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Technical Proposal
for an
Experimental Engineering
Model of a Diffraction Viewer

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1.0 SUMMARY

[redacted] submits the following proposal for Phase II of a program designed to substantiate the principles, utility, and performance potential of a new class of rear-projection viewing equipment based upon the phenomena observed when a direct image is viewed through diffraction gratings. In the recently completed Phase I of this program, the validity of the principles involved in this class of viewer were established and the feasibility of obtaining extremely high viewer resolving power without proportional limitations on exit pupil size were demonstrated. In this, the second program phase, it is proposed to apply the theoretical and optical/mechanical principles derived from the breadboard of Phase I to an experimental engineering model of a full size viewer.

The primary technical objectives of this second phase are to derive the techniques for - and subsequently rule and replicate - diffraction gratings commensurate with a full size viewer; to design and fabricate the corresponding supplementary optics, support structure and enclosures; and to assemble, align and test a complete full size experimental rear projection viewer. Final performance objectives are to obtain 50X magnification over a 10 x 10 viewing area with an effective resolution at the object plane approaching 400 lines/mm.

To accomplish the various sub tasks in this effort, it is proposed that the combined resources of [redacted] be utilized, with [redacted] as the prime contractor and acting as the focal point for all technical, contractual, and liaison matters.

As described in the following sections, this second phase of the program will span a minimum of 12 months (with a potential maximum of 16 months depending upon grating development schedules) and will culminate in the delivery and demonstration of the experimental viewer, a complete second set of optics with gratings, and an engineering report covering operation and maintainence of the viewer, technical characteristics, and results of a performance evaluation.

2.0 BACKGROUND

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Early in 1963, [redacted] supported by [redacted] [redacted] as a subcontractor, received a contract to undertake Phase I of a Diffraction Viewer feasibility development program. Phase I of the program was to conduct the necessary theoretical and experimental work required to demonstrate the feasibility of employing crossed diffraction gratings as a primary technical method of overcoming the limitation of small exit pupil size at high viewing magnifications in a rear projection direct image viewer.

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The concept of using optical diffraction techniques to circumvent the physical limitation of exit pupil size resulted originally from certain joint proprietary efforts between technical staff members of [redacted] These discussions subsequently resulted in the preparation of (1) a jointly owned company application for a basic patent in the optical field and (2) a proposal for the development of a new class of rear projection viewers using optical diffraction techniques for purposes of photo interpretation.

On the basis of the proposal submitted, and follow-up technical discussions with government representatives, sufficient interest was developed and evidenced within customer circles as to result in the placement of a contract for the Phase I effort.

The Phase I effort was initiated in the first quarter of 1963 and was completed in June 1963, with a physical demonstration of feasibility. Phase I produced both theoretical and experimental study results (see [redacted] Final Engineering Report No. 4001) which confirmed the feasibility of high quality, high magnification viewing of low contrast imagery using optical diffraction techniques. These techniques produced a significant enlargement of the effective size of the composite exit pupil over previously limited rear projection viewing methods.

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These study results also indicated that viewing magnifications of the order of 50X could also potentially be achieved with this approach if certain advancements in the fabrication of high quality diffraction gratings were practicable.

At the conclusion of Phase I, the decision to proceed with Phase II of the intended development program rested almost entirely on the state-of-the-art of manufacturing high quality diffraction gratings. The specific characteristics of the diffraction grating required for the intended application must be of such a nature as to yield a nearly uniform distribution of light intensity over nine (9) or more diffraction orders in conjunction with corresponding blaze angle and period relationships compatible with continuous high magnification (50X to 70X) direct image viewing equipment.

In the months immediately following the Phase I portion of the current program, several meetings were held between contractor and customer technical representatives to review and discuss potential technical approaches and plans for the Phase II follow-on effort.

During these discussions, two distinct technical approaches were examined relative to Phase II. One approach was based upon slaving by electro-optical methods the exit pupils to the average motions of the operator's head. The second, and more favored approach was to pursue the use of diffraction grating techniques through subsequent improvement in the state-of-the-art.

It was decided therefore that prior to any final decision being made, a second optical demonstration of the viewer concept would be conducted in conjunction with a review of the diffraction grating fabrication technology. Concurrently, a review of U.S. grating manufacturing sources was made that subsequently resulted in the selection of [redacted] as the company most qualified to solve the diffraction grating problem. This decision was based upon a history of prior work in the area of fabricating high diffraction order gratings in connection with the Printing Industry. The results of this prior work, and the development of new fabrication techniques since their initial attempts, produced the firm

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technical conviction that the required grating was within the limits of technology, even though gratings of the particular characteristics had never been built.

At a contractor-customer meeting in December, 1963, it was mutually agreed between customer representatives and representatives

STATOTHR from [redacted] that the technical approach that would be pursued in the Phase II effort would be based upon the use of high quality diffraction gratings. The slaving concept was temporarily suspended pending the outcome of Phase II developments.

The customer's technical representatives also directed that the Phase II program was to provision for the fabrication of two complete optical systems including the necessary diffraction gratings. Of the two optical systems, one system would be assembled and used in the experimental engineering model of the diffraction viewer for photo interpreter evaluation, and the second unit would be held in reserve in a non-assembled state for subsequent employment in a prototype of an operational viewer.

3.0 PHASE II TECHNICAL APPROACH

3.1 Scope

The technical objectives of this, the second, phase of the diffraction viewer development are to fabricate, test, and demonstrate a full size experimental engineering model viewer which, while not including such operational features as automatic film transport, mensuration devices, etc., will contain all the optical elements and optical performance of an operational viewer. The unit will have the following technical specifications as design goals.

a. 50X magnification (fixed)
b. A nominal 10" x 10" viewing area
c. The exit pupil area will be 3.5" square minimum with minimum variation in illumination to permit comfortable viewing from approximately 20" from a non-rigid position.
d. A minimum resolution of 200 lines/mm (as referred to a high contrast target in the image plane) based upon available off-the-shelf lens.
e. Accomodations for either 70mm or 5" film chips.

In consideration of the experimental nature of the unit, and in the interests of economy, the packaging aspects of the unit (i.e. enclosures, main frame, etc.) will be held to a minimum consistent with structural rigidity to maintain optical alignment and reduction of stray light effects.

Technically, the proposed program will be divided into three distinct development areas. The first of these concerns the steps leading to the fabrication of the final 10" x 10" diffraction grating. As the required characteristics of the grating will require certain advancements in the current art of grating fabrication, an initial research effort will be required to determine the actual manner in which the grating should be ruled. This is principally a function of how best to obtain the most even illumination from each diffraction pattern order and requirements on exit pupil size.

Upon selection of the optimum methods resulting from this research, a series of small 2 x 2 inch sample gratings will be ruled, both to prove the optical calculations of the research effort and to verify the mechanical feasibility of ruling the desired pattern. It is anticipated that a maximum of four distinctly different trial gratings may be required before the performance goals and fabrication techniques are sufficiently developed to permit initiation of work on the final grating. With very favorable progress, no more than two sample gratings may be required; although this cannot be assured at the present time. With the specifications and techniques of the proper grating once established by this method, the final grating would be ruled and replicas produced for incorporation into the final viewer. It is planned that the accomplishment of this grating development be the responsibility of the [redacted] STATOTHR STATOTHR

The second principal development area in the program will concern the design and fabrication of the more conventional portions of the complete optical train in the viewer. Of principal importance in this area are the condensing lenses, objective lens, field flatteners, and the large diameter field lens which just precedes the grating in the optical train. It is planned that this activity be STATOTHR the responsibility of [redacted]

The third and final developmental area in the program is the structural portion of the viewer. This includes the various requirements for mounting the optical elements, the viewer housing, the light source, etc. The design and fabrication of these elements, and the overall integration of the optical elements into the viewer will STATOTHR be the responsibility of [redacted]

The final outcome of the three foregoing areas will be the proposed full size viewer with performance characteristics as listed, and, in addition, one complete extra set of optical elements. This extra set of elements may either be delivered and used by the customer for special purpose research or retained for later incorporation into a final version of the viewer with full operational viewing and mensuration capability.

While the foregoing summarizes the general scope of the program, there are a number of individual points of interest which are useful to a more thorough appreciation of the technical complexity of the viewer development. These are contained in the following sections.

3.2 Required Project Developments

a. Diffraction Grating Development

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[redacted] proposes a three phase grating development program whose goal is to achieve a special ten inch by ten inch aperture diffraction grating master. The four replica gratings produced will be substantially identical. They will be so designed that the energy incident on the grating will be divided into nine equally intense orders (the zero order, and the first four orders on both sides of the Zero order). "Equal intensity" will be taken to mean that the variation in intensity between adjacent orders will not be more than 40 percent, and the overall intensity ratio amoung all orders will not be over two to one.

In the initial research effort the method of meeting these requirements which is most probable of success within the total contract time will be determined. The principal problem in producing such a grating is the problem of achieving the desired energy distribution. A number of methods for realizing the desired characteristics are available. The more promising of these are based upon one or more of the following approaches.

1. Groove Shaping

That shape of the groove is determined which will produce a grating of the required energy distribution. If such a groove is a portion of a circular cylinder the shape is realizable. If a different shape is called for then the task will be more difficult STATINTL and thus more time consuming. Some theroetical investigations of cylindrically shaped grooves have been carried out, [redacted] but only limited experimental background exists.

2. Ghost Grating

A grating with such periodic error is produced that the two first orders, two ghosts on either side of each first order, and the zero order all have equal intensity (eleven images in all). The advantage of this kind of construction is that the groove structure is finer (approximately 3000/inch) and hence less visible. The groove would be required to also have the correct shape as well as having an appropriate periodic error.

3. Double Grating

It may prove to be more simple to make two gratings, each of which has two first orders and a zero order of equal intensity. Two such gratings with parallel grooves would produce five approximately equal orders. Four gratings in all would be required and alignment between the two parallel gratings would have to be quite exact.

During the initial studies still other methods may occur. These will also be evaluated on the same basis, i.e., the probability of achieving the desired end result in the allotted time. At the conclusion of this research phase a report will be issued presenting the most suitable method to produce the required diffraction gratings.

Following determination of the method judged most probable of success, a two inch by two inch sample diffraction grating will be fabricated. A transmission replica of this sample grating will then be made and the relative intensity of the various images will be measured.

Measurements will be conducted using the 5461 mercury line with collimated light incident normal to the unruled side of the grating. A telescope and detector will be angularly scanned through the orders of the grating and the relative intensity of the orders determined.

Two replicas and the measurement record will be delivered. It is unlikely that the first of these rulings will produce replicas having the finally desired degree of energy distribution. Therefore an additional part of effort will be to rule a second two by two inch ruling embodying the knowledge gained from the first. Transmission replicas from this second grating will be measured and the replicas and measurements also delivered. Subsequent two by two inch gratings will be ruled and replicas submitted as required.

It is probable that a total of four attempts will be required to achieve the desired level of performance. The results of these trials will then be used to produce and deliver the final 10 by 10 inch transmission replicas to the nominal specifications already stated, and in detail as mutually agreed on.

b. Optical System Development STATOTHR

STATOTHR The design and development of the optical system for the experimental diffraction viewer will be performed by [redacted] Optics will be built for two complete optical systems with individual elements being assembled and checked only for the experimental engineering model during the present phase of the program.

A total complement of optical elements in an individual viewer system includes the following:

1. Two multi-element condensers mounted in cells.
2. Two field flatteners unmounted.
3. Two commercial high aperture photographic objective lens with modified cells containing adjustable square pupils.
4. Two multi-element 15 inch diameter field lens systems mounted in cells.

The condenser lens will be designed to concentrate the light from

2 alternate as required

2 Comm 8.5"

from the lamp to a very small area on the film plane. At 50X the object scene is .2 x .2 inches and thereby requires a concentration of the lamp output to the small area for efficient operation. 8.5" f/4 lens will utilize a condenser system to illuminate

The objective lens will be a commercially available unit specially selected for the purpose. It is anticipated that a lens with an AWAR of 250 l/mm (as referred to a high contrast target in the image plane) can be obtained. The lens will be capable of 400 l/mm on axis, and approximately 100 l/mm toward the corners of the field. It will have a focal length of approximately 1 inch, and a focal ratio of f/1.0 or faster. If in later viewer models it is desirable to achieve the full 400 l/mm capability, a new lens design will be required.

The field lens will necessarily represent a new design. This unit will employ conventional glass and have four (4) major elements with an overall diameter of approximately 15 inches. The lens is of symetrical design and therefore affords the possibility of placing the diffraction gratings between two identical element sections if required. Coordination with [redacted] in this matter will determine the mounting arrangement of the four elements.

In addition, certain aspects of the optical system design are dependent upon the grating approach, their interface items will be determined after the receipt of contract.

c. Viewer Mechanical Development

In parallel with the diffraction grating development and the design and fabrication of the optics, [redacted] will design and fabricate the optical support and viewer body components. One month after the optical design is begun [redacted] will be supplied with drawings showing the relationship of the optical components and their physical dimensions. After the receipt of this document, [redacted] will design and fabricate the viewer body. Due to the nature of the viewer and its intended use, the design goal will be to provide a clean simple optical support, film holder, illumination assembly, and protective cover. A more detailed description of each subassembly is given below.

1. Optical Element Support Assembly

The optical bed will consist of an H frame mounted on rubber feet. All of the optical components will be mounted on this H frame. The upper surface of the H frame will be machined to provide a common plane for alignment of the optical elements.

The 1" F1 objective lens will also be attached to the H frame bed but will be focusable from the front of the viewer. With the high resolution and low F# of the system this is a desired feature. A simple cam mechanism will be used to provide the actual focusing movement.

The 15" field lenses will be rigidly mounted to the H frame support. A front plate with the proper size opening for the grating will cover the field lenses and also support the few front controls required.

A wooden or sheet metal cover will be fabricated and fixed to the frame to cover the assembly. A section of the latter portion will be hinged to allow access to the optics and for insertion of film and X-Y adjustments.

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2. Light Source and Condenser Optics

[redacted] will provide the light source and its power supply. The wavelength selection will be jointly determined at the first technical liaison meeting. An external blower with a flexible air duct will be supplied for cooling. The blower motor and fan assembly will be packaged with the illuminator power supply in a separate container. This form of external mounting will eliminate vibrations which would be magnified by the 50X power optical train.

The condenser optics will be placed at a fixed location to concentrate the lamp output to the small area on the film as set by the magnification ratio.

3. Film Support and X-Y Translation

The film support structure will accomodate both 70mm and 5 inch film chips (no provision will be made for roll films).

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The film will be held by a vacuum to a flat glass plate through the use of etched grooves in the glass. The groove pattern will cover a full 70mm format. When a 5" square film chip is used, any 70mm square section of the format can be held.

The glass platten will be mounted on a simple X-Y translation mechanism to allow the required object field to be selected anywhere within the 70mm format. The movement of the film will be performed by simple manual controls.

Besides the viewer a second small enclosure will be required. This will contain the light power supply, blower, and vacuum pump. The vacuum line and power cord will follow the air duct from the enclosure to the viewer to provide a neat appearing interconnection. An air valve will be located at the rear of the viewer to control the vacuum for installing and removing the film.

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Subsequent to the fabrication of the viewer body, and after the arrival of the optics at [redacted] all viewer components with the exception of the grating will be assembled and checked out. Even though the grating is not available the unit can be aligned and tested and the resolution tested by observing imagery through the one .4 inch exit pupil which will exist without the grating. The illuminator level may be simulated by insertion of a neutral density filter in the system which will cut the light by the amount expected with the grating. Alignment and focus checks will be made as well as functional tests with film samples.

After the gratings are available a minimum amount of time will be required to finally check out the viewer. A final brightness variation check of all 36 exit pupils will be made after installation in the viewer and the resolution obtainable from each exit pupil determined. These findings, along with other technical material will be included in the final engineering report.

4.0 PHASE II PROGRAM PLAN

As previously indicated, the development of the experimental engineering model viewer will require the combined research talents of [redacted] Overall program direction would be the responsibility of [redacted] supporting in a subcontract capacity. [redacted] would also serve as the focal point for all customer related functions such as reporting, liaison, and such other administrative and/or contractural matters as may be required.

This need for a single focus for all program activities becomes particularly evident when the relative phasing of the individual company sub tasks are considered. These various interrelationships are illustrated in the Phase II Program Schedule of Figure 1. As indicated both [redacted] would be required to initiate separate laboratory and design studies simultaneously upon completion of satisfactory subcontract coverage. Upon completion of these initial efforts [redacted] would then proceed with the fabrication of a series of prototype 2" x 2" gratings while [redacted] fabricates their selected lens design and [redacted] begins design and fabrication of the viewer body. These latter functions are coordinated through the delivery of the optical system component physical specifications to [redacted]

The integration of the optics into the viewer, and all subsequent alignment and fit problems will be considerably more complex than those associated with the integration of the grating, the schedule therefore indicates a viewer body/optical element pre-assembly and checkout period. Even though the final grating may not be available for three (or up to seven months), valuable information can be developed relative to the final viewer's optical characteristics and potential performance during this period.

Upon receipt of the actual grating the final assembly and test of the viewer will then be conducted and an evaluation of the overall performance of the viewer completed.

FIG. 1 PROGRAM SCHEDULE
(Phase II)

TASK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Initial liaison to confirm scope and specifications	▲																	
Formalization of tests and sub-contracts [redacted] STATOTHR	▲																	
Evaluation of grating fabrication techniques [redacted] STATOTHR	▲	—	▲															
Fabrication of prototype gratings [redacted] STATOTHR			▲	—	—	—	—	—	—	—	—	▲						
Delivery of prototype replicas [redacted] STATOTHR						▲		▲		▲		▲						
Design and fabrication of optics [redacted] STATOTHR	▲	—	—	—	—	—	▲											
Delivery of optical component specifications [redacted] STATOTHR			▲															
Design of viewer body [redacted] STATOTHR			▲	—	▲													
Fabrication of viewer body [redacted] STATOTHR					▲	—	▲											
Viewer body/optics assembly and alignment [redacted] STATOTHR							▲	▲										
Fabrication of final grating [redacted] STATOTHR								▲	—	—	▲*	- -	- -	- -	▲			
Grating installation and alignment [redacted] STATOTHR											▲	▲*	- -	- -	▲	▲		
Performance test of completed viewer [redacted] STATOTHR												▲ ▲*	- -	- -	- -	▲	▲	
Demonstration of viewer to customer [redacted] STATOTHR												▲*	- -	- -	- -	- -	▲	
Engineering report Phase II [redacted] STATOTHR												▲*	- -	- -	- -	- -	▲	
Customer/Contractors Coordination Meeting			▲					▲				▲						

*Earliest possible time for given event. (Dependent upon grating development schedules)

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Following this final period of overall viewer evaluation by essentially all parties concerned, the viewer would be delivered and a short indoctrination session held to familiarize the customer with the units characteristics. For customer convenience this meeting could be held at the facilities of [redacted] in [redacted] if desired.

As the proposed program may be expected to span a minimum of 12 months from contract go ahead to delivery of engineering report, it is proposed that quarterly progress reports be prepared and deliverable one week after the close of the 3rd, 6th and 9th months. In addition the conclusions resulting from the scheduled liaison meetings between contractors relative to program direction would be reported separately within one week, e.g., the initial meeting to confirm specifications and contractural arrangements, the commitment to proceed with the final grating based on the latest prototype grating fabrication, etc. In order to minimize project travel costs, [redacted] has consented to serving as the Host for the scheduled liaison meetings. These meetings therefore, are scheduled to be held in [redacted] at the times shown in the project schedule.

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5.0 DELIVERABLE ITEMS

Item	Quantity	Description	Schedule
1	5	Technical Meeting Reports Letter type	Within 7 days after each technical liaison meeting
2	5	Quarterly Progress Reports	Within 7 days of the close of the 3rd, 6th, and 9th months ARO
3	1	Experimental Engineering Model of 50X Diffraction Viewer	A minimum of 12 months* ARO
4	6	Engineering Reports of Operating and Service Instructions, and Design Data	Concurrent with delivery of Item 3
5.	1	Complete Optical Systems (non assembled) including gratings	A minimum of 12 months* ARO

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* Twelve (12) month delivery date is based upon the early development of a successful grating. A sixteen (16) month delivery date will result if four complete diffraction grating technique fabrication trials are required.

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[redacted] No. 6074.01

Cost Proposal

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