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TECHNICAL PROPOSAL 6930-19

DESIGN CONCEPT STUDY
COLOR CONTROL CELL

SUBMITTED:
21 APRIL 1970

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SECTION I

TASK ABSTRACT

25X1 The purpose of this program is to establish a design concept for a Color Control Cell (CCC) which would provide the proper environment to conduct photo interpretation and photo scientific experiments on high-resolution, high-altitude color reconnaissance photography. The effort will consist of specific investigations to define requirements, specify equipment performance, and refine applicable standards and techniques. During the course of the study, existing equipment and techniques will be examined for both interpretation and scientific application to determine if modifications are required. The result of the study will be a report detailing the results of the program and defining, in general terms, the physical and functional characteristics of the CCC.

25X1 All cost information is included in the cost proposal – a separate document accompanying this technical proposal.

SECTION II

INTRODUCTION

25X1 [redacted] To satisfy the ultimate goal of reconnaissance data acquisition about known targets and the discovery of new targets and situations, total systems and subsystems are conceived, designed, fabricated, evaluated, and put into operational use. Although simply stated, the total process is extremely complex and requires a continuing R&D effort to establish, maintain, and upgrade capabilities. The level of accuracy with which the reconnaissance community can acquire essential data with black-and-white systems has substantially increased in recent years. The potential of increased accuracy by adding the spectral dimension to the system has been considered for some time but has been restricted primarily by the resolution of color materials. As a result of significant improvement in the imaging characteristics of color film in recent months, increasing amounts of color are being flown and evaluated. Although much of the equipment and techniques used for black-and-white systems is applicable, problems exist in the analysis and interpretation areas that require consideration. The environment and instrumentation requirements for analysis take on increased importance. It is to satisfy these requirements that the concept of a Color Control Cell (CCC) was conceived. This establishment of a CCC represents a significant and intelligent approach to the image interpretation and assessment problems that have plagued black-and-white systems for so long and are likely to multiply and become of even greater significance in color.

25X1 [redacted] The purpose of the proposed study is to establish a Design Concept for a Color Control Cell which would provide the proper environment for the conduct of photo interpretation and photo science experiments on high-resolution, high-altitude color reconnaissance photography. The program will result in a definition, in general terms, of the physical and functional characteristics of the Cell.

25X1 [redacted] proposes to accomplish the stated objectives by: (1) Analyzing and defining the requirements, (2) specifying the instrumentation performance to satisfy these requirements, and (3) integrating the functional requirements and techniques into a design concept. Phases 1 and 2 above will be accomplished on each of three major investigations:

Photo Interpretation Considerations

Photo Science Considerations

Color Definition (Standards & Techniques)

25X1 During the integration phase, the overall design concept for the CCC will be established. It is at this point that consideration will be given to the separate requirements of both the photo interpretation and photo science efforts to determine if both functions can be performed concurrently (or alternately) in a single Cell.

25X1 The technical discussion in the following section outlines the approach and describes in detail the consideration that must be made in the formulation of a concept design. The work statement (Section IV) describes in concise terms the purpose and scope of the program and outlines, by phase, the approach to be taken to accomplish the objective.

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SECTION III

TECHNICAL DISCUSSION

A. PHOTO INTERPRETATION CONSIDERATIONS

25X1 [redacted] Any reconnaissance problem may be divided into five processes between which four interfaces exist[27], namely:

(1) between the real world and the film - includes sensor and platform;

(2) between the film and release imagery - the duplication and dissemination interface;

(3) between the release imagery and PI's senses - the PI environment and equipment;

(4) between man's senses and his perceptual and intellectual process - PI training, intelligence, motivation, personal attitudes, etc.

25X1 [redacted] Definite applied research and development efforts exist that deal with the first two interfaces, that is, in sensor and platform development and in the duplication process. Much research effort has also been placed in PI studies,as can be seen by examining the references at the end of this technical discussion. These references constitute a partial listing of the bibliography on PI-related tasks and topics compiled by [redacted] 25X1
25X1 [redacted] It is discouraging, however, to note that much of this research is of little value to those involved in the design and production of photo interpretation equipment and procedures. There are several reasons for this:

...The task presented to the interpreter in an experimental situation frequently does not match that in which the PI is involved in a true strategic or a tactical situation. Also a factor is the confusion between strategic and tactical photo interpretation.

...There is often no effort made to match the final results of the program to the problems at hand; for example, the final report of the experimental activities lists the results of the program as a statistical ANOVA table with no interpretation or correlation of the results with the PI problem at hand. Because of the ensuing confusion, the work is ignored by those involved in defining and developing new equipment for PI task or work areas where interpretation functions are performed.

...There exists a widespread tendency to forget that PI activities are not completely describable as a group task. An individual PI may operate within the realm of his own personal preference, background, and training. This implies that application or extrapolation of experimental response by groups to the performance of an individual PI may not be valid.

...The image assessment measures that are used to design and evaluate intelligence gathering systems often do not correlate with the criteria by which PI's evaluate or perform with specific mission materials[19]. Hence, the experimental variables do not account for the variability in the data taken in PI experiments; part of this may be due to the individuality of the responses.

...The environment in which PI studies are performed is quite often controlled, but only to a limited degree. Absolute control or description of the PI environment may help to reduce the variability of PI data taken under experimental conditions. In other words, there exists, outside of the equipment and material with which the PI is working, an environment which may have a large influence on individual response to given tasks.

25X1 [redacted] Concerning the environmental factors, it has long been a requirement for excellent control and dictation of the surrounding conditions in which PI tasks are performed. These factors do influence the motivation of working PI's, which in turn operates upon his capability to supply information to three remaining interfaces that follow from those listed previously and that effectively close the loop:

(5) between the interpreter's perceptual processes and his ability or willingness to transmit the perceived information to a decision maker;

(6) between a decision and the decision maker's individual response;

(7) between the response and the impact it has upon the real world.

1. ENVIRONMENT

25X1 [redacted] To properly evaluate and design color PI support equipment and procedures or to evaluate the mission material, it is essential to be able to control the PI environment. One of the functions of the CCC is to provide this control, and its design should be such that the broadest range of environmental variables may be controlled. Environmental control does not terminate with consideration of illumination conditions only. Important as the background and viewing luminance and spectral properties are in the PI process, other factors need to be considered in terms of relevance to the PI task. Some of these relate directly to the creature comforts of the individual, i.e., is the room too hot or too cold; is the environment clean or dirty; are there noise distractions such as telephones, paging systems, music, conversations? What influence does work area space have on an individual; should all PI's be grouped together under similar conditions, or should individuals be allowed to modify the environment on an individual basis by adjusting their own illumination and surrounding conditions to optimize their own responses? The presence or absence of distractions of various types from coffee pots to miniskirts are truly considerations, in all seriousness, to the vigilance, concentration, and attitude of individuals with respect to their PI tasks at hand. These variables are also of importance to teamwork tasks, and a properly designed CCC may be used by the community to evaluate the effectiveness of individuals and the make-up of PI teams.

25X1 [redacted] In light of possible future uses, consideration may be given to special environments for which current facilities do not constitute reasonable simulations, for example, in manned orbiting surveillance where PI or basic rapid-scan tasks may be performed in flight at high altitudes or in special environments. It is not expected that the CCC, as described by the RFP, will simulate the atmospheric pressure and gas mixture found in an aircraft or spacecraft. However, configurational studies for airborne and spaceborne facilities and requirements may be objectives that will arise in the future. To this end, it is a requirement that the facility be designed to be as flexible as possible, with control over the environmental factors that may occur in human factors and PI color response studies.

25X1 [redacted] The following example illustrates the types of problems that have occurred in the past in attempting to use PI or visual response data and apply it to dictating operational procedures for duplicating mission originals. This work, performed by [redacted] illustrates how the lack of definite environmental control - such as would be provided by a properly designed and equipped CCC - can limit the usefulness of the human factors research performed on PI tasks. 25X1

25X1 [redacted] During World War II, the Tiffany Foundation was commissioned to study the relationship between visual threshold contrast T_c and the angle Ψ subtended by an object at an observer's eye[9]. The measure of threshold contrast was classically defined as:

$$T_c = \Delta B/B$$

where B is a constant adaptation background luminance and ΔB is the luminance difference between a circular target, subtending the angle Ψ at the observer's eye, and the background adaptation luminance B.

25X1 [redacted] As is always the case, there is a detection probability that comes into play, with the threshold state being defined as a probability of detection of 50% ($P(x) = 0.50$). Upon plotting the results of these fixed stimulus presentations, it was found that this detection probability will follow a normal ogival curve (normal distribution function) as a function of the input variable (in this case either ΔB, Ψ or B). Examining the basic data, as presented in Figure 1, for a threshold condition, it was found that the values of T_c for any given adaptation luminance or visual angle could be modified for (1) differing environmental conditions and (2) differing detection probabilities by multiplying T_c by constants that are dependent upon the environmental and detection probability changes desired. Thus, to change the visual threshold contrast to other conditions, this multiplication took the form:

$$T_{cm} = C\, P_c\, T_c$$

where T_c is previously defined for the threshold state

T_{cm} is the modified T_c value

C is an environmental change factor

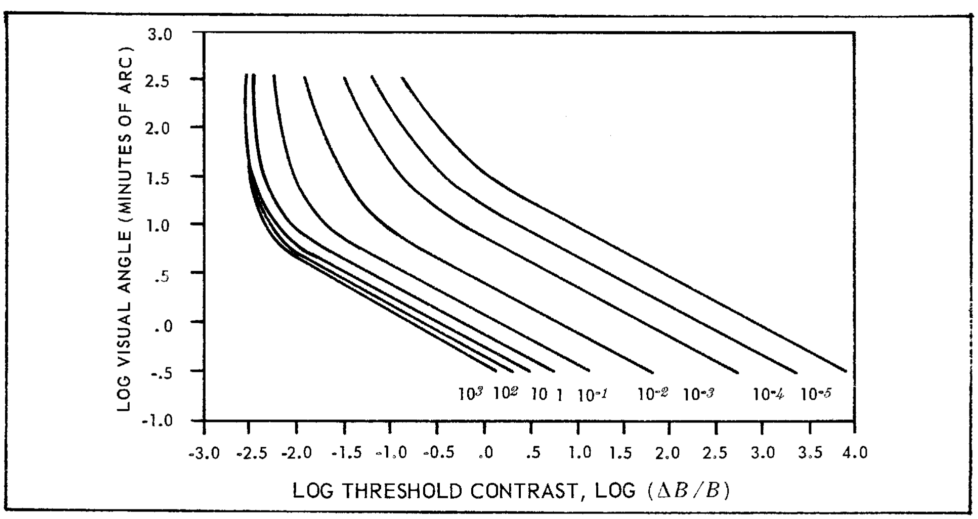

Figure 1. Tiffany Data for Various Adaptation Luminances[9]

P_c is a factor changing the detection probability away from the threshold (50% detection state).

25X1 [redacted] The constant P_c was determined from a simple plot of detection probabilities on probability paper, the straight line resulting because the data follow the normal ogive (Figure 2). By stating the probability of detection P(x), the constant was defined by the linear relationship:

$$P_c = 0.39\ P(x) + 1.00$$

The factor C was determined for various controlled environmental states, a few of which are listed in Table I along with training and task-oriented conversion factors[43].

25X1 [redacted] performed some theoretical work using these data, converting the threshold data to effective density differences and selecting those constants that would perform a conversion to approximate the PI task for differing target detection probabilities. The density conversion took the form

$$\Delta D_{critical} = \log_{10}\left[\frac{1}{1 - C\ P_c\ T_c}\right] = \log_{10}\left[\frac{1}{1 - T_{cm}}\right]$$

The various P_c values were calculated from the equation presented above. The C value was determined by multiplying the conversion constants together (a permissible procedure empirically verified) to form an environmental state that would approximate the PI situation. The conditions were as follows:

(1) outside ± 4° foveal, known size, time, duration (- +++, Table I) $C_1 = 1.31$

(2) conversion from forced choice to ordinary vision, $C_2 = 1.20$

The combined constants were then $C = C_1 \times C_2 = 1.572$.

25X1 [redacted] These computations were completed and the data presented[25]; however, no verification of the procedure was ever performed because the environmental control needed to establish the conditions for the determination of C was not available.

25X1 [redacted] The emergence of high-resolution color material as an intelligence sensor now requires that a sound basis be established for the development of PI techniques and

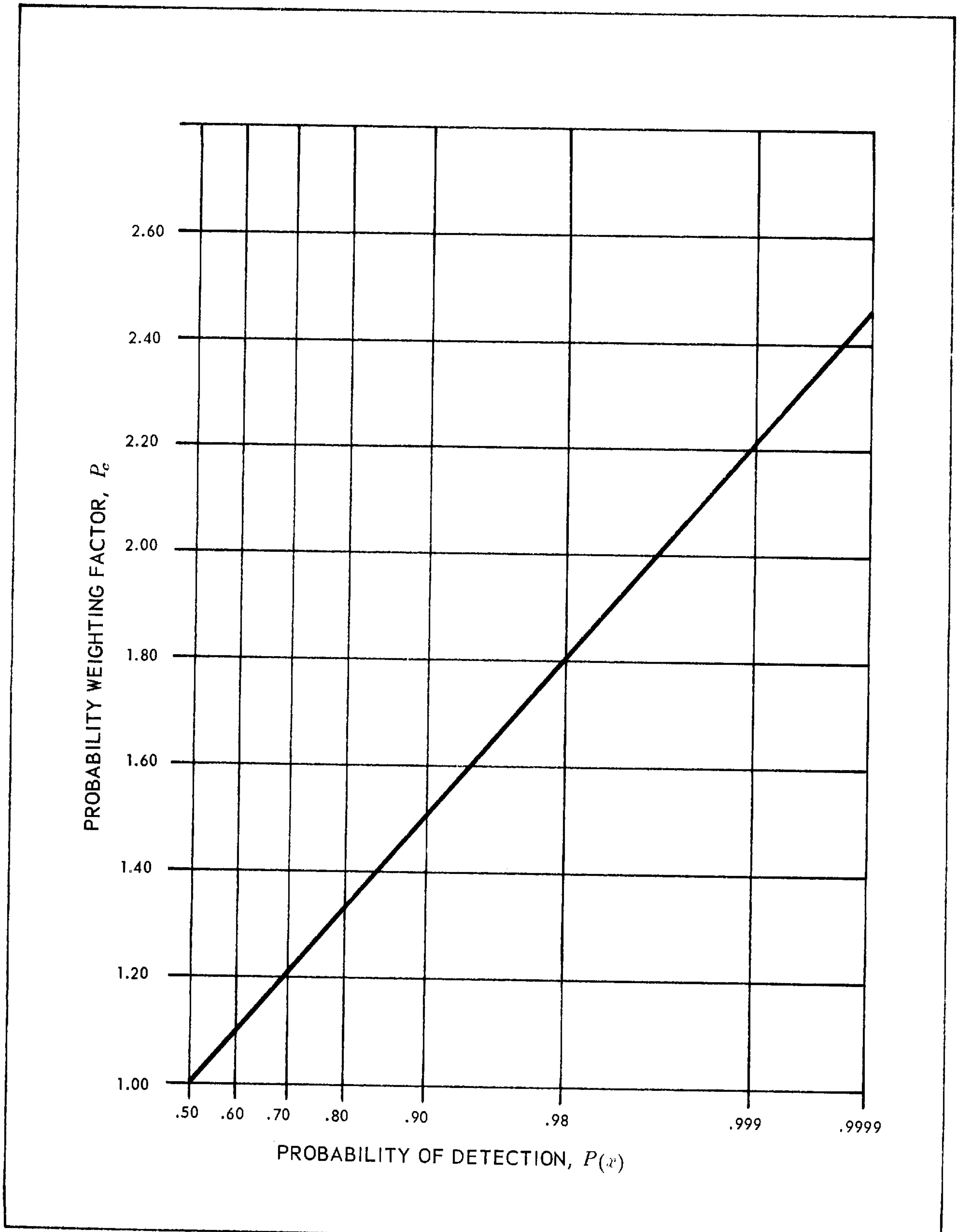

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Figure 2. Probability of Detection Weighting Factors for Taylor Data[43] Presented for P (x) = 0.50

T_c = threshold contrast = $\frac{\Delta B}{B}$

$P(x)$ = probability of seeing

$+$ = knowledge of condition

$-$ = no knowledge of condition

Condition				Conversion Factor (Multiply P_c T_c by)
±4° of foveal	time	size	duration	
+	+	+	+	1.00
+	–	+	+	1.40
+	–	–	+	1.50
+	–	–	–	1.45
+	–	+	–	1.60
–	+	+	+	1.31

Continued vigilance 1.19

Conversion from forced choice to ordinary vision (seeing) . . 1.20

Untrained observer 2.00

Other factors:

1. Oxygen deprivation
2. Dietary
3. Toxic atmospheric conditions
4. Glare
5. Anxiety
6. Sensory deprivation
7. Abnormal thermal conditions

25X1

Table I. Threshold Contrast Environmental Conversion Factors[43] equipment. This is critical if we are to extract essential information from the color material and are to present information of value in understandable terminology to those making policy decisions.

25X1 [redacted] This discussion leads to the criteria around which [redacted] would consider the design and instrumentation of a CCC. 25X1

25X1 ([redacted] The objective of this portion of the study is to determine which criteria are of importance to the conduct of photo interpreter studies, the range over which they are of importance, and the methods of control of these factors. Another result of the study will be an overall environmental facility design and cost estimate for one or more operational CCC. [redacted] will survey the possible uses of the CCC to determine what environmental variables are of significance and to modify the list of considered variables set forth below.

25X1 [redacted]

I. Illuminance Control

A. Downwelling and/or Side Overall Adaptation Luminance

*1. Variable intensity on a spatial basis
2. Variable spectral property
3. Variable diffusitivity and specularity
4. Lack of flicker

*Note: Intensity changes should be made without spectral changes occurring.

B. Surround Luminance Side or Upwelling

1. Variable reflection - spectral hue, saturation, brightness
   a. walls
   b. ceilings
   c. floors
   d. working surfaces

*C. Working Light Sources and Tables - See Equipment

*Note: Consideration for rear and front screen projection apparatus is essential.

D. Monitoring Devices

1. Specularity
2. Spectral Properties
3. Intensity

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II. Spatial Arrangement

A. Capability for Modification of Wall Arrangement

1. Spectral reflectivity changes
2. Wall patterning changes (example: Alternating wall colors that integrate to white)
3. Cubicle construction capabilities
4. Capability to convert to large working area, i.e., open floor arrangement for group studies, team studies, etc.

B. Special Experiment Construction

1. Room entryway allowing the moving of large experimental apparatus
2. Complete environment simulation, on spatial basis, of aircraft, spacecraft, or other facilities likely to be used for strategic tasks in future missions
3. Capabilities for experimenter and subject isolation, yet allowing experimenter to maintain observation of subject

25X1

III. Atmospheric Control

A. Control of Airflow Volume and Mixture and Addition of Special Contaminants or Gases

1. CO_2 level
2. O_3 level
3. O_2 level
4. Food odors
5. Various likely human and industrial odors and pollutants
6. Dust and particulate contamination control

B. Control of Temperature of Airflow

C. Control of Humidity of Airflow

25X1

IV. Distraction Control

A. Noise - control of level and type

1. Telephone-access controlled from outside
2. Control of background noise level
   a. Normal working sounds of building such as conversations, laughing, etc.
   b. Street noises
   c. Total silence
   d. Music
   e. Paging systems

B. Control of Visual or Task Distractions

1. Intrusion of others on task performance or vigilance
2. Peripheral visual distractions
3. Illumination flicker

Note: In individual task experiments, the capability for subject control of some of these variables is a consideration to investigate effects or variance of individual preference.

25X1 [redacted] It is quite possible that not all of these possible factors of visual psychophysical experiments need be considered for inclusion in the CCC. It is necessary to realize that in the design of an "environment" or the establishment of a "neutral environment" there are more factors that may affect PI performance than just the equipment and light source design. The conditions of an individual's thermal, auditory, and atmospheric environment and his satisfaction with his surroundings and work area probably bear a significant relationship to his performance as a PI in strategic situations. Of course, this includes the individual's interaction with his co-workers and the inherent political situation and outlook of the facility. All of these factors, therefore, have the capability of influencing perception and intellectual processes, the basis for which the PI exists, viz., to communicate the information presented visually to him in a manner that interfaces with the inputs of the personnel making the decision or further refining and summarizing the information.

25X1 [redacted] A main feature of the CCC environment will be illumination control on an overall and also on a spatially selective basis. [redacted] will determine how this may 25X1 be accomplished, such that the illumination intensity and spectral properties may be varied independently, and how both the spectral distribution and intensity properties of the overall adaptation illumination may be monitored. This task will also include the consideration of variable specularity of the sources so that the effects of glare on task performance may be tested. Lighting direction, overhead and side or wall illumination, and possible light sources will be considered. Also of importance in performance of the PI task is the absence of illumination flicker. Flicker-free main illumination sources must be considered essential in design specifications. Special flicker experiments may be designed, using illumination sources other than the main room illumination capability, and recommendations made as to how such illumination may be provided. However, main illumination of the area will be designed to be flicker-free.

25X1 [redacted] Control of surround luminance will be considered by [redacted] in terms of 25X1 the spectral properties of reflecting surfaces within the environment and the means by which these secondary sources may be altered spectrally, as well as in total visible reflectance, in the directionality of reflectance, and in the saturation of the surround. The reflecting environment considered by [redacted] will be ceilings, walls, 25X1 floors, and working surfaces on which equipment is placed. Equipment consideration will be listed later in the Proposed Program.

25X1 [redacted] will provide information concerning the type, quantity, and use procedures of various illumination monitoring devices for the spectral properties of the environment as well as for intensity measurements and determination of the directional properties of illumination.

25X1 [redacted] The degree of spatial versatility a CCC should possess will be determined. This will be accomplished through interviews with possible investigators or experimenters the customer knows will occupy or direct the use of the CCC. The types of experiments likely to be performed will influence this design greatly. Consideration will be given to spatial modification of the environment (to the extent that wall or divider complexes may be assembled), the means for controlling illumination under partitioned conditions, as well as the spectral and specular properties of the dividers. The size of individual experimental modules or of possible general work or team work areas will be determined.

25X1 [redacted] Capabilities for moving experimental apparatus of various dimensions are of importance in designing the work flow and entry ways and also constitute design criteria.

25X1 [redacted] Determination of the necessity for simulation of future strategic photo interpreter environments and the equipment to be used in such configurations as represented by aircraft or spacecraft intelligence systems, <u>excluding</u> special high-altitude chamber environments, represents a required task in the design of the CCC.

25X1 [redacted] Special human factor experiments in which the experimenter wishes to observe a subject or to control the experimental environment without direct contact with the subject are possibilities of consideration for CCC design and will be investigated by [redacted] 25X1

25X1 [redacted]

25X1 [redacted] Control of the environment entails more than the visual or spatial arrangement. Requirements of airflow, as it may influence a PI's respiratory environment (including control of temperature, humidity and the airflow mixture), will be investigated. Modification of the air mixture, as is possible under various operational conditions, including CO_2 level, O_2 level, O_3 level (a factor with electrostatic viewing devices), addition of various industrial odors and pollutants of both human and industrial nature, will be considered. Dust and particulate contamination is also of importance in the evaluation of clean work stations or of various equipment configurations.

25X1 [redacted] The isolation of a CCC from the normal building environment will be considered
25X1 by [redacted] in the design of the CCC. Auditory distractions, such as telephone and paging systems, and general background noise of conversation, street noises, music, copying or office machines and even the effects of total silence may all be factors in special facility design experiments that may be performed within the confines of the CCC.

25X1 [redacted] Also to be considered is the control of visual and/or other task distractions, including isolation of subjects from others when performing concentration or vigilance tasks or protection of the subject from other general peripheral distractions.

2. INSTRUMENTATION CONSIDERATION

25X1 [redacted] The choice of presently existing viewing equipment should be consistent with the care in design, from a human factor standpoint, of the environmental integrity of the CCC. It is realized that the CCC will be utilized to evaluate presently existing equipment in terms of their applicability to intelligence information recorded on color emulsions as well as to develop design criteria for future equipment. There are human visual anomalies, viewer and optical defects, colorimetric considerations, and sensor (emulsion) properties for which an accounting must be made before existing equipment and instrumentation may be deemed satisfactory for PI use on color missions.

25X1 [redacted] It may be necessary, in order to glean the maximum amount of information from color materials, that the PI workflow be modified. A facility, in making use of the spectral information provided by color materials, may have to add extra stages in the interpretation sequence. The color image of a given target may be easier to detect. It has yet to be shown conclusively that the color image adds anything to identification and strategic interpretation by a trained interpreter.

25X1 [redacted] There are presently many diverse opinions concerning the true utility of color material in strategic and even tactical missions. It is important to realize that the statements made concerning the true utility are opinions which have not been demonstrated in any rigorous manner either operationally or in a laboratory. It is therefore important to note the significance of the proper design of the proposed CCC; for it is under the controlled environment of this area, with the proper instrumentation, that the utility of color missions relative to black-and-white missions may be properly evaluated. It must also be realized that once color missions become a fact of life and the state of the duplication science of the color mission originals is brought to a par with the resolution capabilities of black-and-white materials, it is unlikely that any switch back to black-and-white missions will be performed. This may tend to be true even though it may be found that the PI information output for color is the same as with black-and-white. This retention of color capabilities may result mainly because the color briefing presentation aids in presenting data to the untrained individuals being briefed. In summary, once color becomes fully operational, it is likely to stay operational because of the monetary outlay to implement it and its ability to differentiate the spectral properties of the ground object. It will be necessary to design new PI equipment and modify existing equipment such that the PI is not hampered by visual and optical problems in his utilization of the color material. The controlled environment of the CCC represents the location at which these design studies should be implemented.

25X1 [redacted] n reviewing the problems that occur with detailed inspection of color materials, there are basically four areas of concern: (1) Spatial and spectral errors introduced by the camera and sensor (the film), (2) spectral confusion resulting from improper viewing conditions and light sources, (3) detail inspection problems introduced by chromatically uncorrected optics or insufficiently corrected optics, and (4) errors due to lateral chromatic aberrations of the human visual system. It should be within the capability of the CCC to perform experiments whereby the significance of the above problem areas may be investigated.

25X1 From a photogrammetric and a mensuration standpoint, failure of what is termed the collinearity condition may lead to errors in dimensioning target detail from color material. The collinearity condition states that the object point (on the ground), the perspective center (nodal point of the lens), and the corresponding image point must all be on the same line. Figure 3 shows how this condition may not be met by color materials and how the dimension of non-axial objects or extended axial objects may be distorted on a chromatic basis. No published information exists on the seriousness of the problem, although recently published data[48] indicate that the photogrammetric residuals from a controlled grid are no greater or smaller with color materials than when black-and-white materials are used.

25X1 In terms of spectral confusion arising when PI tasks are carried out on color materials, this is primarily the result of improper spectral illumination properties. One problem, termed metamerism, occurs when two given colors match under one illumination condition but not under another. Generally, to produce this effect the spectral properties of the transparency or print illumination are discontinuous in nature for one or both sources. Modification of existing light tables to provide light sources that will allow color-matching experiments to be performed is a definite requirement for CCC equipment. Light source standardization for all color material inspection tasks throughout the intelligence community, for original processing, duplication, and inspection and interpretation is an absolute necessity for consistent results to be obtained on a colorimetric basis. The luminance range variability of such equipment is of some consequence since limitations may have to be provided for inspection stations at duplication facilities to provide consistency in overall duplicate density. The luminance range of light sources for PI equipment, whether rear projection viewers or tables, should have greater variability to aid in interpretation in imagery areas approaching the visual subjective black point.

25X1 With regard to the optical equipment likely to be used in PI tasks, severe problems may arise with presently existing microstereocomparator equipment and any other optical arrangements designed to work with black-and-white photography. Obviously, a comparator system using a green filter in the optical path now represents an unsatisfactory approach to limiting the effects of lateral and axial chromatic aberrations of the objective/

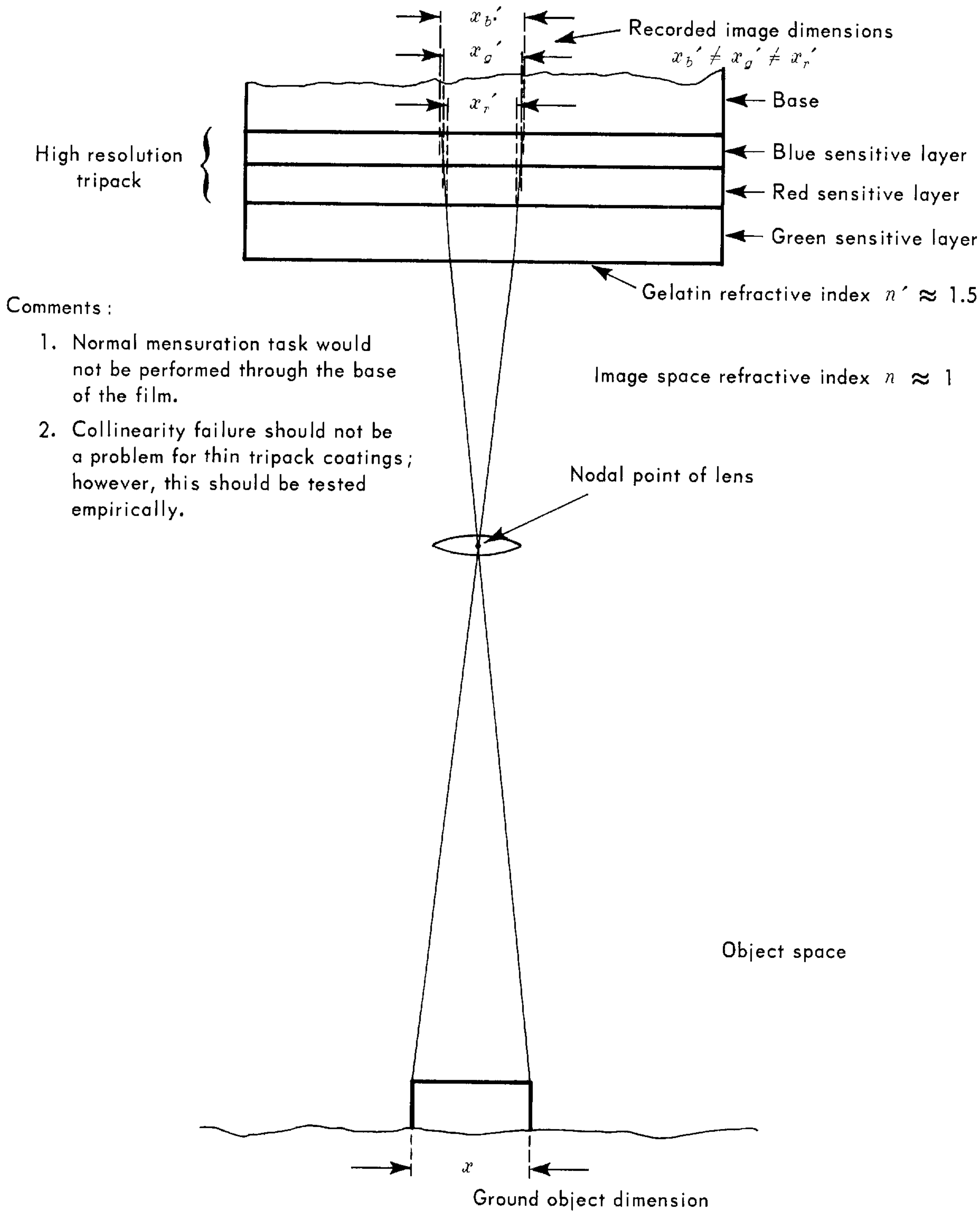

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Figure 3. Example of Failure of the Collinearity Assumption for Color Materials (Errors are exaggerated for illustration purposes)

eyepiece system. Switching to planapochromat objectives or achromat objectives with compensating eyepieces may be a solution. The compensating eyepiece, while correcting for the lateral chromatic aberration of the achromat objective, must also exert a definite amount of correction for coma, spherical aberration, and axial color; its curvature of field and astigmatism must also compensate for the objective as much as possible. Limits on optical magnification of color images must also take into consideration the chromatic properties of the magnifying optics, the emulsion thickness, layer orientation, grain noise properties of the emulsion, and the depth of focus and spherical aberration properties of the objectives used. The consideration of modifications to be made on present PI optical equipment, the evaluation of these modifications, and the evaluation of new designs of future equipment can be performed most validly under a controlled environment such as would exist in the CCC. Initial instrumentation recommendations should be a part of the design study for the controlled environment.

25X1 In performing detailed work on color materials, the optical considerations do not stop with the viewing equipment. Research performed on human visual responses, specifically visual acuity, within different regions of the spectrum indicates that the eye suffers from considerable, but correctable, lateral chromatic aberration[15] (to demonstrate this effect, try reading this page under blue illumination). Some work on correcting optics has been performed[4], and an optical design for the lateral chromatic aberration of the human visual system is shown in Figure 4. This visual anomaly has given rise to the following observation made by many PI's as well as untrained observers when viewing the IR camouflage detection film, type 8443. The saturated red imagery, produced on this film in response to the IR reflectance of healthy chlorophyll-containing plants, gives rise to the visual response that the red image is floating above the film plane or that a semi-stereo effect is being invoked under monocular conditions. This false stereo effect, termed chromatic stereoscopy, is induced by the chromatic magnification differentials of the human eye and by the fact that, in many cases, foveal vision does not occur on the optical axis of the human visual system. Red images, entering the lens system of the human eye, are magnified more than the green or blue images; consequently they appear larger, when chromatically separated by the eye, than do the green and blue images. The perceptual process interprets the greater red image size

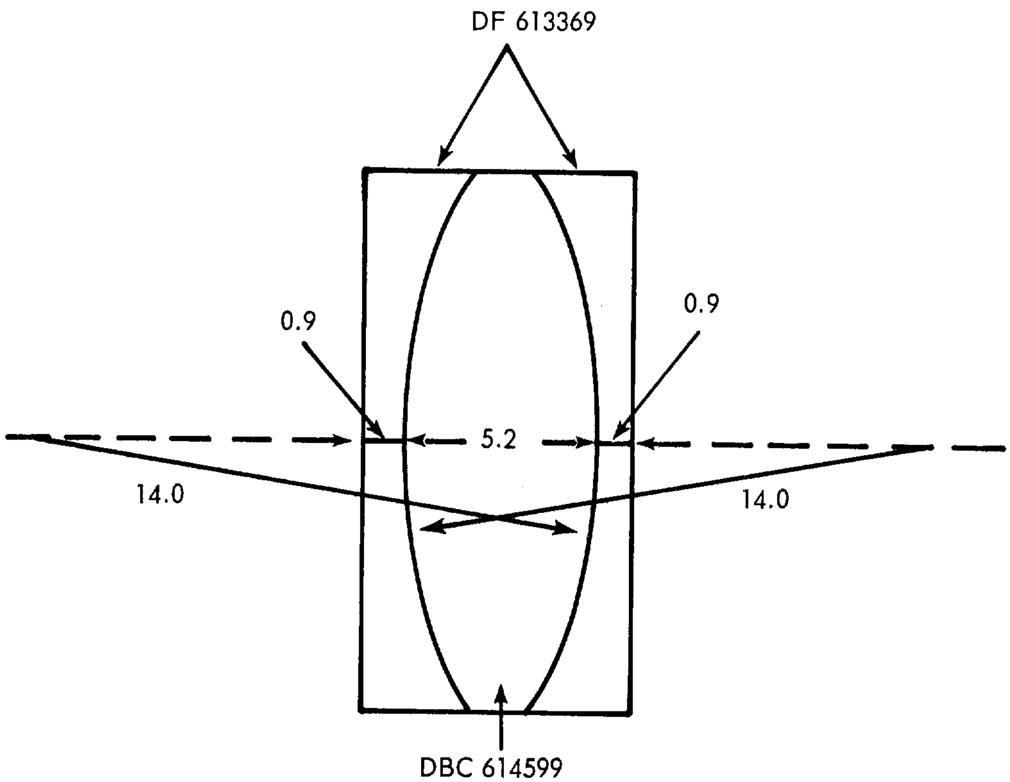

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Figure 4. Visual Chromatic Aberration Correction Optics[4]

to mean that the red image is closer to the observer than the blue and green images. The significance of this effect on mensuration tasks performed on color images has not been investigated. As far as is known, no effort is being made to test PI's for their chromatic aberration effects. The extent to which this type of visual anomaly affects individuals depends on the refractive properties of the individual visual system and the degree of convergence or parallelism of the visual optical axis of the individual. Because of these individual effects, it is difficult and perhaps impossible to dictate a proper standard chromatic correction for all individuals. If the chromatic stereo effect is an important consideration in color mensuration problems, then methods of optical correction, either on the equipment or on the individual, will have to be employed.

25X1 The addition of corrections on the individual may place a restriction on the back focal length of the eyepiece; it must, in any case, be sufficiently large with respect to the equivalent focal length, which determines the magnification. Such eyepieces are designated as "high-eyepoint" devices and are useful where optical correction is provided on an individual basis. From a PI standpoint, visual chromatic aberration correction on future equipment should probably be constructed into the optics and, if possible, be alterable by the user to correct for his personal visual accommodations. The degree to which the evaluation and establishment of optical specifications for precision PI optical equipment can be established is dependent upon the design of controlled visual psychophysical experiments to yield the visual information required for realistic tasks and environments. The environment of the CCC and its importance in the evaluation of current equipment and the design and evaluation of future equipment can be appreciated in this context.

25X1 To summarize, there exist four areas of consideration toward which equipment selection and modification must be oriented: (1) Correcting or working with errors occurring within the sensor (emulsion tripack) and the physical properties of the film, (2) illumination considerations and its effect upon the human visual response (for example, chromatic stereoscopy effects are increased under low illumination conditions because of pupillary dilation), (3) the optical requirements for exacting PI tasks, and (4) working with (or correcting as much as possible) group and individual visual defects and anomalies.

25X1 [redacted] In the equipment selection and modification recommendations phase of the CCC study program, [redacted] proposes to study the relationships and consequences of the following physical and psychophysical system design points and to recommend equipment for inclusion in the CCC that can be used to study these areas: 25X1

1. Failure of the collinearity assumptions, made for black-and-white materials, when applied to color tripacks; and what mensuration errors occur purely as a function of going from a black-and-white sensor to a multilayer package.

2. Illumination system modification recommendations, if necessary, for existing equipment with the goal of providing, throughout the community, illumination spectral and brightness standards that are applicable to original material inspection, duplication inspection, and all PI tasks. In considering light sources and their intensity [redacted] 25X1 will evaluate the possible sources for metameric errors in color matching and will keep in mind the standardization of intensity adjustments for overall scanning tasks. Methods of adjusting the illumination intensity for selected PI tasks will be evaluated, specifically in terms of maintaining a constant spectral distribution throughout the range of intensity adjustment. These illumination considerations will include viewing tables, rear projection equipment, and additive rear and forward projection viewers. 25X1

3. Optical designs for mensuration and microstereocomparator equipment and whatever optical elements intercede between the emulsion, light source, and the PI. Consideration will be given to the optical depth-of-focus problem, in terms of the physical construction of the multipack emulsion and the effects of the optical system on the collinearity situation. Design modifications of present equipment, in association with the visual system and its behavior, are definite considerations for the inclusion of equipment for the CCC. The considerations include the types of objectives, the use of compensating eyepieces, the use of high-eyepoint designs to compensate for visual experiments in which individualized correction must be applied to subjects in order to properly evaluate their performance in light of existing visual anomalies.

4. Visual psychophysical parameters and their influences upon the performed task and the design of future equipment to nullify or (if beneficial) retain or exaggerate

these effects to aid the PI task. The visual and perceptual process, therefore, provides constraints on the selection and proposed modification of viewing tables, projection equipment and whatever viewing devices are required for inclusion in the CCC.

25X1 [redacted] The distinct probability of human factors workload studies and PI workflow sequences for detection, identification, interpretation, and whatever spectrally oriented tasks are injected into the workflow implies that equipment selection and quantity of presently existing equipment required to equip a CCC must be based on what group or team oriented tasks are likely to be performed. Sequence and workflow studies may require duplication of certain pieces of equipment within the confines of the CCC. Thus, [redacted] 25X1
25X1 [redacted] will provide, as a part of this study, the equipment listing required to initially implement the CCC in the context of the experimental programs that are planned for the CCC.

B. PHOTO-SCIENTIFIC CONSIDERATIONS

25X1 [redacted] The accuracy with which the reconnaissance community can evaluate high-altitude black-and-white imagery has increased substantially in recent years. The introduction of color in this community provides potential for a new dimension of data, containing new types of information for the intelligence community. In addition to the analysis of the spatial, intensity, and contrast characteristics of a target, one may now consider the spectral attributes. Many facilities and much of the equipment which have been optimized to handle the three types of information from black-and-white imagery will likely, with modification, handle spectral information as well. It is unlikely that they will do so in optimum fashion at first, but evolutionary refinement of techniques and equipment requirements can be expected to improve analytical capabilities rapidly, at least if the present intense level of interest is maintained. Some new equipment, however, must be conceived, designed, and constructed in order to handle new types of information not previously available from the reconnaissance photograph. The environment of the analysis will take on increased importance, for the acquisition of additional target information will be at the expense of improvements in and additions to our present technology.

25X1 The role envisioned for the objective or photo-scientific function of the Color Control Cell will essentially parallel that of the subjective photo-interpretive function; the difference will be one of primary sensors and interpretive mechanisms (eye and brain - photocell and computer). It is not our intent to compare these functions, merely to show the similarity in the two roles of the CCC. The objective of this portion of the design concept study shall be to define the requirements for the environment and equipment which will be necessary in order to completely specify a chromatic reconnaissance image.

25X1 While this appears to limit the Cell to "image analysis", it is suggested that instead it provides a capability to analyze any variable in the image-producing system in terms of its effect on the final result, i. e., an image which must be interpreted. In this sense, complete comparative and evaluative studies may be conducted on sensors, platforms, sensitized materials, optics, processors, and printers in terms of a large number of response variables: Density (spectral, integral, analytical), resolution, acutance, granularity, modulation transfer, physical surfaces and support properties, etc. Together, these capabilities provide for analysis of almost every variable in the reconnaissance system. For example, the objective analysis of acutance provides information about image motion compensation systems, vibration, focus, astigmatism, various optical aberrations, and resolution. Combined with the analysis of other parameters, numerous conclusions may be drawn about the quality of the image and the system which produced it. Through the use of carefully designed experiments, details of the operation of processors, printers, and analytical hardware may be separated from the characteristics of the overall system.

25X1 In the pursuit of this phase of the program, the environmental and equipment requirements of the Cell will be considered in parallel studies, which will be integrated to produce the overall design concept for the photo-science activities of the CCC. Considerable communication between these studies will be required throughout the program, since environmental requirements will depend to a large extent on the types and characteristics of equipment. Near the end of the program, it will be possible to compare the environmental requirements for the photo-science activities of the Cell with those for the photo-interpretive activities to arrive at a decision concerning the number of CCC's required to meet the requirements of the program effectively.

1. ENVIRONMENT

25X1 As in PI-oriented evaluation tasks, the environment in which objective measurements are made is of considerable importance. Here, however, one is more concerned with the physical characteristics of temperature, humidity, vibrational amplitude and frequency, cleanliness, and illuminants than with sources of distraction such as conversation, odors, and telephones. The importance is no less; it is merely of a different nature. Whether these differences are of a magnitude which will require the use of a separate facility is a question which will be answered during the program and which will very likely depend on the degree of accuracy required of the measurement processes.

25X1 The outline of environmental aspects presented in the discussion of PI studies is pertinent here. A study to determine similar requirements for photo-science functions would differ from that outline as follows:

a. There would be no need to introduce O_2, O_3, CO_2, or various odors into the atmosphere; however, there would be a requirement to control the direction, velocity, and flow of air. Filtration to remove external contaminants such as dust would probably need to be quite stringent, and the potential of construction materials and analysis equipment as generators of internal contamination must also be considered.

b. Little need would exist for the control of distraction sources, other than nominal control of operator distraction. On the other hand, considerable attention needs to be paid to vibrational amplitude, frequency, and sources (both internal and external).

While this treatment is by no means detailed or complete, each of these factors may have a marked effect on the mensuration process. It is likely that the optimum environment for objective analysis would preclude entirely the presence of the human. Unfortunately, or perhaps fortunately, this is seldom possible, requiring creativity on the part of the design engineer to minimize the interference of the operator. For example, it is possible to detect the dimensional changes introduced by the proximity of a thermally radiating operator to a finely calibrated microdensitometer. By careful arrangement of airflow, control of air temperature, location of operator controls, and automation of operations, the design engineer can make it possible for the operator either to control from a distance or leave the machine unattended during periods of critical analysis.

25X1 [redacted] The design concept for the photo-scientific aspects of the CCC will detail the environmental considerations which are considered critical to the mission of the Facility, but it will do so carefully and will not dictate unwarranted precision or accuracy for the sake of generating impressive but expensive design requirements.

2. INSTRUMENTATION

25X1 [redacted] Parallel to the definition of environmental requirements for the CCC, a similar study will investigate and define the requirements for objective analysis equipment. A preliminary phase of this study, completed early in the program, will set forth the types of data and analyses which are required in order to satisfy the needs of the reconnaissance community. This information will be gathered by interview with technical personnel involved in each phase of the community and will be based on their present and projected data requirements. Also considered here will be the results of past and present programs as they relate to feasible analytical methods. Available data will be coordinated to produce a summary of the data requirements of the community, which in turn will be used as a guideline for a second phase of the study. This phase will have, as its objective, the definition of the specifications for the equipment and analysis techniques which will be required to gather and interpret the necessary data. This second phase of the equipment specification study will consider, then, the hardware required to meet the data requirements specified by Phase I.

25X1 [redacted]ar the halfway point in the program, the equipment requirements and environmental considerations will be integrated to form a total design concept for the photoscience functions of the CCC. These concepts, when compared and integrated with the concepts formed for the photo-interpretive function, will provide the information to make the decision between one and two Cells. The integrated results of these separate studies will form the basis for the final technical report: Design Concepts for a Color Control Cell.

C. COLOR DEFINITION

1. STANDARDS

25X1 [redacted] In order to further specify the environmental and equipment requirements of the CCC, existing and proposed standards will be evaluated as potential means of providing a common basis for evaluation results; and modifications, required to direct these standards to the problem at hand, will either be accomplished or specified, depending on the magnitude of the required modification and the scope of this program.

25X1 [redacted] Prior to the formulation of physical design concepts for the Color Control Cell, a study of past, present, and proposed programs will be undertaken to evaluate the requirements for standardized equipment and techniques in the evaluations to be undertaken in the Facility. In particular, consideration shall be given to defining variables, which have a significant effect on the interpretation or mensuration process, and to methods which may be used to minimize or to control the effects of these variables. Variables to be considered shall not be those which affect the process of interpretation of imagery, either visually or objectively. Limited consideration may be given to the variables associated with the production processes (those of original processing and duplication), but only to the extent that they influence the interpretation process. For example, the many techniques which may be used to compare two colors or a color with a standard depend on numerous factors, including object color, brightness, surround or background of the object, spectral sensitivity of the observer, observer background and experience, fatigue (for subjective techniques); spectral sensitivity and bandpass of the sensor, intensity, area, operator experience and background (for objective techniques). While the list is limited, it is sufficient to demonstrate that tradeoffs exist and that, if accuracy and complexity are equivalent, the final decision on a uniform method of color comparison may be based on the controls and standards which are available to control the measurement process. It should be pointed out that, for the most part, these variables are known and that some have been investigated in detail. The objective here is not to extend these investigations so much as it is to consider their results in the formulation of design concepts for the CCC, to assure that due attention is paid to all significant factors which must be considered in the design of such a Facility.

25X1 [redacted] Standards required for the operation of the CCC, but not presently in existence, will be specified in outline form. This phase of the overall program will result in a listing of the variables, associated with each of the activities anticipated for the CCC, and the controls or standards available or required to minimize the effect of each. This information will be provided as a part of the final report and will be used to further define the characteristics of the environment and equipment specified for the CCC itself.

2. TECHNIQUES

25X1 [redacted] Parallel to the study of critical variables and associated standards, a study will be made of existing or proposed color difference systems, both of a subjective (visual) and objective nature. Since the determination of a color difference requires essentially two steps - (a) measurement and (b) computation and analysis - these two aspects of the color difference problem will be treated simultaneously. Visual techniques which involve comparison processes, such as card or chip matching, split-field comparison, and flicker-field comparison, will be evaluated and compared with objective or photoelectric techniques which operate independently of visual sensitivity differences. Other industries (such as the paint, pigment, and dyestuff fields) have spent considerable time evaluating these various techniques and their accuracy. Although the applications are considerably different (seldom is a microscale colorimetric comparison meaningful outside the reconnaissance or microbiological industries), sufficient parallels and similarities exist to allow the use of the data in determining the potential of each technique for CCC application. It may be argued that the majority of these data will be from reflectance measurements, but in both the reflectance and transmittance cases the stimulating characteristic is the spectral distribution of the radiation reaching the observer. While the degree of specularity may differ somewhat, the difference is unlikely to have major significance. Studies which have been conducted by and for the reconnaissance industry, while considerably less in volume, will receive careful consideration in the process of defining the recommendations for CCC equipment and techniques.

25X1 [redacted] The multitude of color difference computation and analysis systems will be considered to determine the approach most likely to yield valid and meaningful data with minimum complexity. Such systems are generally categorized according to two schemes:

(a) basically physical, psychological, or psychophysical (according to the degree to which the visual process is involved) and (b) uniform or nonuniform, depending on whether the system does not or does depend (respectively) on object color or brightness. For example, a difference value determined using a uniform psychophysical system would indicate the same visual magnitude of difference for any color or brightness level viewed. While psychological systems, such as the Munsell system, have been a standby for years, they are arranged in uniform brightness steps rather than uniform chromaticity increments, and as such may have only limited value in applications.

25X1 Psychophysical systems, such as the CIE coordinate system, are more appropriate in that they are based on chromaticity differences, but they are frequently nonuniform. Variations on the CIE theme, such as the CIE-UCS system (Judd's Uniform Chromaticity System-1960), the FMC (Friele-MacAdam-Chickering) Color Difference System, or the Union Carbide Rapid Graphical analysis technique for small color differences, provide uniform means of determining color variation on scales of uniform chromaticity rather than uniform brightness differences.

25X1 Of considerable importance in determining the recommendations of this phase will be the inputs of the previously discussed study on variables and standards. Throughout the study, it shall be a major objective to recommend techniques which will provide required data with maximum accuracy and minimum error, yet which may utilize existing equipment wherever possible. Careful consideration shall be given to the equipment required to implement the various techniques considered; once recommendations are formulated, each piece of existing interpretive hardware designated by the sponsoring agency shall be compared with the technique selected, and modification specifications formulated as required.

25X1 This phase of the investigation will result in a technical summary and discussion of the field of color difference measurement as it is related to CCC requirements, the specification of techniques (both measurement and computational) to be used in assessing color differences between various images or between image and standard, and recommendations for the modification and/or procurement of equipment to implement the specified mensuration techniques.

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SECTION IV

WORK STATEMENT

25X1 [redacted] proposes to carry out the study contract in four phases which are described in detail in this section.

Phase I. Requirements Definition

This phase will be conducted as three separate studies which will be carried out simultaneously. Frequent and continuous communication and correlation will be maintained between the studies, and their results will be combined in a later phase to produce the CCC design concept.

First, a Photo-Interpretation Study will consider the environmental and equipment requirements for the subjective evaluations to be conducted in the Cell. One objective of this study will be to determine which environmental factors are important to the conduct of photo-interpreter studies and tasks and the range over which their variability must be controlled. Another objective will be to determine the equipments for the Cell, based on consideration of the types of studies which are to be conducted and the need for both versatility and flexibility of the CCC.

A second study will define similar requirements for the photo-scientific functions of the Cell. The objective of this study will be to investigate and define the requirements for both equipment and its environment necessary to perform detailed objective analysis of color imagery in support of reconnaissance intelligence collection. The third study conducted during this phase will consider the requirements of both the photo-interpretative and photo-scientific functions of the cell for standards and techniques for color discrimination and definition. During this study, standards applicable to the color image interpretation and analysis field will be reviewed to determine their relevancy. Recommendations will be made for their employment in the CCC, or for the modification or revision required to provide the community with a standards package to form the basis for a cohesive operation. In a similar manner, existing techniques will be reviewed to determine their application to the color definition activities of the Cell, and recommendations will be made concerning their employment.

Phase II. Analysis and Specification

This phase of the contract, conducted over a two-month period, will analyze each of the requirements specified during Phase I, will determine methods which may be used to control critical environmental factors, and will detail the specifications which are required for equipment and techniques to be used in the CCC.

Phase III. Integration

This phase, performed in parallel with Phase II, shall consider the combined environmental and instrumentation requirements of the photo-interpretative and photo-scientific functions of the CCC and determine whether their compatibility will make a single Cell feasible. Following this decision, the phase will solidify plans for both the equipment and environment of the Cell or Cells and will assure that the environment specified is compatible with all equipment recommended. This phase will also prepare the concept package in its final draft form. A three-dimensional facility model, containing space or block allocation for certain essential equipment requirements but not including detailed equipment models, will be prepared to illustrate the concept.

Phase IV. Final Report Publication

A final technical report will be prepared, detailing the design concept for the Color Control Cell.

SECTION V

DELIVERABLE ITEMS

25X1 [redacted] The following items will be delivered by [redacted] during this program: 25X1

1. Reports

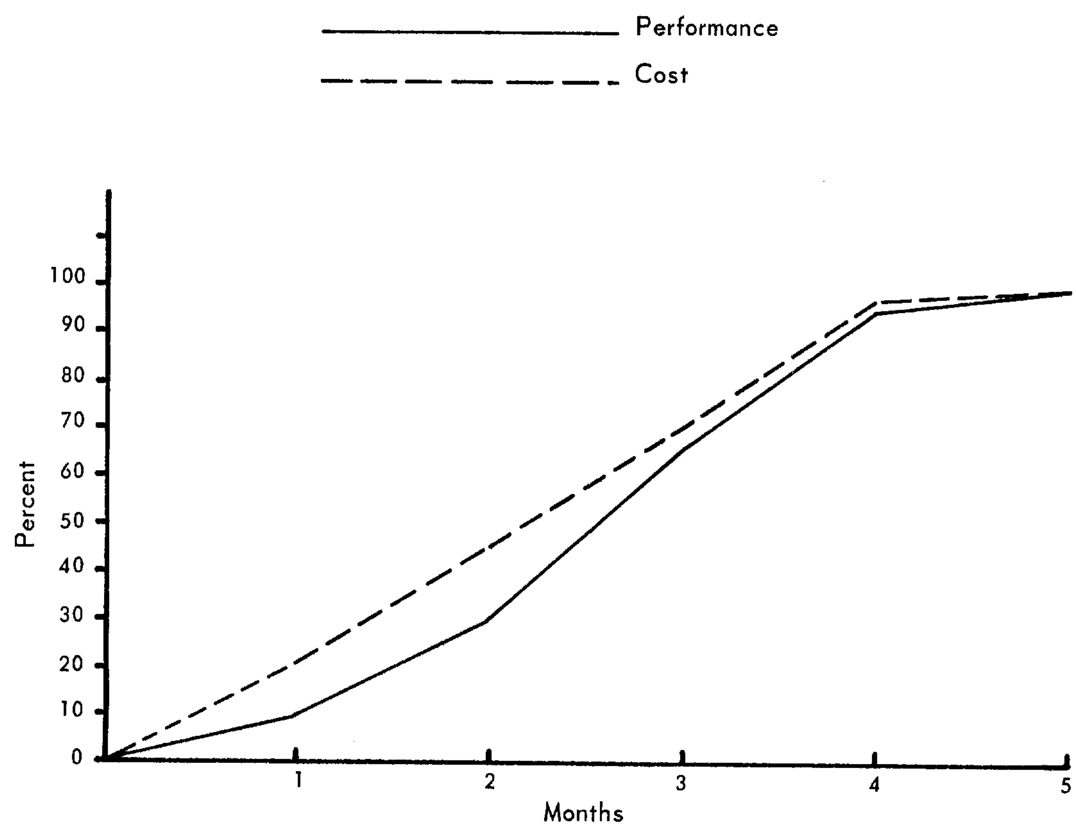
a. A monthly progress report will be prepared as of the last working day of each month and will be delivered by the 15th of the month following the reporting period. This report will conform to Spec. No. DB-1001.

b. A final report will be prepared documenting all work performed on the program. This report will conform to Spec. No. DB-1001 and be delivered within 30 days of the completion of the investigation. Included in this report will be the design concept plus general recommendations for modification of existing equipment and techniques.

2. A model of the design concept to demonstrate the flexibility available in satisfying the environmental and functional requirements.

SECTION VI

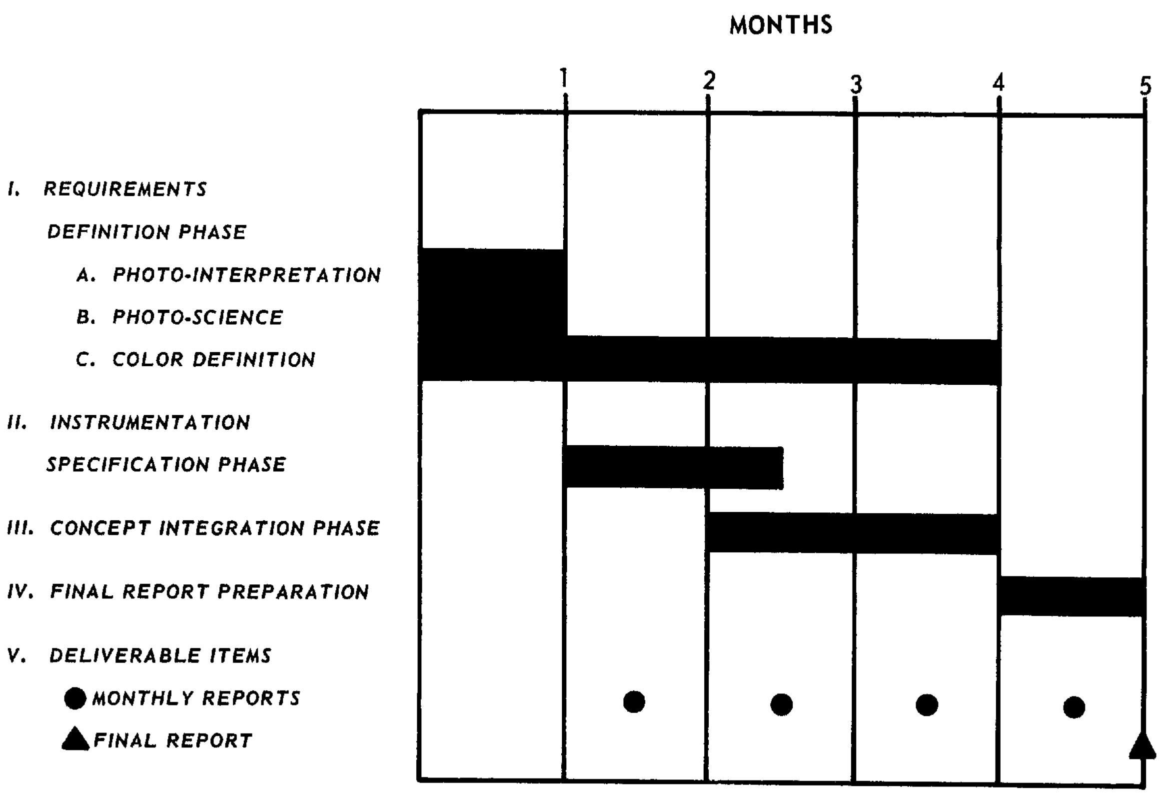
PROGRAM SCHEDULE



SECTION VII

TIME BAR CHART

TIME CHART



SECTION VIII

FINANCIAL CONSIDERATIONS

25X1 [redacted] All cost information is included in the cost proposal - a separate document accompanying this technical proposal.

25X1 [redacted] A breakdown of the manpower requirements for the proposed program is given below.

	Man-hours
Executive Engineer	40
Senior Engineer	180
Photoscientist	900
Photographic Engineer	500
Mechanical Engineer	340
Mechanical Technician	200
Technical Editor	40
Publications Clerk	160
Illustrator	80
Total	2,440 man-hours

SECTION IX

KEY PERSONNEL

Education, background, accomplishments, and other pertinent information concerning key personnel who will be available for the proposed program are included in the attached resumes.

25X1

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Approved For Release 2003/08/05 : CIA-RDP78B05171A000300010010-5

SECTION X

BACKGROUND AND RELATED EXPERIENCE

A. GENERAL EXPERIENCE AND HISTORICAL BACKGROUND

25X1 Established in 1955, [redacted] since that time has specialized in scientific investigation and engineering support services primarily directed to the intelligence and reconnaissance fields. Our major effort has been devoted to theoretical, exploratory, applied and experimental research, advanced systems analysis, and the development of new processes, techniques, and special analysis instrumentation for intelligence systems and related technical disciplines.

For years the company has been widely recognized as a highly proficient analysis, test, and evaluation organization, performing such services with respect to virtually all classes of reconnaissance equipment, including airborne, ground, and laboratory types. As a matter of policy, [redacted] has specifically refrained 25X1 from competition for the production of airborne sensors such as cameras, radars, infrared and electro-optical equipment so that we may act impartially from a test or systems analysis standpoint in considering the products of any manufacturer. Having intentionally preserved a position of objectivity to assure unbiased judgment in performing analysis and/or evaluation functions for our customers, we are dedicated to the application of the total resources of modern science and technology in formulating our recommendations for appropriate equipment and concepts.

The scope of technology encountered in our pursuit of this activity has encouraged and nurtured the evolution of a sophisticated engineering organization, possessing highly diversified skills, which has enabled [redacted] to undertake, and to 25X1 prosecute with some conspicuous success, a number of complex exploratory and applied research programs. Among the programs in this category, we are proud to cite the following brief examples of our continuing contributions to improving the state-of-the-art in a number of technical disciplines:

1. Exploratory, analytical and experimental photogrammetry, including detailed analyses of cameras with variable-rate image motion compensation and focal plane shutters for application to mapping and intelligence requirements.

2. Exploratory and applied research in image quality assessment, and the successful development of the first production image quality assessment system. This effort includes the design and fabrication of the precision automated scanning Micro-Analyzer, as well as the associated digital signal processing equipment unique to this operational integrated system concept.

3. Advanced studies dealing with image analysis, image enhancement, and image manipulation and reconstruction; development of a system which will permit complete digital manipulation and display of any preselected incremental portion of the image and reconstruction to any scale without loss of mensuration accuracy.

4. Research studies and characterization of microscope lenses for application assessment in photomicrography, image exploitation, and microdensitometry. Characterization parameters include nodal point measurement, focal length, resolution vs field position, flatness of field position, flatness of field, magnification.

5. Exploratory research and advanced experimental studies and analysis of concepts related to modulation transfer measurements, including research into standardization of MTF measurement, based upon precisely generated intensity sinusoids, spatial filtration, and Fourier transformation by optical means.

6. Analytical research and measurement of resolution, focal length, and critical parameters relating to reconnaissance lenses.

7. Exploratory and applied research in all phases of photography and the photosciences, including densitometry and microdensitometry, sensitometry, materials research, processing, quality control, and mensuration error analysis.

8. Advanced research and applied engineering in the field of color photography and color materials, color processing technology, and color equipment and chemistry evaluation.

9. Research and applied engineering in physical optics, geometrical optics, and related photographic/photometric technology. Design of specialized optical systems. Research in optical data processing methods.

10. Research, analytical studies, and construction of mathematical models of infrared, radar, and optical sensors for the assessment of designs and for trade-off analysis of sensor performance, considering effects of vibration, atmosphere, and other perturbing influences.

B. EXPERIENCE SPECIFIC TO THIS PROPOSAL

In order to acquaint the reader with [redacted] background and experience, 25X1
as specifically relevant to the proposed program, summaries of recent programs and reports are included on the following pages. Specific objectives, developments, tests, or analyses pertinent to the proposed program are underlined.

[redacted] 25X1

The purpose of this contract was to produce design criteria for a Systems Engineering Group (SEG) Reconnaissance Systems Integration and Evaluation Facility from which an architect/engineer would be able to prepare the final design. Factors that were considered ranged from the mission, organization, and function of the SEG to the type, extent, and nature of the workload of each and every element, as well as their interrelationships with each other. Future development trends were taken into account, functional capabilities of the facility determined, equipment lists prepared, and cost estimates were gathered for both the structure and equipment to be installed. In conclusion, all of these factors were contained in a unified volume, along with recommendations and justifications for the overall project.

EVALUATION OF INTELLIGENCE COLLECTION DEVICES

[redacted] 25X1

This was a technical assistance contract for the maintenance, testing, fabrication, and modification of photographic and electronic intelligence collection devices. Included were tests and evaluation programs on cameras, lenses, processors, photo interpretation equipment, comparators, microdensitometers, data recording equipment, antennas, and other associated electronic and photographic equipment. Included also was the formulation of mathematical models, design of computer programs, development of techniques for processing data and analysis of raw data. Testing of photosensitized materials and chemicals was also included.

TONE REPRODUCTION: PSYCHOPHYSICS IN GRAPH INTERPRETATION

[redacted] 25X1

In the optimization of a tone reproduction system, the function of which is defined as the duplication of reconnaissance negatives and possibly the production of release positives, three output constraint cases are investigated. Two of these cases are found to constitute a near triviality. The third "special" case is stated as the production of duplicate negatives optimized for the generation of release positives intended for photograph interpretation. The classical and contemporary investigations into psychophysical phenomena and photograph interpretation are reviewed. A method, based on psychophysical visual data and human factors, of predicting detection probabilities from tone reproduction curves of release positives is developed on the assumption that the applied visual data are applicable to photograph interpretation. (This abstract is taken from

25X1 [redacted]

ADVANCED COLOR IMAGE ASSESSMENT CONCEPTS

Image assessment procedures currently exist for black-and-white materials only. Color image assessment and densitometry are defined only on the macroscale at present. It is the objective of this report to combine these two fields to generate a color image assessment technique based on those current image assessment measures that can be applied to color tripack materials. The vector and matrix properties of color materials are defined and applied to noise assessment, ensemble averaging, and modulation transfer function. The shortcomings of the effective exposure technique are discussed, and a method is described for generating valid effective exposure tables for color materials. It is possible that similar methods may be used in the generation of target spectral signatures from color imagery. Quality control methods applicable for color trichromatic and black-and-white microdensitometers are reviewed. Information concerning the integral to analytical density conversion for three-color material is presented, and all auxiliary experimental work in support of this program is reported. Of particular interest is the investigation of the problems associated with the use of achromat objectives in trichromatic microdensitometers. (This abstract is taken from

25X1

ADVANCED COLOR IMAGE ASSESSMENT CONCEPTS IMPLEMENTATION

This final report is oriented toward system implementation developed through color image assessment studies. It differs from the previous report (covered in [redacted] 25X1
25X1 [redacted] under which certain theoretical concepts in the field of color image assessment were developed and presented. The purpose of the information contained herein is to aid the customer in the implementation and programming of the routines resulting from this and the previous effort. For this reason, the major part of this report is devoted to FORTRAN program listings, input and output examples, and program documentation (including flowcharts). Topics covered here include direction cosine and results of direction cosine studies of a selection of color materials. Results of the effective exposure table generation procedure are also presented. The analytical modulation transfer function (MTF) routine is presented, as are results of resolution/MTF analysis performed on SO-151 (now 2448) material. (This abstract is
25X1 taken from [redacted]

PHOTOGRAPHIC PERTURBATION ANALYSIS

25X1 [redacted]

This report describes a special photographic research data reduction and analysis facility designed to provide a capability for assessment and statistical analysis of photographic data at the Air Force Avionics Laboratory, Wright-Patterson Air Force Base. To obtain the precise measurements required, a combined microdensitometer-microcomparator system with automatic recording capability was installed and used successfully to solve photographic problems of the Avionics Laboratory. These instruments, along with the other equipment discussed in this report, were used to evaluate infrared, radar recording, electron beam recording, and visible light recording systems. The evaluations were in terms of density and distance measurements, root mean square (RMS) granularity, modulation transfer function (MTF) determination, isodensity traces, and other methods. The facility's visual and photometric measuring instruments and their digital reduction capabilities are described, as well as the reductions and analyses performed on aerospace photographic research during the first eighteen month's operation of the facility. The work performed includes two-dimensional microdensitometry for two-dimensional Fourier analysis in image quality and reconstruction studies, isodensity plotting, granularity measurements, mensuration accuracy of micro-images, interpretation of multispectral photography, etc. Improvements and expansion of capabilities are suggested in the report. (This abstract is taken from [redacted] 25X1

25X1 [redacted]

MENSURATION STUDY

This project investigated errors in the measurement of small objects on high-resolution aerial reconnaissance material. The results of this study demonstrated that a significant, but predictable, bias error does exist that is attributable to such parameters as object size, average density levels, and detail versus background density. Also, several microdensitometer traces were made of selected test targets and a comparison of measurement and actual size was performed. Excellent results were obtained once the traces were corrected for the spread function of the taking system. The instruments used were [redacted] comparator Model 422 and a 25X1
25X1 [redacted] Micro-Analyzer. (This abstract is taken from [redacted] 25X1
25X1 [redacted]

MULTISPECTRAL RADIATION RESEARCH; EVALUATION AND TEST OF V/H SENSORS

[redacted] 25X1

This contract involved three separate areas. Task I, Image Evaluation Research, required the design of a camera capsule and instrumentation recording system to be used for determining and perfecting techniques of evaluating photographic systems. In Task II, six aspects of recording and reproducing multispectral radiation were investigated. These included photographic reproduction in bicolor, conventional color, color/infrared, color/panchromatic, and negative/positive color. Also, a multisensor instrument was designed and constructed to display and to record the integrated radiation in four wavebands corresponding to the blue, green, red, and infrared sensitivities of several color films. Task III, Performance Evaluation and Flight Analysis of V/H Sensors, involved testing of a day sensor manufactured by [redacted] nd a day/night 25X1
sensor manufactured by [redacted] provided 25X1
test criteria, equipment installation, instrumentation, support, and flight test analysis; the U. S. Air Force conducted the actual flight tests.

ATMOSPHERIC EFFECTS ON COLOR AERIAL PHOTOGRAPHY

[redacted] 25X1

The test program described in this report was an experimental program to optimize the production of color aerial imagery by taking into consideration the spectral characteristics of atmosphere, altitude, optical systems, and film type. A haze measurement device was fabricated and used to a high degree of success in determining the atmospheric visibility during each flight. An atmosphere-simulating viewing device is described. This device was fabricated and evaluated to show that color and contrast changes of aerial imagery due to atmospheric conditions can be simulated in the laboratory. Color microdensitometry techniques were developed for data collection from the test imagery. Wratten filters 92, 99, and 98 were selected as the best compromise between narrow-band filters and a high signal output. Focus testing has shown that it is necessary to refocus with a filter change in an optical system employing an achromat lens. Target scale and surround tests indicated that analytical microdensity changed as a function of bar width from 10 to 60 microns for a neutral bar against a yellow background on 2448 type film; indicating that object color will change with scale. (This abstract is taken from [redacted]

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COLOR TONE REPRODUCTION: PROBLEM DEFINITION

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In this report, the reproduction of color in an n-generation duplication cycle is investigated from a systems approach. Beer's law is considered and is utilized to derive a set of matrix equations based on the gamma of each layer. This equation yields a useful set of approximations for predicting tone reproduction. A single generation duplication cycle is investigated by printing a series of color step tablets, printed on type 8442 film, on type SO-118 film and plotting the densities of type 8442 versus the densities of SO-118 (density return curves). Using a neutral balance criterion, the return difference of maximum densities was 0.26, and was 0.18 for minimum densities. This served to shorten the density range of the duplicate to 2.23, as opposed to a density range of 2.67 in the original. Neutrals reproduced well, while colors reproduced poorly; the magenta layer caused the greatest color distortion while the yellow layer the least. In order to investigate the distribution of color densities in a frame of imagery to evaluate the large area transmission density (LATD) concept, cumulative density frequency histograms were made from simulated flight imagery. When plotted on probability paper, departures from a normal distribution were noted for toe and shoulder densities. The validity of LATD measurements depends upon equal variances in density distributions for each layer. The LATD concept was found invalid for the case investigated, since the variances between layers were unequal. The last section of the report discusses research accomplished to date and proposes an eight-part future research effort organized to yield a computer-based duplication control system. (This abstract is taken from 25X1

CONTINUOUS COLOR PROCESSING AND ANALYSIS TECHNIQUES

[redacted] 25X1

This report describes a series of tests conducted on four aerial reversal color films and one reversal color duplicating film, all of which are capable of being processed in the [redacted] 1411-M continuous color processor. Tests of a reversal color paper are also described. Together, these materials provide a reversal color system capable of providing positive color transparencies or prints. Since aerial photographic missions inevitably involve compromises or "trade-offs" among the desirable characteristics of available materials, the purpose of this program, and the object of this report, is not to make judgments between materials, but to provide objective information on which these judgments, in the light of the existing situation, can be made. Detailed information is given on the resolution, sensitometric, and color quality characteristics of these materials. The accomplishment of these objectives required that test methods be designed and validated. The report recommends that provision be made for testing color materials, equipment, and processes on a continuing basis, using the test methods developed on this project. A test of the use of color resolution targets, color samples simulating natural objects, and tone reproduction studies in color is also recommended. (This abstract is taken from [redacted] 25X1

25X1 [redacted]

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LAB STANDARDS

[redacted] 25X1

This report describes research and engineering performed in development of photographic laboratory standards, measurements, and related work. The tasks performed are described briefly in the Introduction and each in detail in the remaining sections. Improvements in devised photographic image assessment techniques employ a digital recording microdensitometer and automatic data reduction by computer. Numerous aspects of this work are represented by instructional documents submitted during the contract period and reprinted in the first 16 appendixes of this report. Representative subjects are: Selection of Edges for Analysis, A Multiple Tracing Technique, Sinc Target Tracing, Significance of Aerial Image Modulation Curves, Granularity Measurement, Recommendations for a Quality Control System, and several computer program write-up and operating procedures. Under a support task certain laboratory standard photographic targets were produced, tested, and delivered; films were tested sensitometrically; USAF laboratory equipment was maintained; and USAF personnel were trained. Under a color film measurement and reproduction task continuous processing of G Gevacolor film was attempted in a Rolor Transflo machine and in the [redacted]T Processor, Model 1411-M. The latter was successful; the former test was not. Also, sensitometric tests were made in continuous processing; and the results are discussed and presented graphically. [redacted]processor modifications for improved solution temperature control are described and recommended; two possible equipment floor plans are suggested. Also described and recommended is the use of trilinear graphs for evaluation of color film reproductions. A discussion of color stability testing culminates in a recommended list of weathering test equipment. Another task required a study of the feasibility of high-speed scanning of aerial film up to 9-1/2 inches wide. This involved development and testing of two prototypes, one with a quartz-iodine lamp as the light source, and the other with a laser light source. A rotating mirror scanner was determined to be the best of all schemes considered. The prototypes demonstrated that scanning could be accomplished with an 80-micron diameter light spot and with film transport speeds up to ten feet per minute. A general scanner design is suggested, and recommendations are made for ancillary data reduction equipment. The final task

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required evaluation of microscope objectives for use in microdensitometers. Five Zeiss Planapochromats and one Epiplan are characterized by means of numerous graphs based on data obtained in tests on a unique microscope lens testing optical bench. (This abstract
25X1 is taken from [redacted] Report FR-67-1.)

CLEAN ROOM FACILITIES

Under a subcontract to [redacted] personnel designed 25X1
and fabricated a controlled environment clean room for installation in an Air Force facility. This clean room system provided for 100% washing of all air entering the room, with relative humidity controlled to within ±1% and temperature controlled to within ±0.2°F. Absolute filters were used, together with two additional sets of filters, in series, to provide preliminary air filtering. Use of vertical laminar air flow prevented contamination of specimen areas by personnel working in the room.

A similar clean room system was designed, fabricated, and installed (under Con-
25X1 tract [redacted] at the Aeronautical Chart and Information Center.

The data set forth herein are submitted in response to an RFP, and shall not be disclosed outside the Government or be duplicated, used or disclosed in whole or in part for any purpose other than to evaluate the proposal; provided, that if a contract is awarded to this offeror as a result of or in connection with the submission of such data, the Government shall have the right to duplicate, use or disclose these data to the extent provided in the contract. This restriction does not limit the Government's right to use information contained in such data if it is obtained from another source.

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PROPOSAL TO DEVELOP A DESIGN CONCEPT FOR A COLOR CONTROL CELL

I. Abstract: This proposal outlines a study which is to result in a design concept for a Color Control Cell (CCC). The cell is required to exploit the intelligence development potential of an emerging family of high altitude, high resolution color reconnaissance photographic materials.

The cell is intended to provide an environment conducive to the conduct of visual psychophysical experiments, evaluation of color viewing equipment, evaluation of photographic imagery, and various associated physical measurements. The development of the concept will also include recommendations for some of the apparatus to be used in the facility, and will consider equipment already proposed.

The total CPFF price proposed for this proposal is [redacted] includ-ing [redacted]

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II. Introduction: The development of a new family of high definition color reconnaissance films, having spatial read-out qualities approaching that of black-and-white films now used in high altitude acquisitions, requires numerous and definitive studies to assess the read-out potential, and fully apply that potential in the intelligence mission. Going from black-and-white acquisitions to color acquisitions, is tantamount to moving from a three-dimensional intelligence record space to one with five dimensions. In addition the length, width, and brightness (or contrast) provided by black-and-white films, color adds hue and chroma.

The additional intelligence provided by color involves two distinctly different concepts: one, the additional conspicuousness that the color dimension provides in the initial detection - coupled with additional discriminateness between object and background necessary to shape recognition; and two, the additional information provided by specification of the object's color, i.e., its chromaticity and brightness (or lightness).

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Color perceptual phenomena, in general, are not well understood. The perceptions as they involve color film require special study and equipment due to physical properties which are peculiar to the color film image. Aside from the perceptual studies which are required, additional studies are needed to solve duplication and evaluation problems connected with color reconnaissance usage.

The increasing usage of color requires not just a study of these problems, but the development of a facility to study them in. This facility or cell should have the property of being able to neutralize, or manipulate the environment such that perceptual phenomena involving the color image can be adequately studied. Additionally, it should be instrumented to monitor and calibrate the environment and materials, and to measure physical and psychophysical phenomena associated with photographic color imagery.

Many of the concepts and phenomena which require study are so intimately convolved that it is difficult to be categorical in outlining an approach. The technical discussion to follow, classifies the tasks to be involved in the cell conceptualization in broad categories.

III. Technical Discussion:

Environment: A study will be made to define the structural features necessary to a room (cell) or rooms ideally suited to:

(1) Psychophysical experiments involving colored objects and color film images.

(2) Testing of film viewing equipments.

(3) Conducting evaluations of, or comparisons between, color acquisition and reproduction systems or materials.

(4) Performing densitometric and spectrophotometric measurements.

The desirability of features such as changeability of wall and work surface colors; and the color quality, intensity and positioning of lighting, will be considered from a practical as well as theoretically ideal point of view. Authorities in the contractor's parent company, who have conducted color visual psychophysical experiments, will be consulted.

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Most of the considerations to follow will bear on the ultimate configuration of the cell.

Color Specification: The various color-order and chromaticity scale schemes and systems will be reviewed in a coordinated effort with the customer and recommendations will be made for adoption in CCC work with regard to:

(1) Routine reporting of object and film image colors.

(2) Color difference (discrimination) work.

(3) Measurement of the color properties of light sources.

Where deemed appropriate, authorities in the field of color measurement and theory will be consulted.

Calibration and Monitoring Instruments: Certain instruments obtain a manifold usage throughout the field of photography and colorimetry associated with photography, and as such require special consideration to meet the suggested needs of the CCC. These instruments fall into three major categories:

(1) Radiometers, necessary to the monitoring and calibration of light sources.

(2) Spectrophotometers, necessary to many colorimetric calibration measurements involving color film; obtaining the data necessary to arrive at transformations from exposure space to color space; arriving at other mathematical relationships peculiar to color photography; and measurement of opaque objects, concerned with ground truth.

(3) Color micro- and macro-densitometers, necessary to control and analysis.

Due consideration will be given to the diverse applications these instruments might be given in the CCC, in recommendations for use of existing or proposed instruments, and recommendations for additional instrumentation deemed necessary by this contractor. Since any serious experimental program will cause considerable data to be generated by the latter two instruments, the role of various data storage and manipulation devices will be examined.

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Color Perception: One of the major roles of the cell is to study a farrago of psychological and physical phenomena associated with the color photographic image. The mechanisms of color perception are, to begin with, only partially understood. The study of these phenomena using photographic images as test objects, further complicates matters due to the distinctly peculiar physical make-up of the image. Added to this is the fact that much of the analysis done on reconnaissance materials requires that the material be examined under magnification. This latter fact adds the complications due directly to the optical system of the magnifier, and also has some effect on the perceived color image, just because it is bigger. For example, this contractor has identified one of the problems as an apparent change in chromaticity with a change in magnification. Just as there is a "falling-apart" of the image under magnification in a spatial sense, there appears to be an analogous degradation chromatically.

Discussions will be held with the customer and various authorities in developing the cell facility and equipment requirements to broach these peculiar problems.

Color Discrimination: To draw a distinction between studies involving the eye, microscope (or viewer), and dye image, (that is, distinctly perceptual problems) and those problems involving discernment of targets obtained with actual photographic systems, we will use the term Color Discrimination. In developing the cell concept we shall broadly classify the kinds of discrimination to be eventually studied as:

(1) That inherent in the film (involving the sensitometric properties of the film, and discriminateness not necessarily determined by the eye).

(2) That inherent in a total photographic system (involving the atmosphere, optical system, etc., and discriminateness determined by the eye, or some electromechanical device).

Equipments required to study the several kinds of color discrimination will be surveyed and recommendations for purchase, design or modification to existing equipment will be made if necessary.

Object Color Determination: In an idealized situation it is conceivable that the object color could be determined directly from the film with a colorimeter. However, not only is the real situation such that the object color cannot be accurately specified with this measurement in an absolute sense, but specification is difficult in a relative sense as well. That is to say, the legion of variables normally encountered in aerial color photography militate against a specific object appearing as the same dye color, when photographed under different conditions. Thus, even a relative comparison of the color of one object to that of another is difficult.

When specification of the object color is important, either in an absolute sense, or in a relative sense, the use of the film as an abridged spectral radiometer is a more practical method than is a strictly subjective (visual) method. Certain major variables (the atmosphere, solar altitude, system spectral response, differing camera exposures, and normal film manufacturing tolerances, as examples) effecting the apparent object color can to a large degree, be accounted for, or their effects studied, when the film is used as a radiometer. Since the Development Objectives submitted to the contractor state the accurate color identification (specification) is an "important sub-task," and "guiding principle," this contractor will apply his special experience with this type of measurement problem to recommendations for CCC equipments and methodology.

Image Color Determination: In the instances where the color of the dye image itself is the principal consideration (in contrast to ascertaining the true (or relative) color of the object photographed), as would be the case in examination of variations between duplicates or in reproduction analysis and control, this contractor will consider the existing colorimeter and densitometer designs and equipment mentioned in the customer proposal request. Other equipment design concepts will be considered if the above-mentioned devices do not seem to meet the suggested requirements of the CCC.

IV. Work Statement:

(1) Define method by which colors are to be reported.

(2) Determine what calibration and monitoring equipment are required in the cell operations.

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(3) Determine instrumentation required to study perceptual phenomena, and the requirements imposed on the cell environment.

(4) Determine what instrumentation is required to measure the color discriminating properties of the total color system.

(5) Consider methodology and determine equipment required to measure the true (or relative) color of objects.

(6) Determine what equipment is required to measure the perceived color of the dye image, and the requirements imposed on the cell environment.

(7) Define the structural and environmental characteristics of the cell.

V. <u>Deliverable Items</u>:

(1) An interim report issued 60 days after start of the study. This report will not contain detailed technical discussions. It will state progress and problem areas on the several tasks in essentially non-technical terms.

(2) A final report which will contain the full technical details of the conceptualized Color Control Cell, to be delivered 30 days after completion of the study. The final report will not contain detailed design data.

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Schedule A

A summary breakdown of labor, burden, and material by labor class is submitted in Schedule A-1 to support the summary figures in the DD 633-4 form.

Schedule A-2 is the detail for Travel & Subsistence

Schedule A-3 is a Schedule of Performance and Time Bar Chart for the proposal.

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Schedule B

The overhead rates used for material, labor, and G & A expense are taken from the latest issue of our KAD Authorized Procedure AC-48, and Rate Schedule for Cost Estimating signed by [redacted] Comptroller, dated 24 February 1970 and approved by the resident Government audit office. 25X1

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