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AIR WEATHER SERVICE
TERMINAL AREA CONSIDERATIONS
CODED GRAPHICS RECORDERS

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-64-455

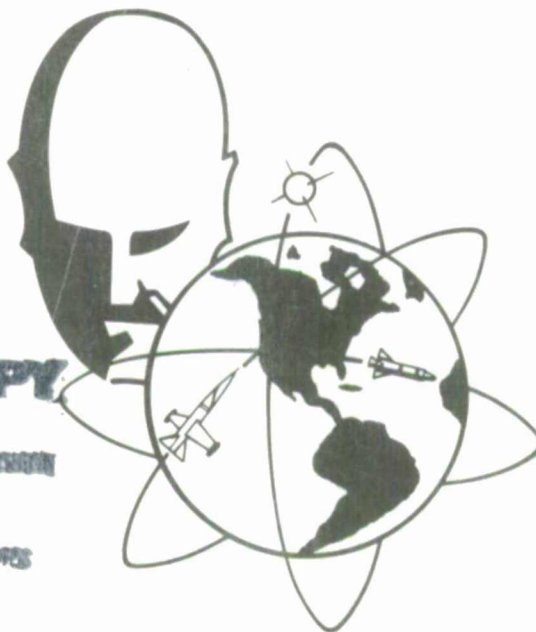
AUGUST 1964

DEPUTY FOR COMMUNICATION SYSTEMS MANAGEMENT
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

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AUGUST 1964

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ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L.G. Hanscom Field, Bedford, Massachusetts

(Prepared under Contract No. AF19(628)-3414 by
ITT Communication Systems, Inc., Paramus, New Jersey)

FOREWORD

This report has been prepared by ITT Communication Systems for the Deputy for Communication Systems Management (ESN), Electronic Systems Division, under contract AF19(628)-3414.

ICS has assigned for internal use report number ICS-64-TR-489.

ABSTRACT

Terminal area graphic recorders were studied with a view to meeting future AWS needs in transmitting graphic meteorological information. Utilizations of digital encoding and modern graphic reproduction techniques may satisfy the requirements of an increased traffic load with no increase in the present nominal 4 kc bandwidth.

"Coded Graphics" is defined as any method for transmitting hard copy having less redundancy than conventional line-by-line scanning facsimile. Generally, only non-white point locations on the copy are transmitted. Transmission of invariant portions, such as geographic background, may also be avoided. The number of non-white points in a message and the encoding method used will determine the length of time required to transmit the information.

Coded graphics recorder techniques show superiority over presently used facsimile by providing multiple copies, and copies with better legibility and esthetic quality. Cost projections over a ten year period show that a savings may be possible using coded graphic techniques.

Seven coded graphics recorder types were found to be applicable by this study. Three of the seven hold promise for future AWS network applications. A study of digital encoding techniques and establishment of a set of performance requirements is scheduled for follow-on contractual activity.

AIR WEATHER SERVICE
TERMINAL AREA CONSIDERATIONS
CODED GRAPHICS RECORDERS

REVIEW AND APPROVALS

This technical documentary report has been reviewed and is approved.


ARTHUR L. STEVENS, Jr., Lt. Col., USAF
Director of Engineering
Deputy for Communications Systems Management

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SECTION I

INTRODUCTION

One of the missions of the Air Weather Service (AWS) is to provide graphic meteorological information (weather charts) to military user agencies. Within the next few years, the Air Weather Service requirements for communication capacity to disseminate these charts will far outstrip the capabilities of present facsimile transmission facilities.

The application of modern analog facsimile equipments will provide an eight-times increase in graphic dissemination capability. However, these equipments will also require an eight-times increase in bandwidth over the transmission paths, with attendant increases in cost. Furthermore, both old and new facsimile equipments are deficient with regard to providing multiple copies and consistently good legibility.

In anticipation of these problems, ESN requested ICS^{*} to conduct a study to determine if modern graphic reproduction techniques, utilizing digital encoding technology, can provide equipments to meet traffic and qualitative requirements with significant savings in transmission bandwidth.

An initial examination of this problem indicated that a coded graphics communication system to support the Air Weather Service must be designed considering the technical characteristics of the coded graphics recorder best suited to satisfying Air Weather Service requirements. Consequently, the major effort of this present study was directed toward determining which coded graphics recording technique should be used as a basis for the AWS coded graphics system and subsystem design effort. A preliminary layout for the terminal area configuration is given in section 4.

Based upon the findings in this study on coded graphics recorders, and upon the findings of a subsequent study on the optimum digital encoding technique for weather graphics information as related to these recorders, the design of a coded graphics communication system can be initiated with reasonable confidence in projected performance, cost and schedule.

This study has shown that the electro-mechanical graphic recorders (Appendix I-1), the electrostatic deflection recorders (Appendix I-2) and video-electrostatic recorders (Appendix II-2) have promising potential for satisfying the requirements for the period from 1966 to 1970. The technical nature of these different systems are covered under their respective titles in section 3, "Technical Analysis".

*Task 11 - QPPR19

These findings are predicated upon the technical state of the art for modern graphic reproduction techniques, and on the efficiency of digital encoding techniques as they may apply.

This study has concentrated on identifying the best technology for reproducing weather graphics (weather maps, plots, etc.) at the receiver terminal. Since an increasing amount of this air weather graphics material is being developed in data processors, there does not appear to be any feasibility problem in the preparation of coded graphic information for transmission to operate any of the graphics recorders discussed in this study.

Seven different coded graphics recording techniques have been studied and compared with regard to performance, equipment costs and operational costs.

SECTION 2

SUMMARY

A study was conducted to determine which graphic recorders hold promise for supporting future weather network requirements for the dissemination of meteorological information. These requirements include an anticipated large increase in the quantity of weather chart information to be transmitted to military agency users. It is desired that no increase in the present nominal 4 kc bandwidth be required to satisfy this increase in transmission capacity.

The utilization of digital encoding, together with modern graphic reproduction techniques, were found to hold promise of satisfying the above stated requirements.

The term "coded graphics" is used to describe any method for transmitting hard copy which has significantly less redundancy than conventional line-by-line scanning facsimile. In general, the coded graphics methods transmit only the locations of non-white points on the copy and avoid the need for transmitting the information concerning the location of white points.

Coded graphics methods can also eliminate the need for transmitting invariant portions of a message, such as the geographic background of weather maps.

The amount of time required to transmit the necessary information will depend on the quantity of such information contained in the message and on the efficiency of the encoding method used. The encoding method which may be used also depends on the nature of the information to be transmitted.

Coded graphics recorder techniques were found to be superior to present facsimile equipment in providing multiple copies and in producing copy with better legibility and esthetic quality. Cost projections over a 10 year period indicate some savings may be realized by use of coded graphic techniques.

Of the coded graphic recorder types presently available or under development, seven types were found to be applicable to this study. Three types have been chosen as holding particular promise for future Air Weather Service network applications. A firm recommendation of recorder types cannot be made until a complete set of AWS coded graphics system performance requirements are clearly and qualitatively established and their relative importance indicated.

This report, in the ensuing sections, points to the areas where further effort in requirements analysis is needed. The development of requirements can also serve as a guide to further manufacture design efforts in the hardware area. Establishing a complete set of performance requirements and study of digital encoding techniques that may be used with coded graphic recorders is scheduled for follow-on contractual activity.

SECTION 3

CONCLUSIONS AND RECOMMENDATIONS

Out of the seven types of coded graphic recorders studied, the electro-mechanical, the electrostatic deflection and the video electrostatic recorders hold the greatest promise for satisfying most of the Air Weather Service graphic requirements in the period from 1966 through 1975. Present evidence indicates that these recorders can support the reliable and economical dissemination of weather charts with good legibility and esthetic^{*} quality.

Of these three recorders, the electro-mechanical type recorder is available now and with modification, could meet most of the needs of a coded graphics communication system.

However, the other two types of recorders have potentials which will not allow them to be ruled out completely at this time. These two recorders are still in the prototype stage and it is likely that the esthetic quality of these two recorders will be improved as refinements in recording techniques are developed. If the esthetic quality of the copy is improved, and if immediate simultaneous multiple copies can be provided, the video-electrostatic recorder could provide excellent service. Likewise, if techniques are developed that would increase the maximum rate of chart reproduction, the development of the electrostatic deflection recorder would be justified.

The conclusions stated above are based upon the present technical state of the art for the reproduction of graphics copy from encoded digital information. It will be necessary to determine the optimum coding for each of the three types of recorders, and this should only be determined after a complete statement of weather chart requirements are obtained from AWS.

* Esthetic quality is defined here as that subjective attribute of the graphic copy that pertains to its pleasing appearance.

SECTION 4

TECHNICAL ANALYSIS

1.0 AWS GRAPHIC NETWORK REQUIREMENTS AND DESIGN OBJECTIVES

1.1 WEATHER CHARTS

One of the requirements of the Air Weather Service is to distribute weather information in pictorial (graphic) form to the military agency users. The graphic products must give a legible and an esthetically pleasing representation of weather data such as, analyses and prognoses at surface and constant pressure levels; detailed wind analyses; and flight weather analyses and prognoses. These graphic products present isoline and symbolic data against a geographic background reference. There are a number of geographic background maps required which may differ in both projection type and in scale. The information content of the background relative to that of the weather data will also vary between products.

The majority of the charts in use are 18" in width, and 12" to 36" in length. Other chart sizes are 6" by 9", 9" by 12" and 36" by 36". A reasonable compromise is to provide for chart reproduction in 18-inch widths (present standard). Smaller size charts can be batch transmitted (simultaneous transmission on the 18-inch wide form). The 36" by 36" chart can be produced by transmitting two 18" by 36" charts and placing them together at the receive location. An 18" by 12" chart has been selected as the average chart to provide a standard of comparison of the various techniques discussed in paragraph 4.2.

The majority of weather charts, today, are manually prepared. The output product furnishes direct input to the facsimile transmitter for transmission in analog form. However, a significant portion of weather data is processed by computers that produce the resultant data in digital form. It is expected in the next few years, that 80% to 90% of the data to appear on the graphic weather product will be computer derived. This data, if properly coded, can be applied directly to the transmission line interface for transmission in digital form to the sinks where the coding can be accomplished by computer programming. Analog facsimile transmission will require digital to analog conversion at the source computer output prior to its input to the facsimile transmitter.

The possibilities of on-line computer operations, as well as other advantages of digital transmission in a computer based AWS Graphic Distribution Network, requires an investigation. Information contained on the remaining 10% to 20% manually derived weather charts can be converted to digital form by available equipment which converts graphic information into digital form.

1.2 PRESENT NETWORK DEFICIENCIES

The facsimile weather networks which are in use today have the following deficiencies:

- (a) Inability to accommodate any appreciable traffic increases or schedule modifications on existing circuits.
- (b) Excessive transmission time per chart.
- (c) Lack of flexibility to modify schedules.
- (d) Lack of immediate simultaneous multiple copies.

The three major facsimile networks in the CONUS (National, High Altitude and Strategic) are 95% filled, leaving a total time available of 230 minutes per day. As a result, it is very difficult to add new chart types, and to modify a schedule to accommodate changing user requirements, without impairing the timeliness of delivery.

The current average transmission time of 14 minutes per chart, when multiplied by the number of charts transmitted, may result in excessive delays (several hours) in chart reception. This delay is often a significant fraction of the useful life of these charts. This slow transmission is another factor which makes schedules relatively inflexible because shifting the position of a chart in the schedule will produce a significant change in its delivery time. Also, there may be some weather information, such as severe weather warnings, that are best presented in graphic form, but that cannot be transmitted on present facsimile networks because of these factors.

Many stations require multiple copies of at least part of the traffic they receive. None of the recorders in the existing networks are capable of simultaneously producing immediate multiple copies. The copy produced on the commonly used electrosensitive paper is opaque and of low contrast, therefore, difficult to reproduce. However, copy produced on electrolytic recorders is translucent and readily reproduced by Ozalid and similar copying processes.

1.3 CODED GRAPHICS RECORDER PERFORMANCE CRITERIA

The performance criteria established by AWS (reference 1) for a weather graphics recorder are:

- (a) Minimum chart handling capacity of 48 - 36" x 36" charts per day.
- (b) Legibility must be of the elite typewriter type consistency.
- (c) Capability of providing from 1 to 3 direct copies.
- (d) Operate on signals received over a nominal 4 kc voice grade channel.

2.0 DISCUSSION OF CAPABILITIES

2.1 FACSIMILE CAPABILITIES

The time required by a facsimile recorder to reproduce a chart of given size is constant and is independent of the amount of information contained on the chart (isolines, alphanumeric characters, symbols, background, etc.). The average 18" x 12" chart as used in this study, contains 780 inches of lines, and 1080 alphanumeric characters and symbols. The foreground (weather information) has 500 inches of isoline and 1000 characters and symbols, while the background has 280 inches of lines and 80 characters and symbols.

Existing high speed analog facsimile equipment, operating at eight times the present standard speed, is only about twice as expensive (\$9,500 per recorder) as the present standard speed equipment (\$4,500 per recorder). The high speed facsimile recorder reproduces any 18" by 12" chart in 1.25 minutes as compared to 10 minutes for standard speed facsimile recorders. For purposes of comparison, with coded graphics recorders this time of 1.25 minutes will be considered a standard time for chart reproduction. However, this increase in operating speed of the analog facsimile equipment requires a proportional increase in the bandwidth needed to carry the signals. Thus, there is a twelvefold increase in line rental costs since the most economical transmission lines are in Telpak groups. Telpak A which consists of 12 voice grade lines would be the cheapest Telpak group with the necessary bandwidth.

The legibility and esthetic quality of the copy produced by analog facsimile is only fair to good while immediate simultaneous multiple copies are not available.

2.2 CODED GRAPHIC CAPABILITIES

The coded graphics technique will permit a higher transfer rate of useful information than the facsimile technique within the same transmission bandwidth.

This is possible because facsimile methods require transmission of large quantities of non-essential pictorial information in order to permit satisfactory reproduction of the desired pictorial information. Coded graphics provide the ability to select the necessary information for transmission and to reduce the amount of non-essential information transmitted. The amount of necessary information will depend on the type of weather chart being transmitted. The amount of the non-essential information which can be eliminated will depend largely on the coding used.

For the range of weather charts, it has been estimated by proponents of various coding methods, that from one-twentieth to one-eighth of the information transmitted by facsimile is sufficient to generate a satisfactory picture at the receiver. (References 2, 3, and 4 and discussions with equipment manufacturers.) Coded graphics transmission of weather charts will, therefore, be from eight to twenty times as fast as facsimile for the same bandwidth. The actual speed will depend upon the particular coding used and will vary with the content of the various weather charts. A more accurate evaluation of the speed which may be expected will require a more detailed knowledge of the overall content of the charts to be transmitted, and of the relative frequency of their occurrence.

Part of the speed advantage of coded graphics is obtained by not transmitting the fixed geographic background of the weather chart. The time which would be required to transmit the background in a coded graphics network has been estimated at from one half to three times the time required to transmit the weather information. This extra transmission time for the background generated at the source must be compared with the necessity of providing a choice of backgrounds stored in a suitable form at the receiver (sink), and selecting the proper one rapidly when required. There will be a tradeoff of costs between producing the background at the source, basically a cost in loss of effective bandwidth, and at the sink in the form of recorder hardware modifications and additions. Estimation of the tradeoffs will require more extensive investigation of the relative information contents of

background and weather information (foreground) data of the various charts. The specific need for contrast between the background and foreground of the various maps must be established. If so established, the need for contrast will affect the transmission coding and bandwidth requirement for source generation of background. It will, in addition, influence choice of a recorder, and the manner of selecting the background where sink generation of background is employed.

The coded graphics network allows for a large reduction in the information transmitted for an individual chart. This reduction carries over to any storage requirements in transit. In addition, the digital form of information representation allows the chart to be processed and manipulated by well-known techniques. The result is an increase in feasibility of the application of store and forward switching to the AWS graphic dissemination network. Store and forward switching will facilitate the selective distribution as well as the interrogation response features of an alphanumeric network.

The most apparent disadvantage of a coded graphics network is that the receiving equipment is more expensive and more complex than facsimile equipment capable of operation at eight times the present standard speed. It is estimated, on the basis of information given herein, that the increased equipment cost will be offset by reduced operating costs within five to ten years of operation.

2.3 TECHNOLOGY OF THE CODED GRAPHICS RECORDER

The apparent advantages of the coded graphics technique over the facsimile technique in the area of bandwidth utilization and digital switching brought an initial investigation into the current technology of coded graphics recorders. It was found that certain types of coded graphics recording techniques offer, in addition, better legibility and esthetic quality of one or more immediate simultaneous multiple copies. Also, the recording speed of these machines would generally exceed the digital transmission speed presently attainable on a voice grade channel. The speed allowed for a given bandwidth depends on the coding and recording techniques of the machine types which can be classified into two categories: curve plotting and row printing machines.

The first category, the curve plotting types, reproduces one complete isoline at a time. This is accomplished by first stating the absolute

X and Y position of the starting point of each isoline and then stating the incremental X and Y movements of the individual segments that constitute the complete isoline. The absolute X and Y position of a segment is given periodically to insure that the isoline is not drawn in error. This limits the possible error in reproducing the graphic information to portions of an isoline. This process is repeated for each isoline on the chart.

A code presently in use with this coding technique uses five bit characters to specify line segments and alphanumeric characters. Control characters are used to select groups of alphanumeric characters and to identify the plotting mode, the printing mode or the positioning information.

The second category, the row printer type, reproduces segments of a number of isolines one row at a time. This is done by sequentially stating the length and direction of segments of the various isolines that intersect a given row (same Y position). After all the isoline segments on one row have been reproduced, the paper is advanced one row (line) and the process is repeated.

A code under consideration with this coding technique uses seven bit characters to specify line segments and alphanumeric characters. Reproduction errors with this technique are limited to small segments of an isoline (on one row).

A limitation of row printing devices is that the time required to print a row is fixed and does not decrease when a row contains fewer marks. This makes the time required to transmit a chart of a given size independent of the content of the chart. This time will have to be as long as is necessary to transmit that chart which has the largest information content. For codes of a given efficiency, and transmission lines of a given bandwidth, a network using row printing devices will require more time to transmit the same traffic than if curve plotting equipment is used. This time will still be shorter than for a facsimile network using the same bandwidth.

The row printing technique may be less sensitive to transmission errors than the curve plotting technique. A single character received in error in a row printer will at most cause one segment of one isoline to have the wrong slope or position, causing an obvious discontinuity in the completed isoline which can easily be corrected by the user. In a curve plotter using increments, a single character received in error will cause the following portion of the isoline, up to the point where the next absolute position

characters occur, to be displaced. This distortion in the isoline caused by a character error in this case is somewhat harder to detect and is also more difficult to correct by the user when it is detected.

As stated previously, a large part of the reduction in bandwidth for coded graphics transmission is made feasible by exclusion of chart background information. This will require the provision of background at the sink. The background may also be required to contrast the transmitted weather information (foreground).

The video recorders of the curve plotting type can produce the chart background by optically superimposing it through slide projection or other means on the recording media. The thickness of the lines constituting the background can easily be varied to meet contrast requirements.

The other kinds of recorders of both types can provide the chart backgrounds in two different ways:

1. Background is preprinted in an arbitrary order on the rolls or stacks of the recording medium. Here again, the thickness, or density, or color of the lines constituting the background can be varied if desired. Format control of the recorder paper advance mechanism provides the correct background for the various charts in the order in which they are received. However, if charts are not received in the same order as the backgrounds which appear on the rolls or stacks of paper, a number of pages will be wasted in order to match the correct background to the corresponding chart. Also, channel coordination will become necessary to assure proper prepositioning of chart background at all selected sinks. This will entail a certain reduction in bandwidth utilization.

2. The various chart backgrounds can be stored in digital form in a permanent buffer (magnetic drum). This information can then be interleaved with the incoming isoline and alphanumeric information. Without further modification the thickness of the lines constituting the background in this case will be the same as that of the isolines. Distinctive encoding of the background information and modifications in the recording mechanism will be required to produce contrast. The effect of these requirements on recorder design should be studied to develop feasibility and tradeoff criteria if necessary.

A discussion of the different kinds of coded graphics recorders of both types is given in the Appendices. The discussion is summarized in

Table 1, Coded Graphics Recorder Comparison Chart and Table 2, Comparison of Estimated Graphics Network Costs. An analysis of these charts reveals that a coded graphics network which used any of the four following coded graphics recorders would not meet most of the main objectives, as stated in section 4.1.3.

- a. X-Y Plotter
- b. Matrix Electrostatic
- c. Matrix Electrosensitive
- d. Video Photographic

The X-Y plotter recorder cannot provide timely delivery, adequate capacity to carry future traffic, economic operation or immediate simultaneous multiple copy.

The two matrix recorders do not provide good legibility, good esthetic quality, or immediate simultaneous multiple copies, and provide only limited capacity for traffic expansion.

The video photographic recorder is excluded from the recommended considerations since it is much higher in price than any of the other recorders without offering substantial advantages.

Table 3, Acceptable Coded Graphics Recorders compares the acceptable recorders. Some of the deficiencies are as follows:

a. The electro-mechanical recorder does not provide weighted lines. This should affect network operation only if both preprinted backgrounds and lack of weighted lines prove unacceptable. Only one manufacturer (Potter Instrument Company) is presently producing a recorder. However, this recorder will require some modification to produce a copy suited to AWS needs.

b. The electrostatic deflection recorder has only a limited ability to increase its rate of operation to meet any large increase in future traffic. It also fails in not providing weighted lines. Although immediate simultaneous multiple copy is available, each additional copy required increases the recorder cost by approximately 10%. The recorder is still in the prototype stage and the manufacturer (Teletype Corporation) indicates none will be available before 12 to 18 months.

c. The video-electrostatic recorder does not have the ability to provide immediate simultaneous multiple copy. The esthetic quality of its copy, like that of the electrostatic deflection recorder copy, is judged to be only

fair to good. However, it can provide weighted lines, and has the greatest capacity to increase its rate of operation to meet increases in future traffic. This recorder is in the prototype stage and the manufacturer (United Aircraft Corporation) indicates none will be available for about 12 months.

As stated before, the feasibility of a coded graphics network is dependent upon the coding and recording techniques.

Optimum coding would result in the transfer of more information over a given bandwidth in the same time period. It has not yet been determined whether the coding methods now employed with each of these recording techniques is the optimum coding for transmission of weather graphics.

TABLE 1
CODED GRAPHIC RECORDER COMPARISON CHART

Type	Estimated Min. Machine Time to Record Average 18"x12" Chart(1)	Estimated Transmission Rate to Meet Minimum Chart recording Time (2)	Immediate Simultaneous Multiple Copies	Legibility	Esthetic Quality	Line Generation Technique	Manual Handling of Charts	Equipment Status	Equipment Cost/Unit	Estimated Paper Cost/Sheet
Electro- Mechanical Recorders	15 sec	2400 bps	Yes	Good- Excellent	Good	Row Printer	No	Available now	\$27,000	1¢
Electrostatic Deflection Recorders	41 sec	1600 bps	Yes (Requires extra heads)	Good	Fair- Good	Row Printer	No	Prototype built under test	\$22,000	1¢
Matrix Electrostatic Recorders	30 sec	1600 bps	No	Fair- Good	Fair- Good	Row Printer	No	Available equip- ment requires some modification	\$20-25,000	3¢
Matrix Electrosensi- tive Recorders	30 sec	1600 bps	No	Fair- Good	Fair- Good	Row Printer	No	Available equip- ment requires some modification	\$20,000	6¢
X-Y Plotter Recorders	180 sec	-	No	Excellent	Good- Excellent	Curve Plotter	Yes	Available now	\$25-30,000	8¢
Video- Electrostatic Recorders	< 1 sec	1200 bps	No	Good	Fair- Good	Curve Plotter	Yes	Prototype built under test	\$27,000	3¢
Video- Photographic Recorders	< 1 sec	1200 bps	No	Fair- Good	Fair- Good	Curve Plotter	No	Available now	\$50,000	15¢

(1) Average chart contains 780 inches of isoline, and 1800 characters and weather symbols. The foreground (weather information) has 500 inches of isoline, and 1000 characters and weather symbols. The background has 280 inches of isoline, and 80 characters and weather symbols.

(2) Transmission rate is a function of coding technique.

TABLE 2
COMPARISON OF ESTIMATED GRAPHIC SYSTEM COSTS
(260 STATIONS - 3 RECORDERS PER STATION)

1 Type of Equipment	2 Recorder Unit Cost	3 Total Equipment Cost	ANNUAL OPERATING AND MAINTENANCE COSTS					9 Total Annual Cost for First 5 Yrs.	10 Total Cost for first 5 Years	11 Total Annual Cost for Second 5 Yrs.	12 Total Cost for second 5 years	13 Total Cost for 10 Yrs.
			4 Paper	5 Personnel	6 Capital Recovery	7 Spare Parts	8 Leased Line Costs					
Electro- Mechanical	\$27,000	\$21,060,000	\$ 475,000	\$3,120,000	\$4,730,000	\$ 840,000	\$ 450,000	\$ 9,615,000	\$48,075,000	\$ 5,309,000	\$ 26,545,000	\$ 74,620,000
Electrostatic Deflection	22,000	17,160,000	475,000	3,120,000	3,854,000	686,000	450,000	8,585,000	42,925,000	5,075,000	25,375,000	68,300,000
Matrix Electrostatic	22,500	17,550,000	1,425,000	3,120,000	3,942,000	702,000	450,000	9,639,000	48,195,000	6,048,000	30,240,000	78,435,000
Matrix Electrosensitive	16,000	12,480,000	2,850,000	3,120,000	2,803,000	499,000	450,000	9,722,000	48,610,000	7,169,000	35,845,000	84,455,000
X-Y Plotter	27,500	21,450,000	3,800,000	3,120,000	4,818,000	858,000	450,000	13,046,000	65,230,000	8,657,000	43,285,000	108,515,000
Video Electrostatic	27,000	21,060,000	1,425,000	3,120,000	4,730,000	840,000	450,000	10,565,000	52,825,000	6,259,000	31,295,000	84,120,000
Video Photographic	50,000	39,000,000	7,120,000	3,120,000	8,760,000	1,560,000	450,000	21,010,000	105,050,000	13,030,000	65,150,000	170,200,000
High Speed Analog Facsimile	9,500	7,410,000	520,000	3,120,000	1,664,000	296,000	5,400,000	11,000,000	55,000,000	9,485,000	147,425,000	102,425,000

Notes: The above costs are based on the following:

Capital Recovery per year is computed by considering a five year life and 4% interest for which the factor is 0.2246.

The estimated annual cost of operating and maintenance personnel is included in column 5.

The spare parts requirements for the second five year period would be higher than for the first five year period i.e., spares for the first five year period being 4% and for the second five year period being 6% of the equipment cost.

It is assumed that space, power and other support facilities would be available at practically no additional cost.

If Capital Recovery is not to be considered then the amount in column 6 may be deducted from columns 9 & 11.

To obtain the approximate leased cost of the above equipment use the costs in column 2 and divide by 3 to find the annual leased cost.

TABLE 3
ACCEPTABLE CODED GRAPHIC RECORDERS

Recorder Type	Immediate Simultaneous Multiple Copy	Legibility	Esthetic Quality	Estimated Charts/Min. at 2400 bits/sec.	Max. Recorder Chart Reproduction Rate	Equipment Status	Estimated* Cost for 10 Years
Electro-Mechanical	Yes	Good to Excellent	Good	0.8	15 sec.	Available Now With Some Modification	\$74,620,000
Electro-Static Deflection	Yes	Good	Fair to Good	1.2	41 sec.	Prototype Stage	\$68,300,000
Video-Electro-Static	No	Good	Fair to Good	2.0	>1 sec.	Prototype Stage	\$84,120,000

* Breakdown of total cost is included in Table 2.

** At highest bit rate machine can accept.

SECTION 5

TERMINAL ARRANGEMENTS IN A CODED GRAPHICS NETWORK

A block diagram of source and sink configuration (Figure 1) which could operate with any of the coded graphics recorders discussed in the Appendices.

It has been assumed throughout this report, that the transmission network for coded graphics will consist of voice grade circuits of 4 kc nominal bandwidth while analog facsimile will require wideband circuits to satisfy speed requirements. Present estimates of traffic volume, based on the results of the AWS survey indicate that circuits dedicated to this weather service will be required unless AUTODIN or AUTOVON can furnish an equivalent service. The need for consideration of AUTODIN or AUTOVON in future design is recognized. The nature of control signals and the supervision required for (a) operation over a dedicated network, (b) operation over AUTOVON, or (c) operation over AUTODIN, will determine the nature of corresponding equipment to be located at transmitting and receiving terminals.

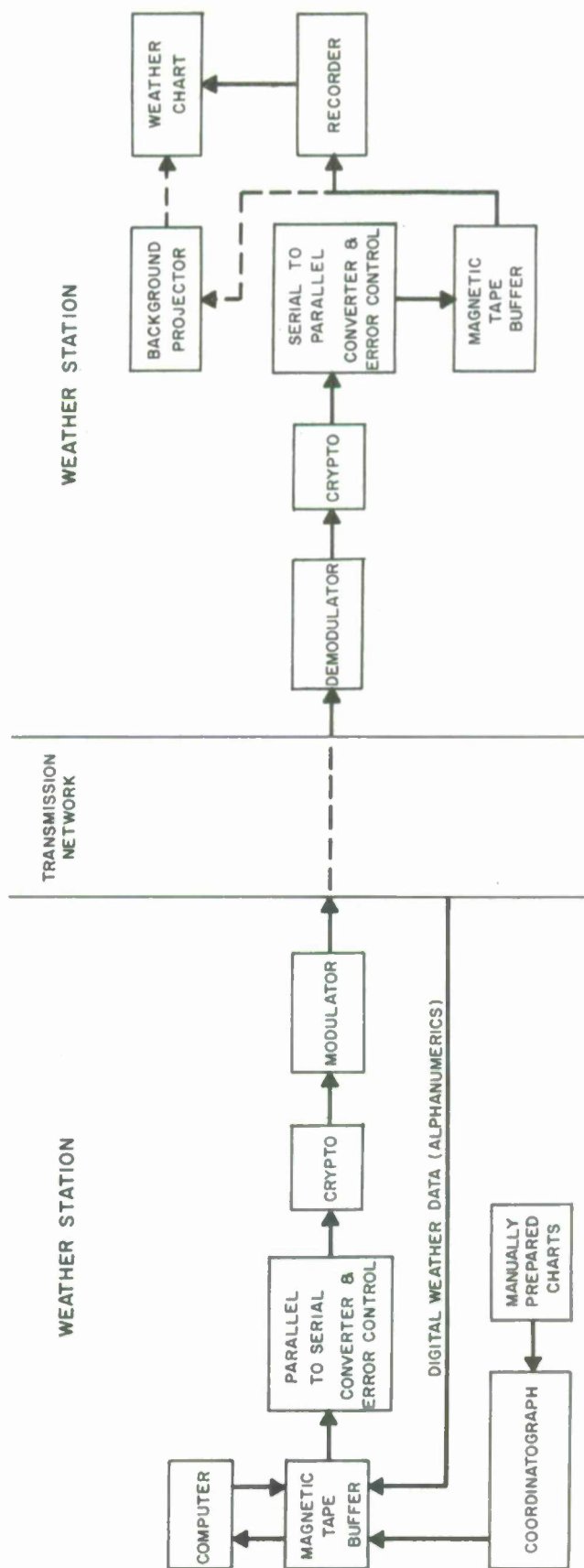
The means for error control will differ for the various coding methods. The selection of a coding method will be affected by consideration of the effect of transmission errors on the received message, and must be coordinated with the type of medium used (i.e. dedicated, AUTOVON, AUTODIN).

Graphic messages will be received from a computer as digital output in parallel form. Conversion will be made to serial form for distribution over the network.

Switching methods used in the transmission network may be affected somewhat by the form of the transmitted information which will depend upon the coding method used. The network will be controlled by a switching program derived from the results of the AWS survey. This program will be readily modified as the requirements of the individual sinks vary with time.

All of the foregoing require more detailed knowledge of the information content of the weather charts to be transmitted by the network. Therefore, definitive design recommendations cannot be made at the present time.

On-base distribution has been placed outside the bounds of this study but it must be considered, just as the need for multiple copies must be considered. Proper selection of receiving equipment may permit the use of slave recorders at each point of use with a saving of time and money over separate on-base distribution methods.



TERMINAL ARRANGEMENT IN A CODED GRAPHICS NETWORK

FIGURE 1

SECTION 6

NETWORK COSTS

Costs are developed in this section and shown on Table 2 for eight different networks, one network for each of the seven coded graphic recorders and one network which incorporates the high speed analog facsimile recorder.

Although information regarding traffic requirements is unavailable at this time, it is expected that a number of circuits will be required by the transmitting stations. As a result, it is estimated that the average station will use three recorders. It is estimated too, that the entire network will require about 75,000 miles of lines. Each of the seven coded graphic networks will require one voice channel per circuit, while the high speed analog facsimile network will require 12 voice channels per circuit. Cost per channel of \$0.50 per mile per month is based on the assumption that government rented Telpak channels will be available. The networks considered are not switch networks.

The cost comparison for the eight networks as shown in Table 2 is based on the following assumptions:

- (a) Principal systems costs are affected by 1) recorder, 2) transmission line, 3) paper, and 4) maintenance costs.
- (b) There are 260 station drops and three recorders per drop.
- (c) There are 75,000 circuit miles in the network.
- (d) Estimated recorder life is ten years.
- (e) There will be five hundred 18" by 12" maps recorded per day per terminal.

SECTION 7

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APPENDIX I
ROW PRINTING TYPE RECORDERS

APPENDIX I
ROW PRINTING TYPE RECORDERS

1.0 ELECTRO-MECHANICAL RECORDERS

Electro-mechanical recorders provide a high quality print, good to excellent legibility and good esthetic quality, and immediate simultaneous multiple copy is available. Although the maximum speed of operation will allow a higher rate of flow of input data, a transmission rate of 2400 bps is sufficient for the recorder to meet the standard comparative time of 1.25 minutes for reproduction of one average 18" by 12" chart.

1.1 TECHNIQUE OF THE ELECTRO-MECHANICAL RECORDER

The electro-mechanical recorder produces graphical plots by converting the digital information into printed characters and printed dots which form lines. Lines are drawn by the row printing technique. Existing printers can produce dot patterns of a 3 x 3 matrix within each character location. This unit features a rapidly rotating drum on which are embossed 180 character sets (10 character sets/inch). For weather chart reproduction a character set will consist of alphanumeric characters, some basic weather symbols and a larger selection of dot patterns than on existing machines. Hammers are provided for each print column position. The dots and characters are formed by causing a hammer to force either pressure sensitive paper or a paper and ribbon against a type face.

At present only one company makes a printer using dot pattern characters for drawing lines. Other machines could be modified by adding dot characters to permit line drawing. Further investigation is needed to determine whether the appearance (esthetic quality) and resolution provided by a 3x3 matrix is adequate for reproduction of weather charts.

1.2 MAXIMUM SPEED

The recorder would be capable of reproducing an average 18" by 12" map in less than 15 seconds. When limited by the transmission capability of a voice grade channel (assume 2400 bits), the comparison standard of 1.25 minutes is met. If 3600 or 4800 bits per second speed lines were available, the chart reproduction time would be reduced to 48 and 36 seconds respectively.

1.3 LEGIBILITY

The legibility of the characters produced by the recorder is superior to characters produced by any other technique. The lines which are produced by dots have good legibility. The overall esthetic quality of the chart is good.

2.0 ELECTROSTATIC DEFLECTION RECORDERS

Electrostatic ink deflection recorders appear to have good legibility and fair to good esthetic quality. A transmission rate of 1600 bps should permit reproduction of an average chart in the comparative standard time requirement of 1.25 minutes. The recording technique appears to limit the maximum rate of chart reproduction to this speed.

2.1 TECHNIQUE OF ELECTROSTATIC DEFLECTION

The electrostatic deflection recorder utilizes the technique of shooting a controlled pattern of ink in a fine jet-like stream onto the paper. A non-clogging distilled ink is fed to the jets, one for every two column positions. The digitally coded information is compared with information in the core-storage of the recorders to derive electrical deflection patterns which affect directional control of the ink jets, and form the desired character or line. These deflection patterns are then applied to electrostatic deflection plates for each ink jet. The non-drying ink used in this process is fixed to the paper by absorption instead of deposition by evaporation. Use of this type of ink serves to prevent the jet tubes from clogging during periods of non-use.

Immediate simultaneous multiple copy is provided by supplying extra recording heads, which cost approximately \$2,500 per head.

Although no such recorder is available for purchase today, it is expected that such a recorder will be placed on the market in 12 to 18 months by the Teletype Corporation.

2.2 MAXIMUM SPEED

The minimum time of chart reproduction is 48 seconds for the average chart, which is about equal to the time for reproduction at a bit rate of 2400 bps. A bit rate of 1600 bps would permit chart reproduction in the comparative standard time of 1.25 minutes.

2.3 LEGIBILITY

Legibility of the copy produced appears to be good, while the esthetic quality seems to be only fair to good.

2.4 STATE OF THE ART

Some of the disadvantages of the electrostatic deflection recorders are:

(1) Only a prototype of an alphanumeric printer using this technique is in existence at present.

(2) The maximum rate of chart reproduction is slower than that of most other techniques and is limited by the inertia of the ink jet.

(3) Character and line esthetic quality is not as good as other techniques.

Reliable recorders at nominal costs should be available in 12 to 18 months.

Not much improvement in the rate of character and line reproduction by the electrostatic deflection recorders can be expected in the next five years, although legibility and esthetic quality should improve.

3.0 MATRIX ELECTROSTATIC AND ELECTROSENSITIVE RECORDERS

Matrix electrostatic and electrosensitive recorders provide fair to good quality print and legibility. A transmission rate of 2400 bps will provide enough information for the recorder to meet the standard comparative time requirement of 1.25 minutes.

Paper handling is not as satisfactory as that of the mechanical recorder. Paper costs are high and immediate simultaneous multiple copies are not provided.

3.1 TECHNIQUE OF THE ELECTROSTATIC AND THE ELECTROSENSITIVE RECORDERS

Matrix electrostatic recorders produce hard copy by converting digital information into high voltage pulses which are discharged through multiple styli formed in a matrix. These pulses electrically charge a special paper which is passed through a cloud of dry powdered ink which adheres to the charged pattern. The paper is subjected to heat and/or pressure to provide permanent copy that can be handled without smudging or smearing.

Matrix electrosensitive recorders operate similarly to matrix electrostatic recorders with the exception that the permanent record is made by an electric current from the matrix styli, which destroys the white surface of highly conductive black-backed paper.

In both matrix recorders, alphanumeric characters, lines and weather symbols are formed by firing different combinations of the matrix styli. Lines are developed by means of a row by row printing technique.

At present, there is no "on-the-shelf" recorder which has been designed to provide weather charts. There are, however, a number of matrix electrostatic and matrix electrosensitive alphanumeric recorders on the market which would require comparatively minor modifications to provide weather charts. Manufacturers of some typical equipment are Burroughs Corporation, Motorola Corporation, Omnitronics Corporation and Radiation, Inc.

3.2 MAXIMUM SPEED

The present maximum speed of the average chart reproduction of low speed matrix recorders (which are economically compatible to the other recorders discussed) is 30 seconds. A transmission speed of 1600 bps would be sufficient for the recorder to reproduce the average chart in the comparative standard time of 1.25 minutes.

3.3 LEGIBILITY

Legibility of the characters and lines produced by the matrix recorders is only fair to good. The esthetic quality is only fair.

3.4 STATE OF THE ART

Some of the disadvantages of the present-day equipment are:

- (1) High paper costs.
- (2) Poor paper handling equipment, which results in paper jams, the smudging of characters and objectionable odors due to burning of paper.
- (3) Character and line esthetic quality is not comparable to other techniques.
- (4) The inability to provide immediate simultaneous multiple copies.

Very high-speed matrix recorders are available today for computer output devices. Their cost is much higher than the devices being considered here, and the information rate required for the speed at which they can operate is also much higher than that permitted by a voice grade line. If traffic densities become large enough to justify the cost of the equipment and wideband lines, such matrix recorders would be able to produce average charts in a matter of several seconds.

Esthetic quality and paper handling ability should be improved while cost of paper should be reduced.

APPENDIX II
CURVE PLOTTING TYPE RECORDERS

APPENDIX II

CURVE PLOTTING TYPE RECORDERS

1.0 X-Y PLOTTER RECORDER

The X-Y plotter recorders produce the most legible charts of any of the presently known techniques. These charts provide good esthetic quality. The maximum speed of operation of the equipment when plotting lines matches a transmission rate of 2400 bits per second, but only 5 to 6 characters per second can be used when symbol printing.

Production of the correct background for the various charts is not provided, and some development will be required to provide them. Since the printing capability is limited to a slow rate, and to an insufficient number of symbols, the X-Y plotter recorders cannot meet the comparative standard time of reproducing one average 18" by 12" chart per 1.25 minutes. The average chart would require more than three minutes to reproduce.

1.1 TECHNIQUE OF THE X-Y PLOTTER

The X-Y plotter recorders produce graphical plots by converting digital information to analog signals which direct the movement and control of a pen and a symbol printer. These recorders use curve plotting to draw the isolines. There are a number of X-Y plotter recorders in use today which plot computer generated information at the computer location. One such X-Y recorder is located at the United States Weather Bureau, Suitland, Maryland. This recorder produces plots from computer generated weather information which are then transmitted by facsimile to the various weather stations.

The computer writes the processed weather information on magnetic tapes. These tapes are then read off-line into a converter which translates the digital code into the required analog commands which operate the pen and symbol printer on the recorder.

In the preparation of a chart, the symbol printer is usually selected first to eliminate the risk of smearing ink by printing after line drawing. The desired symbols are selected and printed at the specified locations with a static and dynamic resolution of up to $\pm 0.05\%$. Three times the maximum number (48) of symbols available today are necessary to satisfy the requirements of weather charts.

The pen is selected after all the symbols have been printed. Commands are given to raise and lower the pen at specified locations and to draw the lines.

1.2 MAXIMUM SPEED

Presently available equipment has a maximum line drawing speed of 25 inches per second and a maximum printing rate of six characters per second. Although the line drawing speed is satisfactory, the character printing rate does not meet the comparative standard time of 1.25 minutes.

1.3 LEGIBILITY

The legibility of a chart prepared by an X-Y plotter recorder is superior to charts prepared by any other method. An extra feature which can improve the legibility is the ability of this equipment to draw lines in a number of colors. The esthetic quality is good to excellent.

1.4 STATE OF THE ART

Some of the disadvantages of present-day equipment are:

- (1) Difficulty in providing the correct prepared backgrounds for the various charts in the order received.
- (2) Non-drying ink is used to prevent clogging and blotting. This special ink tends to smear when the maps are handled.
- (3) High cost paper is required.
- (4) The inability of the X-Y recorders to provide immediate simultaneous multiple copies.

It is expected that within the next decade, line drawing speeds will increase to 40 to 50 inches per second, while printing rates will increase to 10 to 15 characters per second, with a two-to-three time increase in the number of symbols. (Insufficient to meet system requirements.)

It is anticipated that paper costs will decrease and that ink and paper will be improved to prevent the pen clogging, blotting and smearing of present equipment. It is also anticipated that costs of the equipment will decrease considerably.

However, due to mechanical limitations, no significant breakthrough in the state of the art is expected. This is particularly true with regard to significantly increasing the character printing rate.

Equipment of this type is manufactured by Benson-Lelines Corporation and Electronic Associates, Inc.

2.0 VIDEO-ELECTROSTATIC RECORDERS

Video-electrostatic recorders appear to have good legibility and fair-to-good esthetic quality. A transmission rate of 1200 bps will provide enough information to permit average chart reproduction in less than the standard comparative time of 1.25 minutes.

The size of the hard copy will be limited to 18" by 18" by the light intensity of the cathode ray tube and by optical distortion. This size limitation will require manual assembly of larger charts (e.g., 18" by 36"). Immediate simultaneous multiple copies are not provided and paper costs are above average.

2.1 TECHNIQUE OF VIDEO-ELECTROSTATIC RECORDERS

The video-electrostatic recorder converts digital information into lines and characters by the X-Y plotting technique, and displays them on the face of a cathode ray tube. These displays are optically projected onto electrostatically charged paper. Background for the chart is provided by projecting a selected slide onto the same sheet of electrostatically sensitized paper. Line width and density of the background may be made to contrast with that of the CRT display. Development of these electrostatic patterns into visible images is accomplished by brushing the surface of the paper with a dry powdered ink consisting of small black particles of thermo-setting plastic. The particles adhere to the latent electrostatic pattern, developing legible symbols. The developed copy is subjected to heat or pressure, which melts the particles, fusing them to the paper. The resultant permanent copy can be handled without smudging or smearing.

There are a number of companies making such recorders and one company is actively engaged in applying this technique to the production of weather charts. (United Aircraft Corporation)

2.2 MACHINE SPEED

The video-electrostatic technique is capable of receiving one chart in less than one second, if the information flow were at a high enough rate. The delay for processing after reception remains at about three seconds at any speed. A transmission rate of 1200 bits per second will allow chart reproduction in less than one minute.

2.3 LEGIBILITY

The legibility of the characters and the lines produced by this technique are good while the esthetic quality is fair to good.

2.4 STATE OF THE ART

Some of the disadvantages of the present equipment are:

- (1) Lack of immediate simultaneous multiple copies.
- (2) Character and line esthetic quality is inferior to some other techniques.

- (3) Chart size limitation.
- (4) The high cost of special paper.

Esthetic quality should improve somewhat in the next few years.

As coding and plotting techniques, as well as manufacturing techniques, are refined, the cost of recorders and paper should decrease.

3.0 VIDEO-PHOTOGRAPHIC RECORDERS

Video-photographic recorders appear to have fair to good legibility and esthetic quality. A transmission rate of 1200 bps provides enough information to permit chart reproduction in less than the comparative standard time of 1.25 minutes.

Immediate simultaneous multiple copies are not provided and paper costs are high.

3.1 TECHNIQUE OF THE VIDEO-PHOTOGRAPHIC RECORDERS

The video-photographic recorder converts digital information into lines and characters by the curve plotting technique and displays them on the face of a cathode ray tube. These displays are photographed by a camera to produce a microfilm which is then used to prepare a photo reproduced page output. The camera itself is simple, a shuttering system not being required as the entire interior of the system is light sealed. Each frame of the microfilm may remain exposed until a film advance signal is received. Printing speeds of ten or more frames (pages) per second are possible. Alternately, photosensitive paper may be directly exposed by the cathode ray tube.

The correct background for the chart is provided by optically superimposing the prepared backgrounds on the microfilm or the photosensitive paper. Line width and density of the background can be made to contrast with that of the CRT display.

There are a number of companies making such recorders as computer output devices. One company is actively engaged in applying this technique to the production of weather charts on microfilm which are then transmitted by analog facsimile. (Burroughs Corporation)

3.2 MAXIMUM SPEED

The video-photographic technique is capable of producing one chart in less than one second, if the information flow were at a high enough rate. However, photographic processing time must be added. A bit rate of 1200 bps would allow chart reproduction in less than one minute.

3.3 LEGIBILITY

The legibility and esthetic quality of the characters and lines produced by this technique is fair to good.

3.4 STATE OF THE ART

Some of the disadvantages of the present equipment are:

- (1) The lack of immediate simultaneous multiple copies.
- (2) The character and line esthetic quality is inferior to other techniques.
- (3) The high cost of hard copy.

Legibility and esthetic quality of hard copy should improve in the next few years.

As coding and plotting techniques, as well as manufacturing techniques are refined, the cost of recorders and photosensitive paper should decrease.

UNCLASSIFIED

Security Classification

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1. ORIGINATING ACTIVITY (Corporate author) ITT Communication Systems, Inc. Paramus, New Jersey		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	
		2b. GROUP	
3. REPORT TITLE Air Weather Service Terminal Considerations Coded Graphics Recorders			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Study			
5. AUTHOR(S) (Last name, first name, initial)			
6. REPORT DATE 31 August 1964		7a. TOTAL NO. OF PAGES 37	7b. NO. OF REFS 4
8a. CONTRACT OR GRANT NO. AF19(628)-3414		9a. ORIGINATOR'S REPORT NO(S) ESD-TDR-64-455	
b.			
c.		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d.		ICS-64-TR-489	
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11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Deputy for Communication Systems Management (ESN) Electronic Systems Division	
13. ABSTRACT Terminal area graphic recorders were studied with a view to meeting future AWS needs in transmitting graphic meteorological information. Utilization of digital encoding and modern graphic reproduction techniques may satisfy the requirements of an increased traffic load with no increase in the present nominal 4 kc bandwidth. "Coded Graphics" is defined as any method for transmitting hard copy having less redundancy than conventional line-by-line scanning facsimile. Generally, only non-white point locations on the copy are transmitted. Transmission of invariant portions, such as geographic background, may also be avoided. The number of non-white points in a message and the encoding method used will determine the length of time required to transmit the information. Coded graphics recorder techniques show superiority over presently used facsimile by providing multiple copies, and copies with better legibility and esthetic quality. Cost projections over a ten year period show that a savings may be possible using coded graphic techniques. Seven coded graphics recorder types were found to be applicable by this study. Three of the seven hold promise for future AWS network applications. A study of digital encoding techniques and establishment of a set of performance requirements is scheduled for follow-on contractual activity.			

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Facsimile Recording Systems Facsimile Transmission Recording Paper Magnetic Recording Systems Meteorological Charts Digital Recording Systems Electronic Recording Systems Mapping Dielectric Recording Systems Weather Forecasting Weather Stations Analog Systems						

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