted from the display. The various types of 12-bit command words and their bit contents are shown in Figure A-1.

The command words are composed of op-code bits and data bits. The most significant bit of each command word is used to differentiate an op-code word from a data word (a 0 defines an op-code word). The next most significant bits in an op-code word define the type of command being transmitted -- either character, vector, no-op, branch or control. The various types of commands are considered individually below.

A.1.1 CHARACTER COMMAND

The character command is used to specify randomly placed characters to the display. It requires the transmittal of three words -- the first containing the op-code and character code, the second the X position of the character, and the third the Y position. The X and Y values define the coordinates on the CRT where the center of the character is to be placed. The character selection is made based on the character code bits.

When characters are being displayed on a horizontal line in typewriter fashion, only the first two 12-bit words of the character command need be transmitted once the line value (Y) has been established. The display will store and maintain each parameter, such as Y position, until that parameter is commanded to change by a subsequent data word of the same type.

A.1.2 VECTOR COMMAND

The vector command is used to construct randomly placed single or chained vectors. The specification of vector starting points require the transmittal of three words, however vector end points and chained vectors require five words -- op-code, X position, Y position, ΔX or ΔY.

The construction of a vector is begun by defining one end point via the first three vector command words. The op-code word with the vector start bit set to "1" is transmitted plus the X and Y positional values. Whenever the vector start bit is set, the beam motion will be blanked and the ΔX and ΔY values need not be transmitted. In response to these three words, the display positions the beam to the proper coordinates on the CRT.

To actually draw the vector, the other vector end point is defined using all five words. The beam is unblanked and moves to the new end point at a constant velocity -- thus constructing the commanded vector. Vectors can be chained together by continuously specifying new vector end points (one at a time) using the complete vector command of five words. ΔX and ΔY are the arithmetic differences between the end coordinates and the starting coordinates.

A.1.3 NO-OP COMMAND

This command causes no action on the display.

A.1.4 BRANCH COMMAND

The Branch Command can be used to cause the display to jump to another section of PDP-8 memory and to continue accessing display command words starting at the new address. The new address is composed of 12 bits -- 11 bits are stored in word 2 of the command and the Most Significant Bit (MSB), called "Branch High", is stored in word 1.

A.1.5 CONTROL COMMAND 1

This command is used to either set the intensity level of the display or to command an erase operation. Six data bits are provided to supplement either operation. A logical 1 in the erase data bit associates the 6 bits with the erase operation; likewise, a 1 in the Intensity Data bit defines the data as intensity controls.

A.1.5.1 Erase

The MSB in the 6-bit data field being set places the display in a selective erase mode. In this mode, subsequent unblanked beam motion causes symbols in its path to be erased. A different Control Command 1 must be transmitted to reset the selective erase bit when leaving this mode of operation.

The second most significant bit being set places the display in the flood erase mode. In this mode, the entire display area is erased -- either completely or partially depending on the duration of the erase pulse. The last 4 bits of data define 16 levels of erase duration according to the following convention: all 4 bits being 0 gives the maximum erase period, while all bits set to a 1 gives the minimum erase period. A single flood erase action will occur each time such a command is issued.

A.1.5.2 Intensity

The six data bits are used to provide 64 symbol intensity levels using the following convention: the all zeros value turns the intensity off, while the all ones value select the maximum intensity. Once an intensity level is established, it remains active until a subsequent intensity command is issued to change the value.

A.1.6 CONTROL WORD 2

This control command is used to transmit multiple CRT selections, beam settling time delays, and character size selections to the display. Four data bits are provided to supplement the selected function as described below.

A.1.6.1 CRT Selection

When the display system uses more than one CRT it is necessary to route the symbols to the proper CRT. This is accomplished by the 4 bits of data as follows:

Bit 1 - CRT #1 Select - This bit being set routes all subsequent data to CRT #1.
Bit 2 - This bit being set will route subsequent symbols to CRT #2.
Bit 3 & 4 - Spare.

If neither Bit 1 or 2 is set, all subsequent symbols will not appear on either display.

A.1.6.2 Positioning Delay Selection

The 4 data bits select the amount of "settling" time allowed to position the beam prior to constructing the requested symbol. When all these bits are zero, a random positioning delay is selected that is adequate for any deflection over the entire screen.

Bit 1 - 1/2 Screen Delay - This delay can be used to save time if the position change between symbols is less than 1/2 the screen width in both axes.
Bit 2 - 1/4 Screen Delay - This allows additional time savings for deflections less than 1/4 the screen width in both axes.
Bit 3 - Not used - must always be 0.
Bit 4 - Type Mode Delay - This bit being set causes the minimum positioning delay. It is used between successive characters on a typewritten line.

A.1.6.3 Character Size - The 4 data modifier bits are used to select one of 16 character sizes according to the following convention: all 4 bits being 0 select the smallest character size, while all 4 bits being 1 select the largest character size.

A.2 DATA TRANSFER METHOD

The PCP-8 used two methods of data transfer to communicate with the DSDT display. The first method is called Porgrammed Data Transfer (PDT) and involves control information being sent to the display directly from the PDP-8 accumulator. The other method, called Data Break Transfer (DBT) is a high speed direct memory access approach whereby the display fetches data directly from the PDP-8 memory as it requires it.

The computer combines both of these methods to effectively transfer command words to the display system using the interface lines shown in Figure A-2. The operations involved in a typical transfer are described below.

When the computer has new data to be output to the display, it constructs the required sequential display command words. The words are stored in list-form in a block of PDP-8 memory. When the list is complete, the data transfer to the display is ready to commence. The transfer of the actual display command words takes place using the Data Break method. However, the computer initiates the transfer by sending two Programmed Data Transfers to the display -- one specifies the starting address of the data list and the other specifies the word count. The display senses all programmed data outputs using its Device Selector function to select the particular ones addressed to it and to reject the others. When the proper device address compare results, the Device Selector accepts the data from the PDP-8 accumulator and loads it into the appropriate counter -- either address or word. When both counters have been loaded, the Interface Control logic is notified and the Data Break Transfer operation is ready to begin.

The display sends 12 bits of address (those received from the PDT) and raises the Break Request signal to the Data Break interface. It also holds the Transfer Direction and Single Cycle interface lines in the proper state to cause an output transfer from the PDP-8 in the single cycle mode. When the PDP-8 is ready to service the Break Request, it stores the memory address from the display, issues the Break State and Address Accepted signals, and fetches data from the requested memory location. When the PDP-8 has stored the accessed data in its Memory Buffer Register, it issues the BTS1 and BTS3 pulses to signal the display that the requested data is available on the Memory Buffer Data lines. The display increments its address counter, decrements its word counter and stores the data in a 12 bit data buffer register. The first word received is an op-code word, which is immediately processed. The display does not reset the Break Request signal at this time; it is held active to request another memory access from the PDP-8.

The op-code word is processed by decoding the op-code and routing the remaining bits to the appropriate register: character code, control word 1 or control word 2. The no-op command is not routed to any register and therefore it does have any effect on the display. The op-codes for the multiword commands are stored in the op-code decoder and used in conjunction with a 2 bit counter to route the data words which follow to the appropriate register: X, Y, ΔX, ΔY or address.

The Break Request signal remains active and the display continues to fetch, buffer, route and store data words until the Interface Control logic senses that all the data words for one character or one vector command have been received. The display knows that it has received all the words associated with one command when it senses that a subsequent op-code word (detectable as MSB=0) has been stored in its data buffer. The display temporarily holds the subsequent op-code word in its Data Buffer and does not process it until the previous command has been executed. At this time, the Interface Control logic resets the Break Request signal to temporarily discontinue the data flow and it then signals the display to process the character or vector command. The display enters the busy state and processes the command. When the command has been completed, the display leaves the busy state and the Interface Control logic is again enabled to fetch words from the PDP-8 memory.

The Branch, Control Word 1, and Control 2 commands are processed immediately and therefore do not require the display to enter the busy state.

The display continues its processing, one command at a time, until the Interface Word Counter is decremented to zero. Then the interface operation ceases and the display generates a Program Interrupt to inform the PDP-8 that it has read and processed all of the specified data.

Command	Bit 0	Field			
CHARACTER COMMAND	0	0 1 1 0	CHARACTER CODE - 7 BITS		
	1	X POSITION - 11 BITS			
	1	Y POSITION - 11 BITS			

Command	Bit 0	Field			
VECTOR COMMAND	0	0 1 1 1	VEC-TOR START	DON'T CARE	
	1	X POSITION - 11 BITS			
	1	Y POSITION - 11 BITS			
	1	ΔX - 11 BITS			
	1	ΔY - 11 BITS			

Command	Bit 0	Field			
NO-OP COMMAND	0	0 0 0	DON'T CARE		

Command	Bit 0	Field			
BRANCH COMMAND	0	0 0 1 0	BRANCH HIGH		
	1	BRANCH ADDRESS - 11 BITS			

Command	Bit 0	Field			
CONTROL COMMAND 1	0	0 1 0	ERASE DATA	INTEN-SITY DATA	MSB ERASE OR INTENSITY DATA - 6 BITS

Command	Bit 0	Field				
CONTROL COMMAND 2	0	0 0 1 1	CRT SELECT	POS DELAY	CHAR SIZE	MODIFIER DATA BITS 1 -- 4

Figure A-1. Display Command Words

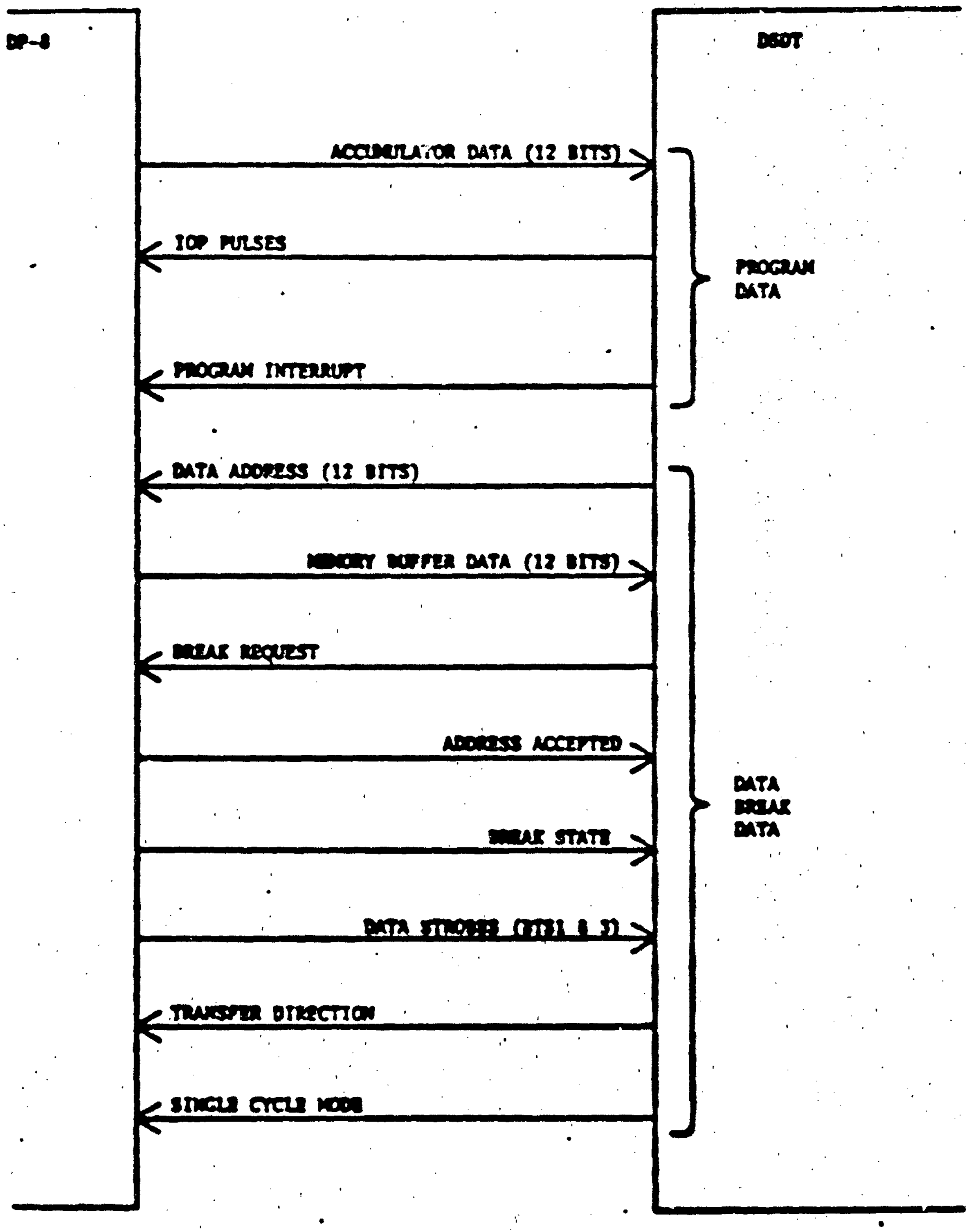

Figure A-2. PDP/DSDT Interface Lines

APPENDIX B

TECHNOLOGY NOTE

DATA DISPLAY TECHNOLOGIES

INDUSTRY REVIEW

By:
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Human Engineering Branch
FAA/NAFEC
March 1975

The purpose of this Technology Note is to list the device technologies that are presently being utilised or considered to produce displays for alphanumeric and graphic portrayal of information forms pertinent to a terminal (tower) information processing system. In addition, where applicable, the extent of the application of the technologies to available devices is described, and an indication of the pertinent performance levels is included.

The sources of information include published advertisements, published technical journal papers, measurements directly on devices, demonstrations of devices and/or technologies, technical discussions with industry and government engineers, and reference material from texts.

The following list enumerates the basic technologies that have been reviewed for possible application to the flight data display program for towers and TRACONS:

1. Direct view cathode ray tube
2. Projection display from stored image
3. Direct view mechanical
4. Direct view solid state
5. Direct view gas discharge (plasma)
6. Loser scanned projection

1. Direct View Cathode Ray Tube

Direct view CRT's comprise the largest groups of display device types in use in the FAA. Limited size and shape configurations are available, and special sizes, round, square, or rectangular, are within the technology capability, up to a diameter of 36 inches. High radius of curvature (flat tube) requirements limit the practical size to a 20-inch (viewable) diameter for safety purposes. Developments in front surface treatments and optical bandpass filters permit CRT's to be viewed, at adequate but reduced performance levels, in direct sunlight conditions.

The need to refresh CRT's imposes a limitation on the amount of data that can be displayed on a single CRT, and the capability for data enhancement by the use of polychromatic techniques is not easily nor inexpensively added.

Present costs range from about $100 for commercial or entertainment type CRT's in quantity to $900 for specially designed CRT's with specially designed filters. These prices can expect to increase primarily because of glass costs and the higher costs of small quantities (1000) for FAA purposes.

Improvements in phosphor efficiency, gun efficiency, deflection sensitivity, and spot size can be expected in the near term when coupled with specific requirements and development programs.

2. Projection display from stored image

a. Deformographics
b. Liquid crystal
c. Photochromic, thermochromic, electrochromic

A. Deformographics

Deformographics display devices, coupled with a Schlieren projection system, have reached a technology level that permits them to display polychromatic, high resolution, controlled persistence, long storage graphics and/or alphanumerics under diverse ambient brightnesses on a flat display surface that is nonreflective, inherently safe, and unlimited as to shape within a practical display diameter limit of approximately 8 feet. As compared to a graphics A/N CRT, it can display approximately four times the data with no flicker.

The only part of this device that is technologically sensitive is the deformable target. Over 150 targets have been assembled into small CRT bottles by two different vendors in order to establish operational reliability and reproducibility.

The performance level of the target is satisfactory, and further scheduled development is well underway to produce targets for specific, limited range, performance for individual applications.

Present costs for individual, multipurpose evaluation consoles, operating as stand-alone intelligent terminals are probably in the \$100,000 to \$200,000 range.

Near term display system costs in production quantities are expected to be in the \$10,000 to \$15,000 range.

The actual(in quantity) costs for the two main parts of the system, over and above a CRT terminal, are

a. Optical system - \$300
b. Deformographic Stoarage Display Tube - \$250 - \$300

These one-time costs are small compared to the overall cost of a display terminal.

The 150-watt projection lamp is expected to cost \$300-400 per year.

This display device, because of its versatility, may be applied as an approach towards a "universal" display system.

B. Liquid Crystal

Liquid crystal slides of approximately 1 to 4 square inches have been developed as light valves. A source of an image must be separately provided, and the image projected onto the crystal.

No commercially available devices exist today, but many are in the development stage. Resolution capability is expected to be very high but the device has not been evaluated to the degree that would permit even cautious optimism.

Because it would utilize a similar Schlieren projection system, it may be compatible with deformographics for certain monochromatic, high resolution applications.

C. Photochromic, Thermochromic, Electrochromic, etc.

There are a number of technologies that have resulted in demonstratable devices that have had potential for ATC displays. The photochromics, thermochromics, and cathodochromics are CRT's with special storage coatings in place of the phosphor. The slow response, slow erasure, reflection inefficiency, and projected contrast ratios have caused these devices to be eclipsed by the deformographics storage display tube as an image generator.

Electrochromics is a solid state version of a digitally controlled, chemically coated, point addressable array, which can alter the reflectivity, or color, of an addressed point under digital control.

The image is projected by Schlieren, Schmidt, or other conventional optical means.

A direct view display of electrochromics is also under consideration.

Projection display systems provide a particular advantage for the air traffic control function. Even though the final display size may be in the 1-square foot to 8-square feet range,

a - projection displays can be adjusted to provide irregular display areas for optimum console use,

b - they can be adjusted to allow variable display size for varying viewing distance conditions, c - they can be standardized for multiple applications using the same basic hardware,

d - they can utilize the best, highest resolution, highest contrast, etc. (depending on requirements) image sources, even though the sources may be severely limited in size due to manufacturing technology,

e - they permit upgrading of the image source, as technology allows, without major electrical hardware changes, and no optical hardware changes.

3. Direct View Mechanical

a. Mechanical projection, small scale
b. Passive, magnetic movement

a. Device development has been limited in this area due to great competition from solid state devices. Multiple legend devices, where peredetermined and fixed formatting is acceptable, can be applied for small data displays.

Where cost and space are prime considerations, several square inches can be allotted to one of a number of this type of indicator.

b. A recent development has been in the area of digitally controlled, magnetically actuated, magnetic particles. By addressing a small area, the particles in that area are rotated to produce a contrasting color. This has not been demonstrated, but the concept is under study by industry.

4. Direct View, Solid State

a. Light Emitting diodes
b. Liquid crystal
c. Thin film (Electroluminescent)

a. LED's are commercially available as low cost, high reliability, high contrast individual character displays. They can be stacked to produce arrays that have a practical limit only with respect to the addressing technique that connects the LED's and provides data control and refresh. For displays up to 500 character positions, practical devices have been made and demonstrated. The use of alpha/numerics and TTY character fonts is restricted to a 5 x 7 dot matrix.

They are very amenable to custom sized arrays, but the smallest character size is approximately 0.3 inches. At least 4 colors are available, but only in separate characters. The next generation of LED devices will be using doped GaP or GaAs and will be able to generate four colors under digital control within a single character.

b. Liquid crystal devices are beyond initial stages of development and are being used for small character size displays such as clocks, wrist watches, calculators, etc. They cannot be fabricated in panels larger than a few square inches. The high resolution potential indicates a future use, as an image control and light amplifier in a projector system, which could be quite small in size. For the near future, it is not an applicable technology. It requires an optical source at present for the information; however, their film technology developments (see below) have been successfully applied to produce larger dot arrays, which appear to hold greater promise for applying the technology. The dot array concept places a discrete LCD at a digitally selected point as an electronically switched spot that can act as a controlled on/off light reflector. A/N are produced on a matrix basis. Questions about life and failure modes have not been satisfactorily answered to encourage larger sized displays.

c. Thin film - Westinghouse Research Labs have been able to develop a method of using thin film technology on a glass plate to deposit the control and drive circuits for a dot addressable display system in an area small enough to be covered by the addressed dot. This appears to solve an addressing and hardware problem for panels of LCD or electroluminescent materials, which are applied also using thin film techniques. The addressing of portions of one million dots (for a 1000 by 1000 point display) is still considered the limiting factor to practical digital panels. They have demonstrated their techniques on a 6 inch by 6 inch panel with 14,000 points.

5. Direct View Plasma

Plasma panels are manufactured by at least four companies and permit displays up to 256 characters, or 8.5 by 8.5 inches in the case of the discrete point address type.

Owens-Illinois produces several sizes up to 8.5 x 8.5 inches and appear to see a limit at 17 inches.

Burroughs produces many types up to an 8 x 32 character display, and a 12 x 40 character display will be marketed at the end of 1975.

Control Data Corporation produced a number of sizes up to 16 by 80 or 20 x 64 characters. They have also built, for the Air Force, an 8-inch by 32-inch panel with a resolution of 33 lines per inch.

Plasma panels presently suffer from low contrast in high ambients, but can be applied as small package displays in or near existing consoles in TRACON environments.

Questions relating to life and reliability still have not been adequately answered.

Multicolor types are not presently practical, but developments in several color technologies are underway.

6. Laser Scanned Projection Systems

At least two approaches are being pursued for utilizing the high energy, small spot size laser beam to create a display.

Several companies market a laser projector, which is analogous to a large CRT without the glass bottle. A laser beam is mechanically or electrically scanned to sweep an image on a screen. This has proven successful but the size of the package does not presently permit its practical consideration for smaller display systems. It was designed as a large screen projector.

Similarly, a laser is used to scan, a barium coated thermoplastic film, which is then used in a Schlieren projection system. This can be packaged in general cubic feet, and may be a potential competitor for other medium and large screen projection systems. This device does not reuse the film, but the technology exists to incorporate a reuseable film process in the system.

Laser devices are not under consideration as small display devices.

APPENDIX C

STATEMENT OF WORK, CONTRACT DOT FA74NA-1103

Attachment #1

DEFORMOGRAPHIC STORAGE DISPLAY SYSTEM

STATEMENT OF WORK

May 30, 1974

Section 1
INTRODUCTION

The intent of this procurement is to obtain a Deformographic Storage Display Tube (DSDT) console from the International Business Machines Corporation (IBM). This is to be a prototype console for evaluation purposes. It will be used at the Federal Aviation Adminstration's (FAA) National Aviation Facilities Experimental Center (NAFEC) to assess the potential of such a device for use in the National Airspace System.

The equipment to be provided is described in the applicable sections of the "Engineering Requirement for a Deformographic Storage Display System" (ER) dated May 15, 1974. Since the ER is written to cover various configurations and options, this work statement defines the particular requirements that are applicable to this procurement. Section 3 contains references to every section of the ER and defines the applicability of each provision of the ER to this specific procurement.

Section 2 defines the scope of this contract and Appendix A provides a technical description of the interface between the equipment to be provided under this contract and the FAA's PDP-8 computer which will be used to control this equipment.

Section 2
SCOPE

The actual equipment to be delivered under this contract is that described in sections 3.3.1 and 3.3.1.1 of the ER as further delineated in the associated paragraphs in section 3 of this Statement of Work. The contractor shall be responsible for all design, development, fabrication, checkout performance testing and delivery of the equipment identified in section 3 herein.

Certain other items and activities, such as spare parts, installation services and site acceptance tests will be provided by the contractor, if requested by the FAA in accordance with the provisions of section 3 herein, but at additional cost over and above the basic scope of this procurement.

The anticipated period of performance is 270 days from contract award to delivery at the NAFEC facilities.

Section 3

ENGINEERING REQUIREMENT CROSS REFERENCE

The following paragraphs define the applicability to this specific procurement of each individual section in the ER dated May 15, 1974. All of the following references in which the symbol "§" is used to indicate a section number refer to the designated sections of that ER.

§1. Directly applicable to this procurement with the understanding that the ER covers various configurations and options which may be procured at a later date, but this procurement involves only a single configuration and certain specific provisions of the ER as further defined below.

§2 - 2.3.3 As stated in the §1 of the ER, these documents would apply to any future procurement of equipments for actual use in the National Airspace System, but are to be "used as a guide whenever feasible" in this contract.

§2.4 Directly applicable with the understanding that this Statement of Work (SOW) is a part of the contract referred to in (a).

§3.1 Same applicability as §1. Further definition of interface requirements is provided in Appendix A of this SOW.

§3.1.1.1a This contract is for an En-Route Console Equipment configuration as further defined in reference to §3.3.1.1.

§3.1.1.1b Not applicable to this contract.

§3.1.1.2 - 3.1.2.5 Applicability to this contract is as defined below in reference to §3.4.5 - 3.4.8 and §3.6 - 4.6.

§3.2 Directly applicable to this contract.

§3.3.1 Items a, c and d are applicable to the extent defined herein. Item b is not applicable to this contract. Only an En-Route console configuration is covered by this contract.

§3.3.1.1 The Government Furnished Equipment referenced in this section shall be delivered to the contractor's facility within 30 days of direction by the FAA to proceed on this contract. The equipment to be installed in the console under this contract shall consist of the following:

1) One Deformographic Storage Display Tube (DSDT).
2) One light source and one Schlieren optical system.
3) The deflection drivers, video driver and erase circuitry required for one DSDT.
4) One set of electronics as defined in subsection (4) in this section of the ER.
5) One viewing screen as defined in §3.4.2.
6) Those power supplies required for the equipment defined in 1) through 4) above.

§3.3.1.2 Not applicable to this contract.

§3.3.2 Directly applicable. The contractor is not required to take corrective action (except by proper application of the changes clause of this contract) to circumvent any discrepancy of the Government's PDP-8 or its interfaces from the descriptions contained in the referenced documents as provided to the contractor by the FAA.

§3.4.1 Only the En-Route console configuration as further defined herein is applicable to this contract.

§3.4.2 Directly applicable to this contract.

§3.4.3 Not applicable to this procurement.

§3.4.4 - 3.4.4.2 No modification of existing designs or design practices are required. Applicability is as defined in reference to §1.

§3.4.4.3 - 3.4.4.4 Directly applicable.

§3.4.4.5 Directly applicable. The PDP-8 is considered to be in the category of "available test equipment" mentioned in this section.

§3.4.5 Outside the scope of this immediate procurement.

§3.4.6 This requirement may be satisfied by providing a list of the standard test equipment used by the contractor in maintaining this equipment.

§3.4.7 - 3.4.7.2 Directly applicable.

§3.4.8 Directly applicable with the understanding that the actual cost and procurement of any spares is outside the scope of this procurement.

§3.4.9 - 3.4.9.3 These paragraphs indicate the Mean Up and Down Times that the FAA desires that equipment of this type will achieve. However, they "are not subject to tests or demonstrations" and do not constitute a warranty of any kind.

§3.5 - 3.5.7.4 Directly applicable except for any references to a dual-tube configuration. It is understood that while all of the optical steps described in 3.5.5.1 will be provided, color is considered a potential growth feature and no specific color performance is required, nor will any special electronics to generate color data be provided under this contract. It is further understood that the phrase "written only once" in §3.5.1 does not preclude multiple scanning of data in the process of writing that data as long as the writing rates of §3.5.14.1 are satisfied: but rather, is meant to preclude any refresh of that data as with a conventional phosphor CRT.

§3.5.7.5 Not applicable.

§3.5.8 - 3.5.14 Directly applicable, except 3.5.9 which has been deleted.

§3.5.15 The interface requirements of this equipment with the PDP-8 shall be as defined in Appendix A of this SOW. All programming of the PDP-8 and other activities required to define and control the data and formats to be displayed by this equipment are outside the scope of this procurement.

§3.6.1 It is anticipated that the bulk of the documentation provided by the contractor will be copies of, or derived from, documents in existence at the time of contract award. Therefore, in order to reduce the expense to the government, the primary requirement is that they be readable and usable for the purposes defined herein. Except as otherwise stated in the applicable sections of the ER or this SOW, delivery of one copy of each required document shall be made no later than at the time of delivery of the prime equipment under this contract.

§3.6.2 Directly applicable.

§3.6.3 Directly applicable. The data intended by the phrases "control requirements, special software sequences necessary to the performance of the DSDT system" is that found in Appendix A of this SOW.

§3.6.4 This plan shall be submitted at least 120 days prior to the start of Acceptance Testing. Approval and/or comments will be provided by the FAA within 30 days of receipt of this plan.

§3.6.5 and 3.6.6 These procedures and sample test data sheets shall be submitted at least 60 days prior to the start of Acceptance Testing, and the FAA's response, either approving or commenting on the submission, shall be provided within 30 days.

§3.6.8 and 3.6.9 Directly applicable.

§3.6.10 This list shall be provided no later than 120 days from contract award. The actual provision of any and all spare parts is outside the scope of this contract.

§3.7.1 Installation materials and services shall be provided by the contractor as requested by the FAA on the basis of actual time and materials, based on the man-day rates and other considerations specified in the cost portion of this contract, over and above the base cost of this procurement.

§3.7.2 and 3.7.3 Directly applicable.

§4.1 - 4.2.3 Directly applicable, except that if the FAA elects to hold site acceptance tests under the meaning of these sections, the performance of these tests by the contractor's personnel shall be at the man-day rates established by this contract and shall be over and above the base cost of this procurement. Notification of intent to hold site acceptance tests shall be made by the FAA at least 60 days prior to delivery of the equipment.

§4.3 These records may be copies of informal notebooks kept by the engineers and technicians in the process of system debugging.

§4.4 and 4.5 Directly applicable, except for IBM-owned proprietary data.

§4.6 Access to such facilities as are listed in this section will be provided, but not necessarily for the exclusive use of an FAA Inspector.

§5.1 The FOB destination shall be the NAFEC facilities at Atlantic City, NJ.

Appendix A
PDP-8/DSDT INTERFACE

A.1 DISPLAY COMMAND WORDS

The PDP-8 Computer controls the DSDT display by transmitting commands over its 12-bit interface to the display. The commands specify pertinent control information and define the symbols which are to be added to or deleted from the display. The various types of 12-bit command words and their bit contents are shown in Figure A-1.

The command words are composed of op-code bits and data bits. The most significant bit of each command word is used to differentiate an op-code word from a data word (a 0 defines an op-code word). The next most significant bits in an op-code word define the type of command being transmitted -- either character, vector, no-op, branch or control. The various types of commands are considered individually below.

A.1.1 CHARACTER COMMAND

The character command is used to specify randomly placed characters to the display. It requires the transmittal of three words -- the first containing the op-code and character code, the second the X position of the character, and the third the Y position. The X and Y values define the coordinates on the CRT where the center of the character is to be placed. The character selection is made based on the character code bits.

When characters are being displayed on a horizontal line in typewriter fashion, only the first two 12-bit words of the character command need be transmitted once the line value (Y) has been established. The display will store and maintain each parameter, such as Y position, until that parameter is commanded to change by a subsequent data word of the same type.

A.1.2 VECTOR COMMAND

The vector command is used to construct randomly placed single or chained vectors. The specification of vector starting points require the transmittal of three words, however vector end points and chained vectors require five words -- op-code, X position, Y position, ΔX and ΔY.

The construction of a vector is begun by defining one end point via the first three vector command words. The op-code word with the vector start bit set to "1" is transmitted plus the X and Y positional values. Whenever the vector start bit is set, the beam motion will be blanked and the ΔX and ΔY values need not be transmitted. In response to these three words, the display positions the beam to the proper coordinates on the CRT.

To actually draw the vector, the other vector end point is defined using all five words. The beam is unblanked and moves to the new end point at a constant velocity -- thus constructing the commanded vector. Vectors can be chained together by continuously specifying new vector end points (one at a time) using the complete vector command of five words. ΔX and ΔY are the arithmetic differences between the end coordinates and the starting coordinates.

A.1.3 NO-OP COMMAND

This command causes no action on the display.

A.1.4 BRANCH COMMAND

The Branch Command can be used to cause the display to jump to another section of PDP-8 memory and to continue accessing display command words starting at the new address. The new address is composed of 12 bits -- 11 bits are stored in word 2 of the command and the Most Significant Bit (MSB), called "Branch High", is stored in word 1.

A.1.5 CONTROL COMMAND 1

This command is used to either set the intensity level of the display or to command an erase operation. Six data bits are provided to supplement either operation. A logical 1 in the erase data bit associates the 6 bits with the erase operation; likewise, a 1 in the Intensity Data bit defines the data as intensity controls.

A.1.5.1 Erase

The MSB in the 6-bit data field being set places the display in a selective erase mode. In this mode, subsequent unblanked beam motion causes symbols in its path to be erased. A different Control Command 1 must be transmitted to reset the selective erase bit when leaving this mode of operation.

The second most significant bit being set places the display in the flood erase mode. In this mode, the entire display area is erased -- either completely or partially depending on the duration of the erase pulse. The last 4 bits of data define 16 levels of erase duration according to the following convention: all 4 bits being 0 gives the maximum erase period, while all bits set to a 1 gives the minimum erase period. A single flood erase action will occur each time such a command is issued.

A.1.5.2 Intensity

The six data bits are used to provide 64 symbol intensity levels using the following convention: the all zeros value turns the intensity off, while the all ones value select the maximum intensity. Once an intensity level is established, it remains active until a subsequent intensity command is issued to change the value.

A.1.6 CONTROL WORD 2

This control command is used to transmit multiple CRT selections, beam settling time delays, and character size selections to the display. Four data bits are provided to supplement the selected function as described below.

A.1.6.1 CRT Selection

When the display system uses more than one CRT it is necessary to route the symbols to the proper CRT. This is accomplished by the 4 bits of data as follows:

Bit 1 - CRT #1 Select - This bit being set routes all subsequent data to CRT #1.

Bit 2 - This bit being set will route subsequent symbols to CRT #2.

Bit 3 & 4 - Spare.

If neither Bit 1 or 2 is set, all subsequent symbols will not appear on either display.

A.1.6.2 Positioning Delay Selection

The 4 data bits select the amount of "settling" time allowed to position the beam prior to constructing the requested symbol. When all these bits are zero, a random positioning delay is selected that is adequate for any deflection over the entire screen.

Bit 1 - 1/2 Screen Delay - This delay can be used to save time if the position change between symbols is less than 1/2 the screen width in both axes.

Bit 2 - 1/4 Screen Delay - This allows additional time savings for deflections less than 1/4 the screen width in both axes.

Bit 3 - Not used - must always be 0.

Bit 4 - Type Mode Delay - This bit being set causes the minimum positioning delay. It is used between successive characters on a typewritten line.

A.1.6.3 Character Size - The 4 data modifier bits are used to select one of 16 character sizes according to the following convention: all 4 bits being 0 select the smallest character size, while all 4 bits being 1 select the largest character size.

A.2 DATA TRANSFER METHOD

The PDP-8 used two methods of data transfer to communicate with the DSDT display. The first method is called Porgrammed Data Transfer (PDT) and involves control information being sent to the display directly from the PDP-8 accumulator. The other method, called Data Break Transfer (DBT) is a high speed direct memory access approach whereby the display fetches data directly from the PDP-8 memory as it requires it.

The computer combines both of these methods to effectively transfer command words to the display system using the interface lines shown in Figure A-2. The operations involved in a typical transfer are described below.

When the computer has new data to be output to the display, it constructs the required sequential display command words. The words are stored in list-form in a block of PDP-8 memory. When the list is complete, the data transfer to the display is ready to commence. The transfer of the actual display command words takes place using the Data Break method. However, the computer initiates the transfer by sending two Programmed Data Transfers to the display -- one specifies the starting address of the data list and the other specifies the word count. The display senses all programmed data outputs using its Device Selector function to select the particular ones addressed to it and to reject the others. When the proper device address compare results, the Device Selector accepts the data from the PDP-8 accumulator and loads it into the appropriate counter -- either address or word. When both counters have been loaded, the Interface Control logic is notified and the Data Break Transfer operation is ready to begin.

The display sends 12 bits of address (those received from the PDT) and raises the Break Request signal to the Data Break interface. It also holds the Transfer Direction and Single Cycle interface lines in the proper state to cause an output transfer from the PDP-8 in the single cycle mode. When the PDP-8 is ready to service the Break Request, it stores the memory address from the display, issues the Break State and Address Accepted signals, and fetches data from the requested memory location. When the PDP-8 has stored the accessed data in its Memory Buffer Register, it issues the BTS1 and BTS3 pulses to signal the display that the requested data is available on the Memory Buffer Data lines. The display increments its address counter, decrements its word counter and stores the data in a 12 bit data buffer register. The first word received is an op-code word, which is immediately processed. The display does not reset the Break Request signal at this time; it is held active to request another memory access from the PDP-8.

The op-code word is processed by decoding the op-code and routing the remaining bits to the appropriate register: character code, control word 1 or control word 2. The no-op command is not routed to any register and therefore it does have any effect on the display. The op-codes for the multiword commands are stored in the op-code decoder and used in conjunction with a 2 bit counter to route the data words which follow to the appropriate register: X, Y, ΔX, ΔY or address.

The Break Request signal remains active and the display continues to fetch, buffer, route and store data words until the Interface Control logic senses that all the data words for one character or one vector command have been received. The display knows that it has received all the words associated with one command when it senses that a subsequent op-code word (detectable as MSB=0) has been stored in its data buffer. The display temporarily holds the subsequent op-code word in its Data Buffer and does not process it until the previous command has been executed. At this time, the Interface Control logic resets the Break Request signal to temporarily discontinue the data flow and it then signals the display to process the character or vector command. The display enters the busy state and processes the command. When the command has been completed, the display leaves the busy state and the Interface Control logic is again enabled to fetch words from the PDP-8 memory.

The Branch, Control Word 1, and Control 2 commands are processed immediately and therefore do not require the display to enter the busy state.

The display continues its processing, one command at a time, until the Interface Word Counter is decremented to zero. Then the interface operation ceases and the display generates a Program Interrupt to inform the PDP-8 that it has read and processed all of the specified data.

	MSB		
CHARACTER	0	0 1 1 0	CHARACTER CODE - 7 BITS
COMMAND	1	X POSITION - 11 BITS	
	1	Y POSITION - 11 BITS	

	0	0 1 1 1	VEC-TOR START	DON'T CARE
VECTOR	1	X POSITION - 11 BITS		
COMMAND	1	Y POSITION - 11 BITS		
	1	ΔX - 11 BITS		
	1	ΔY - 11 BITS		

NO-OP COMMAND	0	0 0 0	DON'T CARE

BRANCH	0	0 0 1 0	BRANCH HIGH	
COMMAND	1	BRANCH ADDRESS - 11 BITS		

CONTROL COMMAND 1	0	0 1 0	ERASE DATA	INTEN-SITY DATA	MSB ERASE OR INTENSITY DATA - 6 BITS

CONTROL COMMAND 2	0	0 0 1 1	CRT SELECT	POS DELAY	CHAR SIZE	MODIFIED EX[illegible] BITS 1 --

Figure A-1. Display Command Words

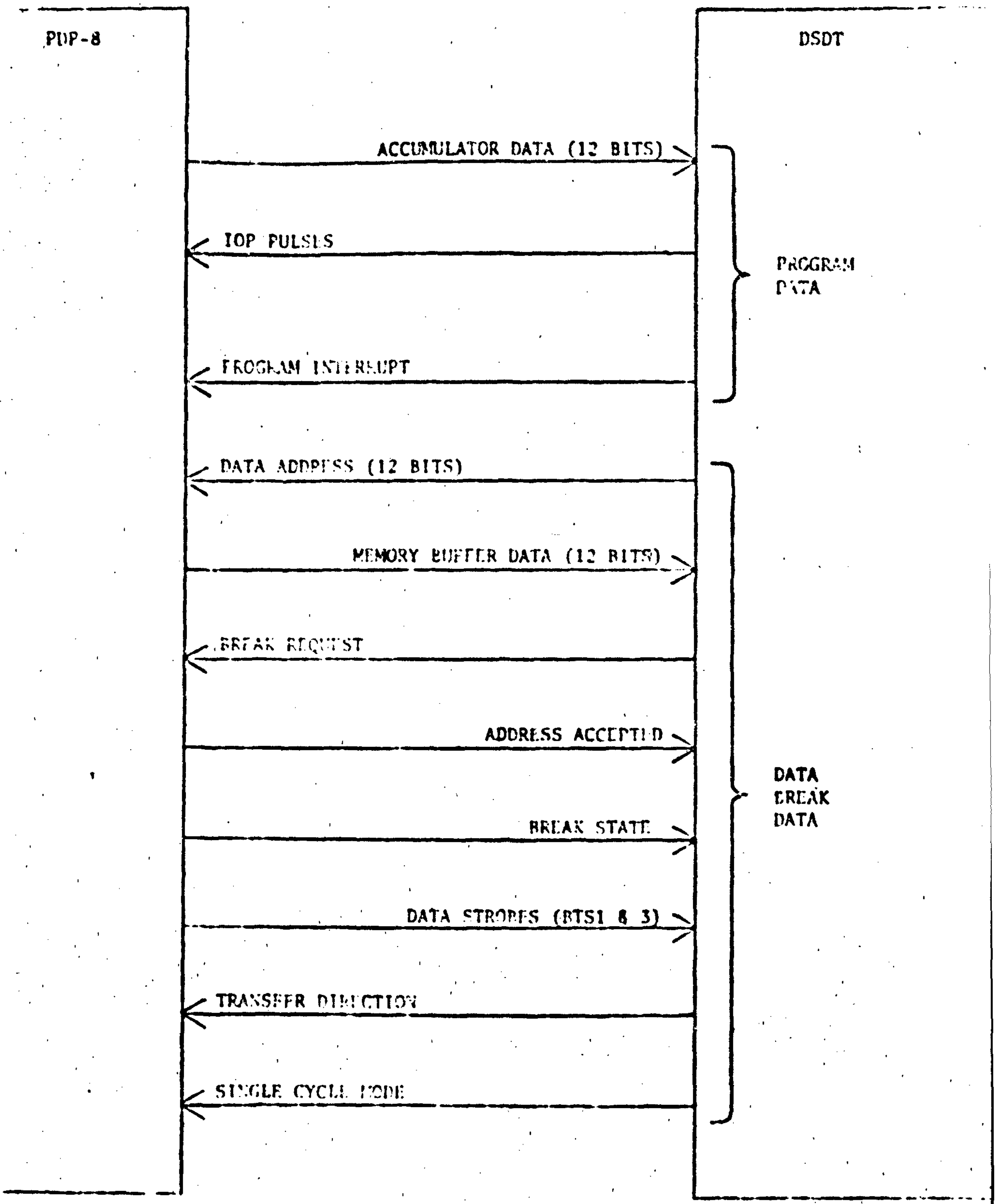

Figure A-2. PDP/DSDT Interface Lines

APPENDIX D

ACCEPTANCE TEST PLAN, IBM CORP., CONTRACT DOT FA74NA-1103

952 5497 4

FAA DEFORMOGRAPHIC STORAGE DISPLAY SYSTEM

ACCEPTANCE TEST PLAN FOR A DEFORMOGRAPHIC STORAGE DISPLAY SYSTEM

M35 Staff

IBM NO 75-M35-002

REVISIONS

ORIGINATING GROUP Projection Display Systems

CONTENT APPROVED BY

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CONTRACT NO* DOT FA74NA-1103

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Section 1

ACCEPTANCE TEST PLAN FOR A DEFORMOGRAPHIC STORAGE DISPLAY (DSD) SYSTEM

1.1 SCOPE

This document defines the design parameters that are to be verified in the performance of the Deformographic Storage Display (DSD) System during an acceptance test procedure.

This document provides an overview of the tests to be performed on the DSD System and is not intended to describe in detail how the tests will be performed at specific test points.

Three supporting documents shall be provided to accomplish the detailed acceptance test. The documents are listed in 2.2 and 2.3.1.

Section 2

APPLICABLE DOCUMENTS

2.1 SPECIFICATIONS - IBM

EA3325 Engineering Requirement for a Deformographic Storage Display System June 10, 1974

2.2 SPECIFICATIONS - IBM

75-M35-003 Acceptance Test Procedure for the Deformographic Storage Display (DSD) System

75-M35-004 Deformographic Storage Display (DSD) System Operation and Maintenance Instructions

2.3 OTHER

2.3.1 IBM DOCUMENTS

75-M35-001 Deformographic Storage Display (DSD) System, Description of

2.3.2 DIGITAL EQUIPMENT CORPORATION DOCUMENTS

PDP8/i & PDP8/L Small Computer Handbook

Section 3

REQUIREMENTS

3.1 GENERAL

This Acceptance Test Plan document defines those tests required to demonstrate that the DSD System complies with the requirements of the Engineering Requirement for a Deformographic Storage Display System, FAA # EA3325. The DSD System will be tested while various test programs are utilized in the PDP-8/I processor to provide the DSD with the proper stimuli to present the desired display patterns for test purposes.

Some requirements of the DSD are expressed in terms of display parameters, i.e., brightness, contrast, storage time, erase time, etc. These parameters shall be measured at the display screen surface with optical measuring devices to obtain quantitative data.

3.1.1 TEST EQUIPMENT AND TEST LEVELS

The DSD shall be provided the necessary stimuli by a PDP 8/I computer or equivalent to exercise the logic and analog circuitry as outlined in this document.

3.1.2 UNIT TEST PROCEDURE (EQUIPMENT ACCEPTANCE TEST PROCEDURE)

Where the requirements of this document are implemented by an DSD Acceptance Test Procedure (IBM 75-M35-003), the test procedure shall reflect the exact requirements of this document. The test procedure shall include as part of its documentation, calculations, measurements, etc., to show that the tests and tolerances utilized are equivalent to those specified herein.

3.1.3 FAILURE CRITERIA

The DSD shall meet all requirements defined in this document.

3.2 TEST CONDITIONS

The DSD shall be cooled by ambient air during the acceptance test, with all parts and louvers uncovered to allow the free passage of cooling air.

Temperature	-	Room ambient (up to 85° Fahrenheit maximum)
Humidity	-	To 90% R.H. maximum
Light	-	Six foot candles maximum incident light from overhead sources.

3.2.1 TEST CONFIGURATION

The DSD shall be tested using a PDP-8/I computer, or equivalent, as the test controller. The computer shall be connected to the DSD through a DW08-B interface adapter unit to obtain the proper signal polarity and levels. Test programs shall be available which will exercise the DSD electronics to drive the DSD deflection and video circuits to produce the desired test patterns, and test point outputs necessary for electrical evaluation and parameter measurement.

3.2.2 TEST INSTRUMENTATION

All oscilloscopes, light meters, etc., used in the performance of the acceptance testing shall be calibrated according to the procedures utilized at the testing site. This calibration shall be evidenced by a visible tag or stamp on the equipment. The tag shall indicate the date of the last calibration and either the due date of the next calibration or the normal calibration interval.

3.2.3 SPECIAL EQUIPMENT REQUIREMENTS

The equipment specified below shall be required in addition to the PDP-8/I and the DW08-B specified in 3.2.1.

3.2.3.1 Computer Test Programs

The DSD testing will require suitable test programs for use by the PDP-8/I to exercise the DSD to generate the test patterns.

3.2.3.2 Display Screen Grid Overlays

A scribed clear plexiglass with test pattern configurations is required to perform the registration accuracy tests.

3.2.4 ALIGNMENT AND ADJUSTMENT

Prior to the start of the acceptance test, all adjustable gains and biases associated with the processor analog electronics, and the deflection and video circuits in the DSD console, shall be properly set in accordance with the DSD System Operation and Maintenance Document, IBM #75-M35-004.

3.3 ELECTRICAL

The following subsections describe the electrical requirements for acceptance tesing of the DSD System.

3.3.1 POWER DISTRIBUTION TEST

Verification of the power grounding and critical signal connections shall be made before applying power to the DSD System.

3.3.2 COOLING FAN OPERATION

Verification shall be made to insure that all cooling fans are operating when power is applied.

3.3.3 POWER SUPPLY ADJUSTMENT

The voltage level from each regulated supply shall be verified to be within ±5% of its nominal voltage.

3.3.4 VOLTAGE SEQUENCING

The power on and off sequencing of the high-voltage section of the DSD console shall be verified for proper operation.

3.3.5 AC INPUT POWER REQUIREMENTS

The nominal AC input power requirements for the two sections of the DSD System are:

	DSD Processor	DSD Console
Voltage	120 V ± 10%	120 V ± 10%
Frequency	60 ± 2 Hz	60 ± 2 Hz
Service	Single phase	Single phase
Power (nominal)	130 Watts	130 Watts

3.3.6 DSD SYSTEM INTERFACE SIGNAL ELECTRICAL CHARACTERISTICS

All DSD System external interface signals are those associated with the PDP-8/I computer. All signals are the standard Digital Equipment Corporation (DEC) -3 Volt interface signals, utilizing the parallel data bus concept. All design parameters, as outlined in "PDP8/I & PDP8/L Small Computer Handbook", shall be followed to assure compatible interfacing.

3.4 <u>LONG TERM PERFORMANCE REQUIREMENTS</u>

Certain performance requirements, as discussed below, shall be performed as an operational check of the test parameters during final checkout and test prior to the final acceptance test. Verification of compliance with these requirements shall be based on the test logs and other documentation available at the time of the acceptance test.

3.4.1 DISPLAY MAGNIFICATION

It shall be demonstrated by mathematical proofs that a display magnification of 7.5 to 18 times is obtainable with the DSD optical system, rather than actual removal and demonstration of the optical system from the DSD Console.

3.4.2 STABILITY

The DSD equipment will be observed to verify that the brightness and focus controls will not need adjustment to meet the performance requirements. The data will be recorded in the equipment test log during checkout and prior to final acceptance tests.

3.4.3 CENTERING

A check shall be made to verify that the projected display center does not vary by more than 1/4 inch from the previous center position. The data will be recorded in the equipment test log.

3.4.4 CHARACTER SIZE

During the final equipment checkout, periodic checks shall be made to verify that the standard character size (IBM 75-M35-002, para. 3.5.9.3) remains within the specified tolerance.

3.5 <u>TEST REQUIREMENTS</u>

The following paragraphs specify the unit level tests to be performed on the DSD System. Testing shall be done using computer test programs which shall functionally exercise all portions of the system. Operation shall be verified through visual monitoring of the display presentations and performance measurement of the resultant visual parameters. Operator intervention shall be required to exercise the various DSD Console switches and computer control switches, and load the different computer test programs during the course of the test.

3.5.1 DSD SYSTEM INTERFACE TEST

All signals to or from the DSD System shall be functionally verified during testing. IBM 75-M35-004 lists all the signals in the interface. The signal interface is to either a DM01 multiplex unit and then to the PDP-8/I computer, or directly to the computer, dependent upon whether the test is being performed at NAFEC or IBM, respectively.

Interface measurements and continuity testing will be done as part of the system build-up and debug, and wiring lists and applicable documentation will be provided for spot checking during the acceptance test.

3.5.2 DISPLAY BRIGHTNESS TESTS

All brightness tests are to be performed in the ambient light specified in 3.2 to exclude the additive effects of the ambient light on the brightness readings.

3.5.2.1 Center Screen Data Brightness

Brightness measurements shall be made parallel to the optical path at the center of the viewing screen using a Model 2020 Gamma Scientific Photometer with microscope.

3.5.2.2 Brightness Control

The brightness control (neutral density filters) shall be implemented to provide four discrete increments of brightness from full brightness down to one-eight or less full brightness.

3.5.2.3 Brightness Variations

Brightness measurements of characters and vectors shall be made over various positions of the screen, including all four corners, to verify that there is no more than 60 percent variation in brightness across the entire screen according to the formula:

$$\frac{B_{max} - B_{min}}{B_{max}} \times 100 = \text{\% of brightness variation}$$

Near-area brightness variation shall be tested by measurement of brightness within a three-inch area and verifying that the variation is less than 40 percent according to the above formula.

3.5.3 CONTRAST RATIO TEST

With the ambient light specified in 3.2, several measurements of the contrast ratio shall be made. The brightness measurement of a display element (character or vector) shall be made, as well as the adjacent background, and the contrast ratio calculated according to the formula:

$$\text{Contrast ratio} = \frac{\text{Display element brightness}}{\text{Background brightness}}$$

and shall be at least 16.

Specular reflectivity of the screen shall be measured as less than 10 percent.

3.5.4 DISPLAY COLOR AND SHADES OF GRAY TESTS

3.5.4.1 Display Color Capability

Verify that the DSD System is capable of accepting the following optical stops. No specific test requirements need be met with the color stops.

1) White on black - conventional (clear) stop

2) Red and green on black - concentric ring stop

3) Four colors (red, green, yellow, white) on black - spatially-oriented four color stop.

3.5.4.2 Shades of Gray

With the conventional stop in place and the maximum brightness control setting, verify that the DSD System is capable of presenting six shades of gray on the viewing screen. Each successively brighter gray shade shall be at least 25% brighter than the preceding shade.

3.5.5 LINE WIDTH, RESOLUTION AND SPOT GROWTH TESTS

3.5.5.1 Line Width

Verify that the maximum line width in a cross-hatch test pattern is no greater than 0.040 inch anywhere on the screen at the 50 percent brightness points.

3.5.5.2 Resolution

While utilizing the resolution test pattern, verify that a pair of lines can be resolved when they are spaced no more than 0.035 inch (center to center) apart, with at least 20 percent modulation according to the formula:

$$\text{Percent modulation} = \frac{B_{max} - B_{min}}{B_{max}} \times 100$$

Where B_{max} is the line center brightness
B_{min} is the line pair overlap brightness.

3.5.5.3 Spot Growth

Verify that the line widths of the cross-hatch test pattern do not vary, from the narrowest line to the widest line, by a ratio of more than 1.4 to 1 over the entire screen surface.

3.5.6 LINEARITY AND REGISTRATION ACCURACY TESTS

3.5.6.1 Linearity

With the plexiglass overlay in place over the screen and the cross-hatch test pattern presented on the screen, verify that the size of any square in the image does not deviate by more than 0.15 inch from the size of the corresponding squares in the scribed line pattern on the overlay.

3.5.6.2 Rewrite Registration Accuracy

Demonstrate with the data block test pattern that a single block of data can be selectively erased and rewritten to within 0.030 inch in either axis of its original position. No other data shall be added or deleted anywhere else on the screen.

3.5.6.3 Overwrite Registration Accuracy

Without selectively erasing the data block of 3.5.6.2, verify that the rewriting of the subject data block can be done such that the overwritten data registers to within 0.030 inch.

3.5.6.4 Selective Erase Accuracy

Verify that the erasure of the data block of 3.5.6.2 is complete while not disturbing adjacent data blocks where the separation distance of the near elements in the two data blocks is 0.30 inch.

3.5.7 CENTERING TEST

Verify that the centering adjustments on the X and Y deflection preamplifiers can move the center point of the rectangular cross-hatch test pattern about the center point of the scribed pattern on the overlay.

3.5.8 DISPLAY STORAGE TEST

With the resolution test pattern on the DSD System display screen, verify that the brightness of the image after 30 minutes of storage is no less than 50 percent of its initial brightness.

3.5.9 CHARACTER REPERTOIRE TESTS

Utilizing the character display test pattern, verify that the character repertoire, designated in 3.5.13 and Figure 3-1 of ER EA3325, is displayed.

3.5.9.1 Character Closure

Verify that the line segments of each character of symbol shall be closed or completed to within 0.015 inch from the idealized fonts.

3.5.9.2 Character Positioning

Insert the character location squares around the characters and symbols and verify that they are centered within the squares which are position-located by the lower left corner.

3.5.9.3 Character Size

Measurement shall be made of the height and width of the alphanumeric characters to demonstrate that their height and width are within ±10% of 0.23 inch and 0.18 inch respectively.

3.5.9.4 Character Spacing

Verify that the center-to-center spacing of the characters is programmable in increments of TBD inch or less.

3.5.10 DATA WRITING AND ERASURE TESTS

3.5.10.1 Writing Rate And Time

By measurement, determine that the DSD System is capable of writing data at a rate of at least 20,000 inches per second at the screen, and that any character or symbol of 3.5.9 can be written in 100 microseconds or less. Verify that the erasure and rewriting of a 100 character data block can be accomplished with a 100 millisecond time period.

3.5.10.2 Erase Time And Control

During cycling of the data block test program, determine by measurement that selective erasure of data is done at such a rate that a square inch of data on the screen is erased in 10 milliseconds or less. Verify that the test program can selectively erase and rewrite randomly placed data blocks in a cyclic fashion. Test the ability of the display to be totally erased under manual control.

3.5.11 INPUT RATE TEST

Utilizing the character display test pattern, verify that the system is capable of accepting and displaying a new character every 100 microseconds or less.

Section 4

QUALITY ASSURANCE PROVISIONS

4.1 QUALITY CONTROL INSPECTION

As inspection by contractor and/or government personnel shall be made to ascertain that the DSD System equipment meets good commercial standards. This inspection shall include any and all tests and checks required to make this determination.

4.2 FACTORY ACCEPTANCE TEST AND EXERCISE

A Factory Acceptance Test shall be performed at the contractor's commencing on or before 7 March 1975 to ascertain that the equipment meets all applicable portions of Section 3.5 of FAA # EA3325. Failure of the equipment to perform to specification shall result in retest and/or mutually agreeable resolution of the equipment performance level and specification differences.

4.2.1 DSD SYSTEM ACCEPTANCE TEST SCHEDULE

Figure 4.2.1-1 provides the general road map of the procedures to be followed prior to preliminary and final customer acceptance test.

4.2.2 PRELIMINARY ACCEPTANCE TESTS

Prior to final customer acceptance testing of the DSD System, a preliminary acceptance test will be conducted to establish compatibility of the DSD System test procedures, system operation and test equipment.

Scheduled start date - 14 February 1975
Scheduled finish date - 28 February 1975

4.2.3 FINAL CUSTOMER ACCEPTANCE TESTS

The final customer acceptance testing of the DSD System is scheduled as follows:

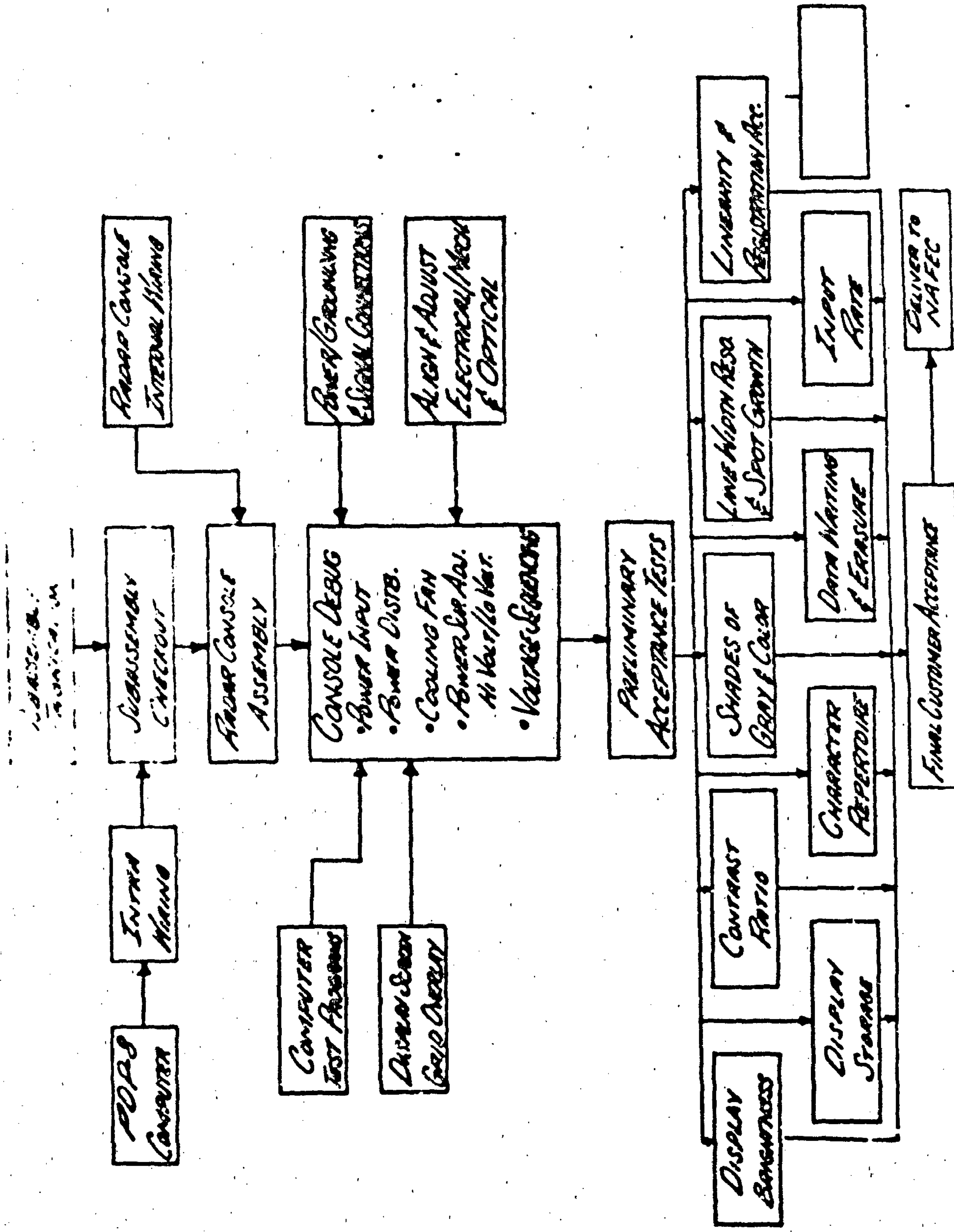
Scheduled start date - 28 February 1975
Scheduled finish date - 14 March 1975

The various customer acceptance tests are itemized in Table 4.2.3-1, Final Customer Acceptance Test Plan.

4.2.4 SCHEDULED DSD SYSTEM SHIPPING DATE

After completion of the final customer acceptance tests the system will be packed and shipped to NAFEC, Atlantic City, N. J.

Scheduled shipping date is on or before 22 March 1975.


PDP 8 COMPUTER
INTRA WIRING
SUBASSEMBLY CHECKOUT
RADAR CONSOLE ASSEMBLY
RADAR CONSOLE INTERNAL WIRING
POWER/GROUNDING & SIGNAL CONNECTIONS
ALIGN & ADJUST ELECTRICAL/MECH & OPTICAL
CONSOLE DEBUG
• POWER INPUT
• POWER DISTB.
• COOLING FAN
• POWER SUP ADJ. HI VOLT/LO VOLT.
• VOLTAGE SEQUENCING
COMPUTER TEST PROGRAMS
DISPLAY SCREEN GRID OVERLAY
PRELIMINARY ACCEPTANCE TESTS
DISPLAY BRIGHTNESS
CONTRAST RATIO
SHADES OF GRAY & COLOR
LINE WIDTH RESO & SPOT GROWTH
LINEARITY & REGISTRATION ACC.
DISPLAY STORAGE
CHARACTER REPERTOIRE
DATA WRITING & ERASURE
INPUT RATE
FINAL CUSTOMER ACCEPTANCE
DELIVER TO NAFEC

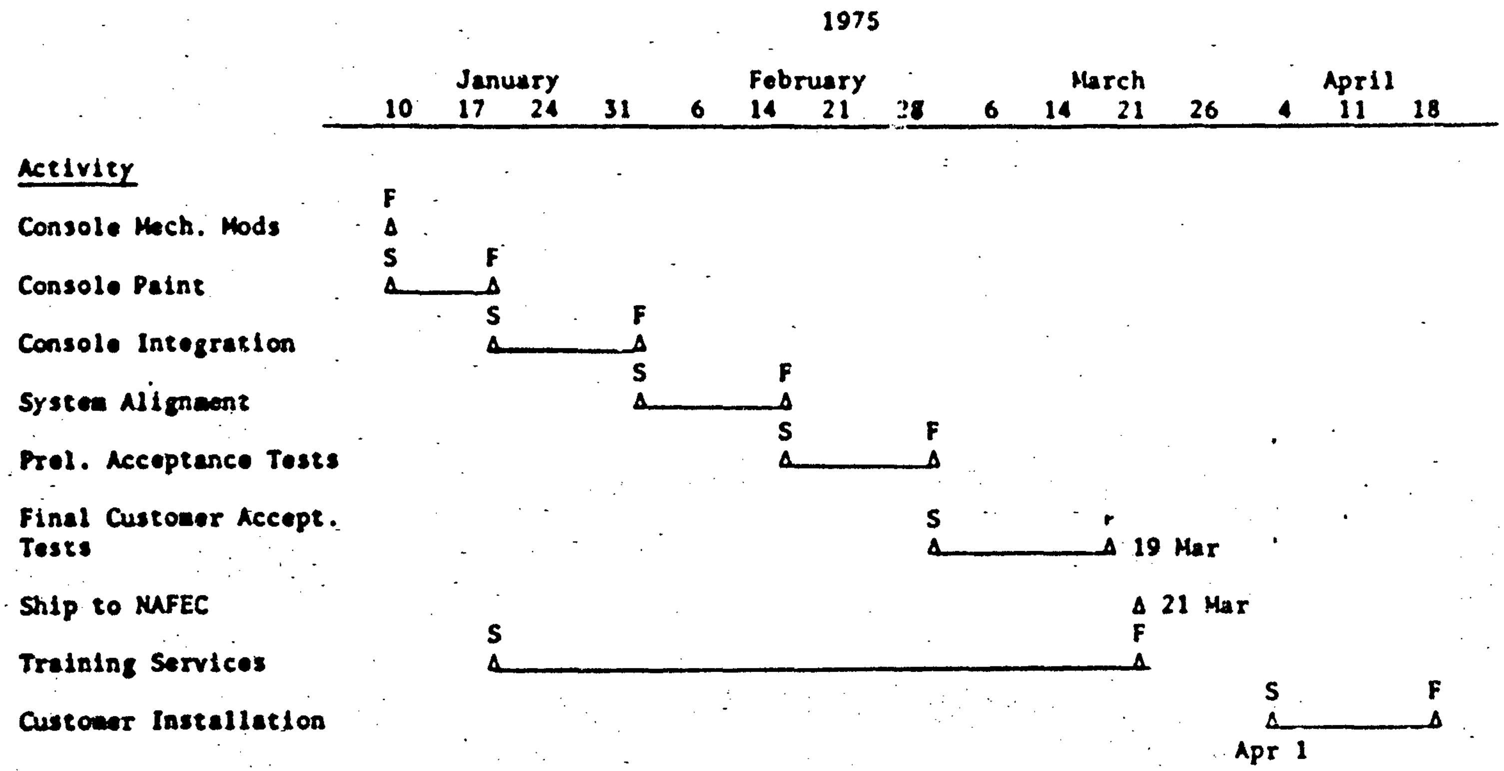


Figure 4.2.1-2. Acceptance Test Plan Schedule

GROUP A - Acceptance Tests

Group A Acceptance Tests are designed to:

1. Provide safety of equipment turn on and subsequent operation
2. Provide proper prime and secondary voltage inputs required for system operation.

Test	Objective	Documentation Req'd	Test Equipment Req'd
1. Critical Power Input and grounding	. Verify ac input power connection, circuit breaker operation and safety ground termination. . Verify critical inter/intra connection term terminations . Power Supply Adjustment (Hi Volt./Low Volt.) . Voltage Sequencing . Cooling Fan Operation . Measure Input Power . Brightness and Focus Adjustments	. IBM 75-M35-002 Acceptance Test Plan for the Deformographic Storage Display . IBM 75-M35-003 Acceptance Test Procedure for the Deformographic Storage Display System . System power distribution schematic . Subassembly Wiring diagrams & Wire Lists . Subassembly assembly prints . Test Data Sheets . FAA ER EA3325	Voltmeter, Ohmmeter, Continuity Checker. Oscilloscope

TABLE 4.2.3-1

FINAL CUSTOMER ACCEPTANCE TEST PLAN

Test	Objective	Documentation Req'd	Test Equipment Req'd
Registration	. Verify optical magnification & Linearity (i.e., Keystoning) . Verify brightness uniformity open gate, i.e. no schlerien stop in projector lens . Test performed strictly to determine optical and light path capability - performed w/o deformographic tube installed	. IBM 75-M35-002 IBM 75-M35-003 . FAA ER #3325	. Photographic Target . Grid Pattern (transparent overlay) . Lollypop light meter (paddle type) . Electronically generated grid pattern

GROUP C - Acceptance Tests

Test	Objective	Documentation Req'd	Test Equipment Req'd
1. Contrast Ratio	. Verify line brightness and background ratio	. IBM 75-M35-002 . IBM 75-M35-003 . FAA ER EA3325	. Pritchard Spectra Photometer
2. Brightness	. Verify line brightness	Same as above	Same as above
3. Shades of Grey	. Verify raster of different shades of grey	Same as above	Same as above with raster test program

TABLE 4.2.3-1 (cont.)

GROUP C (cont.)

Test	Objective	Documentation Req'd	Test Equipment Req'd
4. Line Width	. Verify variations in line width along given line	Same as above	. Pritchard Spectro Photometer, Cross Hatch Test Pattern
5. Display Storage	. Verify Storage characteristics of tube	. IBM 75-M35-002 . IBM 75-M35-003 . FAA ER EA3325	. Same as above . Display Program

GROUP D - Acceptance Tests

Test	Objective	Documentation Req'd	Test Equipment Req'd
1. Character Repertoire	. Verify that character repertoire of Figure 1 designated in 3.5.13 of ER EA3325 is displayed	. IBM 75-M35-002 . IBM 75-M35-003 . FAA ER EA3325	. Display Programs in Digital Equipment Corp PDP-8/I Computer & DSD processor

GROUP E - Acceptance Tests

Test	Objective	Documentation Req'd	Test Equipment Req'd
1. Stability	. Long Term performance check of brightness and focus controls	. IBM 75-M35-002 . IBM 75-M35-003 . FAA ER EA3325	. Pritchard Spectro Photometer, Oscilliscope
2. Selective Erase	. Verify that a square inch of data on screen is erased in 10 milliseconds or less.		. Display Program . Oscilloscope

TABLE 4.2.3-1 (cont.)

4.2.5 TRAINING SERVICES

Training services for FAA can commence 17 January 1975 (Console Integration) and continue through final customer acceptance tests.

4.3 FAILURE VERIFICATION AND RETEST

In the event of a failure which can be isolated to a subassembly or module, the defective items shall be repaired or replaced and those circuits directly affected by the failure shall be retested to the applicable requirements of 3.5. A failure which is verified to be an operator or test equipment failure, shall not be considered to be a relevant failure. Equipment test, in the case of an operator error or test equipment failure, shall continue from the start of the test being performed at the time of the error or malfunction.

APPENDIX E

ACCEPTANCE TEST PROCEDURES, IBM CORP., CONTRACT DOT FA74NA-1103

952 5497 4

ACCEPTANCE TEST PROCEDURE

FOR THE DEFORMOGRAPHIC

STORAGE DISPLAY SYSTEM

Prepared by:
J. A. Schirmer

IBM NO 75-M35-003

REVISIONS

ORIGINATING GROUP Projection Display System

CONTENT APPROVED BY

William M. Nolis, Manager

CONTRACT NO*

DATE

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Section 1

GENERAL INFORMATION

1.1 PURPOSE

This document establishes the procedure required to demonstrate proper performance of the Deformographic Storage Display (DSD) system, serial #1 in accordance with the FAA document ER EA332S.

1.2 TESTS

The acceptance tests performed in Paragraphs 5.1 - 6.23 of this procedure are in accordance with the Acceptance Test Plan for a DSD IBM 75-H35-002.

1.3 FAILURES

In the event that the DSD fails to pass any of the specified tests, appropriate entries shall be made in the Unit Log. All failures shall be investigated, analyzed, and corrective action taken, as required.

1.4 UNIT LOG

Details of all anomalies, test interruptions, failure isolation details, rework, resolution of malfunctions, etc., shall be documented in narrative form in the Unit Log.

1.5 TEST CONFIGURATION

The DSD shall be tested using a PDP-8/I computer as the test controller. The computer shall be connected to the DSD through a DW08-B interface adapter unit to obtain the proper signal polarity and levels. Test programs shall exercise the DSD electronics to drive the DSD deflection and video circuits to produce the desired test patterns, and test point outputs necessary for electrical evaluation and parameter measurement.

1.6 TEST INSTRUMENTATION

All oscilloscopes, light meters, etc., used in the performance of the acceptance testing shall be calibrated according to the procedures utilized at the testing site. This calibration shall be evidenced by a visible tag or stamp on the equipment. The tag shall indicate the date of the last calibration and either the due date of the next calibration or the normal calibration interval.

1.7 MAINTENANCE AND ACCEPTANCE TEST SOFTWARE

The Maintenance & Acceptance Test Software (MATS) is used extensively throughout the following test procedures to generate test patterns for the DSD. For detailed loading and operating procedures refer to IBM 75-M35-004 DSD Operation and Maintenance Instruction (OMI) Section 10 and to Digital Equipment Corporation's Introduction to Programming (DECITP).

Section 2

APPLICABLE DOCUMENTS

IBM 75-M3S-002	Acceptance Test Plan for a Deformographic Storage Display System
IBM 75-M3S-004	Deformographic Storage Display System Operation and Maintenance Instruction
IBM M3S-002-75	Maintenance and Acceptance Test Software - Object Tape
Digital Equipment Corp.	Introduction to Programming
Department of Transportation	Contract #DOT-FA74NA-1103 Serial: 359-0-00 Date: 07/03/74 Project: DSDT for FAA Engineering Requirement (ER) EA3325

Section 3

TEST CONDITIONS AND REQUIREMENTS

3.1 TEST CONDITIONS

The DSD shall be cooled by ambient air during the acceptance test, with all parts and louvers uncovered to allow the free passage of cooling air.

Temperature - Room ambient (up to 85o Fahrenheit maximum).

Humidity - To 90% R.H. maximum.

Light - Six foot candles maximum incident light from overhead sources.

3.2 ALIGNMENT AND ADJUSTMENT

Prior to the start of the acceptance test, all adjustable gains and biases associated with the processor analog electronics, and the deflection and video circuits in the DSD console, shall be properly set in accordance with the DSD System Operation and Maintenance Document, IBM #75-M35-004.

3.3 AC INPUT POWER REQUIREMENTS

The nominal ac input power requirements for the two sections of the DSD System are:

	DSD Processor	DSD Console
Voltage	120V ±10%	120V ±10%
Frequency	60 ±2 Hz	60 ±2 Hz
Service	Single phase	Single phase
Power (nominal)	130 Watts	130 Watts

Section 4

POWER SYSTEM VERIFICATION

4.1 POWER DISTRIBUTION

This test satisfies Section 3.3.1 of IBM 75-M35-002. Verification of the power grounding and critical signal connections shall be made before applying power to the DSD System.

✓1) With a multimeter verify that line voltage in the power outlet receptacle is 115V.

✓2) Install interconnecting cables from the remote unit to the console. The multilead cable attaches to J6 which is located on the rear shelf below head one. Triax cables marked X, Y and Z attach to head one receptacles J5, J4 and J3. For ease of installation it is advisable to temporarily remove the cables from J1 and J2 on the head.

✓3) Verify that the Main Power switch located on the right side of the console switch panel is in the Off position. Plug the console power cable into the power outlet receptacle.

Test Input voltage

Test Equipment Simpson Model 269 multimeter or equivalent

Measurement Line Voltage ________

4.2 COOLING FAN OPERATION

This test satisfies Section 3.3.2 of IBM 75-M35-002. Verification shall be made to insure that all cooling fans are operating when power is applied.

✓1) The arc lamp housing holds a cooling fan which is energized when the main power switch located on the right side of the console switch panel is in the ON position. The lamp is located in head one to the right and just above the DSD tube. Air is exhausted through the top panel of the housing.

✓2) The deflection power amplifier stage located in the bottom section of head one contains a cooling fan. This fan is energized when the low voltage switch located on the console switch panel has been depressed. Air is exhausted from the fan housing toward the focus power supply.

Verify fans: (✓) 3-22-75

4.3 POWER SUPPLY ADJUSTMENTS

This test satisfies Section 3.3.3 of IBM 75-M35-002. The voltage level from each regulated supply shall be verified to be within ±5% of its nominal voltage.

√1) Verify that the main power circuit breaker located on the rear shelf to the left of head one is in the ON position.

√2) Turn the Main Power switch located on the right side of the console switch panel ON. Background lights on the indicators should come on and the 1 OFF indicator should be green. This switch also energizes the power relay in the remote unit. Momentarily depress the reset switch on the front panel to put the remote unit in a reset mode.

√3) With a multimeter verify that line voltage is leaving the power compartment. Check for 115V at the convenience outlet located on the left side of the rear compartment.

√4) Depress 1 LV switch located on the console switch panel. Green should be immediately removed from the 1 OFF switch. In approximately thirty seconds the 1 LV indicator should turn green.

5) With a multimeter, verify the following voltages.

On the A9 card, which is the second card down with TP1 being at the center of the card:

TP1	P65V
TP2	P30V
TP3	P15V
TP4	GND
TP5	N90V
TP6	N30V
TP7	GND
TP8	N15V

On the low voltage power supply located on the slide out shelf:

P40V across R5 (top is positive)

6.7V AC between terminals 3 and 4

On A12 the video amplifier which is located next to the tube shield:

P90V across the 25 μfd cap at the top of the card.

Test: Low voltages

Test Equipment: Simpson Model 269 multimeter or equivalent

Measurement:

3. 115V 119 VAC

5. P65V 65.1 VDC

   P30V 28.5VDC

   P15V 15.2VDC

   N90V -88.8VDC

   N30V -28.6VDC

   N15V -15.1VDC

   P40V 39.05VDC

   6.7VAC 6.92 VAC

   P90V 93.4VDC

   P5 5.2 VDC

4.4 VOLTAGE SEQUENCING

This test satisfies Section 3.3.4 of IRI 75-M35-002. The power on and off sequencing of the high-voltage section of the DSD console shall be verified for proper operation.

1) From step 4 of the Power Supply Adjustment section the 1 LV indicator should be green. This shows that the high voltage delay relay has timed out and the unit is ready for high voltage. Momentarily depress the Reset switch on the front panel to insure that the remote unit is reset.

2) With a scope verify the conditions of the X, Y and Z inputs to the tube. X and Y deflection signals to the yoke should be probed on the terminal board located to the left of the deflection cards. These signals should be at ground potential. Z input to the tube should be probed on the A12 card at the top end of a 5.1K two watt carbon resistor. This signal should be at approximately F80V which is the blanked condition.

3) Depress the 1 HL switch on the front panel. 1 LV should go off; 1 HV should go green. Observe the display screen for any writing.

4) With a scope verify the presence of high voltage. This can be done at low voltage levels at test points on the power supplies. On the focus supply J1-8 represents focus voltage. On the high voltage supply J1-8 represents high voltage and J1-7 represents G2 voltage.

5) To power down the console first depress the 1 LV ~~One~~ switch to allow the high voltage to decay before depressing the Off One switch. This last move removes all power from the head.

Test: X, Y, Z and high voltages

Test Equipment: Scope

Measurement:

2. X gnd GND
   Y gnd GND
   Z P80V 82

851784-1, S/N 1	Focus	J1-8	1-3V	2.7V	1V=1000V	1.4 to 3.6 kV
851759-1, S/N 2	HV	J1-7	3V	3.0V	1V=100V	
	HV	J1-8	10V	10.0V	1V = 1000V	

651785-1, S/N 1 Erase (Floating at HV, did not measure)

Section 5

OPTICAL

These tests are performed with a special reflective test grid in place of the Deformographic Storage Tube (DST). For the method of removing the DST and for the method of aligning the test grid, refer to the OMI.

5.1 OPTICAL DISTORTION & MAGNIFICATION

This test requires that the grid overlay be on the viewing screen.

1) Ignite the arc lamp (see OMI Section 3.1).
2) Make required measurements and record data.

Test: Optical Distortion & Magnification

Equipment:

Reflective test grid in place of CRT

Grid overlay on viewing screen

Scale and magnifier

Measurements:

Measure the deviation of the projected grid from grid overlay in the horizontal and vertical direction at the 9 locations specified:

CHECKED 3-22-75

T.L.	T.C.	T.R.
x = +.025	x = 0	x = -.09
y = -.025	y = -.1	y = -.08
C.L.	C	C.R.
x = +.040	x = 0	x = -.1
y = +.020	y = 0	y = +.02
B.L.	B.C.	B.R.
x = +.065	x = 0	x = -.09
y = +.035	y = +.085	y = +.1

Passed:

5.2 BRIGHTNESS CONTROL

This test satisfies Section 3.5.2.2 of IBM 75-M35-002. Verify that the brightness control (neutral density filters) provide four discrete increments of brightness from full brightness down to one-eight or less full brightness.

1) Measure and record the line brightness produced by the alignment test pattern at a fixed point on the screen for each setting of the brightness control.
2) Quench the arc lamp.
3) Remove the test grid, insert and align a DST (see OMI par. 8.4, 8.5).

Test: Brightness Control

Equipment:

Alignment Test grid pattern

Photometer: Gamma Scientific

Measurements:

Setting 1	(Bright)	=	UNFILTERED	
Setting 2	(dim)	=	0.30	FILTER
Setting 3		=	0.60	FILTER
Setting 4	(dim)	=	0.70	FILTER

Setting 1 + Setting 4 = ✓

Passed:

5.3 DISPLAY MAGNIFICATION

This discussion satisfies Section 3.4.1 of IBM 7S-M35-002. It shall be demonstrated by mathematical proof that a display magnification of 7.5 to 18 times is obtainable with the DSD optical system.

The optical magnification is established by the distance between the DSD target and the projection lens. For the normal console configuration, this distance is: $F\left(\frac{1}{M} + 1\right) = 7.1\left(\frac{1}{11.0} + 1\right) \sim 7.75$ inches

F = Focal Length = 7.1

M = Magnification = 11.0

At 7.5x & 18x these values become:

$$7.5x = F\left(\frac{1}{7.5} + 1\right) \sim 8.06 \text{ inches}$$

$$18x = F\left(\frac{1}{18} + 1\right) \sim 7.5 \text{ inches}$$

The focus adjustment provides a motion that moves the DSDT tube assembly in relation to the projection lens in excess of 2.0 inches.

Alignment of the DSDT tube center and the optical axis is maintained by adjusting the nuts on the leveling studs at the target end of the tube craddle and the leveling knob at the rear.

Section 6

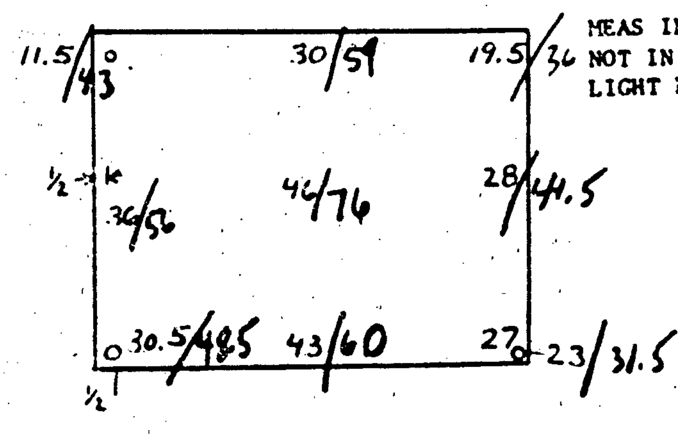
DISPLAY TESTS

For detailed procedures in all following sections, refer to OMI and DECITP.

6.1 PRELIMINARY

1) Power-up the PDP-8 computer and bring the DSD to a standby condition.
2) Load the MATS if required.
3) Start MATS at address 4000. Computer will halt
4) Power-up high voltage to the DSD.

OPEN GATE



MEAS IN FOOTLAMBERTS NOT IN PARALLEL WITH LIGHT PATH

SECOND SET MADE ⊥ TO LIGHT PATH AT CENTER

6.2 CENTERING

This test satisfies Section 3.5.7 of IBM 75-M35-002. Verify that the centering adjustments on the X and Y deflection preamplifiers can move the center point of the rectangular cross-hatch test pattern about the center point of the scribed pattern on the overlay.

3-22-75

1) Set the PDP-8 switch register (SR) to ØØØØ.
2) Erase the display.
3) Press continue - the alignment test pattern will appear.
4) Make the required measurements and record the data, repeating steps 2 and 3, as needed.

Test: Electrical Centering

Equipment:

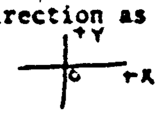
Alignment pattern on DSD

Grid overlay on viewing screen

Scale and magnifier

Measurements:

Measure the excursion and note the direction as the centering pots are adjusted to their two limits.



	Horizontal	Vertical
Full CW	-18 inch	-19 inch
Full CCW	+16.5 inch	+17 inch

Passed:

6.3 LINEARITY

This test satisfies Section 3.5.6.1 of IBM 75-M35-002. With the grid overlay in place over the screen and the cross-hatch test pattern presented on the screen, verify that the size of any square in the image does not deviate by more than 0.15 inch from the size of the corresponding squares in the scribed line pattern on the overlay.

1) Set the PDP-8 switch register (SR) to ØØØØ.
2) Erase the display.
3) Press CONTINUE - the alignment test pattern will appear.
4) Make the required measurements and record the data, repeating 2 and 3, as needed.

Test: Linearity

Equipment:

Alignment pattern on DSD

Grid overlay on viewing screen

Scale and magnifier

Measurements:

Measure the deviation of the projected CRT image from the CRT image from the grid overlay in the horizontal and vertical direction at the 9 locations specified below.

MEASURED 3-22-75

T.L.	T.C.	T.R.
x = -0.065	x = 0,0	x = +0.120
y = +0.1	y = 0,0	y = +0.230
C.L.	**C.**	**C.R.**
x = 0.010	x = -0.020	x = -0.005
y = +0.035	y = +0.015	y = +0.035
B.L.	**B.C.**	**B.R.**
x = -0.010	x = -0.005	x = +0.120
y = -0.050	y = +0.025	y = -0.070

Passed:

6.4 LINE WIDTH

This test satisfies Section 3.5.5.1 of IBM 75-M35-002. Verify that the maximum line width in a cross-hatch test pattern is no greater than 0.040 inch anywhere on the screen at the 50 percent brightness points.

1) Set the PDP-8 switch register (SR) to 0000.
2) Erase the display.
3) Press CONTINUE - the alignment test pattern will appear.
4) Make the required measurements and record the data, repeating steps 2 and 3, as needed.

Test: Line Width

Equipment:

Alignment pattern on DSD

Measuring magnifier

Measurements:

Measure the line width of the horizontal and vertical lines at the 9 locations shown below.

3-25-75	T.L.	3-22-75	3-25-75	T.C.	3-22-75	3-25-75	T.R.	3-22-75	3-25-75
GRAPH 1	H =	.0154		H =		.021	H =	.0170	.120
	V =	.0198		V =			V =		.034
	C.L.			C.			C.R.		
	H =			H =	.0226	.022	H =		
	V =			V =	.0234		V =		
	B.L.			B.C.			B.R.		
	H =	.0290	.0254	H =			H =		
	V =	.0292		V =			V =		

Passed:

6.5 SPOT GROWTH

This test satisfies Section 3.5.5.3 of IBM 75-M35-002. Verify that the line widths of the cross-hatch test pattern do not vary, from the narrowest line to the widest line, by a ratio of more than 1.4 to 1 over the entire screen surface.

GRAPH 1

1) Set the PDP-8 switch register (SR) to ØØØØ.
2) Erase the display.
3) Press CONTINUE - the alignment test pattern will appear.
4) Make the required measurements and record the data, repeating steps 2 and 3, as needed.

Test: Spot Growth

Equipment:

Alignment pattern on display

Measuring magnifier

Measurements

Locate and measure the largest and smallest line widths on the screen.

Largest line width (LLW) = 0.034"

Smallest line width (SLW) = 0.021

Calculate $\frac{LLW}{SLW}$ = 1.6

Passed:

6.6 VECTOR UNIFORMITY

This test satisfies a portion of Section 3.5.2.3 of IBM 75-M35-002. Brightness measurements of vectors shall be made over various positions of the screen, including all four corners, to verify that there is no more than 60 percent variation in brightness across the entire screen according to the formula:

$$\frac{B_{max} - B_{min}}{B_{max}} \times 100 = \% \text{ of brightness variation}$$

GRAPH 1

Near-area brightness variation shall be tested by measurement of brightness within a three-inch area and verifying that the variation is less than 40 percent according to the above formula.

1) Set the PDP-8 switch register (SR) to ØØØØ.
2) Erase the display.
3) Press CONTINUE - the alignment test pattern will appear.
4) Make the required measurements and record the data, repeating steps 2 and 3, as needed.

Test: Brightness

Equipment:

Alignment pattern on DSDT

Photometer: Gamma Scientific

Lambertion reflection for setting 6 FC ambient on screen

Measurements:

Measure worst brightness variation with a 3 inch section of vector

Max = 46 FL Min = 22 Fl

Brightness Variation for a 3-inch Vector Section

Compute variation

$$\frac{46 \text{ Max} - 22 \text{ Min}}{46 \text{ Max}} \times 100 = 51.25\%$$

Passed:

6.7 BRIGHTNESS, CONTRAST

This test satisfies a portion of Section 3.5.2.3 and Section 3.5.3 of IBM 75-M35-002.

Brightness measurements of characters and vectors shall be made over various positions of the screen, including all four corners, to verify that there is no more than 60 percent variation in brightness across the entire screen according to the formula:

$$\frac{B_{max} - B_{min}}{B_{max}} \times 100 = \text{\% of brightness variation}$$

Near-area brightness variation shall be tested by measurement of brightness within a three-inch area and verifying that the variation is less than 40 percent according to the above formula.

Several measurements of the contrast ratio shall be made. The brightness measurement of a display element (character or vector) shall be made, as well as the adjacent background, and the contrast ratio calculated according to the formula:

GRAPH 1 $\quad \text{Contrast ratio} = \frac{\text{Display element brightness}}{\text{Background brightness}} \qquad \frac{44}{1} = 44$

and shall be at least 16.

1) Set the SR to ØØØ2.
2) Erasr the display.
3) Press CONTINUE - the resolution test pattern will appear.
4) Make the required measurements, repeating steps 2 and 3, as needed.

Test: Brightness

Equipment:

Alignment pattern on DSD

Photometer: Gamma Scientific

Lambertion reflection for setting 6 FC ambient on screen

Measurements:

Measure the line brightness and background at 9 locations as shown below. Meter reading to be made within 1 min after a write.

GRAPH 2	T.L.	T.C.	T.R.
Line	____FL	____FL	____FL
Background	____FL	____FL	____FL
	C.L.	C.	C.R
Line	____FL	____FL	____FL
Background	____FL	____FL	____FL
	B.L.	B.C.	B.R.
Line	____FL	____FL	____FL
Background	____FL	____FL	____FL

Brightness Variation for Entire Screen

Compute variation based on values entered on Sheet I

$$\frac{\text{Max Line Bright - Min Line Bright}}{\text{Max Line Bright}} \times 100 =$$

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$$\frac{36 - 4}{36} \times 100 = 89\%$$

Contrast Ratio:

Compute ratio at the 9 locations based on values entered on Sheet I

$$\frac{\text{Line Brightness}}{\text{Background Brightness}}$$ 44:1

T.L.	______	T.C.	______	T.R.	______
C.L.	______	C.	______	C.R.	______
B.L.	______	B.C.	______	B.R.	______

Passed:

6.8 RESOLUTION

This test satisfies Section 3.5.5.2 of IBM 75-M35-002. While utilizing the resolution test pattern, verify that a pair of lines can be resolved when they are spaced no more than 0.035 inch (center to center) apart, with at least 20 percent modulation according to the formula:

$$\text{Percent modulation} = \frac{B_{max} - B_{min}}{B_{max}} \times 100$$

Where B_{max} is the line center brightness

B_{min} is the line pair overlap brightness.

1) Set the SR to ØØØ2.
2) Erase the display.
3) Press CONTINUE - the resolution test pattern will appear.
4) Make the required measurements, repeating steps 2 and 3, as needed.

Test: Resolution

Equipment:

Resolution pattern on DSD

Photometer: Gamma Scientific

Lambertion reflector for setting 6 FC ambient on screen

Measurements:

Measure brightness of line and space between lines in next to finest line group and compute modulation.

$$\text{Modulation} = \frac{\underline{\ 21\ }\ \text{Line} - \underline{\ 6\ }\ \text{Space}}{\underline{\ 21\ }\ \text{Line}} \times 100 = \underline{\ 71.5\%\ }$$

Readings are needed only for the line group that has least modulation as judged by the eye.

.021"

Measure line spacing .021 inches.

6.9 STORAGE

This test satisfies 3.5.8 of IBM 75-M35-002. With the resolution test pattern on the DSD System display screen, verify that the brightness of the image after 30 minutes of storage is no less than 50 percent of its initial brightness.

1) Set the SR to ØØØ2.
2) Erase the display.
3) Press CONTINUE - the resolution test pattern will appear.
4) Make the required measurements, repeating steps 2 and 3, as needed.

Test: Storage

Equipment:

Resolution pattern on DSD

Photometer: Gamma Scientific

Measurements:

Measure the line brightness immediately after a write and then make successive reading on the same line every 5 min for the next half hour.

Initial reading	5:12	36 FL
After 5 min storage	5:12	27 FL
After 10 min storage	5:22	19 FL
After 15 min storage	5:27	12 FL
After 20 min storage	5:32	9 FL
After 25 min storage	5:37	6 FL
After 30 min storage	5:42	4.5 FL

#154
TUBE LOSING STORARGE BECAUS OF FLOOD GUN LEAKAGE.

Passed:

6.10 CHARACTER REPERTOIRE

This test satisfies Section 3.5.9.Ø of IBM 75-M35-002. Utilizing the character display test pattern, verify that the character repertoire, designated in 3.5.13 and Figure 3-1 of ER EA3325, is displayed.

1) Set the SR to ØØ1Ø.
2) Erase the display.
3) Press CONTINUE - the CHAR1 pattern will appear.
4) Make and record the required measurements, repeating steps 2 and 3, as needed.

Test: Character Repertoire

Equipment: Character format on DSD

Measurement:

Verify that the following 26 characters, 10 numeral and 22 special symbols are displayed

A ___, B ___, C ___, D ___, E ___, F ___, G ___, H ___, I ___,
J ___, K ___, L ___, M ___, N ___, O ___, P ___, Q ___, R ___,
S ___, T ___, U ___, V ___, W ___, X ___, Y ___, Z ___

0 ___, 1 ___, 2 ___, 3 ___, 4 ___, 5 ___, 6 ___, 7 ___, 8 ___, 9 ___

× ___, ◇ ___, ⊥ ___, . ___, Γ ___, ▭ ___, / ___, + ___,
≡ ___, ↑ ___, ⧗ ___, # ___, ‾ ___, ⧗ ___, ◁ ___, ⧖ ___,
□ ___, ✓ ___, \ ___, ↗ ___, ? ___, ^ ___

Passed:

6.11 CHARACTER CLOSURE

This test satisfies Section 3.5.9.1 of IBM 75-M35-002. Verify that the line segments of each character or symbol shall be closed or completed to within 0.015 inch from the idealized fonts.

1) Set the SR to ØØ1Ø.
2) Erase the display.
3) Press CONTINUE - the CHAR1 pattern will appear.
4) Make and record the required measurements, repeating steps 2 and 3, as needed.

Test: Character Closure

Equipment:

Character formats on DSD

Measuring magnifier

Measurements:

Measure gaps between the character strokes within a character and enter below:

NOMINAL ≈ .010'

A ___, B ___, C ___, D ___, E ___, F ___, G ___, H ___, I ___,

J ___, K ___, L ___, M ___, N ___, O ___, P ___, Q ___, R ___,

S ___, T ___, U ___, V ___, W ___, X ___, Y ___, Z ___.

0 ___, 1 ___, 2 ___, 3 ___, 4 ___, 5 ___, 6 ___, 7 ___, 8 ___, 9 ___

× ___, ◇ ___, ↓ ___, . ___, ⌐ ___, □ ___, / ___, + ___.

≡ ___, ↑ ___, ⊼ .030 # ___, - ___, ⊻ ___, ◁ ___, ⋈ ___.

◻ ___, ✓ ___, Y ___, ^ ___, ? ___, ∧ ___.

THIS PROM IS WRONG.

Passed:

6.12 CHARACTER SIZE

This test satisfies Section 3.5.9.3 of IBM 75-M35-002. Measurement shall be made of the height and width of the alphanumeric characters to demonstrate that their height and width are within ±10% of 0.23 inch and 0.18 inch respectively.

1) Set the SR to ØØ1Ø.
2) Erase the display.
3) Press CONTINUE - the CHAR1 pattern will appear.
4) Make and record the required measurements, repeating steps 2 and 3, as needed.

Test: Character Size

Equipment:

Character formats on DSD

Measuring magnifier

Measurements:

Measure the height and width of characters and enter below:

Character	Height	Width	Character	Height	Width
A		.190	N		
B	.245	.155	O		.190
C			P		
D	.248	.150	Q		
E			R		
F			U		
G			V		
H			W		
J			X		
L			Y		
M			Z		

Passed:

6.13 CHARACTER UNIFORMITY

This test satisfies a portion of Section 3.5.2.3 of IBM 75-M35-002. Brightness measurements of characters ~~and vectors~~ shall be made over various positions of the screen, including all four corners, to verify that there is no more than 60 percent variation in brightness across the entire screen according to the formula:

$$\frac{B_{max} - B_{min}}{B_{max}} \times 100 = \%\text{ of brightness variation}$$

Near-area brightness variation shall be tested by measurement of brightness within a three-inch area and verifying that the variation is less than 40 percent according to the above formula.

Test: Character Brightness Uniformity

Equipment:

Character formats on DSD

Photometer: Gamma Scientific

Measurements:

Measure brightness variation of the strokes within the characters and enter below the maximum and minimum values within a character:

MEAS 3-22-75

Max: 42

Min: 4.5

Compute: $\frac{42 \text{ Max} - 4.5 \text{ Min}}{42 \text{ Max}} \times 100 = 89.5\%$

6.14 CHARACTER POSITION

This test satisfies Section 3.5.9.2 of IBM 7S-M3S-002. Insert the character location squares around the characters and symbols and verify that they are centered within the squares which are position-located by the lower left corner.

1) Set SR to ØØ12.
2) Erase display.
3) Press CONTINUE - CHAR3 test pattern will appear.
4) Verify that all characters are centered within the position boxes.

Test: Character Position

Equipment: Encased character format

Measurement:

Verify that all 26 characters, 10 numerals, and 22 special characters are centered within the encasing boxes.

A ___, B ___, C ___, D ___, E ___, F ___, G ___, H ___, I ___,
J ___, K ___, L ___, M ___, N ___, O ___, P ___, Q ___, R ___,
S ___, T ___, U ___, V ___, W ___, X ___, Y ___, Z ___.

0 ___, 1 ___, 2 ___, 3 ___, 4 ___, 5 ___, 6 ___, 7 ___, 8 ___, 9 ___.

▾ ___, ∩ ___, ⊥ ___, . ___, ⌈ ___, ? ___, ⍋ ___, / ___, · ___,
≡ ___, ↑ ___, ⍒ ___, ≠ ___, - ___, ▭ ___, ∧ ___, ◁ ___, ⍋ ___,
□ ___, ⁄ ___, \ ___, ↗ ___.

Passed:

6.15 CHARACTER DENSITY

1) Set SR to ØØ15.

2) Erase display.

3) Press CONTINUE - 141 x 72 characters will appear.

4) No measurements required.

6.16 CHARACTER SPACING

This test satisfies 3.5.9.4 of IBM 75-M35-002. Verify that the center-to-center spacing of the characters is programmable in increments of .02 inch or less.

1) Set SR to ØØ11.
2) Erase display.
3) Press CONTINUE - CHAR2 pattern will appear.
4) Make and record measurements.

Test: Character spacing

Equipment:

Character spacing format

Measuring magnifier

Measurements:

Measure the character spacing for each spacing group.

Group 1	.0675	G2-G1 =	.020
Group 2	.0875	G3-G2 =	.0175
Group 3	.105	G4-G3 =	.0175
Group 4	.1225	G5-G4 =	.0225
Group 5	.145	G6-G5 =	.020
Group 6	.165	G7-G6 =	
Group 7		G8-G7 =	
Group 8		G9-G8 =	
Group 9			

Passed:

6.17 CHARACTER SIZE CONTROL

1) Set SR to ØØ14.

2) Erase display.

3) Press CONTINUE - CHAR4 pattern will appear.

4) Verify size control exists.

6.18 GREY SHADES

This test satisfies 3.5.4.2 of IBM 75-M35-002. With the conventional stop in place and the maximum brightness control setting, verify that the DSD System is capable of presenting six shades of grey on the viewing screen. Each successively brighter grey shade shall be at least 25% brighter than the preceding shade.

1) Set SR to ØØØ4.
2) Erase display.

GRAPH 7
3-22-75

3) Press CONTINUE - grey shade pattern will appear.
4) Make and record measurements, repeating steps 2 and 3 as required.

Test: Grey shades

Equipment:

Grey shade format

Photometer: Gamma Scientific

Measurements:

Measure the raster line brightness in each shade area and enter the values below. Make each measurement within 1 minute of a write.

Background Shade I	≈ 1	FL
Raster Line Shade II	2.5	FL
Raster Line Shade III	9	FL
Raster Line Shade IV	29	FL
Raster Line Shade V	36	FL

Passed:

6.19 ERASE ACCURACY

This test satisfies Section 3.5.6.4 of IBM 75-M35-002. Verify that the erasure of a data block is complete while not distrubing adjacent data blocks where the separation distance of the near elements in the two data blocks is 0.30 inch.

1) Erase display.
2) Set SR to ØØØ1.
3) Press CONTINUE - BLCK1 pattern will appear.
4) Make spacing measurements.
5) Set SR to ØØØ3.
6) Press CONTINUE - nine data blocks will be erased.
7) Verify erase.

Test: Erase Accuracy Date:

Equipment: Measuring magnifier

Measurements:

Spacing: Measure the guard band between several distributed data blocks.

Block 1: UP = _____, DOWN = _____, LEFT = _____, RIGHT = _____
Block 2: UP = _____, DOWN = _____, LEFT = _____, RIGHT = _____
Block 3: UP = _____, DOWN = _____, LEFT = _____, RIGHT = _____
Block 4: UP = _____, DOWN = _____, LEFT = _____, RIGHT = _____
Block 5: UP = _____, DOWN = _____, LEFT = _____, RIGHT = _____

Erase: Verify data blocks are erased
Verify other data blocks are not affected.

Passed:

6.20 REWRITE ACCURACY

This test satisfies Section 3.5.6.2 of IBM 75-M35-002. Demonstrate with the data block test pattern that a single block of data can be selectively erased and rewritten to within 0.030 inch in either axis of its original position. No other data shall be added or deleted anywhere else on the screen.

1) Erase display.
2) Set SR to ØØØ1.
3) Press CONTINUE - BLCK1 pattern will appear.
4) Locate the 9 selective erase blocks and measure their locations relative to X and Y reference lines in the small reference grids.
5) Set SR to ØØØ3.
6) Press CONTINUE - the 9 blocks will be erased.
7) Set SR to ØØØ7.
8) Press CONTINUE - the 9 blocks will be rewritten.
9) Measure the new relative X and Y positions for the 9 blocks.

Test: Rewrite accuracy

Equipment: Measuring magnifier

Measurements:

TL:	RX1	____			TC:	RX1	____			TR:	RX1	____		
	RX2	____	ΔX	____		RX2	____	ΔX	____		RX2	____	ΔX	____
	RY1	____				RY1	____				RY1	____		
	RY2	____	ΔY	____		RY2	____	ΔY	____		RY2	____	ΔY	____
CL:	RX1	____			CC:	RX1	____			CR:	RX1	____		
	RX2	____	ΔX	____		RX2	____	ΔX	____		RX2	____	ΔX	____
	RY1	____				RY1	____				RY1	____		
	RY2	____	ΔY	____		RY2	____	ΔY	____		RY2	____	ΔY	____
BL:	RX1	____			BC:	RX1	____			BR:	RX1	____		
	RX2	____	ΔX	____		RX2	____	ΔX	____		RX2	____	ΔX	____
	RY1	____				RY1	____				RY1	____		
	RY2	____	ΔY	____		RY2	____	ΔY	____		RY2	____	ΔY	____

Graph 6:32 Passed:

WITHIN 0.010"

6.21 OVERWRITE ACCURACY

This test satisfies Section 3.5.6.3 of IBM 75-M3S-002. Verify that the rewriting of a data block can be done such that the overwritten data registers to within 0.030 inch.

1) Erase the display.
2) Set the SR to ØØØ1.
3) Press Continue - BLCK1 pattern will appear.
4) Set the SR to ØØØ7.
5) Press CONTINUE - 9 blocks will be overwritten.
6) Examine the overwritten blocks under magnification. Due to the nature of the DSD the spacing of lines can only be measured if they are more than one resolution unit (RU) apart (the resolution unit was established in Test 6.8). If lines are separated by less than about ½ resolution unit, the two lines merge into a brighter line. If the separation is between about ½ RU and 1 RU the lines interfer and result in a single dim line. Record observations.

Test: Overwrite accuracy

Equipment: Measuring magnifier

Measurements

Block	$\Delta < \frac{1}{2}$ RU (bright line)	$\frac{1}{2}$ RU $< \Delta <$ RU (dim line)	$\Delta <$ RU (Measure)
TL			
TC			
TR			
CL			
CC			
CB			
BL			
BC			
BR			

(Check column 1 or 2, or insert measurement in Column 3)

Passed:

6.22 WRITING RATE AND TIME

This test satisfies Sections 3.5.10.1 and 3.5.11 of IBM 75-M35-002.

6.22.1 LINE RATE

By measurement, determine that the DSD System is capable of writing data at a rate of at least 20,000 inches per second at the screen.

1) Erase display.
2) Set SR to 0006.
3) Press CONTINUE.
4) Measure the length of the vector which appears.
5) Erase display.
6) Turn high voltage off.
7) Connect an oscilloscope to L25-10 on the digital backpanel. (Vector Gene
8) Press CONTINUE.
9) Scope trace will resemble Figure 6.22.1 - measure T_1 and calculate line speed.
10) Set SR to 0006 - program will halt.
11) Turn on high voltage.

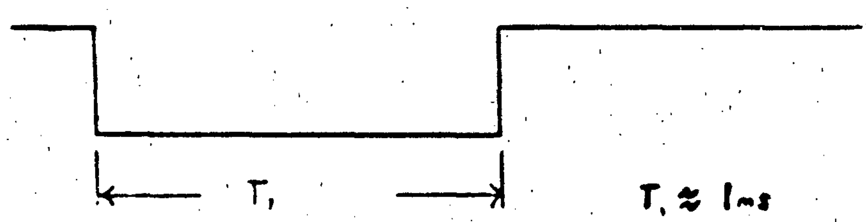


Figure 6.22.1

TEST: Line Speed   Date:

EQUIPMENT:

Scale

Oscilloscope

MEASUREMENTS:

Vector length = 20 "

T_1 = 4.25 ms

Calculate line speed

$$\frac{\text{Vector length}}{T_1} \times 1000 = 4.706 \text{ inches per second}$$

Passed:

6.22.2 CHARACTER TIME

Verify that any defined symbol can be written in 100 us or less.

1) Erase display.

2) Set SR to ØØ1Ø.

3) Press CONTINUE - CHAR1 pattern will appear.

4) Verify that characters appear.

5) Erase display.

6) Turn high voltage off.

7) Attach scope to N12-2 on digital backpanel (character generatoR)

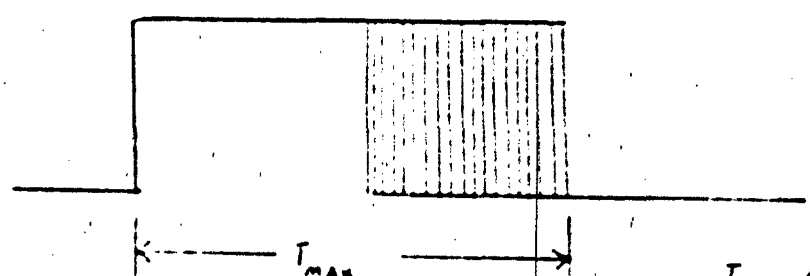
8) Set SR to ØØ5Ø.

9) Press CONTINUE - program will not halt.

10) Scope trace should resemble Figure 6.22.2, measure T_{max}.

11) Set SR to ØØ1Ø - program will halt.

12) Turn high voltage on.



$T_{max} \approx 90\mu s$

Figure 6.22.2

TEST: Character Time

Date:

EQUIPMENT:

Oscilloscope

MEASUREMENTS:

Verify character write ________

T_{max} = ________ us

Passed:

6.22.3 DATA RATE

Verify that the system is capable of accepting and displaying a new character every 100 microseconds or less.

1) Erase the display.
2) Set the SR to ØØ17.
3) Press CONTINUE - BLCK4 pattern will appear.
4) Verify characters are written.
5) Erase the display.
6) Turn high voltage off.
7) Connect oscilloscope to N12-2 on the digital backpanel (character generate).
8) Set SR to ØØ57.
9) Press CONTINUE - program will not halt.
10) Set scope time base to alternate, delayed.
11) Set A sweep rate to 10 us/centimeter and to auto trigger.
12) Set B sweep rate to 1 ms/centimeter and to manual trigger.

13) Set delay vernier to ØØØ.

14) Adjust trigger levels, gains, and trace separation until the scope trace resembles Figure 6.22.3.

15) As the delay vernier is moved, the intensified area and the "expanded" trace will jump from one trigger point to the next. Continue until the largest T_R has been measured. This is T_{RMax}.

16) Set the SR to 0017 - the program will halt.

17) Turn high voltage on.

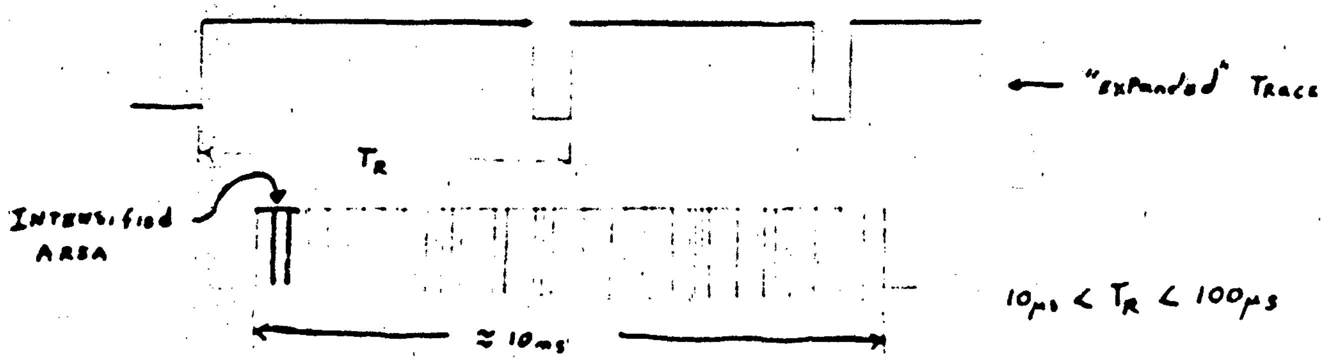


Figure 6.22.3

TEST: Data Rate Date:

EQUIPMENT: Tectronix 547 oscilloscope or equivalent

MEASUREMENTS:

Verify character write

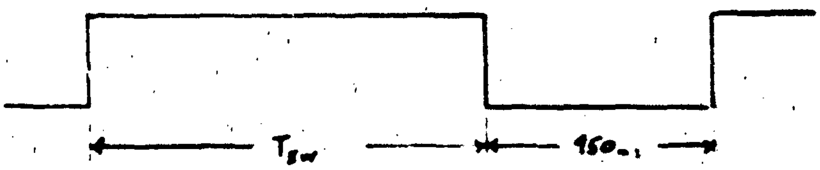
T_{RMax} = ________us

Passed:

6.22.4 ERASE/WRITE CYCLE RATE

Verify that the erasure and rewriting of a 100 character data block can be accomplished with a 100 millisecond time period.

1) Erase the display.
2) Set SR to ØØØ5.
3) Press CONTINUE - BLCK3 pattern will appear.
4) Press CONTINUE - verify that erase and rewrite occurs - repeat step 4 as required for verification.
5) Erase display.
6) Turn high voltage off.
7) Connect oscilloscope to N12-2 on digital backpanel (character generate).
8) Set SR to ØØ45.
9) Press CONTINUE - program will not halt.
10) Scope trace will resemble Figure 6.22.4 - measure T_{EW}.
11) Set SR to ØØØ5 - program will halt.
12) Turn on high voltage.



$T_{EW} \approx 100$ ms

Figure 6.22.4

TEST: Erase/Write Time

Date:

EQUIPMENT: Oscilloscope

MEASUREMENTS:

T_{EW} = ________ ms

Passed:

6.23 ERASE TIME AND CONTROL

This test satisfies Section 3.5.10.2 of IBM 75-M35-002.

Determine by measurement that selective erasure of data is done at such a rate that a square inch of data on the screen is erased in 10 milliseconds or less. Verify that the test program can selectively erase and rewrite randomly placed data blocks in a cyclic fashion. Test the ability of the display to be totally erased under manual control.

1) Erase display.
2) Set SR to ØØØ1.
3) Press CONTINUE - BLCK1 pattern will appear.
4) Set SR to ØØØ3.
5) Press CONTINUE - 9 data blocks will be erased.
6) Set SR to ØØØ7.
7) Press CONTINUE - erased blocks will be rewritten.
8) Verify cyclic operation by repeating steps 4-7 as required.
9) Measure the size of one of the erased blocks.
10) Calculate the erased area.
11) Erase the display and verify erasure.
12) Turn high voltage off.
13) Connect an oscilloscope to N12-2 on the digital backpanel (character generate).
14) Set SR to ØØ43.
15) Press CONTINUE - program will not halt.
16) Scope trace should resemble Figure 6.23, measure T_E.
17) Set SR to ØØØ3 - program will halt.
18) Turn high voltage on.
19) Calculate erase time for 1 sq in. block.

TEST: Erase Time and Control Date:

EQUIPMENT: Oscilloscope

MEASUREMENTS:

Verify erase/write

Verify manual erase

Block size: x = _________"

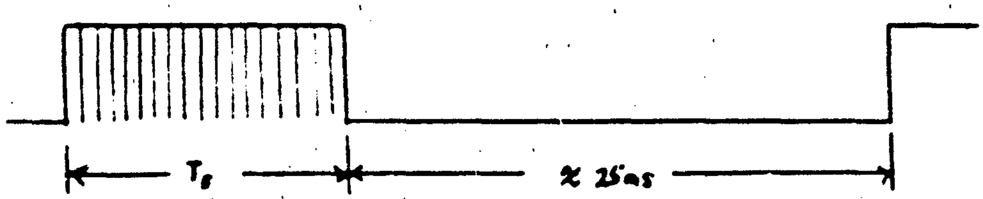
y = _________"

Block area = x · y = _________"

T_E = _________ms

Erase time, 1 sq in. = T_E ÷ Block area = T_{ESq} = _________ms

Passed:



T_E ≈ 10ms

Figure 6.23

Section 7

TEST MATRIX

	4.1	4.2	4.3	4.4	5.2	5.3	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	6.10	6.11	6.12	6.13	6.14	6.15	6.16	6.17	6.18	6.19	6.20	6.2[illegible]	6.22	6.23
3.3.1	X																												
3.3.2		X																											
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3.5.9.4																						X							
3.5.10.1																												X	
3.5.10.2																													X
3.5.11																												X	

APPENDIX F

IBM LETTER TO DR. CARLO BROGLIO, OSEM,
DATED MAY 30, 1975

IBM

International Business Machines Corporation

Owego, New York 13827
607/687 2121

May 30, 1975

Office of Systems Engineering Management
Federal Aviation Administration
800 Independence Avenue
Washington, DC

Attn: Dr. Carlo J. Broglio
Systems Analyst

Gentlemen:

IBM is pleased to respond to your request for estimates regarding the ultimate production prices of consoles based on the Deformographic Storage Display Tube (DSDT) Technology. In the absence of a detailed specific definition of the consoles to be priced, we have made engineering estimates based on the following assumptions:

1. The consoles would be functionally identical to the unit we recently delivered to NAFEC except that they would interface with the CCC in the enroute centers rather than the laboratory computer at NAFEC. The internal packaging and circuit technology would be completely redone to provide maximum cost advantage for a large volume production run.

2. The recurring and non-recurring costs are based on a 1000-unit buy with 100 units delivered during the second year and 25 units per month in the 25th through 60th months.

3. Labor, overhead and all other rates, factors and elements of cost are based solely on 1975 rates and quotations. Therefore, these estimates are in 1975 dollars and would have to be factored upward to allow for cost escalation resulting from inflation. For schedule assessment purposes we assumed a go-ahead in the first quarter of 1976.

4. These estimates assume that the CCC provides the display data in a format reasonably compatible with the DSDT; i.e., more or less in accordance with the approach followed with the NAFEC unit. Within these groundrules, this console would be able to provide the functions presently incorporated in the Flight Strip Printer, the Flight Strip Posting Console, and the Computer Readout and Update Display. In addition, this console has the graphics capability to provide a backup capability for the Plan View Display (PVD) with the information being periodically updated from the CCC

rather than refreshed many times a second as with the PVD. The display surface can also be zoned off to present other types of data simultaneously with flight strips, such as weather, NOTAMS and other tabular or graphical data.

5. An IBM-modified GFE cabinet was assumed. However, there would not be a major cost impact if the cabinet were fabricated by IBM rather than modifying a GFE structure.

6. The unit would be designed and built to good commercial practice with the 2100 series of specs as a general guide. This same type of approach was very successfully used on the CCC and provides significant cost advantages without any loss of reliability or performance.

7. This estimate does not include any of the following items since they are not part of the basic console cost and we did not have the necessary information to do an accurate estimate:

   a) Shipping and installation
   b) Training
   c) Maintenance or warranty
   d) Modifications or additions (if any) to the CCC hardware or software.

8. The non-recurring estimate does include all the normal non-recurring design and start-up activities we thought would be applicable, such as t[illegible], test equipment, conversion of packaging and technology, maint[illegible]ility and reliability analysis, quality engineering, manuals and other documentation, interface design, human factors analysis, etc.

9. The recurring price estimates are also complete figures including, in addition to direct hardware costs, testing, program management, engineering support to manufacturing, general and administrative expense, and all other elements that normally go into a unit selling price.

10. Two configurations have been estimated: a console with a single DSDT and a console with two DSDTs projecting on a single viewing screen. In the dual-DSDT unit the CRT; light source; lens system; deflection, video and erase circuits; and all associated power supplies have been duplicated. In all other respects, the two configurations are identical, i.e., only one set of electronics, power supplies, etc., have been assumed for such functions as interface, display generation and overall unit control. In addition, there is very little difference in the cabinet, mirrors and viewing screen whether one DSDT or two is assumed. Since the second DSDT projector is essentially a duplicate of the first, there is no significant difference in non-recurring costs.

On the basis of these assumptions, our engineering estimates are as follows:

Single-head console:	$28,000 each
Dual-head console:	$41,000 each
Non-recurring expense:	$4.6 million

W L Grogan

W. L. Grogan, Controller
Avionics Systems

WLG:at

APPENDIX G

PROGRESS REPORT FAA-16-734, EVALUATION OF DSD, ANA-200 TO ARD-100

ANA-230

Progress report - PAA 16-234 (Activity 03)
Evaluation of the Deformographics Storage Display

Chief, Simulation and Analysis Division, ANA-200

ARD-100

The Deformographics Storage Display (DSD) fabricated by IBM, Owego, N.Y., was delivered to NAFEC in May 1975. Following installation, site acceptance testing and software integration, which was completed in July, the system has been subjected to a series of engineering tests. The information contained herein is (1) a summary of the display performance data collected to date, (2) a near-term expected performance improvement summary, and (3) tentative conclusions relative to the deformographic display technique. This information complements the data from the factory acceptance tests which we provided to ARD-110 in April, and other data and performance characteristics provided to ARD-110 in the interim.

We are also preparing a follow-on data report which will include all of the baseline data and other pertinent display characteristics measured or derived. By agreement with Mr. John Edgbert ARD-110 this data report will contain an analysis of the DSD performance as compared against the engineering requirement for an en route electronic tabular display that is being formulated by Mr. Edgbert. We understand that the purpose of this comparison is to determine whether the DSD should be considered as a candidate in competition with other displays which can or may meet the engineering requirement. We expect receipt of the final version of Mr. Edgbert's document in the very near future.

Engineering Analysis Summaries

Measured Performance

The following display characteristics were measured under the same conditions, with no change in controls operating levels:

1. Brightness over the full 22- by 32-inch screen: minimum 24 foot-lamberts, maximum 39 foot-lamberts.

2. Line width variations over the 39-inch diameter screen: maximum 0.025 inches, minimum 0.023 inches.

3. Smallest useable character block on 22- by 32-inch display: 0.142 inches high by 0.107 inches wide. Since a minimum of 20 percent is included in each dimension for space, this results in a character of 0.125 by 0.07 inches. This corresponds to 0.645 percent dimensionally vertically and 0.33 percent horizontally, regardless of final display size.

4. Minimum line-to-line spacing over the display: 0.033 inches for parallel vectors.

5. Background brightness, fluorescent room lighting conditions with 20 to 30 foot-candles ambient: less than 1 foot-lambert measured.

6. Contrast ratio (as above): worst case 25:1; best case 39:1 under 20 to 30 foot-candles ambient.

7. Data registration rewrite accuracy: with erasure between rewrite 0.012 inches, without erasure-less than .001 inches.

8. Data linearity: 0.8 percent overall worst case at top of screen.

9. Optical Magnification: 13X.

10. Flood erase time for 10,000 characters on screen: 200 milliseconds.

11. Screen gain: 1.8 to 1.

12. Writing rate: 500 inches/second, maximum character time 100 microseconds.

13. Long-term stability (draft): less than 0.001 inch over a week including on and off cycles.

14. Long-term character size and brightness: no measureable change in data rewritten over a 1-week period.

15. Gray shades: six linear shades visible.

16. Selective erase accuracy repeatability: same as rewriting accuracy. Safe separation distance between data for erasure: 0.15 inches on a 22- by 32-inch display.

17. Storage time: 12 minutes to 50 percent brightness, 30 minutes to 10 percent brightness.

18. Character closure, size positioning, and spacing: all nominal and not critical.

19. Erase time for selective erase, after switching: same as one write character time; maximum of 100 microseconds per character.

20. Optical distortion: insignificant (less than .1 percent).

21. Dust, smoke, and normal building vibrations do not measurably affect performance.

Near-Term Expected Performance

Based upon extrapolation of data resulting from our engineering tests, and information provided by IBM relative to their on-going DSD improvement

3

program, the following improvements in DSD performance are already achieved or are considered realizable for any additional units fabricated.

1. Typical nominal character size on a 20-inch-square display to be equal in size to standard pica typewriter type (.094 inch high by .067 inch wide).

2. Typical brightness improvements as a function of display size and lamp wattage choice to result in more than 100 foot-lamberts on a 20-inch-square screen.

3. Erase time to be less than 50 milliseconds for a full screen of data.

4. Selective erase separation zone: 0.1 inch maximum on 22- by 32-inch display.

5. Data linearity: 0.2 percent.

6. Borderless, tiled, edge overlapped or butted displays with continuous display addressable viewing surface.

7. Long-term storage of displayed data: 30 minutes to 50 percent brightness.

8. Very long-time storage of data with retained high performance (2-4 hours) with subliminal refresh.

9. Minimum of two colors for data.

<u>Conclusions</u>

Taking into consideration the above information, combined with our daily observations of the DSD operation and the maintenance procedures applied over the past 3 months, we have formulated the following set of preliminary estimates of DSD capabilities and potential:

1. The electronic design is more than adequate for prolonged testing and use in laboratory or field operation.

2. The performance demonstrated is clearly satisfactory for the intended display of tabular data and graphics.

3. The 5-inch CRT, which is a critical subunit of the DSD, is presently being produced at IBM and by other CRT subcontractors and appears to offer no production problems.

4. The optical system is considered established, useable, and implementable, and variations of it to produce other size displays, or to remote the image from the CRT and optics, are considered well within the capabilities of modern optical design.

5. The stability of the optics and CRT are greater than that presently accepted for operational use.

6. The lamp source is a long term, inexpensive unit well proven in military applications.

7. The inherent design of the DSD appears to satisfactorily solve existing problems of reflections, excessive contrast, glass tube safety, parallax, heat generation, power consumption, maintainability, power failure (fail safe) and others which presently are absorbing agency manpower and dollars.

8. The options available for screen size, screen material, multiple image overlap, microfilm projector incorporation, constant contrast over widely varying ambients, and multiple function usage are unmatched by any other display device.

W. H. KOCH

cc:

ANA-230:GSpanier:amh:x3194:Oct 21 75

AEM-20
ARD-110
ARD-120
ARD-404

APPENDIX H

IBM CORPORATION, EXECUTIVE SUMMARY OF A PROPOSAL
FOR A DSD EVALUATION CONSOLE

EXECUTIVE SUMMARY OF A PROPOSAL

FOR A

DSD EVALUATION CONSOLE

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HIGHLIGHTS OF THE PROPOSED APPROACH	4
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CONCLUSION	14

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ES-2	System Block Diagram	7
ES-3	Baseline Display Format	8
ES-4	Experimental Prototype Console	11

EXECUTIVE SUMMARY

During 1975 the FAA completed one of the most significant advances ever made in command and control systems. NAS Stage A is an outstanding example of the proper application of advanced data processing and display technology against a highly complex requirement. However, in the midst of this impressive progress, one obvious anachronism remains: the system still relies on manually-handled strips of paper produced by electro-mechanical printers.

For more than a decade the FAA and IBM have worked together to develop creative, effective solutions to problems such as this. Over the past year, IBM has been working with SRDS and NAFEC on a display technology that fully satisfies the requirements for electronic display of flight progress data and other tabular information.

The technology is called Deformographic Storage Display (DSD). This "Executive Summary" provides an overview of a recommended next step in applying DSD to the FAA's flight strip/tabular data needs -- a step which would allow the FAA to evaluate the numerous benefits for air traffic control that are inherent in this powerful new display technology. A detailed description of the proposed hardware, software and integration concepts has also been prepared. We would appreciate an opportunity to submit this more detailed "white paper" for the FAA's consideration.

THE DILEMMA

There are some good reasons why printed flight progress strips and manual posting consoles are still being used. Whatever their limitations, paper strips do provide an almost unlimited capacity for displaying flight progress information in an uncrowded format. The large viewing surface of a manual posting console allows the strips to be spread out for the user's convenience. And if failures occur anywhere in the system, paper flight strips will continue to provide static flight data.

Nonetheless, manual posting of flight progress strips has major deficiencies -- so much so that its replacement seems to hinge primarily on finding a suitable electronic display alternative. But until recently an acceptable alternative was not available. Most electronic displays have only a fraction of the data capacity of a manual posting console. Furthermore, on most displays any failure or loss of power can wipe out the displayed information.

Therefore, until a better approach could be found, the choice was between two equally undesirable alternatives. One alternative is the present manual approach. It imposes such handicaps as (1) the time-consuming process of handling physical strips of paper, (2) the noise and maintenance associated with printers, (3) a lack of closed-loop response and total system integration, plus (4) numerous duplications of operator effort when interacting with a partly-automated/partly-manual display system.

The only other alternatives that were previously available were CRTs or perhaps plasma displays. However, the maximum practical data capacities of such displays are quite limited. This tended to require some or all of the following expediencies in attempting to meet the operational requirements: (1) dividing the data over multiple display surfaces, (2) elimination of duplicate flight strip postings, (3) dropping the less frequently used data from each strip, and (4) compressing the total display surface area by reducing empty spaces within and between strips.

While some improvement in display efficiency is desirable, the net effect of such an approach would be that the system becomes "display-bound" -- the limitations of display capacity become a significant constraint on system operation. Future flexibility and growth are also limited by the fact that the displays are already saturated. Operators are forced to call up background information that used to be available at a glance. Data is squeezed together. The ability to provide the controllers with all the information they desire is compromised by the lack of display capacity. And the number of display units packed into each sector position would continue to proliferate.

A BETTER SOLUTION

It was IBM's privilege to have a major role on the FAA team that successfully implemented NAS Stage A. We are equally pleased to be able to offer an exciting yet practical solution to the remaining need for an electronic replacement for the manual posting consoles. By teaming the flexibility and capacity of the DSD with the power of the NAS data processing system that is already in place, the FAA will be able to achieve much more than just replacing paper flight strips. The DSD will allow the FAA to continue to expand the important overall thrust of the NAS program: providing air traffic controllers with the most useful and pertinent information available and displaying this data in the most concise and readily-assimilated form possible.

The NAS Enroute System Test Facility in Building 149 at NAFEC is a unique and powerful facility for evaluating and optimizing a totally-electronic flight data display system. The DSD is uniquely capable of providing the hardware basis for such an evaluation/optimization task. A merger of these two capabilities would be a major step toward achieving an all-electronic flight data system.

Therefore, we have worked out a rather detailed and specific proposal to define (1) the implementation of an advanced, large-capacity display console based on the DSD technology, and (2) the integration of this console into the NAFEC facility. The proposed approach allows a very thorough and realistic assessment of such a concept in the total ARTCC environment. Careful thought has been given to the hardware, software and integration aspects of such a program. An aggressive, yet achievable, program plan has been developed whereby this system can be in operation within eight months of go-ahead.

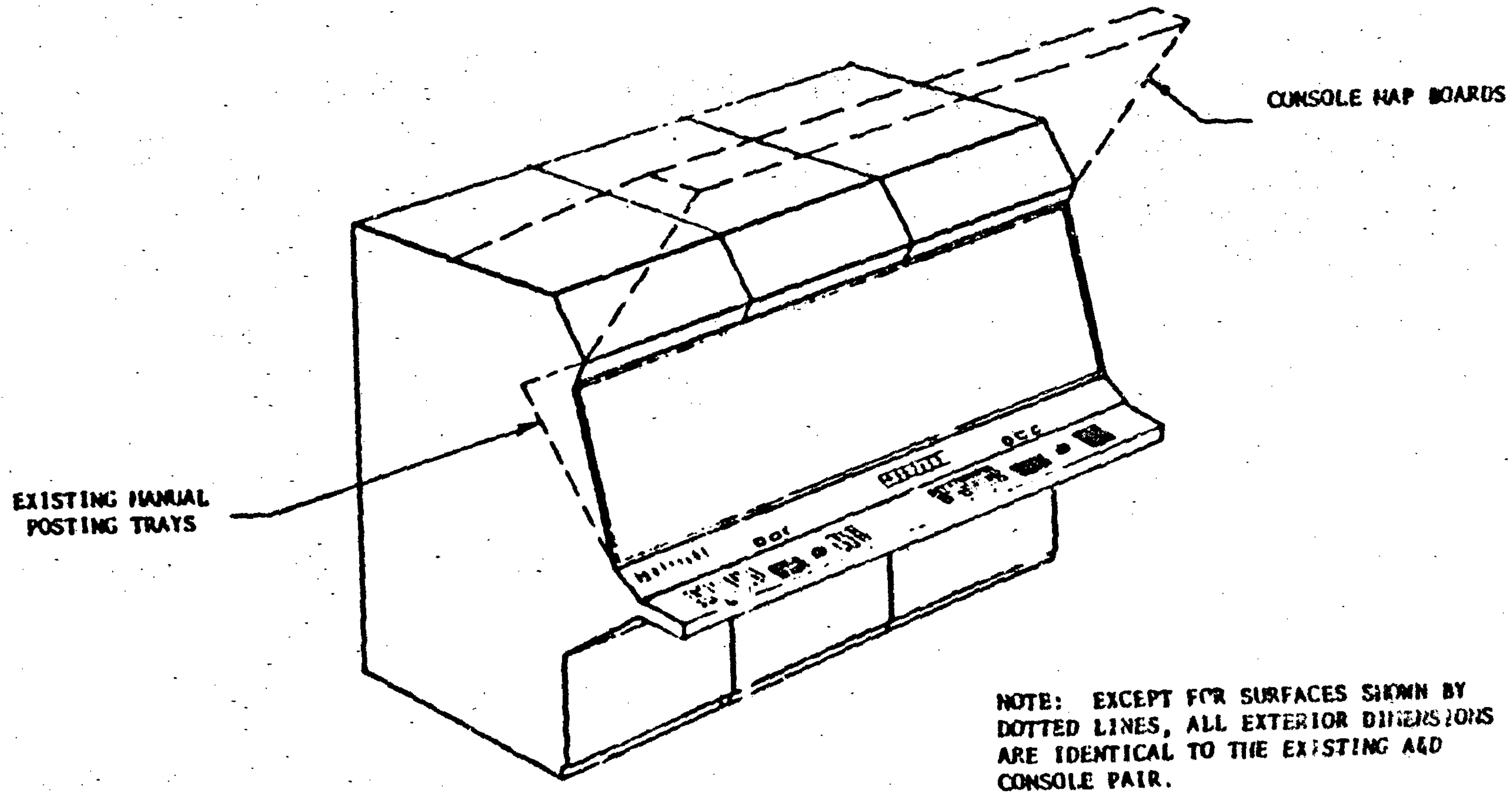
The proposed hardware configuration builds on the proven performance of the experimental prototype DSD console delivered to NAFEC in May 1975. Those who have seen this unit in operation have consistently been impressed with the maturity of the DSD technology and its unequaled performance as a large-capacity tabular display.

The proposed approach for integrating DSD technology into the NAS simulation facility at NAFEC is very straightforward. The proposed equipment would interface to the NAS system through a standard I/O adapter on the Central Computer Complex (CCC). No other interfaces or hardware interconnections would be required. Obviously, IBM is thoroughly familiar with the interface to the CCC. We are equally familiar with the NAFEC NAS software and this approach requires only minimal modifications to the programs already in place.

HIGHLIGHTS OF THE PROPOSED APPROACH

The basic concept being proposed by IBM is a DSD Evaluation Console that would, as a minimum, provide all of the functions of the "A" and "D" pair of manual posting consoles for one sector. The Evaluation Console is configured as a modular, electronic display that is physically interchangeable with an existing A and D pair of manual posting consoles. A comparison of overall dimensions and form-factor is given in Figure ES-1.

A continuous rear-projection display surface 24 inches high by 72 inches long would replace the present manual flight strip posting area.



NOTE: EXCEPT FOR SURFACES SHOWN BY DOTTED LINES, ALL EXTERIOR DIMENSIONS ARE IDENTICAL TO THE EXISTING A&D CONSOLE PAIR.

Figure ES-1. DSD Evaluation Console Dimensions

The overall height, width and depth of the Evaluation Console would be identical to an existing A and D console pair, and the existing Console Map Boards can be mounted directly above the unit.

The DSD Evaluation Console will provide all of the functions of the Flight Strip Printer, the Computer Readout Display (CRD) and the manual posting areas. The existing alphanumeric keyboard quick action keys and communications facilities will each be incorporated into the Evaluation Console as unmodified GFE. The Console will provide the required logic and I/O circuits to interface with the keyboard and quick action keys and will consolidate their interface back to the CCC with its own.

This means that the Evaluation Console will not have to interface with the Non-Radar Keyboard Multiplexer, the Common Logic Unit, nor any other I/O equipment outside of the CCC. This is depicted in Figure ES-2 which indicates that the console's sole interface would be with a pair of General Purpose Input and Output Adapters in the CCC's Peripheral Adapter Module (PAM). Communication equipment and interfaces would not be modified but would be installed intact into the front shelf area of the Console. No modification of the Plan View Display position nor the Computer Display Channel will be involved.

Within its 24 x 72 inch display surface, the Evaluation Console will display up to 114 complete flight strips plus two Computer Readout/ Preview areas. (The CRD areas will have more than twice the capacity of the present CRDs.) The format and character size of the 114 strips in the initial display format baseline will be essentially identical to the present paper strips. As shown in Figure ES-3, the screen will be divided into nine columns: seven columns with 14 strips each, plus two additional columns each containing eight strips and a 7 x 10 inch CRD area.

The DSD Console would not, however, be limited to reproducing the existing flight strip and CRD formats. Starting from these familiar formats as a baseline, the FAA can reprogram the display to evaluate any

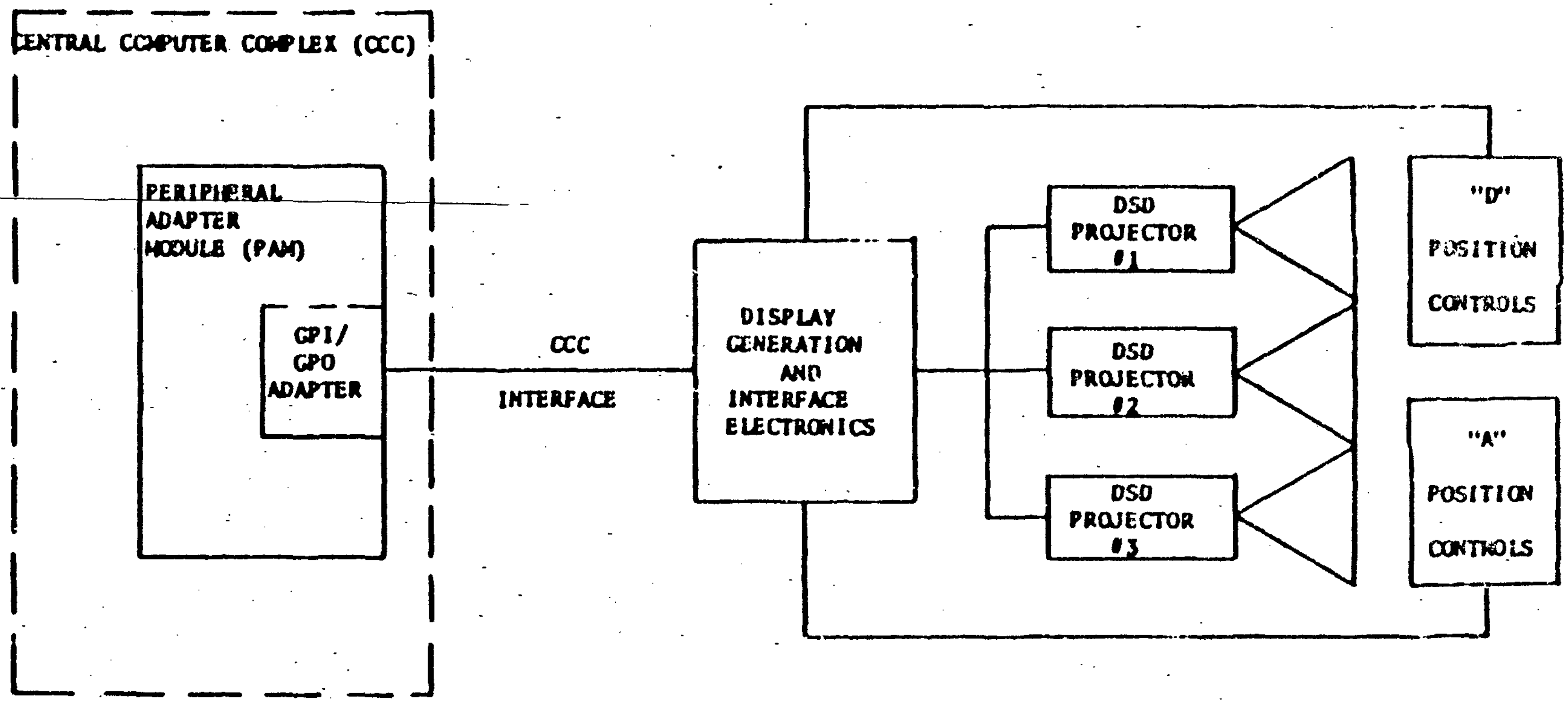


Figure ES-2. System Block Diagram

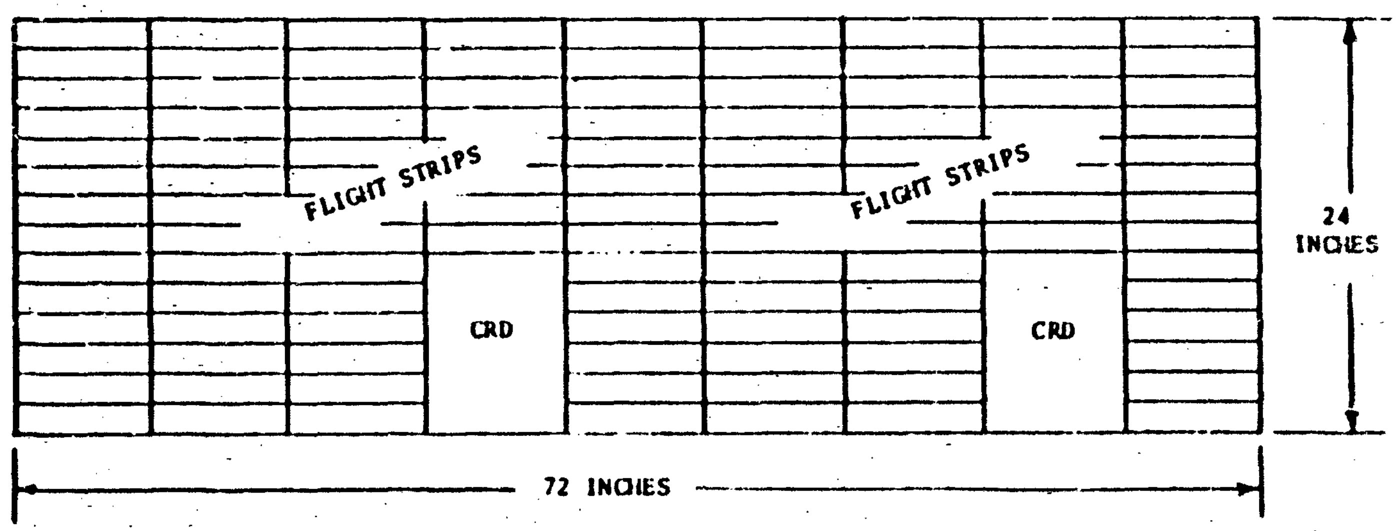


Figure ES-3. Baseline Display Format

type of format it desires: improved flight strip formats, flow control information, all other types of tabular data and graphical plots, selection menus and other interactive format elements. Indeed, the tremendous capacity and flexibility of the DSD will open up new concepts in display utilization that previously have not been practical to consider.

There are some important advantages in being able to start with formats that are essentially identical to those used with the existing paper strips, manual consoles and CRDs.

1. It does not arbitrarily impose new, predetermined formats nor a lower flight strip capacity on the FAA. Instead, it allows the FAA to determine, in an evolutionary manner, what changes and improvements it desires to make over the present formats.

2. It allows a familiar, non-threatening, initial starting point for any controllers who are asked to evaluate the DSD Console.

3. It provides a valid means for comparing the DSD Console with the existing manual consoles without complicating the comparison by using two different formats. Similarly, it provides a common point of reference and comparison in evaluating potential format changes and new functions.

4. It minimizes the impact on existing NAS software.

The foregoing are ideal features for any evaluation console. In essence they mean that a DSD Evaluation Console can emulate the formats produceable on almost any other type of display -- ranging from the present paper flight strips to electronic displays with a variety of data capacities and screen sizes. Thus, the installation of a DSD Evaluation Console at NAFEC will provide the FAA two important capabilities: (1) it will allow the direct evaluation of a very important new display technology, and (2) it will be an unusually powerful display evaluation tool for use in a wide range of future concept development programs.

Integration of the Evaluation Console into the NAFEC Enroute complex will have a minimal impact on existing NAS software. A key factor in simplifying the CCC software is the use of a microprocessor internal to the Evaluation Console. This microprocessor effectively emulates the CCC interface to a Flight Strip Printer and a Computer Readout Device.

The NAS software modifications will be designed to allow the Evaluation Console to operate in parallel with a conventional A and D console pair in the same sector. This will facilitate direct comparison of the two approaches.

DSD CHARACTERISTICS

The potential and the practicality of applying DSD technology against this type of requirement has already been impressively demonstrated by the original DSD experimental prototype at NAFEC (Figure ES-4). This unit has provided six months of trouble-free operation which have demonstrated the following major characteristics of a DSD console:

1. Storage. No power is required to retain an image. A flicker-free display is provided without refresh. Electronic bandwidths are reduced by a factor of 10 while capacity is simultaneously increased by a factor of 5 or more over the fastest known refreshed displays. A single display generator can readily drive a number of DSD projectors.

2. Data Capacity. The DSD is a very high resolution display. The experimental prototype has been used to display as many as 56 full flight strips on a single DSD tube using basically the same format as the current paper strips.

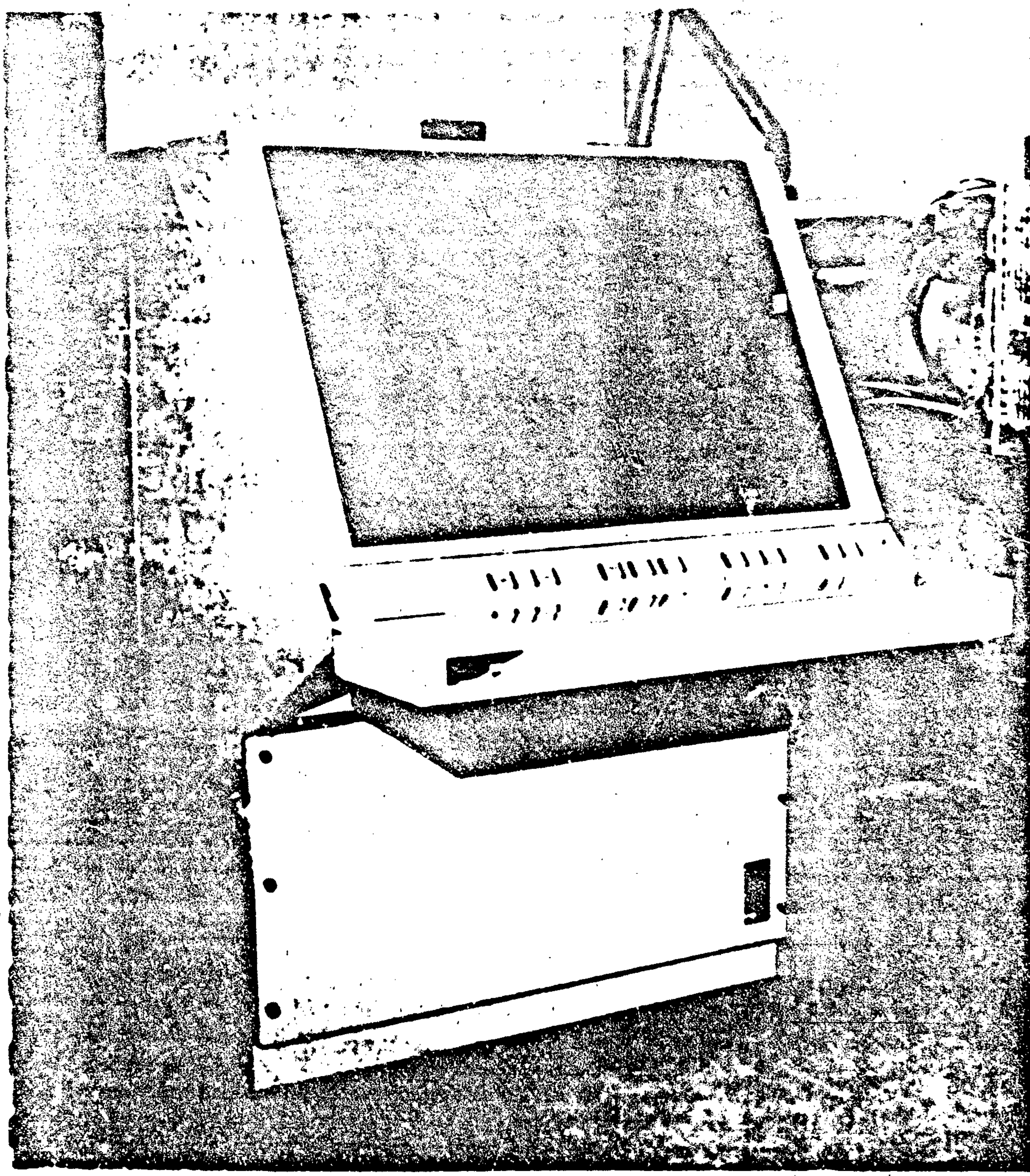


Figure ES-4. Experimental Prototype Console

3. Screen Size. The ability to display 56 full flight strips would be of little value on a 14 x 14 inch (20 inch diagonal) display. This amount of data would require 1/16-inch-high characters and such tiny characters could not be read from a reasonable viewing distance. However, 56 flight strips are quite readable from even a few feet away on the 22 x 32 inch screen of the experimental prototype. Since the DSD is a projection display, it can accommodate almost any conceivable character size and screen size.

4. Maintainability/Reliability. The experimental prototype at NAFEC has provided trouble-free performance. If maintenance is ever required on a DSD projection unit, all removable or repairable assemblies are mounted in the rear of the cabinet -- the front of the unit will only contain two fixed mirrors and the viewing screen. Simple, direct access will be available from the rear to all electronics, the light source, tube and all power supplies. Maintenance and operations functions need never interfere with one another. In a tower installation, the DSD tube and its electronics could be mounted below the floor of the operational area and be accessed for maintenance from the floor below.

5. Commonality/Modularity. A single projection system design (tube, optics, electronics) can be used for many screen sizes and a variety of applications. DSD projection units can be arranged to project contiguous images on a single, continuous screen, thus providing a modular building block approach to control-room display requirements. In the case of the proposed Evaluation Console, a "continuous array" of three 24 x 24 inch display areas from three DSD tubes is used to provide a total display area of 24 x 72 inches.

This concept of a Continuous Array Display (CAD) was originated by the FAA as a modular building block technique for achieving maximum display commonality throughout the FAA -- for example, between Enroute Centers, Towers and ARTS facilities. Since the proposed Evaluation Console is physically configured to the dimensions of the Enroute Center manual posting consoles, this particular configuration might appropriately be designated the "E-CAD" configuration for Enroute Continuous Array Display. This would differentiate this configuration from such alternative possibilities as towers (T-CAD), ARTS facilities (A-CAD), oceanic applications, flight service stations, etc. Each of these applications could use the same basic tube and electronics but with the different screen sizes and physical arrangements of the same basic building blocks as appropriate for each situation.

SYSTEM IMPLICATIONS

Figure ES-2 depicts a proposed initial system configuration for integrating a DSD Evaluation Console into the NAS System Test Facility at NAFEC. Clearly, it represents a very straightforward and uncomplicated approach. It also provides a very powerful configuration for full-scale evaluation of the use of an electronic tabular display.

However, IBM recognizes that the FAA is also interested in other related system improvements such as flow control and backup modes of operation for greater total system reliability. We would like to emphasize that the proposed system does not preclude or complicate expansion to a more sophisticated configuration in the future. To the contrary, it is an ideal first step toward such an objective. A two-step approach -- display subsystem first, data processing subsystem second -- has a number of important advantages:

1. It gives the FAA a significant headstart on the total problem because the DSD Evaluation Console can be on-line many months sooner than would otherwise be possible.

2. It uncomplicates the overall implementation of the total system by allowing the FAA to start from the existing NAS concepts and hardware/software base. Newer, improved techniques can then be

developed in an orderly, evolutionary manner rather than taking a high-risk, all-at-once plunge. Yet it in no way limits the ultimate capability of the system.

3. As a matter of fact, the DSD Console will provide a much more powerful system development and evaluation tool than any other known display approach.

In summary, then, the DSD Evaluation Console is not a competitor nor a threat to other, broader concepts regarding flight data handling. It is complementary and supportive of such a goal. Additional data processing capabilities can be added to the overall system at any time with very little impact on the proposed initial configuration. The packaging and architecture of the Console are such as to allow the addition or substitution of a different interface without affecting the basic design or features of the unit.

CONCLUSION

IBM is gratified that as early as 1973 the FAA had the foresight to press ahead with plans to specify and procure a DSD experimental prototype console. This initial FAA venture with DSD proved to be highly successful. As a result, there is a rapidly growing awareness throughout the FAA of the major implications of the DSD's unusual performance characteristics in regard to air traffic control.

However, because FY76 planning was completed before these results were known, no provision has been made to fully exploit the DSD's potential in the near future. Given the time required to evaluate and deploy any new concept into the NAS system, it would seem imperative that the next step begin as soon as possible. And an operationally-realistic evaluation in Building 149 at NAFEC seems like a most appropriate "next step".

IBM fully appreciates the fact that an unplanned program such as this poses significant problems for the FAA, particularly in a time of budget stringencies. But we feel that it would be a disservice on our part to fail to come forward with recommendations for moving ahead in applying such a greatly needed technology against the FAA's requirements. The proposed approach seems reasonable in scope and will provide meaningful, worthwhile results in the shortest possible time frame. It creates a powerful display system base from which even more ambitious systems concepts can be built. From the standpoint of both cost and effectiveness, the sooner this type of concept can be implemented, the sooner the FAA can begin to reap the benefits.

Therefore, IBM stands ready to work with the FAA in any way we can to surmount the initial difficulties of getting an unplanned program underway or, perhaps, to modify existing plans to take into account this new opportunity for further upgrading the nation's overall air traffic control capability. As a starting point we have prepared a detailed "white paper" defining the specific hardware, software and integration tasks required. We would appreciate the opportunity of discussing the program described in this "white paper" with the FAA at your earliest convenience.

APPENDIX I

ANA-1 LETTER TO ARD-1, DEMONSTRATION OF IBM DEFORMOGRAPHICS STORAGE TUBE, DATED SEPTEMBER 17, 1975

Demonstration of the IBM Deformographics
Storage Tube Display

Director, ANA-1

ARD-1

In the course of test and evaluation of the projection/light valve display technique as exemplified by the IBM Deformographic Storage Tube Display (DSTD), the Data Entry and Display Technology group has formulated several judgments relative to this display technique: (1) its performance is better than anticipated and represents a real breakthrough in display developments, and (2) two major display concepts or principles are now made possible, which if validated and accepted by the operating services could have significant impact on the agency's display planning. These principles, along with the inevitable acronyms are:

1. <u>Noninterfering Maintenance Remoted Optical Display (NIMROD)</u>

It appears feasible to package the DSTD electronics, optics and CRT (display generation assembly) in a form that allows the remoting of this assembly from the display viewing screen. This will permit on-going maintenance totally isolated from the operational area of the facility. The advantage of this capability from the aspect of maintenance staffing and reduced impact on the ATC operation is evident.

2. <u>Continuous Array Display (CAD)</u>

If the above remoted assembly is combined with other display generation assemblies, mounted side-by-side, a continuous viewing screen of unlimited horizontal dimension is attainable. Such a viewing screen, free of bezels or CRT mounting hardware, can provide a capability for displaying any type of data, in any form or format, at any location on the viewing surface, through software control. Alternately stated, this CAD capability would provide a display base that could accommodate any future concept which generates information for the controller. This will eliminate the need for implementing discrete displays for each discrete data generating function.

Both principles can be applied in those ATC environments which employ data display; ARTCC, TRACON, Tower Cab or Flight Service Station. This capability, coupled with the very promising performance of the first article DSTD, indicates that projection type displays offer definite promise in the technology goal of developing a universal ATC display.

The question now arises as to whether the concepts of NIMROD and CAD justifies or warrants further expenditure of funds to explore their potential. In order to configure a suitable vehicle for further experimentation, an additional "head" (CRT, optics, and electronics) and repackaging of our present DSTD is necessary. This, along with specialized engineering services from IBM, will cost approximately $175K. To determine whether this amount of money should be allocated, we would suggest that the operating services be queried as to their interest in further development work. We further suggest that the most practical vehicle for ascertaining the extent of their interest and support in this area is a demonstration of the DSTD, and of the various concepts and principles outlined in this letter. The ATC configurations to be emphasized would be the enroute and tower cab and we would employ mockup and dynamic display techniques to convey our message.

If you are amenable to the idea, we would recommend a demonstration date during the week of November 3, 1975. Planning officers from the Western Region and the San Diego terminal facility will be at NAFEC during this period to view work being done relative to future tower cab experimentations. This group can be complemented with other representatives of SRDS and the operating services as you designate. If you concur with our recommendation, we will proceed with necessary coordination and arrangements. Our contact will be Mr. Edward M. Alzner, ANA-230, extension 3393.

ROBERT L. FAITH

cc:
ARD-104
ARD-110

ANA-230:EAlzner:amh:x3393:9/17/75

APPENDIX J

REQUEST FOR RD&E EFFORT, 9500-1-#AT-100-29

REQUEST FOR R, D & E EFFORT

PERSON MOST FAMILIAR WITH REQUEST — Name: Wesley E. Rowland — AAT-120

PART I

INSTRUCTIONS - Originating organization must complete all of Part I and insert the Program Service routing symbol in Part II (unless originator is Program Service).

SUBJECT OF REQUEST: Feasibility Demonstration of Improved Radar Displays for Terminal Radar Approach Control Cabs (TRACABs)

REQUEST NUMBER: AT-100-29

PURPOSE OF REQUEST, OPERATIONAL PRIORITY:

As you know, FAAR 6410.1 dated 11/4/66 resulted in BRITE I TV type displays for use in control tower cabs for local control purposes. Subsequently, Form 9550, AT-100-12, dated 5/23/68 requested R&D action to adapt the BRITE display concept for approach control use. The culmination of this effort led to the agency policy of TRACAB installations at all newly qualified radar locations starting with the FY 1969 F&E ASR establishment program.

Exceptions to this policy have only been granted where individually justified. TRACAB requirements have been satisfied by installation of BRITE II and BRITE IV displays in tower cabs. To the best of our knowledge, no follow-on state-of-the-art effort has been undertaken to provide improved type of displays for this type use. (Continued)

ROUTING SYMBOL	Initials	Rtg. Sym.	Date	SIGNATURE OF DIRECTOR	DATE	DESIRED COMPLETION DATE
AAT-1		AAT-120		Dir. Ser., Air Traffic Service		March 1, 1975
		AAT-101				
		AAT-100				

PART II

INSTRUCTIONS - To be completed by Program Service (if not the originating organization).

ROUTING SYMBOL	Initials	Rtg. Sym.	Date	SIGNATURE OF DIRECTOR	DATE	No Comment	Comment Attached	
AOP-4								

PART III

Signature of Director, ARD

PART IV

R, D & E ACTION

Investigation of improved display technologies and equipment for application to tower cab displays is being pursued and will continue under subprogram 144-170, Terminal Tower Sustaining Engineering. When these efforts result in the verification of a potential improvement to the system we will set up a demonstration for Air Traffic Service representatives. More definitive information on cost and schedule will be determined as the experimental effort progresses. We estimate that this additional information will be available by December 1, 1974.

ROUTING SYMBOL	Initials	Rtg. Sym.	Date	X APPROVED / REJECTED — SIGNATURE OF DIRECTOR ARD	DATE	PERSON TO CONTACT
ARD-1						
AAT-1						

AEM-100 COMMENTS RE 9550-1, AT-100-29, 7/15/74, "FEASIBILITY DEMONSTRATION OF IMPROVED RADAR DISPLAYS FOR TERMINAL RADAR APPROACH CONTROL CABS (TRACABS)"

We have discussed this subject briefly with AAT-100 and believe the following may serve to amplify the information contained in the 9550-1.

Basically, the request was prompted by two factors:

- o Some dissatisfaction with the quality of the BRITE display presentation for performing radar approach control functions in the tower cab has been expressed by the field.

- o During a visit to NAFEC by AAT-100 and subsequent discussions with NAFEC and ARD personnel, it was suggested that advances in display technology, such as the Deformographic Display System, may offer a potential means of realizing an improved display for this application.

In addition to the requirement to perform satisfactorily in the extremely varied light conditions experienced in control tower cabs, other aspects fundamental to the application of interest are as follows:

- o The data to be displayed includes a plan view presentation of radar, beacon and map data derived from broadband video inputs.

- o Since the TRACAB locations are programmed for ARTS II or [illegible] systems, it is also necessary that the display system be capable of simultaneously presenting the alphanumeric/numeric data supplied by these systems.

2

Part 1 continued

We understand that the state-of-the-art has advanced to the point that displays can be produced which will not be adversely affected by ambient light levels, direct sunlight, fade out or glare, and extraneous surface reflections, all of which are prevalent to varying degrees in TRACAB environments. These improved displays must be of a high resolution/high contrast to be easily and readily viewed under high and low ambient light conditions being encountered.

The feasibility demonstration should be of sufficient magnitude to allow a follow-on retrofit program for TRACABs if the R&D effort is successful.