The Evaluation of Several Display Parameters for the Flight Service Automation System

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16. Abstract

This report presents information on flight service station (FSS) displays and is part of the FSS Automation Program. FSS specialists from manual and automated facilities evaluated a variety of display options. The options included standard and high resolution, P39 and P40 phosphors, monochrome and color, and several methods of formatting and coding graphic and tabular weather information, and weather radar. Results showed (1) the standard resolution, 512 by 640 pixels, was equivalent to the high, 768 by 1,024 pixels, (2) the yellow-white P40 was preferred to the green P39, (3) there were no problems with smear of afterimages or with flicker at 30 hertz (Hz) interlaced frame rate, and (4) monochrome displays were quite acceptable, but color was preferred. With respect to formatting information, (5) two sizes of characters were preferred for graphic displays, and (6) weather radar was most successfully presented by contouring and coded fill, next by showing the raw radar in variations of color or brightness, and least by using coded contours only.

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INTRODUCTION

PURPOSE.

The purpose of this report is to provide information on flight service station (FSS) displays which can provide guidance in specifying the Model 2 FSS Automation System. Specific objectives are:

1. Determination of resolution requirements for the graphic display with respect to raster, bandwidth, and bit plane memory size.

2. Evaluation of the adequacy of various combinations of phosphor, refresh rate, filters, and surface treatments of the display cathode-ray tubes (CRT's).

3. Evaluation of a number of techniques for coding and formatting a variety of weather, weather radar, and tabular information.

4. Comparison of monochrome and color displays.

BACKGROUND.

The work reported here was accomplished under the Federal Aviation Administration (FAA) Technical Center Program Document 13-251, FSS Automation, Subprogram 132-402, Project No. 274, Human Factors Activities, June 1978.

The automation program in the FSS will require a transition from complete reliance on printed material in the form of teletyped listings and facsimile charts to CRT displays. This change will have far-reaching implications for the design and use of the FSS. It affects the individual work station, the layout of positions, the amount and location of ambient lighting, job allocations, communications, maintenance, and training. Since there are as many as 1,200 positions under consideration, with at least two displays each, the monetary implications of display decisions are significant.

The determination of the minimum requirements necessary for graphic displays in the FSS has been a matter of study for several years. The most important issue, at least in terms of cost, relates to the amount of display and memory resolution needed to provide high quality weather graphics and radar information. Given the decision to use digital bit-plane memory refresh rather than video disc, the alternatives were narrowed down to two: high resolution with 768 by 1,024 pixels (picture elements or addressable points) and standard resolution with 512 by 640 pixels.

The resolution decision has a significant impact on the degree of the sophistication required by the display and on the size and speed of the memories. The high resolution display must have a bandwidth of at least 13.8 megahertz (MHz) and up to 38.3 MHz, depending on the choice of phosphor and refresh rate. The lower figure would require a fairly expensive but commercially available display, the latter something at the "state-of-the-art." With standard resolution, the corresponding values become 5.6 to 12.3 MHz. The former is well within the range of any good quality commercial monitor; the latter is easily obtainable, but with a three- to four-fold price increase. The difference between high and standard resolution in memory size alone is a factor of 2.4 to 1.

An attempt was made several years ago to demonstrate the effects of resolution and bandwidth on the display of weather graphics using closed-circuit television operating at different rasters and using filters to control bandwidth. While the advantages of high resolution seemed questionable at that time, the validity of simulating a digital system with analog video was sufficiently open to doubt to postpone the decision until the comparison could be made on digital equipment similar to that proposed for the automated system. The availability of that equipment made the present study possible.

The choice of a phosphor for the CRT display impacts a number of important design decisions: the maximum brightness obtainable, the refresh rate necessary to avoid flicker, the likelihood of smear or ghosts, the color of the display, and the ability to provide filters for the maximization of contrast. While adequate brightness and contrast are unlikely to be problems in the automated FSS environment, the trade-off between refresh rate and smear or ghosting is important. The choice of a high efficiency (high brightness) phosphor with low storage or lag would require a 50- to 60-hertz (Hz) refresh rate to avoid flicker. The light output of these phosphors decays so quickly that there would never be a problem with afterimages, but a higher refresh rate means faster writing times, faster memory, and higher bandwidth (38.3 MHz and 12.3 MHz for the high and standard resolution, respectively). One of the questions this study will address is whether the FSS system can use a medium storage phosphor, such as the P39 or P40, at a low refresh rate without flickering or creating a problem with reading new information through the afterimage of the old. It will also attempt to determine whether there is a clear preference between the green P39 and the yellow-white P40.

Another display option that has been of considerable interest for some time is the use of color. Recent improvements in color video, the availability of new operational and technical color displays, and the compelling use of color maps and radar on television weather presentations, all suggest that color is an important new dimension for any weather display. Since color would require a significant increase in acquisition and maintenance costs, its use should be contingent on some demonstrable benefit.

The objective evaluation of color has been a persistently difficult methodological problem in human factors (Christ, reference 1). Connolly (reference 2) and Hopkin (reference 3) have both found that even experienced controllers may think they are performing better with color, although they are not. Since subjective data can be misleading in this area, only careful controller performance testing or simulation studies can provide the kind of quantitative information needed to make the design trade-offs between the increased system cost and improved system performance. This type of study is beyond the time and resources of the present effort. Nevertheless, an attempt was made to get whatever information that was available on color displays within this FSS context, and comparisons were made with monochrome displays where appropriate.

STUDY DESCRIPTION

SUBJECTS.

Ten experienced FSS specialists were used to observe and evaluate displays. Three specialists came from Millville, New Jersey, and two from North Philadelphia, Pennsylvania — both manual facilities; one specialist from Washington, D.C. Meteorological Aeronautical Presentation System (MAPS), and two each from Indianapolis, Indiana, and Atlanta, Georgia — both Aviation Weather and NOTAM System (AWANS).

DISPLAYS.

Three preflight positions were set up, each with two displays (figure 1). The left display listed tabular information, and the right, graphics. One position used two P39 14-inch tubes in Conrac RQB-14 monitors. The second position used two P40 14-inch tubes in the same type of monitor. The third position used two MGA C-351A color monitors, also 14 inches. For each series of trials, a keyboard was available to call up each of the different tabular and graphic products. Of the two P39 tubes, the one used for tabular information had a bandpass filter (one matched to the spectral output of the phosphor) and an antireflective coating, while the one used for graphics had a neutral density filter and no surface treatment for reflections. Of the two P40 tubes, both had neutral density filters, and the tabular display had an antireflective coating. The front surface of the graphic display was etched to break up reflections. The two color displays were equipped with neutral density filters.

All of the monochrome displays had a useful display area of 8 inches vertically by 10.67 inches horizonally. Due to certain hardware limitations of the Genisco equipment, the usable display area on the color tubes was 7 by 9.75 inches.

DISPLAY GENERATION.

Each of the preflight positions was driven by one of three Genisco GCT-3000 display controllers, all of which are under control of an Interdata 8/32 computer. (A schematic of this system is shown in figure 2.) A Genisco drives two monochrome displays at each position under one of two conditions: (1) standard resolution using a 512 by 640 element bit plane memory up to three bits per pixel, refreshed at 30 Hz, interlaced, or (2) high resolution, using 768 by 1,024 element bit plane memory up to three bits per pixel, refreshed at 40 Hz, interlaced (see figure 3). The color displays can only be driven at 525 by 640, at 30 Hz, and at three bits per pixel.

GRAPHIC PRODUCTS.

There are two sets of graphic products: one for monochrome displays (figure A-1) and one for color displays (figure B-1). While the products used were designed primarily as a vehicle to demonstrate and evaluate the display characteristics, they will also help to obtain specialist reactions to the type and format of the information that should be presented with this system.

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FIGURE 1. FSS LAB SHOWING THREE TESTING POSITIONS AND SIX DISPLAYS

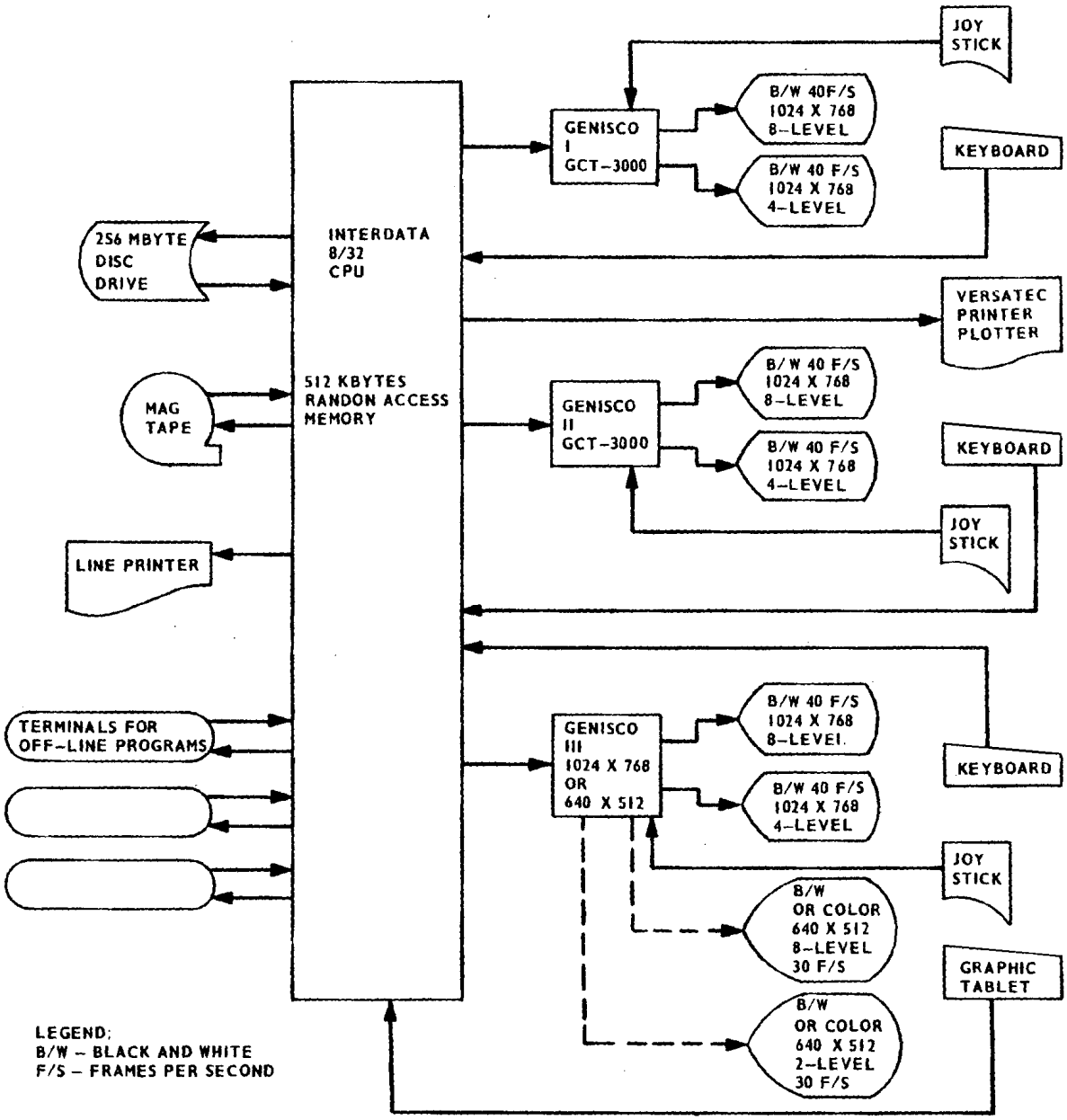

FIGURE 2. SCHEMATIC OF INTERDATA/GENISCO/DISPLAY

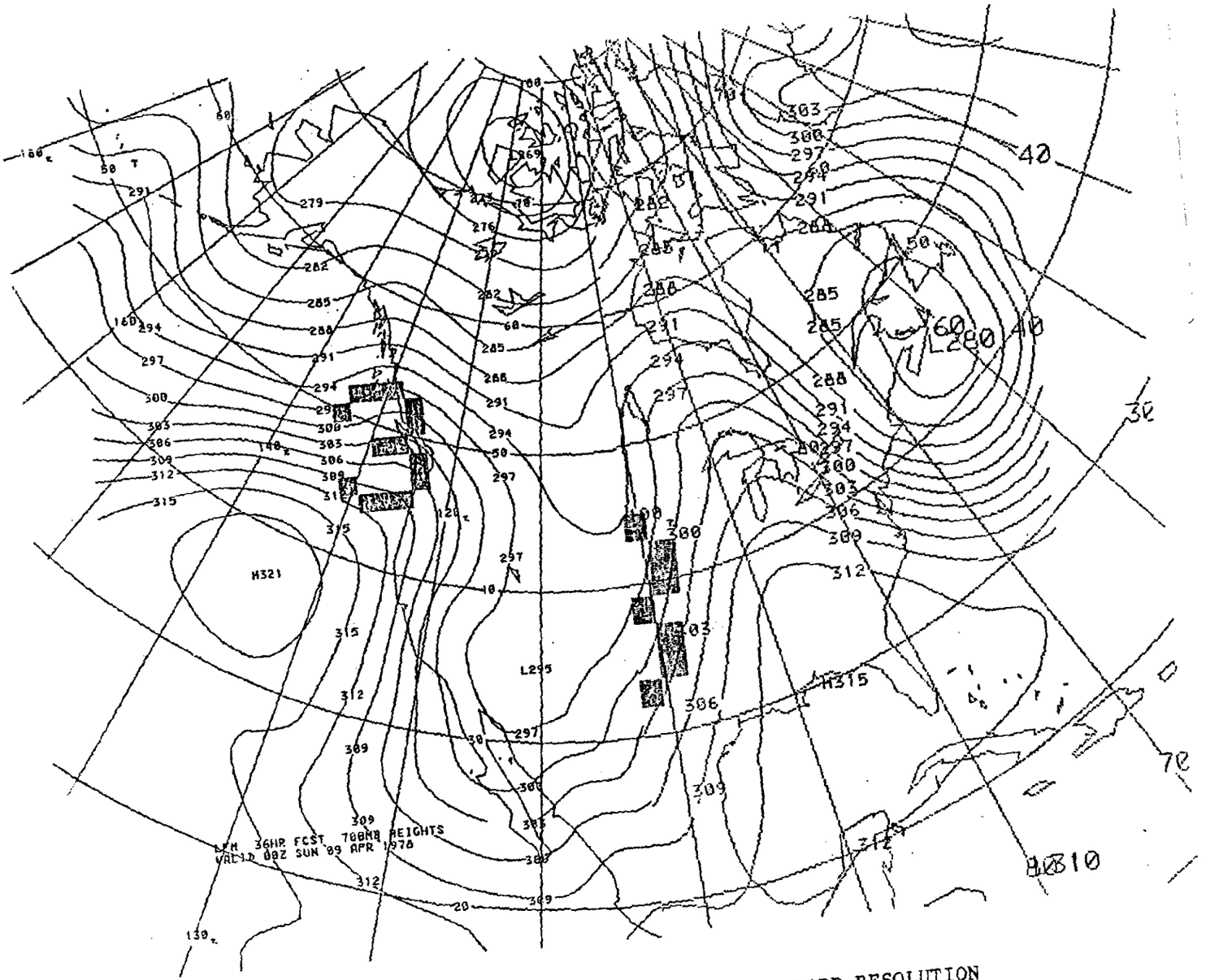

FIGURE 3. DISPLAY SHOWING HIGH AND STANDARD RESOLUTION

Graphic products and alphanumeric textual material were created with software which was specifically developed for this test and stored on the disk. This software consisted of:

1. A new graphic method for generating character fonts and special symbols of up to 32 by 32 pixels in size.

2. A program which translates the National Weather Service's Automation of Field Operations System (AFOS) graphic products to a format which is compatible with the Genisco display system.

3. An interactive graphic editor which is capable of modifying existing AFOS products or creating new graphics based on the present facsimile weather graphics, weather radar, or any other symbolic or contour representations of interest.

The Product Index (Form A, figure A-1) was used for monochrome displays and items numbered 00 to 13 and 26 to 30 are graphic items shown on the graphics (right hand) display. Items numbered 14 to 25 are tabular items shown on the left display and are alphanumeric characters only. The Product Index (Form B, figure B-1) was used for the color displays. Items numbered 00 to 15 and 28 to 32 are graphic items, and 16 to 27 tabular. The software used to generate the products is such that basic inputs were made twice; once for standard resolution, which includes the color, and again for high resolution. The intention was to have these products identical so that only experimental conditions would vary. However, in a few instances, the input itself varied slightly. For example, in graphic product 02, marginal visual flight rules (VFR) conditions are shown as a dotted line in standard resolution and as a solid line in high resolution. These discrepancies, as they affect the analysis, will be assessed in the results section.

Another difference between the two resolutions was the use of different character fonts to produce characters of the same size. The characters in all graphic and tabular products, except 00 and 06, were set at the specified height of 0.15 inch. This required a 7- by 10-pixel font on the standard resolution display and a 10- by 14-pixel font on the high resolution display. The standard resolution characters are 8 inches by 10 pixels divided by 512 lines to equal 0.156 inch. For high resolution, the size is 8 inches by 14/768 = 0.146 inch. The standard resolution character fonts are shown in figure 4, and the high resolution character fonts are shown in figure 5.

Formula:

$$\frac{\text{Usable tube height by number of pixels in height of the character}}{\text{Total raster lines per display}}$$

"Small" characters tested on graphic display 06 are 8 inches by 7/512 = 0.11 inch on the standard, and 8 inches by 10/768 = 0.104 inch on the high.

It should be noted that the 5 by 7 and 7 by 10 fonts on the standard and high resolution displays are based on fonts built for those specific formats. The 10 by 14 font is a 5 by 7 using a hardware "zoom" feature. While this does not affect its legibility, it does appear more stylized. (See table 1.)

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FIGURE 4. STANDARD RESOLUTION CHARACTER FONTS

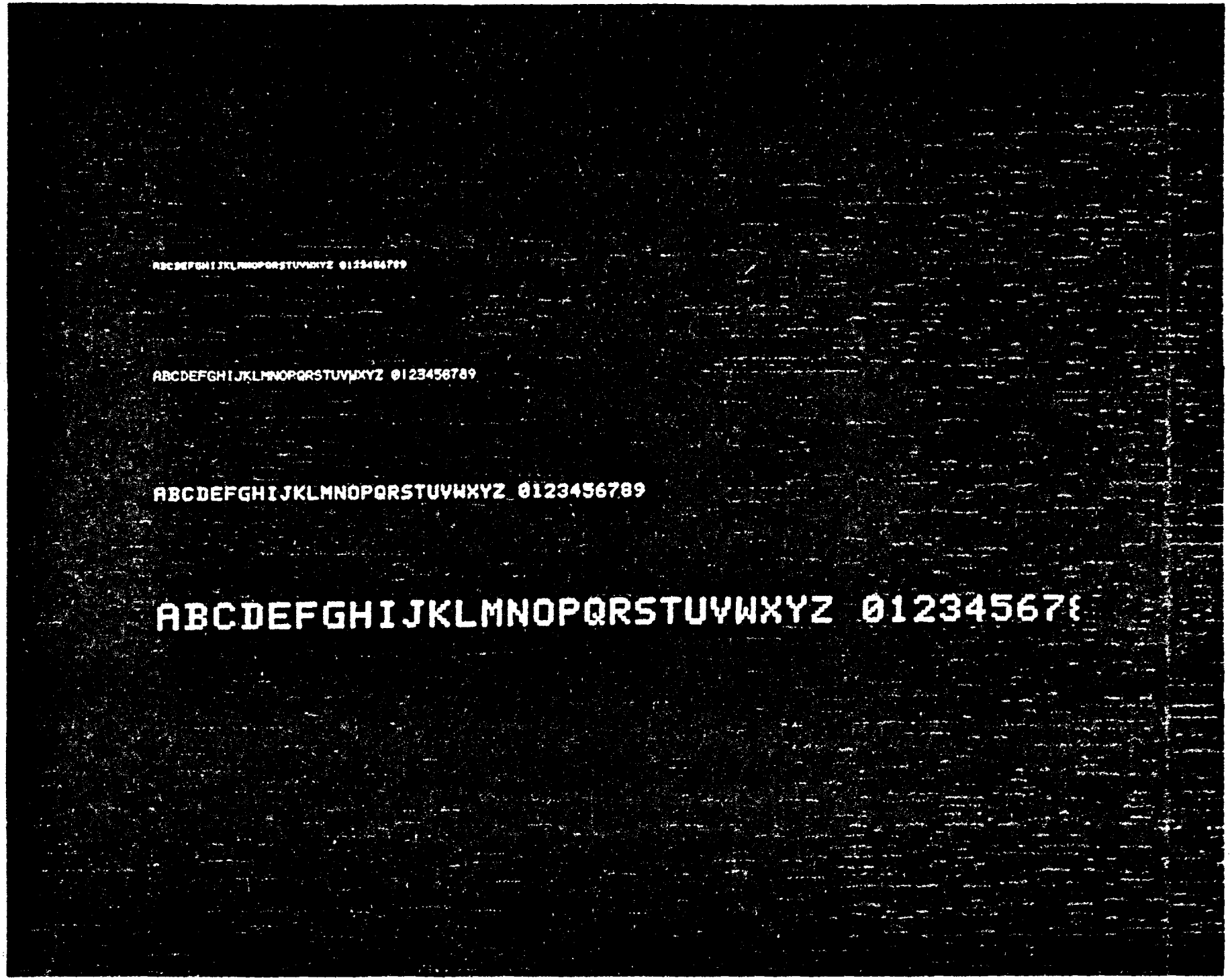

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FIGURE 5. HIGH RESOLUTION CHARACTER FONTS

TABLE 1. ALPHANUMERIC FONTS

Character Format (pixels)	Character Size: Standard Resolution (inches)	Character Size: High Resolution (inches)
5 x 7	0.11*	0.073
7 x 10	0.156*	0.104
10 x 14	--	0.146

*Because the usable display area of the color tube was 7 by 9.75 inches as opposed to 8 by 10.67 inches for the monochrome, the height of the 5 by 7 character was 0.0957 inch, and the 7 by 10 character was 0.1367 inch.

EXPERIMENTAL DESIGN.

In any particular application, the amount of usable resolution is limited by viewing distance, screen size, the kind of information being displayed (alphanumeric and/or graphic), and a number of specific task-related factors pertaining to precisely how the display will be used. A problem in evaluating display characteristics is that, from a purely subjective viewpoint, a high resolution display may have a "better" appearance than one with standard resolution. This does not mean that more information can be seen, that the information can be seen more clearly, or that the display can be used under less favorable conditions. It means only that at first glance it seems to be of higher quality or more pleasing. The experiment described below is based on these considerations and practical limitations faced when bringing field personnel to the Technical Center for data collection.

Due to the limited number of subjects, it was necessary to use a repeated-measures design. This permits the collection of more information and minimizes experimental error. Other limitations in the design were imposed by the logistics of the testing. That is, it would have been overly complex to reorder the graphic products or to attempt to shift, within a run, between standard and high resolution. Too many different questionnaire forms would also have proved unwieldy.

All subjects saw the displays in the same sequence: standard resolution, high resolution, and, finally, color. While this approach may have certain restrictions, the choice was limited by the number of subjects. The concern is not whether high resolution is better than standard, or color better than both, but rather which one is capable of providing a good display for the information shown. The order permits the specialist to evaluate each display and product on its own merit, and not in comparison to another which may naively be regarded as better.

DATA COLLECTION.

Data were collected during the week of June 25, 1979. Each of the 10 subjects was given a brief explanation of the purpose of the study (figure 6). Two questionnaire forms were used for data collection. Form A was used for the monochrome displays using P39 and P40 phosphors, high and standard resolution; and Form B was used for the color displays. Five questionnaires were completed per subject: four, Form A; one, Form B. Each subject was able to refer to the appropriate Product List while filling out the questionnaire. The subjects went through the four monochrome runs during the morning session and the color run in the afternoon. In addition to filling out the questionnaire, most of the specialists offered comments on the displays.

RESULTS

The responses to questionnaire A are tabulated in appendix A, and the responses to questionnaire B are tabulated in appendix B. Each of the questions is shown together with the response alternatives, and beneath them the number of subjects selecting each response. Form A, used for the monochrome displays, shows four rows of response data, one for each of the phosphor/resolution combinations. To the right of each row of responses are the mean and the median for that row. Form B, for color, was only administered once, and only one set of responses is shown.

The first analysis of data consisted of an analysis of variance on each question in the Form A questionnaire. More specifically, this is a two-by-two factorial with repeated measures design and tests for significance due to resolution, significance due to phosphor and significance due to resolution by phosphor interaction (Meyers, reference 4). Fifty such analyses of variance were performed, one for each of the Form A questions. These results are shown in appendix A. Items discussed are limited to those where a significant difference appeared.

The first such item was question A5, "Were reflections a problem while viewing the tabular display?" This was significant at the 0.05 level; the P40 tube rating better than the P39. Since both these tubes had antireflective coatings, the difference would appear to be due either to the preference of the neutral density filter of the P40 over the bandpass filter of the P39 (which increases its contrast), or the general preference for the P40 phosphor which was apparent in many questions, although not often at a statistically significant level.

Question A7, "What do you think of the color of the tabular display?" shows a significant result. In this case, high resolution was preferred over standard, with resolution significant at the 0.04 level. This must be regarded as an anomaly, since no color difference exists between the two conditions of resolution. Closer examination revealed that the variance due to phosphor differences was 7 times greater than the variance due to resolution; the error term for phosphor was 16 times greater.

Answers to question A15, referring to graphic product 02, "How good is this product in permitting easy identification and use of the information it contains?" showed that resolution was significant at the 0.04 level. Standard resolution was preferred over high resolution.

We have asked you to NAFEC* to help evaluate a number of different display alternatives that are being considered for the Model 2 Automated FSS. In order to help you judge these displays, we have generated several tabular and graphic products that we feel might be useful to the specialist, and we are interested in your opinion of these products. But remember, once the hardware decisions have been made, there will be considerable additional effort put into determining optimum formats and the most useful combinations of graphic information.

You will see these displays in a predetermined order. We want each of you to give his or her own opinion on what is being shown. After everyone has had an opportunity to evaluate all the options, we will hold a discussion session so that you can share your opinions with the others and ask any questions you like about the new system.

For each series of observations, you will be given an index of tabular and graphic products. Each of these can be called up on the appropriate display by entering the 2-digit number plus "return" in the active keyboard. When you have been seated at a position, go through all items on the index to get a feel for the range of products. Adjust the brightness and contrast so that each item is at its best -- for you. Then, go through them again with the questionnaire and rate each product that requires a rating. Add your comments on any display option that you feel necessary. PLEASE, do not discuss any of the displays with your fellow observers until the discussion session.

Please respond to each question in the questionnaire by drawing a circle around the number that comes closest to your opinion. Work carefully, as in some cases the legend on the alternatives is different.

* FAA Technical Center

FIGURE 6. FLIGHT SERVICE STATION AUTOMATION DISPLAY STUDY

Question A17 is identical to question A15, but refers to graphic product 03. Resolution is significant at the 0.01 level, phosphor at the 0.05 level, and the resolution by phosphor interaction is significant at the 0.05 level. In this case, the P39 phosphor at standard resolution is significantly poorer than the other phosphor resolution combinations. This is one of only three questions on which the interaction is significant.

In question A18, which refers to graphic product 04, the P40 phosphor was rated better than the P39 at the 0.04 level.

Question A21 asked the subjects to rate the size of the alphanumeric characters on product 06; (0 = much too small, 3 = just right, and 6 = much too large). The difference due to resolution was significant at the 0.05 level, even though both standard and high resolution characters were rated slightly higher than "just right." The 7 by 10 character font on the standard resolution display produced characters 0.156 inch high and had a mean rating of 3.7, while the 10 by 14 font in high resolution made a 0.146-inch character which was rated 3.3. The smaller character seems closer to the specialists' idea of "just right."

Question A22 refers to graphic product 06, "How good is this product in permitting easy identification and use of the information it contains?" Results show a significant difference between phosphors at the 0.05 level; P40 was preferred to the P39.

Considering graphic product 09, question A29 asked, "How useful is this product for showing radar returns?" Resolution was significant at the 0.04 level of confidence; high resolution was preferred over standard.

Question A31 is identical to A29, except that it refers to graphic product 10. Phosphor was significant at the 0.01 level, and the resolution by phosphor interaction was significant at the 0.04 level. P40-standard rated higher than the others.

Question A32 again used graphic product 10, and asks, "Does this use of brightness, dashes, and solid lines facilitate understanding of the pattern?" Resolution was significant at 0.05, phosphor at 0.01; and the resolution by phosphor interaction was significant at 0.05. The P40-standard combination was preferred to all others.

Questions A33, A35, and A37 showed a significantly higher rating for the P40 phosphor. All questions concerned the usefulness of products using contoured radar with fill.

Questions A43 to A50 were about the graphic displays in general — as opposed to referring to a specific graphic product. The P40 phosphor was significantly preferred over the P39 for brightness (A44), contrast (A45), reflections (A46), and color (A47). With respect to reflections, the P40 graphic display had the neutral density filter and the etched surface, while the P39 had the bandpass filter and no other antireflective treatment.

On the final question on Form A, "In general, how do you rate the graphic display for operational use?" resolution was significant at the 0.05 level, with the standard resolution preferred over the high. As in previously-mentioned results,

the variance due to phosphor was three and a half times as large as that due to resolution, but the phosphor error term was six and a half times larger. The difference, not statistically significant, was again in favor of the P40.

To summarize the results thus far, both phosphors and both resolutions are seen as adequate by our sample of specialists, but there is a distinct preference for the P40 over the P39. There is no clear preference for either high or standard resolution.

The remaining portion of the analysis will address the comparison of monochrome and color displays and the differences among the graphic products. The responses to the color display, Form B questionnaire, are presented in tabular format similar to Form A questionnaire. The mean and median are calculated for each question.

In the evaluation of the use of color for tabular data, seven different colors were used, with one color per tabular product, as follows: 18 = Red, 19 = Purple, 20 = Cyan, 21 = Yellow, 22 = Blue, 23 = White, and 24 = Green.

The first 49 questions on Form B are dedicated to rating tabular color products. An analysis of variance was done for the seven colors plus the P39 and P40 phosphors under standard resolution for each of the following questions on tabular display:

1. How good are these characters for ease of reading or legibility?

2. How do you rate this product for sharpness or resolution?

3. How is this in terms of adequate brightness?

4. How is this in terms of adequate contrast?

5. What do you think of the color?

6. Was there any flicker?

7. How would you rate this for operational use?

Two of the questions resulted in statistically significant differences: contrast was significant at the 0.02 level, and flicker was significant at greater than 0.001. With respect to contrast, the blue tabular display was significantly poorer than both the cyan and the P40 at the 0.035 level of confidence. No other differences were significant.

Regarding flicker, both the P39 and the P40 phosphors were significantly better than the green, cyan, and white displays, and the P40 was also better than the yellow display.

An analysis was made to evaluate differences in the graphic displays that could be attributed to color. The following characteristics were evaluated for the overall impression of the graphic displays (information in parentheses indicate form and question numbers):

Sharpness or resolution	(A43, B81)
Brightness	(A44, B82)
Contrast	(A45, B83)
Reflections	(A46, B84)
Flicker	(A48, B85)
After images, ghosting or smear	(A49, B86)
Operational suitability	(A50, B87)

Two of the seven analyses of variance were significant at greater than the 0.05 confidence level; reflections and operational use. While the analysis of variance showed the difference in ratings on reflections to be of statistical significance, none of the individual contrasts between color, P39, and P40 were significant at even the 0.10 level.

In the questions on operational use, there was an overall significance at the 0.025 level, P40 rated better than P39 at the 0.06 level, and color rated better than P39 at 0.06, and better than the average of P39 and P40 at 0.035. However, color was rated better than the P40 at only the 0.19 level of confidence.

The remainder of this analysis is devoted to examining the differences between specific graphic products and the comparison of the P40 standard display in color with regard to these products.

Graphic product 00 is a typical AFOS product obtained from the National Weather Service. There was no significant difference in its ratings of overall quality as a function on P40 display versus color, although the color rating was higher.

The next four graphic products are basic weather presentations. Products 01 and 02 are more typical of the material currently in use in the Flight Service Stations with pressure contours, fronts, highs and lows, and in instrument flight rules (IFR) and maintain VFR (MVFR) areas. Products 03 and 04 are similar but show the type of radar information that might be included on the facsimile radar summary chart rather than visibility conditions. An analysis was made of the data of these four products using P40 phosphor, standard resolution, and the color display. In response to the question "How good is this product in permitting easy identification and use of the information it contains?" no significant differences between the four products emerged. The preference for color as compared to the P40 was apparent, however. There was no interaction between the mode of presentation and the products.

Graphic products 05 and 06 were developed primarily to evaluate the utility of characters smaller than the specified 0.15 inch. Product 05 was intended to have only the standard characters while product 06 used, in addition, a smaller font for information not referred to frequently. Table 2 shows the actual size of the characters and the average rating of each size.

TABLE 2. CHARACTER SIZE AND RATING FOR GRAPHIC PRODUCTS 05 AND 06

	Color		P40	
Graphic Product	05 standard (inch)	06 small (inch)	05 standard (inch)	06 small (inch)
Size	0.137	0.096	0.156	0.110
Rating*	3.2	2.6	3.7	3.0

*Rating Scale: 0 = Much too small
3 = Just right
6 = Much too large

The difference in the ratings of the two "standard" characters (3.2 versus 3.7) is not significant, but the rating of the small characters on the color display (2.6) is significantly lower than the small characters on the monochrome (3.0) at the 0.024 level. For questions A24 and B64 "How useful is it to have two sizes of characters on a product for high and low priority information?" the mean rating was 5.2 for the P40 and 4.6 for the color, with 3.0 being "makes no difference." The preference for two character sizes was significant at the 0.001 level for monochrome and the 0.02 level for color; the two ratings were not significantly different from each other.

The questions which rated the ease of use of the 05 and 06 products (B60, B62, A19, A22) showed no significant difference between the products or between the color and monochrome versions.

Graphic products 07 to 14 represent various ways of encoding raw radar data using contours with and without fill. Monochrome and color graphics numbered 07, 08, 10, and color product 14 use various combinations of solid and dotted lines that vary in brightness and color. Graphic products 11 to 13 (in monochrome and color) utilize dashed or solid fill in different brightness or colors as an additional means of showing the level of intensity of weather radar returns. An analysis of variance for the seven graphic products compares P40, standard resolution, and the color version. The analysis revealed significant differences among the various ways of coding the radar data, significant preference for the color versus the monochrome, and significant interaction between the different coding schemes and color/monochrome dimension. The advantage of color was much greater with contours only, than with contours and fill. Due to the significant interaction, additional analyses were made separately for the monochrome and color displays. With monochrome and color, results revealed a strong preference for fill over contours only. With monochrome, fill was preferred at better than the 0.001 level. However, no significant preference emerged among the different contour schemes or the different means of providing fill. With color, significant differences were noted within the major groups. Also, there was additional color coding of this information, GP14, which used six different colors and no dotted lines. Table 3 lists the different color products, their mean ratings, and shows which are significantly different from the others.

TABLE 3. COLOR GRAPHIC PRODUCTS IN ORDER OF INCREASING PREFERENCE

Graphic products	GP10	GP08	GP09	GP07	GP14	GP13*	GP12*	GP11*
Means	3.7	3.8	4.1	4.5	4.7	5.5	5.6	6.0

*Indicates fill, others are contours only.

Note: Products shown above a common line are not statistically different from each other.

For the raw radar products, an analysis of variance was performed on the responses to the question, "Is this an operationally useful display of raw radar data?" These were questions A39 and A41 for monochrome products 27 and 30, respectively, and B76, B77, B78, B79, and B80 for color products 28 to 32. Only the P40 standard resolution monochrome products were included in this analysis. The seven products differed at the 0.05 level, but no further analysis of these products produced a significant difference; i.e., no difference between the average for color versus the average for monochrome, nor within the two groups. Three-bit monochrome codes of brightness appeared equal to three-bit color codes for the raw radar sample data used.

An attempt was made to determine whether there were any important differences between the FSS specialists who worked in automated facilities and those who worked in FSS manual facilities. While the two groups are too small (five in each) to make it likely that statistically significant differences could be obtained, a cursory look at data plotted separately for the groups indicated general agreement on most of the questions.

An important source of additional information are the comments of the specialists — those made on the questionnaires and those made at the discussion sessions held when all the questionnaires had been completed. The information presented here will be limited to the specialist's comments on the weather products that were displayed rather than the display characteristics.

1. There was a generally favorable reaction to the combined surface analysis and weather depiction charts, as well as the combined surface analysis and radar summary charts.

2. All weather displays need adequate geographical reference — state boundaries on national maps; state boundaries and other prominent landmarks on local weather maps.

3. Generally, favorable comments were received on the local map with pilot weather reports (PIREP's) displayed. The large scale of the local area and the inclusion of the PIREP's were most noteworthy. When PIREP's and local weather tended to be too cluttered, the smaller-sized characters helped, as did the use of two colors for the different kinds of information.

CONCLUSIONS

1. No significant preference was noted for high resolution versus standard resolution. A good quality standard resolution display (512 by 640 addressable pixels) with a 512- by 640- by 2-bit memory is capable of meeting the specialists display requirements. The appreciably higher costs of the high resolution alternative is not justifiable.

2. The specialists showed a definite preference for the P40 phosphor as compared to green P39. At no time was the P39 preferred. The 30 and 40 hertz refresh rates used with these phosphors were adequate to avoid flicker.

3. There were no statistically significant differences among the four monochrome alternatives with regard to reflections and surface treatments. There does not appear to be any potential problem with reflections if reasonable attention to room lighting is afforded.

4. Color tends to be preferred over monochrome in comparable graphic presentations. The preference for color is only occasionally statistically significant.

5. In displaying weather radar information in monochrome, contoured and filled displays were rated best, raw radar second, and contoured radar without fill is last. The same relationship existed for color.

6. Use of two sizes of alphanumerics for data on graphic displays, 7 by 9 (0.1406 inch) and 5 by 7 (0.11 inch) was preferred. The 7 by 9 is preferable for tabular displays. It was generally agreed that 0.15-inch characters are larger than necessary.

7. Good background maps are essential to the interpretation of weather graphics.

RECOMMENDATIONS

1. On the basis of the experiment conducted, and reported herein, it is recommended that a standard resolution display system (512 by 640) be procured in production quantities for the Model 2 Flight Service Automation System.

2. The P40 phosphor is recommended for the production specification for the specialist cathode-ray tube (CRT) monitors. Some P40 CRT's should be introduced to the Atlanta, Georgia, Washington, D.C. and Indianapolis, Indiana, Flight Service Stations (FSS's) to see if the preference is general and maintained over time.

3. Although the reflection problem was not considered serious by the specialists with any of the surface treatments tested, a neutral density filter with the P40 phosphor is recommended for production versions of the flight specialists displays.

4. If color displays could be provided at comparable cost to the monochrome system, then the production display specifications should include the color requirement only because the color was preferred over monochrome. However, there is no evidence at this time that color would enhance the performance efficiency or even the morale of the FSS specialists. Monochrome displays are, therefore, recommended.

5. On the basis of strong specialist preferences indicated in this study, weather radar displays for the Model 2 FSS specialist displays should be provided in monochrome with "contoured and filled" display presentation.

6. It is recommended that two sizes of alphanumeric characters be provided for the specialist displays:

a. 7 by 9 (0.1406 inch) and 5 by 7 (0.11 inch) for graphics

b. 7 by 9 for tabular

7. From an operational viewpoint, background maps with geopolitical boundary references are recommended for all geographically referred graphical display products.

REFERENCES

1. Christ, Richard E., Four Years of Color Research for Visual Displays, Human Factors Society 21st Annual Meeting, 1977.

2. Connolly, Donald W., Spanier, Gerard, and Champion, Florence, Color Display Evaluation for Air Traffic Control, FAA, SRDS, Washington, D.C. May 1975.

3. Hopkin, V. David, Colour Displays in Air Traffic Control, International Conference on Displays for Man-Machine Systems, IEE Conference Publication No. 150, April 1977.

4. Meyers, Jerome L., Fundamentals of Experimental Design Boston, Allyn and Bacon, 1966.

APPENDIX A

FORM A QUESTIONNAIRE (MONOCHROME DISPLAYS)

This appendix incorporates the responses to the questionnaire used to evaluate the quality of monochrome displays. A summary of the analysis of variance data is also included. Figure A-1 shows the Product Index used with this questionnaire.

00 200MB TEMPERATURE

01 SURFACE ANALYSIS & WEATHER DEPICTION (A)

02 SURFACE ANALYSIS & WEATHER DEPICTION (B)

03 SURFACE ANALYSIS WITH RADAR (A)

04 SURFACE ANALYSIS WITH RADAR (B)

05 LOCAL MAP WITH WEATHER & PIREPS (A)

06 LOCAL MAP WITH WEATHER & PIREPS (B)

07 CONTOURED RADAR A

08 CONTOURED RADAR A

09 CONTOURED RADAR B

10 CONTOURED RADAR B

11 CONTOURED & FILLED RADAR (A)

12 CONTOURED & FILLED RADAR (B)

13 CONTOURED & FILLED RADAR (C)

14 SEVERE WEATHER WATCH (WW)

15 WBC AREA FORECAST (FA)

16 INFLIGHT ADVISORY (AIRMET-WA)

17 CONVECTIVE OUTLOOK (AC)

18 SURFACE AVIATION WEATHER REPORTS (SA)

19 PILOT WEATHER REPORTS (PIREPS-UA)

20 TERMINAL FORECAST (FT)

21 AMENDED TERMINAL FORECAST

22 WINDS & TEMPERATURE ALOFT FORECAST (FDUS1)

23 RADAR WEATHER REPORTS (RAREPS-SD)

24 TWEB ROUTE FORECAST & SYNOPSIS

25 SEVERE WEATHER WATCH BULLETIN (WW)

26 RAW RADAR (DIGITIZED)

27 RAW RADAR (DIGITIZED)

28 RAW RADAR (DIGITIZED)

29 RAW RADAR (DIGITIZED)

30 RAW RADAR (DIGITIZED)

FIGURE A-1. PRODUCT INDEX, FORM A

NUMBER OF RESPONSES TO EACH CATEGORY UNDER THE FOUR MONOCHROME VIEWING CONDITIONS
(FORM A QUESTIONNAIRE)

1. In general, how good are the characters on the tabular display for ease of reading or legibility?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	-	-	-	3	1	3	3	4.6	4.8
P40Std	-	-	-	-	2	3	5	5.3	5.5
P39Hi	-	-	1	2	2	2	3	4.4	4.5
P40Hi	-	-	-	1	1	5	3	5.0	5.1

2. How do you rate the tabular display for sharpness or resolution?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	-	-	2	-	2	3	3	4.5	4.8
P40Std	-	-	1	-	1	5	3	4.9	5.1
P39Hi	-	-	-	3	2	1	4	4.6	4.5
P40Hi	-	-	-	1	-	5	4	4.2	5.3

3. How is the tabular display in terms of adequate brightness?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	-	-	1	1	2	1	5	4.8	5.5
P40Std	-	-	-	-	1	1	8	5.1	5.9
P39Hi	-	-	-	2	3	2	3	4.6	4.5
P40Hi	-	-	-	1	-	5	4	5.2	5.3

4. How is the tabular display in terms of adequate contrast?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	-	-	6	3	-	3	3	4.4	4.8
P40Std	-	-	-	-	1	2	6	5.5	5.7
P39Hi	-	-	-	2	2	2	3	4.5	4.5
P40Hi	-	-	-	1	-	4	5	5.3	5.5

5. Were reflections a problem while viewing the tabular display?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

yes, serious problem — some (acceptable) — no

								mean	mdn
P39Std	-	3	1	2	-	1	3	3.4	3.0
P40Std	-	-	1	4	2	1	2	3.9	3.5
P39Hi	-	1	2	2	1	2	2	3.7	3.5
P40Hi	-	-	1	2	-	4	3	4.6	5.0

6. What do you think of the character size on the tabular display?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

much too small — just right — much too large

								mean	mdn
P39Std	-	-	2	6	2	-	-	3.0	3.0
P40Std	-	-	1	6	2	1	-	3.3	3.2
P39Hi	-	2	-	7	1	-	-	2.8	2.9
P40Hi	-	-	2	6	1	3	-	2.9	2.9

7. What do you think of the color of the tabular display?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor — acceptable — excellent

								mean	mdn
P39Std	2	2	1	-	2	2	1	2.9	2.5
P40Std	-	1	-	1	2	4	2	4.4	4.8
P39Hi	1	1	1	1	2	3	1	3.5	4.0
P40Hi	-	-	1	-	-	7	2	4.9	5.1

8. Was there any flicker in the tabular display?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

yes, serious problem — some (acceptable) — no

								mean	mdn
P39Std	-	-	-	1	1	-	8	5.5	5.9
P40Std	-	-	-	-	-	-	10	6.0	6.0
P39Hi	-	-	-	-	-	1	9	5.9	5.9
P40Hi	-	-	-	-	-	-	10	6.0	6.0

9. Did you notice afterimages, ghosting or smear in the tabular display?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

yes, serious problem — some (acceptable) — no

								mean	mdn
P39Std	-	-	-	2	-	2	6	5.2	5.7
P40Std	-	-	-	3	-	1	6	5.0	5.7
P39Hi	-	-	-	3	-	1	6	5.0	5.7
P40Hi	-	-	1	3	-	-	6	4.7	5.7

10. In general, how do you rate the tabular display for operational use?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor — acceptable — excellent

								mean	mdn
P39Std	-	-	2	2	1	3	1	4.10	5.50
P40Std	-	-	1	-	1	2	6	5.20	5.67
P39Hi	-	-	-	3	1	3	3	4.60	4.83
P40Hi	-	-	-	1	1	5	3	5.00	5.10

11. Graphic product, 00. How do you rate the size of the alphanumeric characters on this display?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

much too small — just right — much too large

								mean	mdn
P39Std	-	-	3	7	-	-	-	2.70	2.79
P40Std	-	2	2	6	-	-	-	2.40	2.67
P39Hi	-	-	5	5	-	-	-	2.50	2.50
P40Hi	-	-	4	5	-	1	-	2.80	2.70

12. Graphic product, 00. How do you rate the overall quality of this product?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor — acceptable — excellent

								mean	mdn
P39Std	-	-	-	5	-	-	5	4.50	3.50
P40Std	-	-	-	2	-	5	3	4.90	5.10
P39Hi	-	-	-	3	1	4	2	4.50	4.75
P40Hi	-	-	-	1	1	7	1	4.80	4.93

13. Graphic product, 01. How useful do you feel a product like this is?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent		
								mean	mdn
P39Std	-	1	-	-	2	4	3	4.70	5.00
P40Std	-	-	-	2	2	3	3	4.70	4.89
P39Hi	-	-	1	1	3	2	3	4.50	4.50
P40Hi	-	-	-	1	1	6	2	4.90	5.00

14. Graphic product, 01. How good is this product in permitting easy identification and use of the information it contains?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent		
								mean	mdn
P39Std	2	1	-	5	-	1	1	2.80	3.00
P40Std	-	-	2	3	2	2	1	3.70	3.50
P39Hi	-	-	-	3	4	2	1	4.10	4.00
P40Hi	-	-	1	1	2	4	2	4.50	4.75

15. Graphic product, 02. How good in this product in permitting easy identification and use of the information it contains?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent		
								mean	mdn
P39Std	2	2	2	-	1	3	-	2.50	2.00
P40Std	-	1	1	3	1	2	2	3.80	3.50
P39Hi	-	1	5	2	1	1	-	2.60	2.30
P40Hi	-	1	4	3	1	1	-	2.70	2.50

16. Graphic product, 03. How useful do you feel a product like this is?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent		
								mean	mdn
P39Std	-	1	2	-	1	3	3	4.20	4.83
P40Std	-	-	1	2	2	3	4	4.80	5.17
P39Hi	-	-	2	1	1	3	3	4.40	4.83
P40Hi	-	1	2	1	-	3	3	4.10	4.83

17. Graphic product, 03. How good is this product in permitting easy identification and use of the information it contains?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent		
								mean	mdn
P39Std	2	2	1	1	1	2	1	2.70	2.50
P40Std	-	-	-	2	2	4	2	4.60	4.75
P39Hi	-	-	1	1	2	4	2	4.50	4.75
P40Hi	-	-	1	1	2	4	2	4.50	4.75

18. Graphic product, 04. How good is this product in permitting easy identification and use of the information it contains?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent		
								mean	mdn
P39Std	1	2	2	3	-	1	1	2.60	2.50
P40Std	-	-	2	3	2	2	1	3.70	3.50
P39Hi	-	5	1	2	1	2	-	2.20	1.50
P40Hi	-	2	4	2	-	2	-	2.60	2.25

19. Graphic product, 05. How good is this product in permitting easy identification and use of the information it contains?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent		
								mean	mdn
P39Std	-	-	1	3	4	-	2	4.00	4.83
P40Std	-	-	-	3	2	2	4	4.80	5.00
P39Hi	-	-	2	1	4	2	0	3.90	4.00
P40Hi	-	-	-	4	2	4	-	4.00	4.00

20. Graphic product, 05. How useful do you feel a product like this is?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent		
								mean	mdn
P39Std	-	-	2	1	1	4	2	4.30	4.75
P40Std	-	-	-	3	1	4	2	4.50	4.75
P39Hi	-	1	1	2	-	4	2	4.10	4.75
P40Hi	-	-	-	4	1	3	2	4.30	4.50

21. Graphic product, 05. How do you rate the size of the alphanumeric characters on this product?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	much too small			just right			much too large		
								mean	mdn
P39Std	-	-	-	6	2	2	-	3.60	3.33
P40Std	-	-	-	5	3	2	-	3.70	3.50
P39Hi	-	-	2	5	3	-	-	3.10	3.10
P40Hi	-	-	-	6	3	1	-	3.50	3.33

22. Graphic product 06. How good is this product in permitting easy identification and use of the information it contains?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent		
								mean	mdn
P39Std	-	-	3	1	1	1	4	4.20	4.50
P40Std	-	-	2	-	1	3	5	5.10	5.50
P39Hi	-	-	1	2	-	7	1	4.60	4.93
P40Hi	-	-	1	2	-	6	1	4.40	4.83

23. Graphic product, 06. How adequate are the smaller characters on this product for the type of information they show?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	much too small			just right			much too large		
								mean	mdn
P39Std	-	1	1	8	-	-	-	2.70	2.88
P40Std	-	-	1	8	1	-	-	3.00	3.00
P39Hi	-	-	2	7	-	1	-	3.00	2.93
P40Hi	-	-	2	6	-	2	-	3.20	3.00

24. Graphic product, 06. How useful is it to have two sizes of characters on a product for high and low priority information?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	makes it harder to use			makes no difference			greatly improves product		
								mean	mdn
P39Std	-	-	-	3	-	1	6	5.00	5.67
P40Std	-	-	1	-	2	-	6	5.20	5.79
P39Hi	-	1	-	1	2	2	5	4.80	5.50
P40Hi	-	1	-	1	2	-	7	5.00	5.79

25. Graphic product, 07. How useful is this product for showing radar returns?

	/ 0 /	1	/ 2	/ 3	/ 4	/ 5	/ 6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	1	1	5	1	-	1	-	2.22	2.08
P40Std	1	4	2	-	2	-	-	1.78	1.88
P39Hi	-	3	4	1	1	1	-	2.40	2.10
P40Hi	-	3	2	3	1	-	-	2.20	2.25

26. Graphic product, 07. Does this use of brightness and dashes and solid lines facilitate understanding of the pattern?

	/ 0 /	1	/ 2	/ 3	/ 4	/ 5	/ 6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	1	2	3	3	-	1	-	2.20	2.17
P40Std	1	3	4	1	1	-	-	1.80	1.76
P39Hi	1	3	4	1	1	-	-	2.10	1.83
P40Hi	-	4	3	1	3	-	-	2.30	2.17

27. Graphic product, 08. How useful is this product for showing radar returns?

	/ 0 /	1	/ 2	/ 3	/ 4	/ 5	/ 6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	1	4	3	1	-	-	1	1.90	1.50
P40Std	1	4	1	-	2	1	-	2.11	1.38
P39Hi	-	4	4	1	-	1	-	2.00	1.75
P40Hi	-	3	1	4	-	1	-	2.30	2.50

28. Graphic product, 08. Does this use of brightness and dashes and solid lines facilitate understanding of the pattern?

	/ 0 /	1	/ 2	/ 3	/ 4	/ 5	/ 6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	-	6	2	1	-	-	1	1.90	1.33
P40Std	1	4	2	1	1	1	-	2.00	1.50
P39Hi	1	4	3	1	-	1	-	1.80	1.50
P40Hi	1	4	1	3	-	1	-	2.10	2.00

29. Graphic product, 09. How useful is this product for showing radar returns?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor acceptable excellent

							mean	mdn
P39Std	-	5	1	2	1	1	-	2.40	2.17
P40Std	-	3	4	-	2	1	-	2.40	2.00
P39Hi	-	1	3	4	-	1	1	3.10	2.90
P40Hi	-	2	3	3	-	-	2	2.90	2.50

30. Graphic product, 09. Does this use of brightness and dashes and solid lines facilitate understanding of the pattern?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor acceptable excellent

							mean	mdn
P39Std	-	1	5	2	2	-	-	2.50	2.30
P40Std	-	3	4	1	1	1	-	2.30	2.00
P39Hi	-	1	2	5	1	-	1	3.00	2.90
P40Hi	1	1	4	2	-	-	2	2.70	2.25

31. Graphic product, 10. How useful is this product for showing radar returns

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor acceptable excellent

							mean	mdn
P39Std	-	3	4	2	1	-	-	2.10	2.00
P39Std	-	1	2	3	3	1	-	3.10	3.17
P39Hi	-	6	-	3	-	1	-	2.20	2.00
P40Hi	1	1	4	2	1	1	-	2.40	2.25

32. Graphic product, 10. Does this use of brightness and dashes and solid lines facilitate understanding of the pattern?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor acceptable excellent

							mean	mdn
P39Std	-	3	4	2	1	-	-	2.10	2.00
P40Std	-	1	2	3	2	2	-	3.20	3.17
P39Hi	-	5	1	3	-	1	-	2.10	1.50
P40Hi	2	-	4	2	1	1	-	2.30	2.25

33. Graphic product, 11. How useful is this product for showing radar returns?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor acceptable excellent

								mean	mdn
P39Std	-	-	-	-	2	3	4	5.22	5.33
P40Std	-	-	-	-	-	3	7	5.70	5.79
P39Hi	-	-	-	1	1	2	6	5.30	5.67
P40Hi	-	-	-	-	-	3	7	5.70	5.79

34. Graphic product, 11. Does this use of area fill, brightness and shading, facilitate understanding the pattern?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor acceptable excellent

								mean	mdn
P39Std	-	-	-	-	-	4	6	5.60	5.67
P40Std	-	-	-	-	-	3	7	5.7	5.79
P39Hi	-	-	-	1	1	3	5	5.20	5.50
P40Hi	-	-	-	-	-	3	7	5.70	5.79

35. Graphic product, 12. How useful is this product for showing radar returns?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor acceptable excellent

								mean	mdn
P39Std	-	-	-	1	1	7	1	4.80	4.93
P40Std	-	-	-	1	1	2	6	5.30	5.67
P39Hi	-	1	1	1	2	1	4	4.30	4.50
P40Hi	-	-	1	-	2	3	4	4.90	5.17

36. Graphic product, 12. Does this use of fill, brightness and shading, facilitate understanding the pattern?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor acceptable excellent

								mean	mdn
P39Std	-	-	-	1	-	8	1	4.90	5.00
P40Std	-	-	-	1	1	3	5	5.20	5.50
P39Hi	-	-	-	2	1	3	4	4.90	5.17
P40Hi	-	-	-	1	2	3	4	5.00	5.17

37. Graphic product, 13. How useful is this product for showing radar returns?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	-	-	-	2	1	2	5	5.00	5.50
P40Std	-	-	-	-	-	3	7	5.70	5.79
P39Hi	-	-	-	2	1	4	3	4.80	5.00
P40Hi	-	-	-	-	-	5	5	5.50	5.50

38. Graphic product, 13. Does this use of area fill, brightness and shading, facilitate understanding the pattern?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	-	-	-	1	4	3	5	5.20	5.50
P40Std	-	-	-	-	1	2	7	5.60	5.79
P39Hi	-	-	-	1	2	4	3	4.90	5.00
P40Hi	-	-	-	-	-	5	5	5.50	5.50

39. Graphic product, 27. Is this an operationally useful display of raw radar data?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	-	-	-	2	4	3	1	4.30	4.25
P40Std	-	-	1	3	2	1	3	4.20	4.00
P39Hi	-	-	1	4	2	1	2	3.90	3.50
P40Hi	-	-	-	6	1	1	2	3.90	3.33

40. Graphic product, 27. What is your judgment of the overall quality of this radar display?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	-	-	1	2	-	6	1	4.40	4.83
P40Std	-	-	2	2	2	2	2	4.00	4.00
P39Hi	-	-	-	4	3	1	2	4.10	4.83
P40Hi	-	-	2	4	2	1	2	3.90	3.50

41. Graphic product, 30. Is this an operationally useful display of raw radar data?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	-	-	1	1	5	2	1	4.20	4.10
P40Std	-	-	1	2	2	2	3	4.40	4.50
P39Hi	-	-	-	2	4	2	2	4.40	4.25
P40Hi	-	-	-	5	2	-	3	4.10	3.50

42. Graphic product, 30. What is your judgment of the overall quality of this radar display?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	-	-	1	2	4	1	2	4.10	4.00
P40Std	-	-	2	2	1	2	3	4.20	4.00
P39Hi	-	-	-	2	4	2	2	4.40	4.25
P40Hi	-	-	1	3	3	-	3	4.10	3.85

43. In general, how do you rate the graphic display for sharpness or resolution?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	-	-	-	2	1	3	4	4.90	5.17
P40Std	-	-	-	-	-	4	6	5.60	5.67
P39Hi	-	-	-	1	3	2	4	4.90	5.00
P40Hi	-	-	-	-	-	7	3	5.30	5.21

44. How is the graphic display in terms of adequate brightness?

	/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
	poor			acceptable			excellent	mean	mdn
P39Std	-	-	-	1	2	3	4	5.00	5.17
P40Std	-	-	-	-	-	4	5	5.60	5.67
P39Hi	-	-	-	1	3	1	5	5.00	5.50
P40Hi	-	-	-	-	-	3	7	5.70	5.79

45. How is the graphic display in terms of adequate contrast?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor acceptable excellent

								mean	mdn
P39Std	-	-	-	2	1	3	4	4.90	5.17
P40Std	-	-	-	-	-	5	5	5.50	5.50
P39Hi	-	-	-	1	4	2	3	4.70	4.50
P40Hi	-	-	-	-	-	4	6	5.60	5.67

46. Were reflections a problem while viewing the graphic display?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

yes, serious problem some (acceptable) no

								mean	mdn
P39Std	1	1	1	3	-	1	3	3.50	3.17
P40Std	-	1	-	1	3	1	4	4.50	4.50
P39Hi	-	2	2	1	2	1	2	3.40	3.50
P40Hi	-	-	2	1	2	2	3	4.30	4.50

47. What do you think of the color of the graphic display?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor acceptable excellent

								mean	mdn
P39Std	1	-	2	3	-	2	2	3.51	3.17
P40Std	-	-	-	1	-	6	3	5.10	5.17
P39Hi	-	2	1	3	1	1	2	3.40	3.17
P40Hi	-	-	-	1	1	5	3	5.00	5.10

48. Was there any flicker in the graphic display?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

yes, serious problem some (acceptable) no

								mean	mdn
P39Std	-	-	1	-	-	1	8	5.50	5.88
P40Std	-	-	-	1	-	-	9	5.70	5.94
P39Hi	-	-	-	-	-	1	9	5.90	5.94
P40Hi	-	1	-	2	-	1	6	4.80	5.67

49. Did you notice afterimages, ghosting or smear in the graphic display?

	/ 0 /	1	/ 2 /	3	/ 4 /	5	/ 6 /		
	yes, serious problem			some (acceptable)			no		
								mean	mdn
P39Std	-	-	1	-	-	-	8	5.50	5.88
P40Std	-	-	-	1	-	-	9	5.70	5.94
P39Hi	-	-	-	-	-	1	9	5.90	5.94
P40Hi	-	1	-	2	-	1	6	4.80	5.67

50. In general, how do you rate the graphic display for operational use?

	/ 0 /	1	/ 2 /	3	/ 4 /	5	/ 6 /		
	poor			acceptable			excellent		
								mean	mdn
P39Std	-	-	-	3	1	2	4	4.70	5.00
P40Std	-	-	-	-	-	4	6	5.60	5.67
P39Hi	-	-	-	2	3	2	3	4.60	4.50
P40Hi	-	-	-	1	1	5	3	5.00	5.10

SUMMARY OF ANALYSIS OF VARIANCE UNDER MONOCHROME VIEWING CONDITIONS
(FORM A QUESTIONNAIRE)

Question A1

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	0.625	1	0.625	0.349	.569
Error	16.125	9	1.792		
Phosphor	4.225	1	4.225	4.460	.064
Error	8.525	9	0.947		
Res. by Phosp.	0.025	1	0.025	0.033	.859
Error	6.725	9	0.747		

Question A2

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	0.400	1	0.400	0.224	.648
Error	16.100	9	1.789		
Phosphor	2.500	1	2.500	1.406	.266
Error	16.000	9	1.778		
Res. by Phosp.	0.100	1	0.100	0.265	.619
Error	3.400	9	0.378		

Question A3

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	1.225	1	1.225	.917	.363
Error	12.025	9	1.336		
Phosphor	5.625	1	5.625	3.045	.115
Error	16.625	9	1.847		
Res. by Phosp.	0.225	1	0.225	1.000	.343
Error	2.025	9	0.225		

Question A4

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.025	1	.025	.016	.903
Error	14.225	9	1.581		
Phosphor	9.025	1	9.025	4.457	.064
Error	18.225	9	2.025		
Res. by Phosp.	.225	1	.225	.503	.496
Error	4.025	9	.447		

Question A5

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	2.500	1	2.500	3.214	.107
Error	7.000	9	.778		
Phosphor	4.900	1	4.900	5.128	.050
Error	8.600	9	.956		
Res. by Phosp.	.400	1	.400	.324	.583
Error	11.100	9	1.233		

Question A6

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.900	1	.900	1.227	.297
Error	6.600	9	.733		
Phosphor	.400	1	.400	1.714	.223
Error	2.100	9	.233		
Res. by Phosp.	.100	1	.100	.375	.555
Error	2.400	9	.267		

Question A7

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	3.025	1	3.025	5.762	.040
Error	4.725	9	.525		
Phosphor	21.025	1	21.025	2.532	.146
Error	74.725	9	8.303		
Res. by Phosp.	.025	1	.025	.026	.876
Error	8.725	9	.969		

Question A8

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.400	1	.400	1.714	.233
Error	2.100	9	.233		
Phosphor	.900	1	.900	2.250	.168
Error	3.600	9	.400		
Res. by Phosp.	.400	1	.400	1.714	.223
Error	2.100	9	.233		

Question A9

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.625	1	.625	.789	.397
Error	7.125	9	.792		
Phosphor	.625	1	.625	.372	.557
Error	15.125	9	1.681		
Res. by Phosp.	.025	1	.025	.060	.811
Error	3.725	9	.414		

Question A10

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.225	1	.225	.574	.468
Error	3.525	9	.392		
Phosphor	5.625	1	5.625	1.938	.197
Error	26.125	9	2.093		
Res. by Phosp.	1.225	1	1.225	2.436	.153
Error	4.525	9	.503		

Question A11

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.100	1	.100	.474	.509
Error	1.900	9	.211		
Phosphor	.000	1	.000	.000	1.000
Error	4.000	9	.444		
Res. by Phosp.	.900	1	.900	2.613	.140
Error	3.100	9	.344		

Question A12

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.025	1	.025	.039	.847
Error	5.725	9	.636		
Phosphor	1.225	1	1.225	.815	.390
Error	13.525	9	1.503		
Res. by Phosp.	.025	1	.025	.039	.847
Error	5.725	9	.636		

Question A13

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.000	1	.000	.000	1.000
Error	12.000	9	1.333		
Phosphor	.400	1	.400	.783	.399
Error	4.600	9	.511		
Res. by Phosp.	.400	1	.400	.545	.479
Error	6.600	9	.733		

Question A14

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	11.025	1	11.025	4.465	.064
Error	22,225	9	2.469		
Phosphor	4.225	1	4.225	2.919	.122
Error	13.025	9	1.447		
Res. by Phosp.	.625	1	.625	.738	.413
Error	7.625	9	.847		

Question A15

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	2.500	1	2.500	5.625	.042
Error	4.000	9	.444		
Phosphor	4.900	1	4.900	2.827	.127
Error	15.600	9	1.733		
Res. by Phosp.	3.600	1	3.600	1.810	.211
Error	17.900	9	1.989		

Question A16

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.625	1	.625	1.216	.299
Error	4.625	9	.514		
Phosphor	.225	1	.225	.252	.627
Error	8.025	9	.892		
Res. by Phosp.	2.025	1	2.025	.785	.399
Error	23.225	9	2.581		

Question A17

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	7.225	1	7.225	9.256	.014
Error	7.025	9	.781		
Phosphor	9.025	1	5.025	5.006	.052
Error	16.225	9	1.803		
Res. by Phosp.	9.025	1	9.025	5.335	.046
Error	15.225	9	1.692		

Question A18

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	5.625	1	5.625	2.455	.152
Error	20.625	9	2.292		
Phosphor	5.625	1	5.625	5.870	.038
Error	8.625	9	.958		
Res. by Phosp.	1.225	1	1.225	1.830	.209
Error	6.025	9	.669		

Question A19

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	2.025	1	2.025	4.314	.068
Error	4.225	9	.469		
Phosphor	2.025	1	2.025	4.314	.068
Error	4.225	9	.469		
Res. by Phosp.	1.225	1	1.225	1.569	.242
Error	7.025	9	.781		

Question A20

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.400	1	.400	.396	.545
Error	9.100	9	1.011		
Phosphor	.400	1	.400	.507	.494
Error	7.100	9	.789		
Res. by Phosp.	.000	1	.000	.000	1.000
Error	3.500	9	.389		

Question A21

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	1.225	1	1.225	5.444	.045
Error	2.025	9	.225		
Phosphor	.625	1	.625	1.216	.299
Error	4.625	9	.514		
Res. by Phosp.	.225	1	.225	.669	.434
Error	3.025	9	.336		

Question A22

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.225	1	.225	.336	.576
Error	6.025	9	.669		
Phosphor	1.225	1	1.225	5.444	.045
Error	2.025	9	.225		
Res. by Phosp.	3.025	1	3.025	2.951	.120
Error	9.225	9	1.025		

Question A23

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.625	1	.625	.918	.363
Error	6.125	9	.681		
Phosphor	.625	1	.625	5.000	.052
Error	1.125	9	.125		
Res. by Phosp.	.025	1	.025	.130	.726
Error	1.725	9	.192		

Question A24

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.400	1	.400	1.385	.269
Error	2.600	9	.289		
Phosphor	.400	1	.400	2.250	.168
Error	1.600	9	.178		
Res. by Phosp.	.000	1	.000	.000	1.000
Error	1.000	9	.111		

Question A25

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.250	1	.250	.800	.397
Error	2.500	9	.313		
Phosphor	.250	1	.250	.364	.563
Error	5.500	9	.688		
Res. by Phosp.	.694	1	.694	1.818	.214
Error	3.056	9	.382		

Question A26

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.400	1	.400	.590	.462
Error	6.100	9	.678		
Phosphor	.100	1	.100	.375	.555
Error	2.400	9	.267		
Res. by Phosp.	.900	1	.900	3.115	.111
Error	2.600	9	.289		

Question A27

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.111	1	.111	.229	.645
Error	3.889	9	.486		
Phosphor	.444	1	.444	.471	.512
Error	7.556	9	.944		
Res. by Phosp.	.000	1	.000	.000	1.000
Error	3.000	9	.375		

Question A28

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.000	1	.000	.000	1.000
Error	2.500	9	.278		
Phosphor	.400	1	.400	.396	.545
Error	9.100	9	1.011		
Res. by Phosp.	.100	1	.100	.167	.693
Error	5.400	9	.600		

Question A29

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	3.600	1	3.600	6.000	.037
Error	5.400	9	.600		
Phosphor	.100	1	.100	.310	.591
Error	2.900	9	.322		
Res. by Phosp.	.100	1	.100	.310	.591
Error	2.900	9	.322		

Question A30

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	2.025	1	2.025	2.710	.134
Error	6.725	9	.747		
Phosphor	.625	1	.625	.918	.363
Error	6.125	9	.681		
Res. by Phosp.	.025	1	.025	.060	.811
Error	3.725	9	.414		

Question A31

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.900	1	.900	1.588	.239
Error	5.100	9	.567		
Phosphor	3.600	1	3.600	9.529	.013
Error	3.400	9	.378		
Res. by Phosp.	1.600	1	1.600	6.000	.037
Error	2.400	9	.267		

Question A32

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	2.025	1	2.025	4.893	.054
Error	3.725	9	.414		
Phosphor	4.225	1	4.225	10.787	.009
Error	3.525	9	.392		
Res. by Phosp.	2.025	1	2.025	4.893	.054
Error	3.725	9	.414		

Question A33

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.000	1	.000	.000	1.000
Error	5.000	9	.625		
Phosphor	1.778	1	1.778	11.636	.009
Error	1.222	9	.153		
Res. by Phosp.	.000	1	.000	.000	1.000
Error	2.000	9	.250		

Question A34

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.000	1	.000	.000	1.000
Error	11.500	9	1.278		
Phosphor	.100	1	.100	.141	.716
Error	6.400	9	.711		
Res. by Phosp.	1.600	1	1.600	3.692	.087
Error	3.900	9	.433		

Question A35

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	2.025	1	2.025	1.123	.317
Error	16.225	9	1.803		
Phosphor	3.025	1	3.025	8.442	.017
Error	3.225	9	.358		
Res. by Phosp.	.025	1	.025	.014	.909
Error	16.225	9	1.803		

Question A36

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.100	1	.100	.122	.735
Error	7.400	9	.822		
Phosphor	.400	1	.400	.298	.599
Error	12.100	9	1.344		
Res. by Phosp.	.100	1	.100	.141	.716
Error	6.400	9	.7111		

Question A37

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.400	1	.400	.590	.462
Error	6.100	9	.678		
Phosphor	4.900	1	4.900	5.128	.050
Error	8.600	9	.956		
Res. by Phosp.	.000	1	.000	.000	1.000
Error	5.500	9	.611		

Question A38

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.400	1	.400	.507	.494
Error	7.100	9	.800		
Phosphor	2.500	1	2.500	4.500	.063
Error	5.000	9	.556		
Res. by Phosp.	.100	1	.100	.265	.619
Error	3.400	9	.378		

Question A39

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	1.225	1	1.225	3.128	.111
Error	3.525	9	.392		
Phosphor	.025	1	.025	.039	.847
Error	5.725	9	.636		
Res. by Phosp.	.025	1	.025	.083	.780
Error	2.725	9	.303		

Question A40

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.400	1	.400	1.714	.223
Error	2.100	9	.233		
Phosphor	.900	1	.900	.764	.405
Error	10.600	9	1.178		
Res. by Phosp.	.100	1	.100	.167	.693
Error	5.400	9	.600		

Question A41

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.025	1	.025	.184	.678
Error	1.225	9	.136		
Phosphor	.025	1	.025	.043	.840
Error	5.225	9	.581		
Res. by Phosp.	.625	1	.625	1.000	.343
Error	5.625	9	.625		

Question A42

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.100	1	.100	1.000	.343
Error	.900	9	.100		
Phosphor	.100	1	.100	.130	.726
Error	6.900	9	.767		
Res. by Phosp.	.400	1	.400	.783	.399
Error	4.600	9	.511		

Question A43

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.225	1	.225	.802	.394
Error	2.525	9	.281		
Phosphor	3.025	1	3.025	3.120	.111
Error	8.725	9	.969		
Res. by Phosp.	.225	1	.225	.802	.394
Error	2.525	9	.281		

Question A44

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.025	1	.025	.083	.780
Error	2.725	9	.303		
Phosphor	4.225	1	4.225	5.828	.039
Error	6.525	9	.725		
Res. by Phosp.	.025	1	.025	.130	.726
Error	1.725	9	.192		

Question A45

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.025	1	.025	.060	.811
Error	3.725	9	.414		
Phosphor	5.625	1	5.625	7.105	.026
Error	7.125	9	.792		
Res. by Phosp.	.225	1	.225	.802	.394
Error	2.525	9	.281		

Question A46

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.225	1	.225	.503	.496
Error	4.025	9	.447		
Phosphor	9.025	1	9.025	7.236	.025
Error	11.225	9	1.247		
Res. by Phosp.	.025	1	.025	.027	.872
Error	8.225	9	.914		

Question A47

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.100	1	.100	.474	.509
Error	1.900	9	.211		
Phosphor	25.600	1	25.600	4.861	.055
Error	47.400	9	5.267		
Res. by Phosp.	.000	1	.000	.000	1.000
Error	2.000	9	.222		

Question A48

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.625	1	.625	.616	.453
Error	9.125	9	1.014		
Phosphor	2.025	1	2.025	2.089	.182
Error	8.725	9	.969		
Res. by Phosp.	4.225	1	4.225	2.170	.175
Error	17.525	9	1.947		

Question A49

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	.025	1	.025	.033	.859
Error	6.725	9	.747		
Phosphor	.225	1	.225	.802	.394
Error	2.525	9	.281		
Res. by Phosp.	.025	1	.025	.083	.780
Error	2.725	9	.303		

Question A50

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution	1.225	1	1.225	5.444	.045
Error	2.025	9	.225		
Phosphor	4.225	1	4.225	2.919	.122
Error	13.025	9	1.447		
Res. by Phosp.	.625	1	.625	2.143	.177
Error	2.625	9	.292		

Question

SOURCE	SUM OF SQUARES	DEG FREED	MEAN SQUARE	F	SIGN.
Resolution		1			
Error		9			
Phosphor		1			
Error		9			
Res. by Phosp.		1			
Error		9			

APPENDIX B

FORM B QUESTIONNAIRE
(COLOR DISPLAYS)

This appendix incorporates the responses to the questionnaire used to determine the quality of color displays. Figure B-1 shows the Product Index used with the Form B questionnaire.

00 200MB TEMPERATURE
01 SURFACE ANALYSIS AND WEATHER DEPICTION (A)
02 SURFACE ANALYSIS AND WEATHER DEPICTION (B)
03 SURFACE ANALYSIS WITH RADAR (A)
04 SURFACE ANALYSIS WITH RADAR (B)
05 LOCAL MAP WITH WEATHER AND PIREPS (A)
06 LOCAL MAP WITH WEATHER AND PIREPS (B)
07 CONTOURED RADAR A
08 CONTOURED RADAR A
09 CONTOURED RADAR B
10 CONTOURED RADAR B
11 CONTOURED AND FILLED RADAR (A)
12 CONTOURED AND FILLED RADAR (B)
13 CONTOURED AND FILLED RADAR (C)
14 CONTOURED RADAR C
15 CONTOURED RADAR D
16 SEVERE WEATHER WATCH (WW)
17 WBC AREA FORECAST (FA)
18 INFLIGHT ADVISORY (AIRMET-WA)
19 CONVECTIVE OUTLOOK (AC)
20 SURFACE AVIATION WEATHER REPORTS (SA)
21 PILOT WEATHER REPORTS (PIREPS-UA)
22 TERMINAL FORECAST (FT)
23 AMENDED TERMINAL FORECAST
24 WINDS AND TEMPERATURE ALOFT FORECAST (FDUSI)
25 RADAR WEATHER REPORTS (RAREPS-SD)
26 TWEB ROUTE FORECAST AND SYSNOPSIS
27 SEVERE WEATHER WATCH BULLETIN (WW)
28 RAW RADAR (A)
29 RAW RADAR (B)
30 RAW RADAR (C)
31 RAW RADAR (A)
32 RAW RADAR (B)

FIGURE B-1. PRODUCT INDEX, FORM B

NUMBER OF RESPONSES UNDER COLOR VIEWING CONDITIONS
(FORM B QUESTIONNAIRE)

1. Tabular product, 18. How good are theses characters for ease of reading or legibility?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	2	1	4	3	4.80	5.00

2. Tabular product 18. How do you rate this product for sharpness or resolution?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	1	4	4	5.10	5.25

3. Tabular product, 18. How is this product in terms of adequate brightness?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	2	2	5	5.10	5.50

4. Tabular product, 18. How is this product in terms of adequate contrast?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	2	3	4	5.00	5.17

5. Tabular product, 18. What do you think of the color of this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	3	1	4	2	4.50	4.76

6. Tabular product, 18. Was there any flicker with this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
yes, serious problem		some (acceptable)				no	mean	mdn
-	-	1	1	1	-	7	5.10	5.79

7. Tabular product, 18. How would you rate this product for operational use?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	2	1	3	4	4.90	5.17

8. Tabular product, 19. How good are these characters for ease of reading or legibility?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	1	2	3	1	3	4.30	4.17

9. Tabular product, 19. How do you rate this product for sharpness or resolution?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	2	2	5	5.10	5.50

10. Tabular product, 19. How is this product in terms of adequate brightness?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	2	1	2	5	5.00	5.50

11. Tabular product, 19. How is this product in terms of adequate contrast?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	2	2	3	3	4.70	4.83

12. Tabular product, 19. What do you think of the color of this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	3	3	1	1	1	3.60	3.17

13. Tabular product, 19. Was there any flicker with this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
yes, serious problem			some (acceptable)			no	mean	mdn
-	-	1	2	-	1	6	4.90	5.67

14. Tabular product, 19. How would you rate this product for operational use?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	2	2	2	2	2	4.00	4.00

15. Tabular product, 20. How good are these characters for ease of reading or legibility?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	2	3	4	5.00	5.17

16. Tabular product 20. How do you rate this product for sharpness or resolution?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent		
							mean	mdn
-	-	-	-	1	5	4	5.30	5.80

17. Tabular product, 20. How is this product in terms of adequate brightness?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent		
							mean	mdn
-	-	-	1	3	1	5	5.00	5.50

18. Tabular product, 20. How is this product in terms of adequate contrast?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent		
							mean	mdn
-	-	-	-	2	4	5	5.20	5.25

19. Tabular product, 20. What do you think of the color of this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent		
							mean	mdn
-	-	-	2	2	4	2	4.60	4.75

20. Tabular product, 20. Was there any flicker with this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
yes, serious problem			some (acceptable)			no		
							mean	mdn
-	-	3	1	2	-	4	4.10	4.00

21. Tabular product, 20. How would you rate this product for operational use?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	2	2	4	2	4.60	4.75

22. Tabular product, 21. How good are these characters for ease of reading or legibility?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	3	3	3	4.80	4.83

23. Tabular product, 21. How do you rate this product for sharpness or resolutions?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	-	4	4	2	4.80	4.75

24. Tabular product, 21. How is this product in terms of adequate brightness?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	-	3	4	3	5.00	5.00

25. Tabular product, 21. How is this product in terms of adequate contrast?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	-	4	3	2	4.90	4.83

26. Tabular product, 21. What do you think of the color of this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	2	4	1	3	4.50	4.25

27. Tabular product, 21. Was there any flicker with this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
yes, serious problem			some (acceptable)			no	mean	mdn
-	-	2	2	-	1	5	4.50	5.50

28. Tabular product, 21. How would you rate this product for operational use?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	5	1	3	4.60	4.30

29. Tabular product, 22. How good are theses characters for ease of reading or legibility?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	2	2	1	3	2	4.10	4.50

30. Tabular product, 22. How do you rate this product for sharpness or resolution?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	2	1	7	-	4.50	4.79

31. Tabular product, 22. How is this product in terms of adequate brightness?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	1	2	1	6	-	4.20	4.67

32. Tabular product, 22. How is this product in terms of adequate contrast?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	1	1	1	1	6	-	4.00	4.67

33. Tabular product, 22. What do you think of the color of this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	1	2	2	1	3	1	3.60	3.50

34. Tabular product, 22. Was there any flicker with this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
yes, serious problem			some (acceptable)			no	mean	mdn
-	-	-	1	1	1	7	5.40	5.79

35. Tabular product, 22. How would you rate this product for operational use?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	1	1	2	2	4	-	3.70	4.00

36. Tabular product, 23. How good are theses characters for ease of reading or legibility?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	2	-	5	3	4.90	5.10

37. Tabular product, 23. How do you rate this product for sharpness or resolution?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	-	6	3	5.10	5.17

38. Tabular product, 23. How is this product in terms of adequate brightness?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	1	1	2	3	3	4.60	4.88

39. Tabular product, 23. How is this product in terms of adequate contrast?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	1	4	4	5.10	5.25

40. Tabular product, 23. What do you think of the color of this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	4	1	2	3	4.40	4.50

41. Tabular product, 23. Was there any flicker with this product?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

yes, serious problem — some (acceptable) — no

						mean	mdn
-	1	3	-	1	1	4.00	4.50

42. Tabular product, 23. How would you rate this product for operational use?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor — acceptable — excellent

						mean	mdn
-	-	-	3	1	5	1	4.40	4.70

43. Tabular product, 24. How good are these characters for ease of reading or legibility?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor — acceptable — excellent

						mean	mdn
-	-	-	3	2	2	3	4.50	4.50

44. Tabular product, 24. How do you rate this product for sharpness or resolution?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor — acceptable — excellent

						mean	mdn
-	-	-	2	2	2	4	4.80	5.00

45. Tabular product, 24. How is this product in terms of adequate brightness?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor — acceptable — excellent

						mean	mdn
-	-	-	2	1	3	4	4.90	5.17

46. Tabular product, 24. How is this product in terms of adequate contrast?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	2	3	4	5.00	5.17

47. Tabular product, 24. What do you think of the color of this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	5	1	2	2	4.10	3.50

48. Tabular product, 24. Was there any flicker with this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
yes, serious problem			some (acceptable)			no	mean	mdn
-	1	2	1	1	1	4	4.10	4.50

49. Tabular product, 24. How would you rate this product for operational use?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	3	2	2	3	4.50	4.50

50. How good do you think the tabular display, using the best of the colors you saw, would be for operational use?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	-	2	7	5.50	5.79

51. Graphic product, 00. How do you rate the size of the alphanumeric characters on this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
much too small			just right			much too large	mean	mdn
-	1	3	6	-	-	-	2.50	2.67

52. Graphic product, 00. How do you rate the overall quality of this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	1	-	6	5.50	5.88

53. Graphic product, 01. How useful do you feel a production like this is?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	-	2	-	8	5.60	5.88

54. Graphic product, 01. How good is this product in permitting easy identification and use of the information it contains?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	-	1	8	5.60	5.88

55. Graphic product, 02. How good is this product in permitting easy identification and use of the information it contains?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	2	1	6	5.20	5.67

56. Graphic product, 03. How useful do you feel a product like this is?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	1	2	6	5.30	5.67

57. Graphic product, 03. How good is this product in permitting easy identification and use of the information it contains?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	-	2	7	5.50	5.79

58. Graphic product, 04. How good is this product in permitting easy identification and use of the information it contains?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	-	4	2	4	5.00	5.00

59. Graphic product, 05. How useful do you feel a product like this is?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	-	2	7	5.50	5.79

60. Graphic product, 05. How good is this product in permitting easy identification and use of the information it contains?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	-	2	7	5.50	5.79

61. Graphic product, 05. How do you rate the size of the alphanumeric characters on this product?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
much too small			just right			much too large	mean	mdn
-	-	-	7	3	-	-	3.30	3.21

62. Graphic product, 06. How good is this product in permitting easy identification and use of the information it contains?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	-	1	3	6	5.50	5.67

63. Graphic product, 06. How adequate are the smaller characters on this product for the type of information they show?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
much too small			just right			much too large	mean	mdn
-	-	4	6	-	-	-	2.60	2.67

64. Graphic product, 06. How useful is it to have two sizes of characters on a product for high and low priority information?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
makes it harder to use			makes no difference			greatly improves product	mean	mdn
-	-	2	1	1	1	5	4.60	5.50

65. Graphic product, 07. How useful is this product for showing radar returns?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	4	3	2	1	4.00	3.83

66. Graphic product, 07. Does this use of color, solid and dashed lines facilitate understanding the radar pattern?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	3	3	-	4	4.50	4.17

67. Graphic product, 08. Does this use of color, solid and dashed lines facilitate understanding the radar pattern?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	2	3	1	3	1	3.80	3.50

68. Graphic product, 09. Does this use of color, solid and dashed lines facilitate understanding the radar pattern?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	4	2	3	1	4.10	4.00

69. Graphic product, 10. Does this use of color, solid and dashed lines facilitate understanding the radar pattern?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	1	4	2	3	-	3.70	3.60

70. Graphic product, 11. Does this use of area fill, color, and shading, facilitate understanding the radar pattern?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor acceptable excellent

							mean	mdn
-	-	-	-	-	-	10	6.00	6.00

71. Graphic product, 12. Does this use of area fill, color, and shading, facilitate understanding the radar pattern?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor acceptable excellent

							mean	mdn
-	-	-	-	1	2	7	5.60	5.79

72. Graphic product, 13. Does this use of area fill, color, and shading, facilitate understanding the radar pattern?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor acceptable excellent

							mean	mdn
-	-	-	-	1	3	6	5.50	5.67

73. Graphic product, 14. Does this use of color coding facilitate understanding the radar pattern?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor acceptable excellent

							mean	mdn
-	-	-	-	5	3	2	4.70	4.50

74. Graphic product, 15. Does this use of color coding facilitate understanding the radar pattern?

/ 0 / 1 / 2 / 3 / 4 / 5 / 6 /

poor acceptable excellent

							mean	mdn
-	-	-	1	4	3	2	4.60	4.50

Graphic product, 28. Is this an operationally useful display of raw radar data?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	-	2	-	8	5.60	5.88

76. Graphic product, 28. How useful is this example of color coded radar?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	-	2	1	7	5.50	5.79

77. Graphic product, 29. How useful is this example of color coded radar?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	-	3	6	5.40	5.67

78. Graphci product, 30. How useful is this example of color coded radar?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	1	4	4	5.10	5.26

79. Graphic product, 31. How useful is this example of color coded radar?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	-	2	4	4	5.20	5.25

80. Graphic product, 32. How useful is this example of color coded

75.

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	
-	-	-	1	2	2	5	5.10	5.50

81. In general, how do you rate the graphic display for sharpness or resolution?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	-	1	1	8	5.70	5.88

82. How is the graphic display in terms of adequate brightness?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	1	-	-	9	5.70	5.94

83. How is the graphic display in terms of adequate contrast?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	-	1	-	9	5.80	5.94

84. Were reflections a problem on the graphic display?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	1	2	-	4	3	4.60	5.00

. Was there any flicker in the graphic display?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
yes, serious problem			some (acceptable)			no	mean	mdn
-	-	1	-	-	2	7	5.40	5.79

86. Did you notice afterimages, ghosting or smear in the graphic display?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
yes, serious problem			some (acceptable)			no	mean	mdn
-	-	-	-	-	-	10	6.00	6.00

87. In general, how do you rate the graphic display for operational use?

/ 0 /	1 /	2 /	3 /	4 /	5 /	6 /		
poor			acceptable			excellent	mean	mdn
-	-	-	-	1	-	9	5.80	5.94