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WADC TECHNICAL REPORT 52-306

# REVIEW OF THE LITERATURE ON AERONAUTICAL CHART DEVELOPMENT AND DESIGN FOR USE UNDER RED LIGHTING

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*JULY 1952*



**WRIGHT AIR DEVELOPMENT CENTER**



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# REVIEW OF THE LITERATURE ON AERONAUTICAL CHART DEVELOPMENT AND DESIGN FOR USE UNDER RED LIGHTING

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*July 1952*

*Aero Medical Laboratory*
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Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

# FOREWORD

This review was prepared at Tufts College, Medford, Massachusetts under Contract No. W33-038 ac-14559 for research on the design of aviation maps for legibility under low level red lighting, with Dr. Mason N. Crook as principal investigator. This contract was administered by the Psychology Branch, Aero Medical Laboratory, under Research and Development Order No. 694-15, "Legibility of Verbal, Numerical and Graphic Information," with Captain C. M. Seeger as project engineer.

## ABSTRACT

A brief review of previous and current research and suggestions for the design of aeronautical charts for use under red light is presented. Certain major aspects of the problem have been attacked more directly in England than in the United States. Scattered research in the United States has begun to show trends, and general interest in the problem is on the increase.

## PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDING GENERAL:

ROBERT H. BLOUNT
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

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## REVIEW OF THE LITERATURE ON AERONAUTICAL CHART DEVELOPMENT AND DESIGN FOR USE UNDER RED LIGHTING

### I. INTRODUCTION

The purpose of this review is to make available a summary of such previous work and suggestions for the improvement of the legibility of aeronautical charts under red cockpit light as have come to our attention in the course of current research on that problem. A few moments may be well spent in tracing the historical development of aeronautical charts for general use. It was the set of charts already in existence which, perhaps unfortunately, prescribed the content and format of charts for use under special conditions of artificial lighting. Until recently, American charts for use under red and ultra-violet lighting were adaptations of materials in use and no effort was made to design navigational aids for use under a specific set of operational lighting conditions.

Table 1, taken from a report (7) prepared for the Office of Naval Research by Dunlap and Associates, provides a brief review of the historical development of aeronautical charts through 1950. The authors use the table to demonstrate the lag in map and chart development. They point out, for example, that the charts covered in the table do not meet the increasing needs of high speed flight. Because of the large scales used, most such charts cover relatively small areas. A series of charts is therefore often necessary for cross-country flight, and the effectiveness of normal navigation and emergency procedures is impaired. In addition, many charts are too large to handle comfortably in the average single seater cockpit.

Inspection shows, also, that such charts are badly cluttered and, in some areas, difficult to use even under normal conditions of illumination and operation. It appears that once a reasonably satisfactory format was found, for example the World Aeronautical Charts, demands for increased navigational information were met by adding that information to the existing charts. In this way more and more navigational data were crammed onto the charts, the resulting cluttering tending to reduce the over-all efficiency of the charts as navigational aids.

The early 1940's saw the production of Approach and Landing, Instrument Landing Systems, Radio Facility, Radio Direction Finding, Local Aeronautical, Route, and AAF Flight Charts. Often these charts were duplications or "blow ups" of segments of the

Table 1[a]

Historical Development of Aeronautical Charts

| Date | Title | Scale | Approximate dimensions | Approximate area | Main features |
|---|---|---|---|---|---|
| 1905 | Post Office Route Maps | 1" = 1 statute mile | Various, depending on locality | Various, depending on route | Roads |
| 1914 | Rand McNally State Maps | Various scales | 10" x 14" | Size of State | Railroads |
| 1923 | Air Service Strip Maps | 1" = 8 nautical miles | 10 1/2" x -- | 50 miles x length of route | "Route Oriented," flight lines, magnetic headings, airports, isogonic lines, railroads and roads |
| 1929 | Rand McNally Air Trail State Maps | Various scales | 10" x 14" | Size of State | Radio facility information |
| 1932 | Sectional Aeronautical Charts | 1" = 8 nautical miles | 34 3/4" x 23 1/2" | 248 x 168 miles | Standardization of aeronautical information for all flight functions |
| 1937 | Regional Aeronautical Charts | 1" = 16 nautical miles | 29" x 22" | 416 x 288 | Increased aeronautical detail |
| 1943 | World Aeronautical Charts | 1" = 16 nautical miles | 29" x 22" | 416 x 288 | International standardization of symbols, increased aeronautical detail |

[a] After Kishler, Waters, and Orlansky (7)

Table 1
(continued)

| Date | Title | Scale | Approximate dimensions | Approximate area | Main features |
|---|---|---|---|---|---|
| 1941 to 1950 | Approach and Landing Charts | 1" = 5 statute miles | 8" x 10 1/2" | 35 x 35 miles | Duplication of WAC areas in the interest of greater detail and improved readability for special functions. |
| | Instrument Landing Systems Charts | 1" = 4 statute miles | 8" x 10 1/2" | 28 x 28 miles | |
| | Radio Facility Charts | 1" = 38 nautical miles | 8" x 11" | 380 x 266 miles | |
| | Radio Direction Finding Charts | 1" = 32 nautical miles | 42 3/4" x 27 1/2" | 1,280 x 768 miles | |
| | Local Aeronautical Charts | 1" = 4 nautical miles | 27" x 19" | 108 x 76 miles | |
| | Route Charts | 1" = 32 nautical miles | 67" x 28 1/4" | 2,016 x 800 miles | |
| | AAF Flight Charts | 1" = 16 nautical miles | 59" x 14" | 896 x 208 miles | |
| | World Planning Charts | 1" = 80 nautical miles | 46 1/2" x 31 1/4" | Continents | Information required for world wide operational and tactical planning |
| | Loran Charts | 1" = 30 nautical miles | 53 3/4" x 36" | 1,500 x 960 miles | Information required for new electronic navigation techniques |
| | Radar Charts | 1" = 16 nautical miles | 19" x 23" | 288 x 224 miles | |
| | Jet Navigation Charts | 1" = 60 nautical miles | 18 1/2" x 15 1/2" | 960 x 780 miles | Information appropriate to the unique requirements of jet flight |

World Aeronautical Charts with the addition of the navigational data demanded by the particular operation; however, they represent the first development of maps and charts for particular operations and specific functions.

At the same time that charts were being developed for specific operations, it became apparent that they were not adequate for use under some of the conditions in which the operations for which they were developed were to be carried out. Since many were developed as navigational aids during blind or night flight operations, it was necessary that they be useful under the conditions of illumination prevailing in the cockpit during those operations. The requirements of cockpit illumination are established by the nature of the flight operation. On night combat missions, these requirements are four. (1) The illumination must be adequate for operation, maintenance and navigation of the aircraft in all phases of the mission: take-off, cross-country approach, penetration, return and landing. (2) If contact flying, fighting or bombing are required, cockpit illumination must preserve the dark adaptation necessary for vision outside the cockpit. (3) Under these conditions the illumination must not be allowed to produce an impenetrable glare on the windscreen. (4) The illumination must be invisible, or as nearly invisible as possible, to the enemy. Once these requirements were met, available maps, charts and other navigational aids, difficult enough to use under optimal conditions, suffered a further loss in usefulness. The necessity for adapting navigational aids to night cockpit lighting became obvious.

Two approaches to the problem of cockpit lighting have been taken. One involves the use of ultra-violet sources and fluorescent materials; the other utilizes low level, red floodlighting. Several difficulties arise when maps and charts are used under either of these systems. Common to both of the illumination systems are the problems which arise when printed materials are to be used under relatively low levels of illumination and at less than maximal contrasts with their backgrounds.

Fluorescent printing materials are generally unstable. Among the most stable are those which fluoresce predominantly in the yellow and yellow-green wave lengths of the visible spectrum. Unfortunately, wave lengths in these regions appear to have the most deleterious effects upon dark adaptation. Their use is to be avoided. When materials which fluoresce strongly in the long wave-length regions are chosen, they are found to be unsatisfactory because of their lack of stability. In addition, there appears to be some doubt as to the effect of ultra-violet and near ultra-violet wave lengths upon dark adaptation.

Under red floodlighting the chromatic characteristics of maps and charts disappear, leaving only brightness or density and texture differences perceptible. Therefore, it becomes necessary to present, on the basis of the remaining differences, the material which, under normal illumination, is presented by chromaticity differences. Textures fine enough not to impair the legibility of overprinting are likely to be indistinguishable under low illumination. A large part of the information therefore has to be conveyed by brightness differences.

## II. DEVELOPMENT OF AAF ALL PURPOSE CHART

Apparently the first American attempts to solve these problems were made shortly after 1940, for a conference (1) was called in 1942 by the Maps and Charts Division of the Directorate of Photography "for the purpose of determining the suitability of maps developed for use at night under red and ultra-violet light". Conferees were presented samples of maps and charts designed for use under ultra-violet and under red floodlighting. The following is a list and brief description of all those experimental sample charts which we have been able to obtain with the generous cooperation of Colonel J. E. Morrison of the Aeronautical Chart and Information Service, St. Louis:

1. Cape Guardafui - (791) - AAF, scale 1:1,000,000

Compass roses, rivers, streams, swamps, coastline and some cultural and radio data appear in blue. Some contour lines with elevations are used and are printed in a pale magenta. Roads are in brown. No hypsometric series is used. Land areas appear in tan. The range of typographic variables appears to be the same as on charts in general use. Under ultra-violet, overprinting shows against a fluorescent background, dark blue for land areas, light blue for water.

2. Cape Guardafui - (791) - AAF, scale 1:1,000,000

Compass roses, rivers, streams, swamps, coastline and some cultural and radio data appear in blue. Some contour lines with elevations are used and are printed in pale magenta. Roads are in brown. No hypsometric series is used. Land areas appear in purple, making the chart similar to the British purple charts to be described. The effect of brown and magenta overprinting on purple ground (under red light) is to drop the magenta and greatly diminish the brown, effectively "dropping out" data appearing in these two colors. The range of typographic variables appears to be the same as on charts in general use. Under ultra-violet, overprinting shows against a fluorescent background, salmon for land areas, light blue for water.

3. Cape Guardafui - (791) - AAF, scale 1:1,000,000

This chart is the same as number 2 above, except that land areas appear in a pinkish-tan. Against this lighter background the overprinting does not "drop out" with red illumination. Under ultra-violet, overprinting shows against a fluorescent background, dark yellow for land areas, light yellow for water.

Reports of tests and evaluations of the various materials were also presented and discussed. The results of this conference can be summarized by listing the six conclusions and the recommendation made on the basis of examination of the sample materials and their tests and evaluations:

Conclusions

"1. An all-purpose map which could be used in daylight, under ultra-violet light at night, or under red light at night, and which would have essentially a similar appearance under either of these types of illumination is to be printed for general use.

"2. A map surface must be illuminated to a brightness of not less than 50 microlamberts [.046 ft.-lamberts] in order for ordinary size print to be legible at lap reading distance (15-18 inches). It must be illuminated to about 5 microlamberts [.0046 ft.-lamberts] for broad marking (requiring about 20/200 visual acuity) to be legible. These figures apply irrespective of the color or type of illumination.

"3. At the brighter illumination (50 microlamberts) mentioned in (2) above, a greenish-yellow color raises the dark adaptation threshold about 0.6 logarithm units with four to six minutes needed for a return to normal, whereas with a red color the threshold is raised only 0.3 logarithm units with a return to normal in less than one minute. At 5 microlamberts the dark adaptation threshold is raised 0.3 logarithm units by the yellowish-green fluorescent maps with a return to normal in about three minutes, whereas red light at this brightness affects the dark adaptation threshold not at all.

"4. The maps with weak fluorescent base are very near optimal brightness for use at night under the general conditions for which they will be employed by the Army Air Forces.

"5. Light reflected from a greenish-yellow fluorescent map lighted with ultra violet light is more visible outside the aircraft than is light reflected from a map lighted to the same brightness with red light.

"6. The use of a stable red fluorescent base on the maps for use under ultra violet light is highly desirable."

Recommendation

"1. That the Army Map Service and other organizations supplying fluorescent maps to the Army Air Forces for use at night under ultra violet light utilize, in so far as possible and feasible, inks and bases which fluoresce only in the longer wave lengths of the visible spectrum, preferably red."

It is interesting to note that the recommendation above calls for utilization of fluorescent materials and omits any reference to the tonal keying of maps and charts for use under red floodlighting, although the conclusions previously stated appear to point to superiority of red floodlighting over ultra-violet used with fluorescent materials.

Some of the experimental charts evaluated in the above report were on the scale of 1:1,000,000, and were superior for use under red light to the all-purpose charts on that scale which later came into general use. A series of target charts adapted for night use was also produced by the Army Map Service in 1942. The samples that we have seen are for regions in the far Pacific. Admittedly on large scale charts, designed only for penetration of target areas, some of the complexity of small scale navigational charts can be avoided. However, the 1942 target charts incorporate some aids to legibility that might well have been used on the later all-purpose charts. For example, the important bearing and target data appear in over-size type (10-point or larger) and heavy blue ink; important roads, railways, and other cultural symbols appear in broad stroke-widths; names of important cities, especially target cities, appear in over-size type; cluttering by superfluous information is obviously kept at a minimum. The effect of these characteristics is to fit the charts well for use under low levels of red light.

In 1943 a number of charts were prepared for the Aeronautical Chart Service[1] which appear to be modifications of standard aeronautical charts in use at that time, and were designed for use at night under white, ultra-violet, red and amber lights. The charts were evaluated (2) by determining the effects upon night visual acuity of viewing the charts under ultra-violet and red light and by measuring the brightness of the charts under ultra-violet light. As a result of this evaluation, two conclusions were reached:

"1. No significant disturbance of the night visual acuity of the dark adapted eye is caused by viewing the new all-purpose aeronautical charts under ultra-violet or red light, provided the intensity of the illumination is kept to the minimum required to see the smallest print on the chart."

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[1]Later the Aeronautical Chart and Information Service

"2. The new all-purpose aeronautical charts appear satisfactory in so far as visual requirements are concerned."

"All-purpose" charts, tonal keyed for use under the several kinds of night lighting, soon came into operational use. The early examples that we have seen were AAF charts. The AAF charts, under the sponsorship of the Aeronautical Chart Service, began to appear about this time, in a variety of scales and types, which corresponded generally to those of the aeronautical charts prepared by the Coast and Geodetic Survey. Through the 1940's the chart publishing activities of the Aeronautical Chart Service expanded, and the designation "AAF" was eventually dropped.

Aside from impregnation with fluorescent material when adapted for night use, the AAF charts differed only in minor details from those previously in use. Radio data were a little larger in letter size and stroke-width, but other printed material was in finer stroke-width at a given type size. Road and railroad symbols were in wider strokes, but for the road symbols some of the gain in legibility may have been lost by the use of a lighter shade of gray.

Certainly the combination of ultra-violet light and fluorescent materials made the all-purpose charts usable at night. But it would appear that, except for a few details as radio data, there was little gain in legibility under white, red, or amber light. It should be pointed out, however, that differences between the earlier charts and the experimental charts from which the all-purpose charts were derived were occasionally large and striking. In some instances, excellent principles of chart design for use under red light were applied on the earlier experimental charts which are not found on the later all-purpose charts. Be that as it may, the all-purpose charts appear to be most representative of operational charts adapted for night flying in the period between 1942 and 1945.

## III. DEVELOPMENT OF BRITISH "PURPLE" CHARTS; AMERICAN VERSUS BRITISH CHARTS

By the time the problem of maps and charts for night use had been attacked in America, the British had already made considerable progress. Apparently as early as 1935 aeronautical charts tonal keyed for night use under red floodlighting had been produced. In contrast to the all-purpose charts in America, the British charts did not appear to be limited adaptations of previously existing charts, nor were they designed for use under ultra-violet light.

British charts differ from American in many respects: (1) projection, (2) hypsometric tints and general use of color, (3) elevation designation, (4) type size and style, (5) symbols,

(6) navigational data, and especially (7) the use of special color techniques for disappearance under red light of details less important for night flying. The following table presents a comparison, in terms of differences such as those listed above, between some typical American and British charts published during approximately the same period.

Table 2

| ITEM | AMERICAN (all purpose) 1940-43 | BRITISH (air) 1939-1945 |
|---|---|---|
| Projection | Lambert Conformal Conic | Conical Orthomorphic (in the GSGS 4072 series) |
| Hypsometric scale | Green, through tan to brown hue gradient, brightness progressing unsystematically from dark to light with increasing elevation | Monochromatic (purple) hue gradient, brightness differences progressive from light to dark with increasing elevation |
| General use of color | Gross and striking differences, some of which are listed below or discussed in the text. | |
| a) for roads | medium density road grey | bright red or aero red |
| b) for water | for water areas, low density blue; for smaller streams, high density blue | for oceans, low density blue; for inland water and sometimes for shoals and inlets, high density blue |
| c) for woods | none | medium density green (on some charts) |
| d) for contour lines | aero red | same red as for roads |

Table 2 (continued)

| ITEM | AMERICAN (all purpose) 1940-43 | BRITISH (air) 1939-1945 |
|---|---|---|
| Elevation designation | hypsometric series, contour lines (1,000 ft.), elevation of larger cities printed (for cities above 1,000 ft.), highest spot elevations given for each grid square where elevation is above 1,000 ft., highest spot elevation for entire chart overprinted in larger numerals on white | hypsometric series, occasional contour lines in red, prominent elevations spotted in black on white with increase in type size above 1,000 ft. |
| Type face (on body of chart) | a standard modern face set in capitals and in lower case, water masses and ways in capital and lower case italics | capital and lower case italics with a few exceptions set in capitals in a standard modern face for emphasis |
| Type size (smallest on body of chart) | smaller place names in 6-point lower case, sometimes narrow letters; radio data in 8-point lower case; elevation numerals in bold strokes | smaller place names in 6-point lower case, regular type or italics, close spaced; elevation numerals in light strokes |
| Symbols | generally those still in use | generally the same, with a few exceptions, e.g., different symbols for smaller towns, fewer contour lines |
| Radio data | overprinted in magenta or aero red; adds considerably to cluttering; not always easily legible under red light | not printed on chart |
| Special color techniques | the use of magenta or aero red for radio and some navigation data | (see above) purple for hypsometric tints; green, which appears fairly dense under red illumination, for woods; heavy density blue for water masses and ways; red for contour lines; red for roads |

The data of Table 2 offer some basis for comparison of the two different types of charts. The British charts give the general impression under both daylight and red light of being cleaner and simpler. Fewer small towns and other details are shown, and the lack of overprinted radio data reduces the cluttering. However, the green wooded areas shown on large scale charts are of such a density that they tend to confuse the elevation pattern under red light. In general, the differences suggest that the American all-purpose charts represented only minor modifications of charts already available, while the British charts represent extreme modifications in the direction of adaptation for use under red light. The development of the British purple charts is described in the following excerpts from a recent communication from the British Air Ministry (13).

"Until the advent of the 1939-1945 war, the majority of topographical maps used by the Royal Air Force were of necessity Army maps with layer tinting in brown. Experience showed these maps to be unsuitable when used at night both from the colour aspect under amber cockpit lighting and in regard to their portrayal of cultural and topographic features. It was therefore decided to produce a topographic series which would not only emphasize the features used by the aviator for map reading at night but which would be printed in colors most suited to his operational limitations.

"In so far as the color question was concerned....purple was selected solely in terms of visual effectiveness. The characteristics and availability of materials or limitations of printing processes did not affect this selection.

"Roads and contours, being of little use to the aviator at night, were printed in red which, under an amber light, reduced their visibility; railways and lakes were emphasized by the use of black and blue respectively."

There can be little doubt that the effective use of color by the British materially improved the legibility of their charts under red and amber light. But during the period in question, typographical variables were not manipulated so effectively as the color variables. Fine stroke-widths and close spaced italics tended to impair the legibility of the print under low illumination. In American charts, on the other hand, the color treatment was not changed, but an effort was made to print the newly added radio data in type more legible than that previously used.

The apparent difference in emphasis in map and chart development may well have been a function of differences in geographic area and nature of combat operations required of the two air services.

## IV. RECENT DEVELOPMENTS

Since 1945 the British have retained their basic color scheme, with minor changes. The elevation tints appear to be somewhat more reddish. There is less use of dense blue in coastal waters, and roads are in a subdued orange-red. These changes result in a somewhat brighter effect under both white and red light, with improved contrast between overprinting and background. A certain amount of experimental work, however, has been done with elevation series in other colors. One example is a chart of the Lyon area, with a gray elevation series, which has been evaluated in flight (16). It was found to give a good impression of the terrain, but the overprint was not sufficiently legible.

The recent treatment of typography on British charts shows a trend toward decreased use of italics and increased use of larger sizes of regular type in both capitals and lower case. There has been work on the development of more legible symbols, e.g., a series of airdrome symbols has been designed and flight tested for legibility under night conditions (17). Further developments of this sort should continue to improve the usefulness of the British charts.

In America since 1945, the drive toward making charts more legible and useful in all phases of flight operations has steadily gained impetus. Various organizations have from time to time conducted developmental, evaluative, or experimental work aimed at chart improvement.[2] Up to this time, no basic changes in the design of the more elaborate colored charts have reached the operational level, but substantial improvements have been made in the large scale Approach, Landing, and Radio Facility Charts, on which the problems are simpler in some respects.

As it would be difficult to intersperse the various contributions into a meaningful chronological pattern, a summary will be given by organizations. Not all of the organizations mentioned below have been concerned directly with the red light problem, but it can be assumed that improvements in general chart legibility will in most cases be helpful with red light. The following list should be considered a sampling rather than an exhaustive survey.

A large amount of both the background work and actual production of aeronautical charts has been done by the Coast and Geodetic Survey. Among other organizations which are credited as sources, have done developmental work, or have sponsored research, the following might be mentioned: Army Map Service,

[2] It should be pointed out that considerable research in the areas of legibility of type, recognizability of geometrical forms, discriminability of colors, etc., some of it current, has an indirect bearing on the chart problem.

Corps of Engineers, Geological Survey, Department of Agriculture, Civil Aeronautics Administration, and Office of Naval Research. In addition, the agencies below have done active work bearing either directly or peripherally on the red light legibility problem.

A. The Mapping and Charting Research Laboratory, Ohio State University (under contract with the Photographic and Reconnaissance Laboratory, Wright-Patterson Air Force Base)

At the Mapping and Charting Research Laboratory a large project attacking a constellation of cartographic variables is under way. The work from that laboratory which has come to our attention to date has been on analysis of legibility as affected by scale and projection factors on aeronautical charts (14) and relief on maps and models (11). Improvement of these elements in over-all utility and legibility will probably reflect itself in improved legibility under red light, although that aspect of the problem has not been directly attacked.

B. The Hydrographic Office

The Hydrographic Office is continuously concerned with the improvement of charts on a broad basis, and has produced experimental approach and landing charts for night use, including some with light overprinting on a dark blue or black ground.

C. The Aeronautical Chart and Information Service, Washington and St. Louis

The Aeronautical Chart and Information Service is also continuously in process of developing and trying out improvements. One problem the Service has concerned itself with is that of visual representation of the terrain for easy recognition from the air. An Experimental Flight Chart of the desert region between Atar and Tindouf in Algeria, prepared for the Chart Service by the Geological Survey in 1945, illustrates the use of a shading technique instead of contour lines. The coloring is a light brown. On this chart, one innovation well suited to night lighting is the approximate elevation shown in large figures in each 30' square. A somewhat similar example is a World Aeronautical Chart of the Min River area, published by the Chart Service in 1946. The terrain is quite rugged. The shading, in a reddish brown, is too dark for easy legibility under red cockpit light, but the large elevation figures are again used. Other experimentation with shading techniques has been carried out at the St. Louis plant of the Chart Service.

Also at St. Louis, an experimental green hypsometric series has been produced. The spectral characteristics of this series have been determined and are on file (9). Like the series now in use, it does not show sufficiently uniform brightness progression under red light, but it represents an exploratory attempt.

Some experimentation has been done with the color of overprinted radio data. In some cases aero red has been substituted for magenta, and on recent charts blue is being tried. These are progressive steps in the direction of improving legibility of the radio data under red light.

Marked improvements have recently been made, for use under both day and night lighting, in Approach, Landing, and Radio Facility Charts. Some of this will be discussed in another connection below.

An experimental small scale chart for high speed, high altitude jet navigation, identified as the XJN 9-3, has been developed to meet joint USAF-ONR specifications. Here we shall consider only the characteristics of this chart which are important for use under low level red light.

The XJN retains the green to brown hypsometric series, but restricts the use of contour lines to more prominent elevations, thereby reducing cluttering to some extent. To further reduce cluttering and produce greater legibility of radio navigation data, the radio data have been separated. The face of the chart bears topographic, hydrographic and cultural features and radio data to the extent that civilian broadcasting stations, radio beacons, and air navigation light lines and radio range stations are located and identified. The reverse side of the chart bears these radio data in addition to the remainder of the necessary radio range information: flight paths, reporting points, fan markers, etc. All radio and navigation data are printed in aero red. On the face of the chart they are set in eight-point capitals and numerals while cultural information, cities and towns, etc. are printed in black and vary between eight-point lower case, eight-point capitals and occasional larger type sizes, but with finer stroke-width. On the reverse side of the chart all data are in aero red on a gray background or on white flight paths. Unfortunately, some of the usefulness of separating radio data by presenting them alone on the reverse side of the chart is offset by printing them in six-point narrow stroke-width type. Furthermore, much of the information is printed in finer stroke-width (fan markers, radio range directional signals, etc.) and is difficult to use under low level red light. The adoption for this chart of the airdrome symbol showing orientation of the various runways should be a useful modification. Previously such a symbol was seen only on some large scale charts.

Although the XJN is especially fitted to the demands of jet navigation, the chart was prepared specifically for use as an "all purpose" chart and represents a definite improvement, at least for use under red light, over any "all purpose" chart previously developed. The separation of radio navigation data for presentation on the back of the chart represents a large step in the direction of one possible solution to the cluttering and over-all legibility problem.

D. Dunlap and Associates (under contract with the Office of Naval Research)

During the development of the XJN, Dunlap and Associates were developing for the Office of Naval Research a chart, the XDA 9 3-1, to serve the same function as the XJN. The XDA shows many elements common to the XJN. At the same time there are several major differences. Since a complete description of the development and characteristics of the XDA appears in a series of reports (3, 6, 7, 8, 12) to the ONR and are available through that source, only brief mention will be made of the chart's utility under red light.

Contour lines and the hypsometric series have been eliminated from the XDA, relief being shown by a shading technique, with the result that cluttering is somewhat reduced. The XDA, like the XJN, separates radio and navigation data, presenting some of it on the reverse of the chart sheet and further reducing cluttering. On neither the face nor the reverse of the chart is all radio and navigation data presented in aero red as on the XJN. Radio and radio range data appear in aero red but airdrome names, symbols, and related information appear in a deep blue which yields greater visibility under red light than does aero red. The reverse side of the chart which presents only radio navigation data and airdrome data suffers in part from the same shortcoming under red light as the XJN, for light line, six-point numerals in aero red are used to some extent.

On the basis of the differences between the XJN and the XDA one would predict that the XDA should yield greater legibility under red light than the XJN, in spite of the fact that it was not developed as an "all purpose" chart. A recent report by Dunlap and Associates (7) describes a comparison of the two charts under red light. The techniques used suggested that the XDA was superior to the XJN. However, the fact that one chart appeared to be superior to the other need not imply that the superior chart is adequate for use under red light nor that the legibility problem is solved.

E. The Aero Medical Laboratory, Wright-Patterson Air Force Base

While many of the preceding developments in chart design have resulted in improved legibility under red light, few of them have been the product of concerted effort on the red light problem per se. During the past few years the Aero Medical Laboratory has been involved in the red light problem through consultations with the Chart Service, the making of evaluations and recommendations, the transmitting of material to be evaluated by others, and the sponsoring of a contract with Tufts College for research on the legibility of charts under red light. Among the materials submitted by the Chart Service to the Aero Medical Laboratory, and evaluated for them by Tufts College, have been Aeronautical Chart Service Approach and Landing Charts, Coast and Geodetic Survey AL Charts, Jet AL Charts, and several sets of both regular and experimental Radio Facility Charts. The result of this joint effort has been the revision of old and the development of new experimental charts, and improvements in the regular editions of such charts, for legibility under red light. Samples of such charts and evaluations are on file (9). As a minimum number of terrain features are shown, and ordinarily no hypsometric series is used on charts of this type, the problem of color is very much simplified. Efforts have therefore been concentrated on reduction of cluttering; increase of legibility of type by manipulation of such variables as size, stroke-width, spacing, etc.; maintenance of high contrast between overprinting and background; and generally effective use of such color as is required.

F. The Institute for Applied Experimental Psychology, Tufts College (under contract with the Aero Medical Laboratory, Wright-Patterson Air Force Base)

In addition to the evaluations mentioned above, the Institute for Applied Experimental Psychology has been engaged in basic research on two main aspects of the red light legibility problem.

One aspect of this research consists in an attempt to solve the "color problem", where the color problem includes the selection of chromas and luminances for hypsometric series, the maintenance of high contrast when different colors of overprinting and backgrounds are combined, and the use of color to reduce cluttering and to separate (under red light) information of varying degrees of importance for night navigation. An analysis of the color problem and reports on progress made are also available (10, 15) and need not be described in detail.

The second aspect is the experimental investigation, directed toward specification, of the optimum characteristics of typographical presentation. This work is concerned with the variables of type size, stroke-width, height-width ratio, letter spacing, color, and contrast. Developments in this area are to be found in progress and technical reports (5, 15) submitted to the Aero Medical Laboratory. To facilitate work on the typographical variables a printing press as well as a specially designed and manufactured set of type has been acquired by the Institute. Subsequent research with these materials should contribute to the specification of typographic relations optimum for use under low levels of red illumination.

Ultimately, the group at Tufts expects to provide recommendations which will incorporate the principles of optimal typographic and colorimetric design suggested by its research.

G. The Armed Forces-National Research Council Vision Committee

The Vision Committee recently appointed a Working Group to evaluate the problem of legibility of maps and charts under red light. A meeting was held, in September 1952, in which the legibility of charts was explored in the context of general problems of visibility in night flying. The report submitted to the Vision Committee included a number of suggestions for directions of further research on the several related problems.

## V. SUMMARY AND CONCLUSIONS

The foregoing review describes work and suggestions directed toward the improvement of the legibility of aeronautical charts under red cockpit light. It is clear that such efforts in the United States have been largely fragmentary. In spite of this, considerable progress has been made, and trends for major improvements in future charts are evident. One of these is toward the realization that a single solution of the typographic and color problems may not be adequate for all operational situations. Current developments indicate a heightening of interest and a promise of more concerted effort in the near future.

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