MEMORANDUM FOR THE RECORD

SUBJECT: Analysis of [redacted] STAT
Proposal for Color Duplicating System

1. [redacted] SA/RED, requested the Advanced Technology Branch/RED, to evaluate the proposal o[redacted]or a color duplicating System. This proposal is dated 1 December 1969 and came to RED throug[redacted] STAT STAT STAT

2. The objective of [redacted] in this proposal, is to produce a color copying system with at least 500 lines/mm resolution. The basis for this system would be a free-radical material. STAT

3. At the present stage of development [redacted] has some materials that could be used in a color mode but it appears that they have a very long way to go. This will be explained later. STAT

4. [redacted] wants to use the following approach to producing a color copying system 1) Examine ~~six~~ five alternative methods of color image formations for feasibility 2) work in depth on one or two of these systems, based on the feasibility study and then 3) work to fine tune the material that looks the best at this stage. STAT

5. Attachment A describes the five systems, their color formation mechanism and the means of development. The analysis/synthesis filters indicates the sizes of the colored imaging/reimaging particles and their composition.

6. The image recording/playback mode in four of the five proposed systems is of the additive type, with its associated disadvantages. A discussion of the additive vs. subtractive systems of color formation ~~follows.~~ may be found in Appendix B.

7. As an introduction, all "conventional," true color photographic systems analyze a scene in terms of its red, green and blue components. This practice is described in the theory of color vision and is followed in every commercially available color film of the true color variety.

8. Because the scene is analyzed in terms of its red, green and blue components, it is necessary to synthesize the scene in a similar fashion. That is, the image must modulate the amount of red, green and blue light in amounts similar to their presence in the original scene. The means of color modulation may be either additive or subtractive. ~~In additive systems~~,

9. In evaluating the proposal, I will examine the following areas: What are some independent views of the [redacted] materials; how do they present their proposed work in this document; and what is the analysis from the chemical, physical and mechanical standpoint. STAT

10. As independent inputs for this evaluation I contacted a project monitor at Wright Patterson Air Force Base and referred to a materials evaluation done at [redacted] for NPIC. The project monitor at WPAFB, has contracts with [redacted] for a camera speed Free Radical film. He indicated that as of January 1970, [redacted] still has significant problems with material stability and coating eveness. This substantiates the information ~~derived~~ in ~~from~~ the SRI evaluation ~~evaluating,~~ which indicated similar problems with stability and eveness of coating. STAT STAT STAT

11. The proposal itself suffers from poor organization and a tendency to be misleading. For example, references from Mees and [redacted] [redacted] are used to support [redacted] case; these references are out of context with the original source and often have no relationship to [redacted] use of them. [redacted] also confuses work that is done and proven, with work that is theoretical and yet to be performed. STAT STAT STAT

12. The chemistry of Free Radical Imaging Systems has been established but the modifications needed for the color duping systems, as proposed by [redacted], have not. The outstanding requirements are the establishment of a panchromatic sensitized direct reversal system with neutral density (grey). [redacted] has produced pansensitized materials but they are not direct reversal nor do they produce neutral blacks. [redacted] proposes a mechanism of spectral STAT STAT STAT

sensitization of its N-viny/carbozole material that is seriously in question; d~~iscussion with an inhouse chemist and photo-chemist~~ associated with a photo-s~~cience contractor~~ indicates a low probability of success of this mode of s~~pectral sensitization~~ (see attachment) see appendix D.

13. The physical problems with the proposed [redacted] materials relate STAT to the inherent disadvantage of additive color systems. - limited resolution (estimated on the order of 1/4X that of 3404) and high base (~~see attachment~~) density (requiring additional viewing light). The color reproduction capabilities of additive systems may also be a problem.

14. In each of the systems, there are severe mechanical problems relating to production of the original material and its additive screen and processing of this material. The color filters used for imaging must be very small to maintain resolution and must remain in registration throughout the process. In a proposed dye-bleach system [redacted] indicates it will use a STAT tripack with between layer lamination so that the layers may be separated for processing and then relaminated in exact register, for viewing; neither the mechanics nor the chemistry of this system is simple. In another proposed system, a solvent/leach is needed for reversal processing--then the process is no longer dry, which is claimed as an advantage of Free Radical Systems.

15. Recommendations.

On the basis of [redacted] present position in black and white tech- STAT nology, with the associated stability and coating problems, it is recommended that action on a color system be deferred. [redacted] is now in the process STAT of setting up a "commercial" type coater which it is hoped will resolve their stability/coating problems. On the basis of the literature and technology of color photography, I would not advise supporting an additive color system.

PROCESS	METHOD (Additive/ Subtractive) (Positive/Neg)	ANALYSIS FILTERS	SYNTHESIS FILTERS	COMMENTS
MODIFIED DUFAY	Additive Positive	Dye Particles ⟷ (.25-50 microns)		Requires reversal of F-R film by a solvent leach method and reexposure. Alternative is F-R b+w positive film but this does not give a neutral image color
lor Center Formation I	Additive Positive	Gelatin encapsulated dyes	Color centers of F-R molecules	Requires optical development by IR and dye (~~synthesis~~ analysis) bleaching by U.V.
olor Center Formation II	Additive Positive	Solid dye Spheres	Color centers of F-R molecules	" "
vinylcarbazole Sensitivity	Additive Negative	Colored starch granules	Colored starch granules	Polymerization of n-vinyl from exposure produces an insoluble oligomer. Unexposed areas are soluble and filters removed in chem treatment
e-Bleach out	Subtractive Positive	Dye (tripack)	Dye (tripack)	Methods not well defined — may require separation of tripack for bleaching processing

Appendix B

Additive vs Subtractive Color Systems

6. The image recording/playback mode in four of the five proposed systems is of the additive type, with its associated disadvantages. A discussion of the additive vs. subtractive systems of color formation follows.

7. As an introduction, all "conventional," true color photographic systems analyze a scene in terms of its red, green and blue components. This practice is described in the theory of color vision and is followed in every commercially available color film of the true color variety.

8. Because the scene is analyzed in terms of its red, green and blue components, it is necessary to synthesize the scene in a similar fashion. That is the image must modulate the amount of red, green and blue light in amounts similar to their presence in the original scene. The means of ~~color modulation may be either additive or subtractive.~~ In additive systems, varying amounts of red, green and blue light ~~are~~ are mixed to produce a given color. The earliest means of color photography used three projectors, one with the red separation positive (the black and white transparency of the scene as recorded with a red fitler) and a red filter, the green separation positive and the green filter, and the blue separation positive and a blue filter. The image from each of these projectors was overlapped and the colors in the original scene were reconstructed. The three projector mode of color reconstruction is unwieldy and requires precise registration so its analogue was developed. If small particles or beams of red, blue and green light are presented to the eye, it will integrate the three signals seeing them as a single color. This the method of reconstruction used in color televisions and color mosaic photographic systems.

Appendix 15 Cont.

[illegible]. In the subtractive synthesis method of reconstruction dyes of cyan (absorbs red, transmits blue and green), magenta (absorbs green, transmits red and blue) and yellow (absorbs blue, transmits red and green) are overlapped in varying amounts yielding all colors the dyes can reproduce. Examples of these types of materials are conventional color films, as SO 242, SO 121, Ektachrome, etc.

[illegible]. Each of the systems has its advantages and disadvantages. The additive systems requires simple processing treatment, since it is nothing more than a black and white panchromatic sensitive emulsion overlayed with a grid of red, green and blue filters. Its simplicity of processing must he weighted against its significant disadvantages. The color filter screen used for exposure and viewing limits resolution to the diameter of the individual color filters. This screen must be kept in accurate registration with the sensitive material. Another disadvantage of the additive system is the loss of light through the filters. Red, green, and blue filters each absorb 2/3 of the spectrum and therefore 2/3 of the incident light. If only one color is present, for example, the material will appear to have a base fog density of about .48. From a theoutical standpoint, the additive system may not provide color reproduction of as high as quality as the subtractive system.

[illegible]. The subtractive system provides good color reproduction and has higher resolution than the additive systems. The disadvantages are that the dyes used in color films may fade more readily than those used in the filters of the additive systems. Also, the SUBTRACT. additive system requires a complex processing procedure and producing the emulsion itself is difficult.

D-R-A-F-T/[redacted] STAT
29 January 1970

APPENDIX C

RESOLUTION OF ADDITIVE SYSTEMS

As described in Appendix B the additive system of color imaging requires a screen of filters for both analyzing the spectral components of the scene and for imaging these observed colors. The size of these filters is essentially the limiting factor in resolution of these materials, as each filter can be considered an imaging center.

[redacted] mentions filter sizes on the order of .2 to .3 microns as goals of the process. They believe they can get filter sizes of 1 micron with present technology. It is interesting to compare these values with the estimated grain size of a high resolution fine grain film like 340Y.[redacted] discusses grain sizes for typical photographic materials; on the basis of this. 45microns was chosen as a reasonable (if not large) grain size. The area would then be .166micron^2. This is about 1/4 the area of each of the imaging centers in the proposed [redacted] work. As a rule of thumb resolution can be expected to change in a linear relationship with imaging center diameter. If this is the case the resolution of the additive screen system would be at best 1/2 of the 3404 (considerably less than the 500 l/mm desired).

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APPENDIX D

Discussion of Spectral Sensitization of N-Vinylcarbozole

In the proposal concerning a color duplicating system, [redacted] STAT describes a mechanism of spectral sensitization that has been questioned by two members of the Advanced Technology Branch and a photo-chemist from [redacted] STAT

As described by [redacted] STAT "polymerization (of N-Vinylcarbozole) can be made to take place at a specific wavelength by energy transfer techniques if the monomer is adjacent to a color center." These color centers are starch grains, dispersed throughout the finder which contains the photosensitive N-vinyl carbozole and the activator, carbon tetratromide. The mechanism of spectral sensitization via "energy transfer techniques" is in question because in silver halide systems it is necessary that the sensitizing dye actually be absorbed to the surface of the silver halide crystals. When this condition is met there will be energy transfer from the dye to the Ag X crystal, resulting in sensitization to these wavelengths the dye absorbs. In the [redacted] STAT they describe a similar technique but with no contact between the dye (starch grain) and the sensitive media (the N-vinylcarbozole).

For the above reaction to work it would require very significant engrgy to polymerize the n-Vinycarbozole; there is a very significant question as to whether this energy could be provided by absorbtion of the proper wavelengths by the dyed starch granules.