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DESIGN REPORT

SLIDE VIEWING SYSTEM

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DESIGN REPORT
SLIDE VIEWING SYSTEM

Note: The main paragraph numbers used correspond to those used in MSM-S-137-2. The subjects treated, therefore, will satisfy SCM-100-D.

1. Tradeoff Discussions

Introduction: The complete treatment of all of the tradeoffs involved in designing the SVS would be a very complex and difficult task. Indeed, a complete analysis is not really possible within the design schedule for this job and many decisions must be based on past experiences or even rather arbitrary assumptions in order to get the work done. The previous design reports have discussed the tradeoffs relevant to the design of each major subsystem. Therefore, this report will discuss the tradeoffs concerning mainly the arrangement of the subsystems into a system and treat those topics which we believe to be most relevant to the design of a successful slide viewing system. The system design requires inputs from several different engineering disciplines, mechanical engineering, optical engineering, electrical engineering as well as system engineering.

Resume of System Mission: The principle function of the slide viewing system is to present views of terrestrial objects as if they were seen in the acquisition tracking system of the MOL vehicle. The principle problem to be solved is to transform photographs of these objects taken from a different vehicle into images that would be seen from a moving orbital vehicle through the acquisition tracking system. Figure 1. In order to do this it is necessary to introduce systematic distortions of the diapositive photograph of the terrestrial scene. As the vehicle passes over the scene, the slant range to the object is continuously changing as well as the apparent perspective angle. Therefore, the simulation system must include a zoom system to compensate

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106 SYSTEM

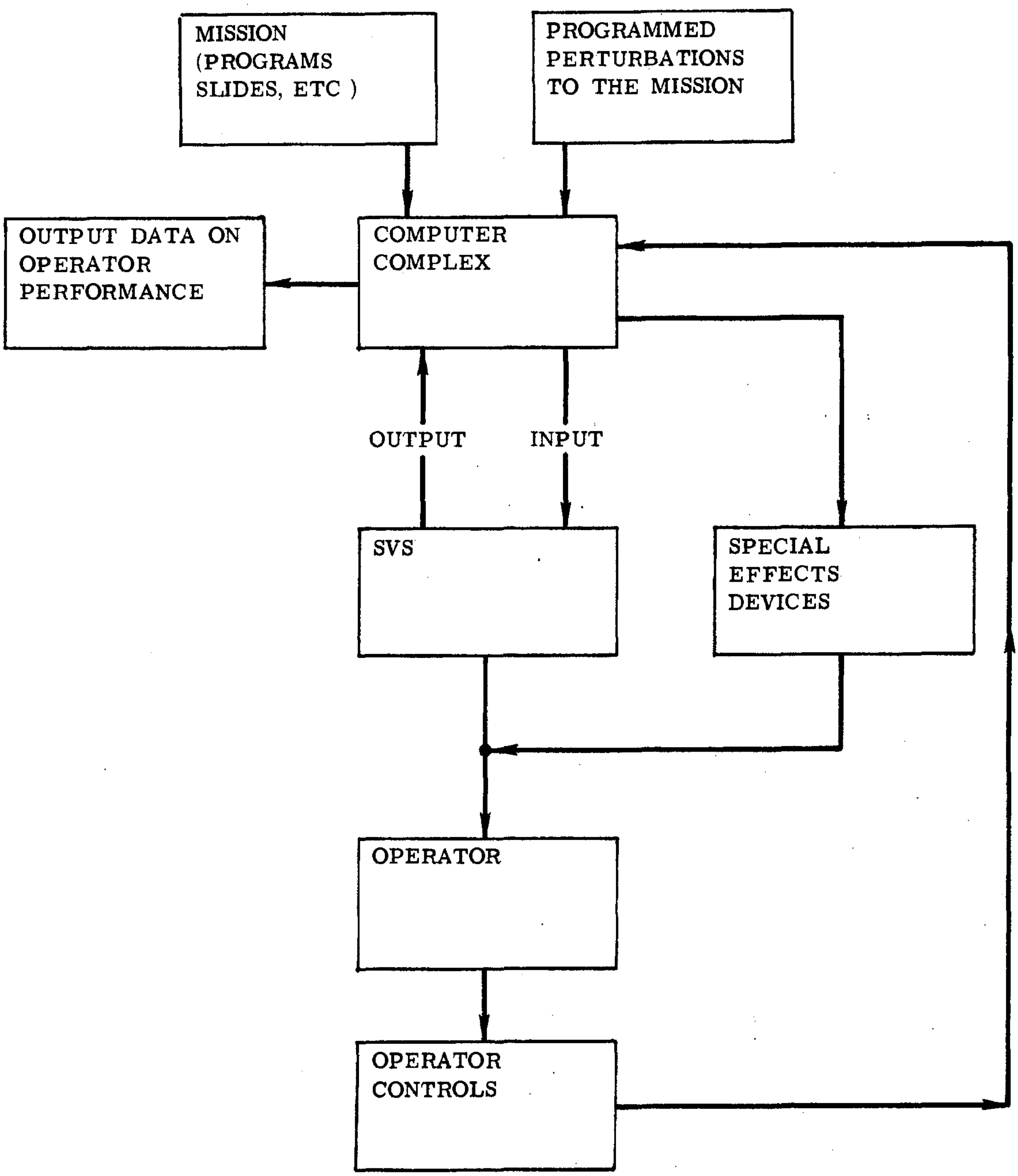

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Figure 1

for slant range variation as well as a cylindrical system for correction and variation of apparent perspective in the still, as seen from a moving vehicle. The cylindrical magnification effect and the tracking geometry also require the use of an image rotation device in the system. Because it is necessary to simulate imperfect tracking operations, it is necessary to selectively scan the field of view over the input diapositive. Because of the effects of variable illumination due to sun angle, it is necessary to have an intensity control on the apparent brightness of the scene. This control is also used with special effects devices to simulate atmospheric haze. Because the acquisition tracking system of the MOL vehicle has two magnifications which may be rapidly changed by the astronaut, it is necessary to simulate this change in magnification as well. Because the input diapositives are available in two principle series with differing photographic scales from which we wish to observe the same apparent sized object in the eyepiece, it is necessary to have a step magnification consistent with the scale of the input material. The nature of this mission is such that on the average, a different terrestrial object is to be viewed every ten seconds throughout a ten minute pass. Presumably because many decisions and operations are to be performed within this relatively short time span of ten seconds, it is necessary that the target diapositives be changed at a rate consistent with the slew rates of the Gimbal mirror system on the MOL vehicle. For this reason, it is necessary to change input diapositives with a minimum down-time between changes of one second or less. Because the brightness of the earth, as seen from a space vehicle is quite high, of the order of a thousand foot lamberts, it is necessary that the light source used in this system be capable of simulating such light intensities.

Functional Mission Requirements, Salient Topics: Accordingly, the above functional mission requirements determine the principle functional blocks that must be accommodated in the slide viewing system for simulation of the acquisition tracking system. The sequence of system components is shown in Figure 2. The input diapositives are accommodated in a supply which feeds a transport system which transports the diapositive into the viewing position where it is positively located by the positioner. After the viewing operation the slide is transported to the dump. The dump is a similar magazine system as that used in the slide supply.

Type of Diapositive Material to Be Used: The principle tradeoff to be considered in the slide handling system, aside from the details of the actual hardware, is whether roll film or individual diapositives should be used. Roll film presents a problem because successive orbital passes will not always pass over a given sequence of targets in the same order. Because of the rotation of the earth in respect to the path of the orbiting vehicle, this would present a very complicated original film handling and duplicating problem in that as many rolls of film would need to exist as planned orbital passes. It is clear that individual diapositives which can be arranged in any order provide a much more flexible and useful approach to this problem. Therefore, roll film handling systems, while much easier to design from a mechanical viewpoint were discarded as a possibility. Because each slide or diapositive view could conceivably be used as much as thirty-four hundred times during the expected life of this equipment or the scene, it is necessary that great care be given to the handling of the diapositive. It is necessary to protect the diapositive from dirt and scratches which might occur during handling which could destroy illusions of realism in the simulator. Brief considerations had been given to the use of a transparent glass vacuum platen which could handle cut film and frames. It is obvious in light of the above facts that cut film would be subject to great wear through such repeated handling and we are not at all sure that a transparent vacuum platen can be constructed which will pull the cut film flat uniformly within an acceptable time much smaller than one second. It

S.V.S. SYSTEM

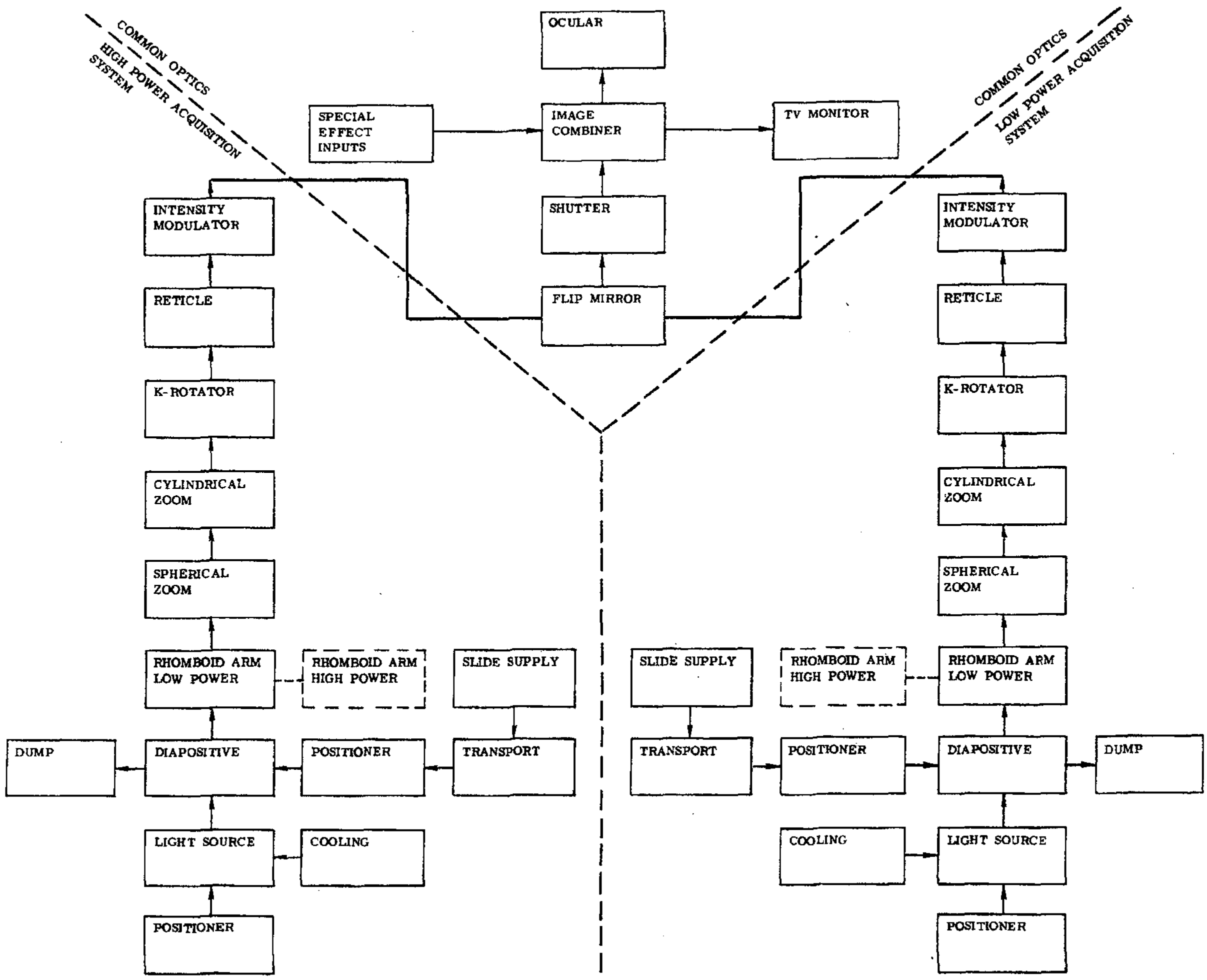

Figure 2

should be pointed out that desired ground resolutions of the order of two feet preclude the use of seventy millimeter small format input photography. Therefore, the principle sources of input photography for this ground resolution have rather large formats. In this case up to nine and one half by nine and one half inches. This large format makes it difficult to pull down in such a short time with a transparent vacuum platen. For these reasons and because the optical viewing system requires a flat field, it appears necessary that the cut film must be sandwiched in some kind of a rigid transparent carrier or that glass diapositive slides be used. Mounting diapositive film between glass plates presents potential problems due to Newton rings which would be an artifact destructive to realistic simulation. Some experiments were performed to attempt to eliminate Newton rings from such a diapositive mounting. Time was not available to conduct a real research effort on this subject, but the principle methods used in the current photo-optical trade were studied fairly carefully. These three approaches are, use of lycopodium powder to separate the film diapositives from the nearby glass mounting surfaces, the use of frosted glass to suppress Newton rings or the use of low reflective coatings. All three of these approaches exhibited fairly serious disadvantages. The lycopodium powder is clearly visible at the magnifications used in this system and looks like dirt. The lightly frosted glass which is the most useful method used in the industry, degraded the resolution of the diapositive significantly, at the higher system magnifications. The use of anti-reflection coated glass cover slips would be extremely costly even if they worked. However, because there is really no completely satisfactory low index coating available, this approach has never proven to be successful according to the literature search that we performed. After considering the above reasons, we arrived at the use of a glass base diapositive of the terrestrial scene. Other reasons are that these diapositives are in regular use in the photographic facilities handling such photography and processing techniques are well established. Some effort was directed at obtaining diapositives on plastic bases rather than glass. Unfortunately, the emulsions available from Kodak on plastic bases are usually intended for use in the photo-engraving and printed circuit industries and the high resolution aerial positive emulsion that is required for this system is not available. Because of the foregoing we were limited to handling glass diapositives. Therefore, it became necessary to design frames and a mounting system for them which could be handled by high speed conveyor machinery. Thus, the design of the present slide used in the system is the result of a rather more complex relationship than might at first hand be readily appreciated.

Photo-optical Image Transformations: The transformations associated with the picture distortions required for the mission simulation determine in part, the sequence of the optical elements used in the viewing train. The tradeoff discussion concerning the scanning means used has been described in the report on the Rhomboid Arm X-Y Drive and will not be further discussed here. The first function to be performed by the optical train is to be able to scan in X and Y over a fixed diapositive, while maintaining an accurate focus; therefore, the first element in the optical system is the rhomboid arm. The spherical zoom is a linear transformation which can be placed anywhere in the optical train without introducing any effects due to mutual coupling. The effect of spherical magnification is the same with respect to the input diapositive regardless of where it is introduced into the optical system. The position of the spherical zoom is, therefore, determined purely by considerations of optical design rather than the effect of its transformation from the input image. These facts are not true of the cylindrical zoom. Cylindrical zoom has associated with it, the azimuth of maximum magnification which must be related correctly to the perspective distortions that are desired in the input image. Therefore, it is preferable to place the cylindrical zoom system in the same space reference frame as the input diapositive. For this reason, the cylindrical zoom effect preceeds the K-rotator in the optical system. The effect of the K-rotator, therefore, is to rotate the apparent azimuth of the observer with respect to both the input diapositive and the perspective distortions applied to it. Because critical observations are to be made of the pointing ability of the astronaut when using this system, it is necessary that a very precise bore sight relationship exist between the pointing reticle and the input diapositive. If the reticle were to be placed between diapositive and any of the above distortion optics, the reticle itself would be distorted. However, in order to maintain the maximum precision of the reticle placement within the optical structure, it is desirable that the reticle be placed in the optical train as closely as possible to the input diapositive. The first position in the optical train at which these conflicting requirements can be satisfied is to place the reticle at the focal plane of the cylindrical zoom collimator which is behind the K-rotator. This is the first position at which the distorting optics would not affect the shape of the reticle.

Unfortunately, each of the distorting systems and the scanning system has associated with it, a runout. This runout is an effect which is observed if the reticle is projected back through the optical system, to the diapositive and if the various distortion optics move through their ranges. The result is that the reticle position apparently shifts with respect to a chosen target on the diapositive. The specification applied to the system for the allowable limit of this runout corresponds to the limit of human visibility or plus and minus one minute of arc as seen in the output eyepiece. If this runout or freedom from runout were to be achieved by pure mechanical and optical construction methods then extremely critical assembly would be needed. The use of precision techniques would result in very slow delivery, surely inconsistent with the schedule desired on this program.

System Configuration and Reticle Location: Because of the substantial distances between the slide changing mechanism and main optical bench and the eye point of the astronaut in the test cabin, a relatively long optical path is used in order to close this distance. The length of this path is further increased because of the necessity to change magnifications between two slide handling systems in the rather congested area next to the cabin (for each eyepiece). Great difficulty was experienced in the original packaging concept of this system with the distortion optics which were mounted on a horizontal optical bench leading up to the eyepiece. These difficulties are related to the small distance between the zoom lens and the anamorph group which also must accommodate a hinged joint. Between the anamorph and the reticle, the optical system is extremely close coupled and no folds are possible. After a long study of the site and the optical folds constrained in the above ways, it was found impossible to place all four slide changers on the seismic block while simultaneously delivering their outputs to an eyepiece with horizontal optical benches. For these reasons a vertical optical path was chosen which makes very compact use of floor area with respect to the slide changer but which uses a somewhat longer optical relay system in order to get to the eyepiece in the cabin. At one time, concern was unofficially expressed about acoustic inputs which might travel through the optical structure to the astronaut and perhaps cause invalid conclusions to be drawn from simulation data. This later fact gave added weight to our choice of the present system which consists of a completely separate eyepiece pedestal which can be mechanically decoupled from the moving hardware items on each slide changer. This independent eyepiece pedestal, while providing great flexibility in site layout, poses problems of stability of alignment of the eyepiece with respect to the input imagery. Such instabilities would be caused by temperature gradients in the room causing the eye point to shift; the insertion or removal of filters; the alignment and repeatability of the image selector which switches the eyepiece view from one slide changer to the other; and finally the residual wedge error of the intensity modulator system. A preliminary estimate of the magnitude of the deviation of the eyepiece center line with respect to the optical axis of the instrument is of the order plus or minus ten minutes of arc. Therefore, in order to meet the bore sight accuracy requirement of plus or minus one minute of arc, it is necessary that the measuring reticle be placed on the slide changer part of the system for the maximum mechanical integrity with the diapositive coordinate system and for freedom from the above misalignment causes. By use of this particular configuration, the reticle alignment will only be affected by the K-mirror, the anamorph lenses, the zoom lens, and the rhomboid arm.

<u>Discussion of Distortion Optics, Runout & Possible Means for Compensation:</u> As may be inferred from the foregoing discussion, it is becoming clear that only two alternate means for insuring freedom from image bore sight runout exists. (1) Build the equipment with a sufficient degree of precision and stability so that one minute tolerance can be met; or (2) correct the runout errors by means of some kind of compensation system. The kinds of compensation systems which could be used here are many but in the end would probably consist of some kind of a computer, either analog or digital, which would store the correction functions and add this into the X-Y positioner command signals. As stated above, Itek does not believe that the required mechanical precision can be had within the allowable delivery dates required for this program and therefore, has really come to the conclusion that either Itek or General Electric must provide the above mentioned correction functions. If Itek is to provide the correction, this would be accomplished by supplying a small digital, or possibly, analog computer with the slide viewing subsystem. If General Electric is to provide the compensation, Itek will provide a procedure by which means General Electric can determine for itself the

character of the runout corrections. We believe this latter course is preferable because if at any time it is felt that correction data needs to be renewed or corrected, the General Electric Company will have the means to do this in their own facility with a minimum of down time. This later scheme presupposes that a reasonable alignment procedure can be followed using a moderate number of data observation points so that each slide changer can be capable of being fully corrected within a few hours. The exact nature of these corrections will be discussed below in Section 2. A typical flow diagram of these error corrections is shown in Figure 3.

<u>Second Order - Non-linear Effects</u>: In addition to the above coordinate corrections from runout, high order term small amplitude, corrections are also required. The classes of effects concerned here are such items as potentiometer non-linearity, potentiometer loading, departure of experimental functions from ideal functions (such as the intensity modulator whose response is not strictly exponential). Other effects of this nature are runouts associated with gearing to potentiometers and mechanical drives such as the X-Y drive of the rhomboid arm. Another class of calibration error consists of determining the zero offsets for all commandable parameters of the system such as K-mirror, azimuth anamorph settings, zoom settings and so on. Another kind of zero offset error which has not yet been fully evaluated or appreciated is that one due to the temperature coefficients of the potentiometers used in this system or due to variations in electrical circuitry such as voltage reference supply, thermal potentials, line resistance effects, and so on. Many of the small order corrections can be predetermined on subassemblies and calibration curves could be provided: however, we believe that consideration should also be given to means by which the system can be self calibrating on an on-line basis. This is a further argument for our system concept of computer correction of the assembled system in the General Electric site. It should also be noted

FLOW DIAGRAM
OF
ERROR CORRECTION

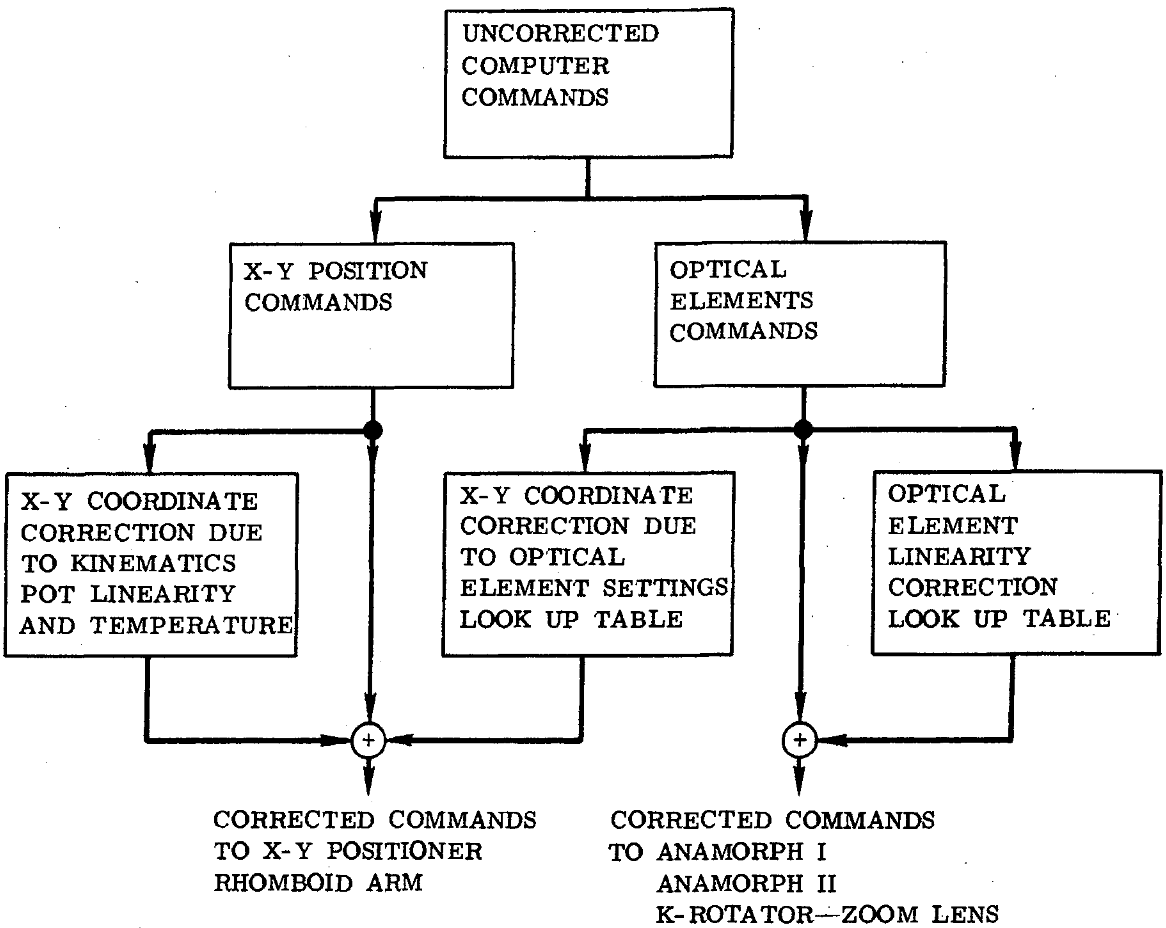

Figure 3

that the details of this correction procedure are intimately related to the location of the reference reticle and the system. Therefore, if more optical elements are introduced between the reference reticle and the diapositive, more computer corrections must be handled by the control system.

Figure 4 illustrates our current thinking on how the correction will be applied. A standard test plate will be used which will define the X-Y coordinate system for all of the slide changers as well as the measuring apparatus which will be used to determine the coordinates of targets on each diapositive. This test plate will be of a precision significantly greater than any of the measuring means used to observe target coordinates. Our present concept uses a plate consisting of twenty-five crosses placed over the X-Y operating range of the equipment. The grid crosses will be calibrated on a STK-I stereo comparator at our Alexandria, Virginia, Image Analysis Center. This plate also provides a convient vehicle for other tests for calibrating the system. Therefore, five standard U.S. Air Force, 1951 tri-bar test targets per MIL-STD-151A will be included in order to determine that this system is capable of operating at full resolution over the X-Y range of the input diapositive. A spoked wheel pattern will be used to both determine the angular transfer function of the K-rotator as well as its X-Y runout. A pair of crossed graduated scales will be used to calibrate the zoom magnification. Similar crossed scales will be used for the calibration of the anamorph system. The test patterns are designed to be used with a special reticle also shown in the Figure 4. The operator aligns all four reticle marks on the test pattern so that both the functional relationship and the X-Y runout calibration can be determined simultaneously. While this makes a somewhat more different reticle setting, many fewer observations need to be made. The use of this calibration plate also implies the need for a sensitivity joy-stick control for moving and controlling the

* Drawing # 122 629

position of the various servo loops on the instrument. In order that the accuracy of this setting be greater than that which the astronaut is capable of performing when he is using the system an auxilliary high power eyepiece will be used for this calibration which can be rigidly mounted directly on the slide viewer. This eyepiece will be removed for normal use of the system. By this means all of the above calibration operations will be carried out under more critical conditions than those used by the operator. The above calibration reticle has precision adjustments so that it can be aligned with the system reticle which the astronaut would see in normal use. Itek is undertaking an analysis to determine the proper number of observations to be taken in order to adequately define the above corrections for an orderly rapid calibration procedure.

Assembly Alignment Procedures: Previous experience with the alignment with this kind of optical system has indicated that a carefully planned systematic alignment procedure must be followed. The usual alignment procedure such as used on an optical bench of centering and assembling the system element by element is not really practical in a system which is mechanically complex in its alignment. The ordinary step by step alignment procedure means that the system would have to be assembled as a whole and that the replacement of any element would probably imply the realignment of all succeeding elements. Therefore, we have made it a standard design practice to align the system on a modular basis. This means that a special assembly fixture is used to preadjust groups of optical elements which are then installed on a rugged optical bench structure. The modules will thus conform to standard dimensions and will be interchangeable with a minimum of field alignment. The principle adjustments which are made in this way are those of centering the optical components on a module so that the optical axis of the module is placed within predetermined tolerances to a standard dimension. In some cases, it will be necessary to focus the module, that is, move it in an axial direction along the optical bench. In line with this concept, most of the optical axes of this system is aligned with respect to a precisely machined key-way running throughout the system. The key-way was chosen over other means for centering modules mainly because of ease of fabrication and checking straightness as well as providing a mechanically simple scheme which means that each module can be designed relatively independently from its neighbors. Each module is attached by means of a semi-kinematic joint. The detailed arrangements of the pads vary from module to module according to individual requirements but the general scheme and philosophy is the same, namely, each module is attached to a flat surface by three pads of relatively small area. The pads are machined from bases which are relatively massive. Therefore, it is relatively difficult to induce bending moments into the bases of the modules during the attachment process. A further advantage of this construction procedure is that in cases of critical alignment, it is possible to correct machining tolerances by scraping on the above pads. Since three point suspensions are in some cases slightly unstable, the steady screw system is also applied. This scheme has proven successful in the construction of many optical instruments and provides most of the advantages of kinematic design and eliminates some of the disadvantages due to unstable configurations.

Location of Target Coordinates: A coherent system of measuring X-Y coordinates in the plates are a fundamental importance in designing the system. By coherent we mean that the system of the above mentioned test plate is used to calibrate each X-Y positioner in the system and also the measuring engine or coordinate on graph which used to measure the X-Y locations of targets in the diapositives. The X-Y calibration plate and the target plates use the same kinematic locating system which is schematically shown in Figure 5. This system consists of three threaded metal inserts on each slide frame. One of these inserts fits in conical hole and serves as an X-Y locator in the

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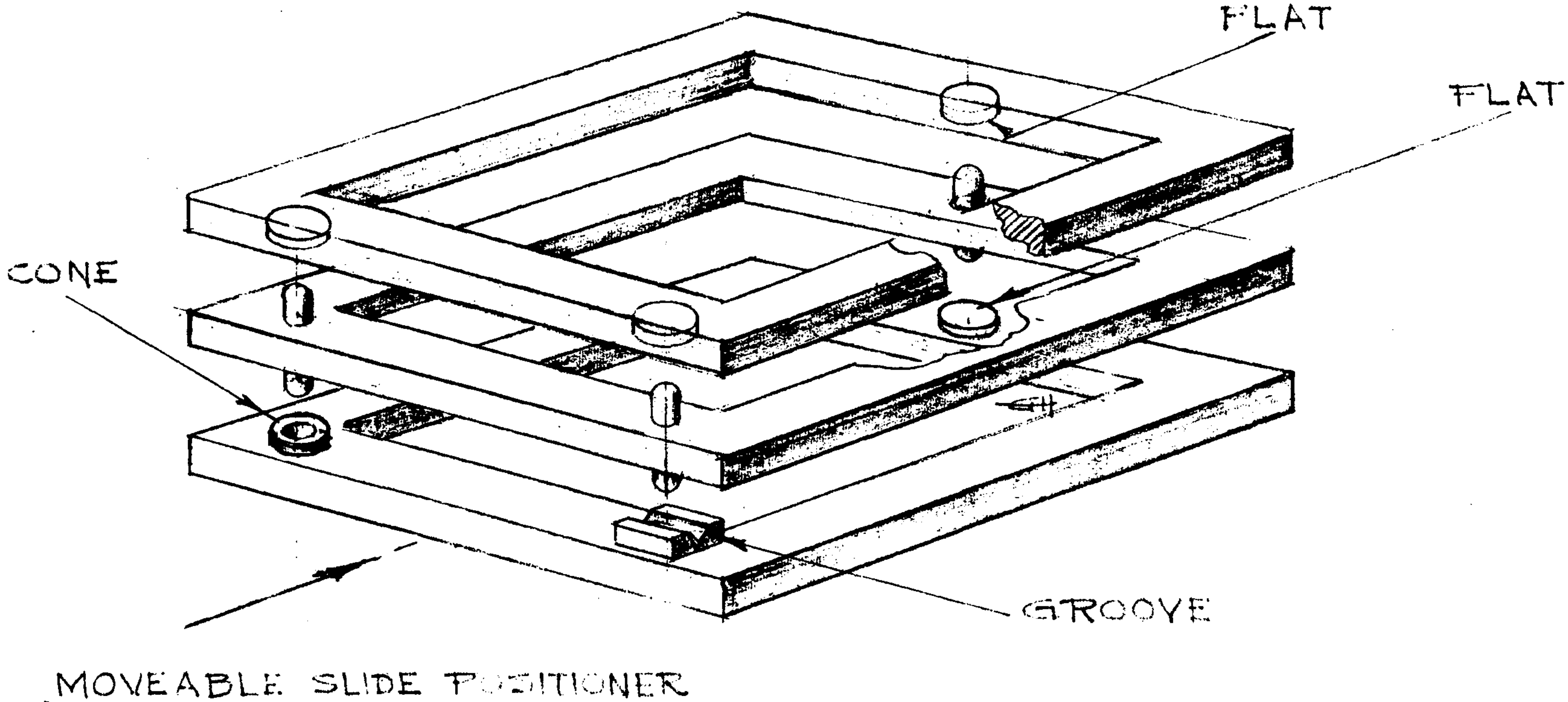

SLIDE MOUNTING KINEMATICS

Figure 5

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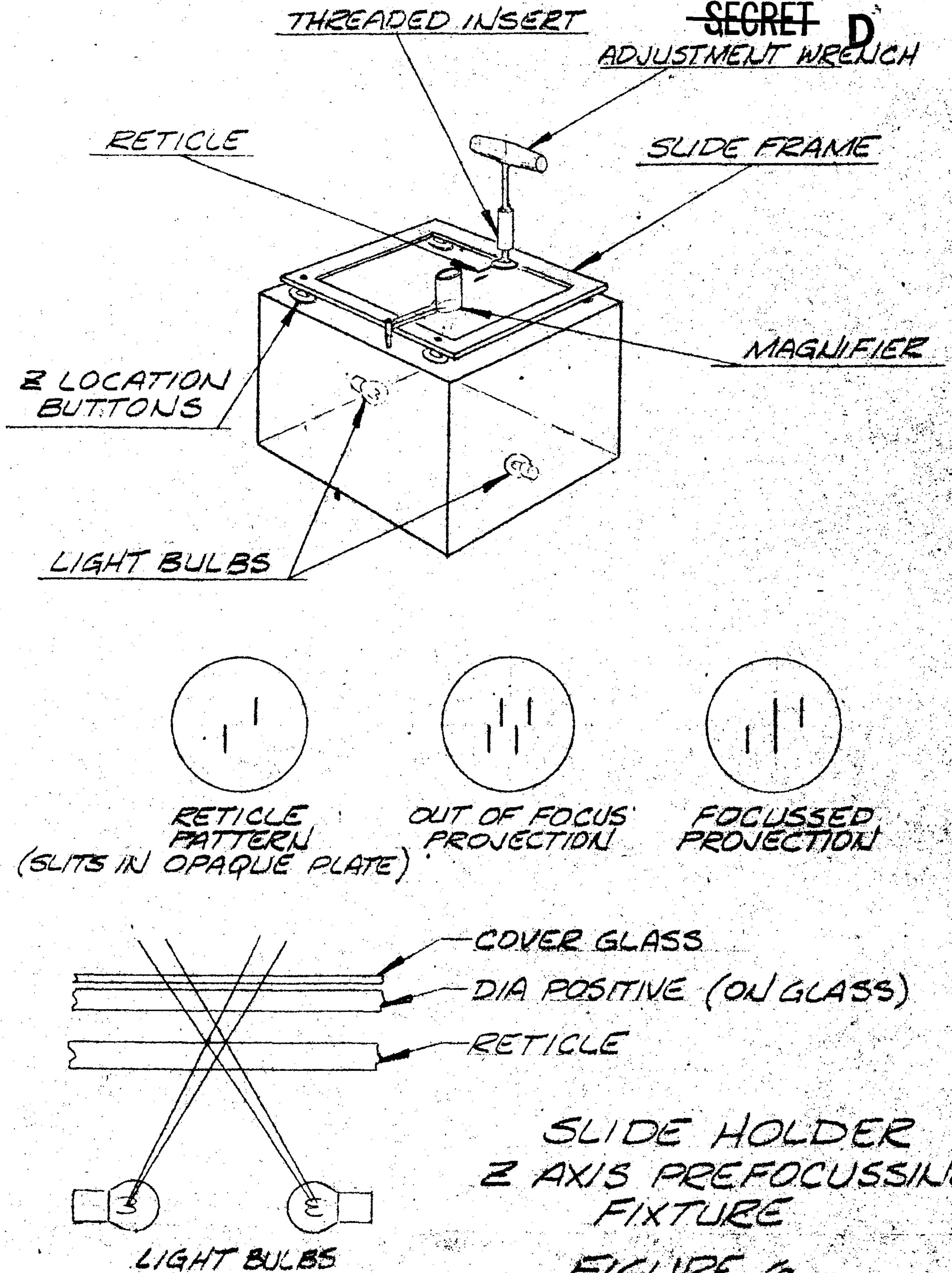
slide with respect to the slide positioner. A second insert fits into a grooved hole and locates the plate in an angular way in the X-Y plane. The third insert engages with a flat pin on the positioner and therefore, locates the slide in the other plane. The slide positioner, as a whole, pushes the slide up against the three flat pads on the fixed portion of the slide positioner. Therefore, by use of a completely kinematic approach in the slide positioner in its engagement with the slide, each slide as it is handled by each slide changer will repeat its position within a very close limit. Similar positioning schemes have held position limits as small as two microns.

Target Focus Setting: The same metal inserts are also used to assure the best focal plane for each slide. Each insert is threaded and engages with a special wrench so that the height of each slide can be carefully preset on a suitable alignment fixture. The scheme we recommend is schematically shown in Figure 6 and is adapted from a technique for calibrating aerial cameras which has been in use for many years. The scheme consists of projecting the images of fine slits from two light bulbs onto film surfaces. The slit images are positioned in such a way that when the observer looks at them through an appropriate magnifying glass he sets the threaded insert through the slide so that two lines line up opposite each other and become one straight line thereby taking advantage of the eye's vernier acuity. By this means it is possible to perform alignments one order of magnitude more sensitive than would be indicated by consideration of the slit images themselves. The fixture contemplated here has the further advantage that all adjustments of the fixture are arranged so that the operator has no other critical task to perform than turning the three focusing screws of the threaded inserts on each side.

Performing this focusing operation optically rather than mechanically corrects for the refractive index of the plate as well as its thickness. This is necessary because the thickness variations between glass plates exceeds



SLIDE HOLDER
Z AXIS PREFOCUSSING
FIXTURE

FIGURE 6

our depth of focus allowance for this particular item. In summary of the foregoing it should be obvious that the full capability of the slide handling and positioning system can only be completely exploited when the above alignment and assembly techniques are followed and that we are convinced that careful consideration should be given to having Itek help set up the slide target measuring and assembly operation so as to assure proper operation of our equipment and full compliance with the ultimate customer's specifications.

System Installation Procedure: The entire slide viewing and eyepiece system consists of several major subassemblies. These are, beginning from the eyepiece: The eyepiece box consisting of the beam splitter and optical selector which is mounted on a pedestal and a foundation ring. Two slide viewing subsystems consisting of two elevators separately demountable with two foundations, a main box frame with separate foundations which carry the slide transport and X-Y positioner. The light source and power supply group which is mounted on another foundation and finally the optical tower which contains all of the major optical elements of the system in one group. There are two slide viewing systems for each eyepiece. By breaking down the assembly in these large blocks we reduce the weight of any one block to a manageable value and make the shipping operation easier than if the entire unit were sent assembled. The entire duplex system described above is 9100 pounds.

The general philosophy to be followed in the erection of this equipment is as follows: Each slide viewing system will be assembled on the floor at Itek in approximately the same configuration as it will have in the Philadelphia site. In preparation for shipping, the equipment will be dismantled systematically and critical dimensions will be recorded so that when reassembly is performed in Philadelphia the same alignment conditions and stress conditions within the structure will occur as during the original construction. The principle alignment problems to be involved are those associated with duplicating the exact mounting geometry with the foundation between Philadelphia and Itek. The above major subassemblies will be attached to foundation plates usually made up of eye beam weldments by means of pads of carefully selected areas. When the system is disassembled at Itek, the foundations will be exposed; before dismantling of the foundations critical dimensions will be recorded. This will consist of two kinds of dimensions. The X-Y dimensions will be controlled by means of templates or trams so that the exact relationship of the foundation plates can be registered and duplicated in a different location. It is expected that the floor surfaces will not be flat either at Itek or Philadelphia so a leveling operation be performed on these foundation plates. The foundation plates can be grouted into the correct X-Y location by means of templates. At Itek the vertical coordinate of each mounting pad will be determined using a precision level. The precision, attainable by this method is of the order of a thousandths of an inch in elevation. Upon reassembly at Philadelphia shims will be added to each mounting pad to duplicate the level readings obtained at Itek. Therefore, the exact foundation geometry will be duplicated from one site to the other. We believe that this scheme is simple and straight forward and will be sufficiently accurate as long as the floor deflections in both sites are small compared to the alignment accuracies sought. While this scheme will insure stress free reassembly of the equipment in Philadelphia, residual differences in height from one slide viewing system to the other and to the eyepiece pedestal may occur and can be easily accommodated by the adjustments provided in the relay optical system as described in that design report. When installing this same equipment at Vandenburg Air Force Base, it is necessary only to use a different foundation plate for the eyepiece pedestal because of the difference in cabin dimensions between that facility and Philadelphia.

No changes will be needed for the slide handling systems themselves because of the relay optical system flexibility.

System Reassembly: Care must be taken in the reassembly of this system because there is insufficient ceiling height in the cabin test area to move the slide viewing system with a crane from above. Therefore, Itek requested permission from General Electric to use the adjacent room called the "high bay area" where there is a thirty foot overhead clearance and a ten ton hoist available for the primary re-erection of the instrument. It is expected that the modules will be received in the "high bay area". The main box will be unpacked and set up. The crane will be used to install the optical system which we call the optical tower onto the main box frame in this area. The box frame will be equipped with temporary wheels so that it can be rolled into the cabin test area with a minimum of difficulty. As described above, the box frame foundation will be installed in the cabin test area after installation and location of foundations.

The first assembly task in the cabin area is to install the eyepiece column and the eyepiece box on top of it so that the eyepiece exit pupil will be adjusted with respect tothe cabin for the correct dimensions. Adjustments are provided on the top of the column so that the eye point can be moved anywhere within a cube approximately two inches on a side within the cabin. Once the eyepiece column assembly is installed and properly checked out for location, it is possible to wheel in the box frame with the optical tower and install it on the prealigned foundations. The height of this assembly is such that it may interfere with some of the fluorescent lighting fixtures in the cabin test area. Therefore, it may be necessary to temporarily remove some of these fixtures during the moving operation, and in one case of the slide viewing system which is mounted directly under the air conditioner, it may be necessary to remove one or more fixtures. After the above installation procedure, it will be necessary to assemble the relay optic boxes on top of the optical tower. When this is done, the optical path will be closed and it would be possible to begin optical alignment of system. However, it would be preferable to complete the assembly of the remaining hardware before this is done to avoid any possible accidental dislocations of equipment. After the above operations, the slide elevator foundation plates will be installed. It is possible with our present thinking that only the elevator foundations will interfere with the above moving operation and therefore, might not be necessary to remove the light source foundation for this installation procedure. The light source and power supplies are mounted to an intermediate table structure which is placed within the box assembly on the prepared foundations. It may be necessary to correct the position of the light source assembly with respect to the box during this assembly operation. After the final location is established, the light source and light source table will be pinned to the foundation. Installation of the elevators may present some rigging and moving problems that are difficult to anticipate at this time. However, we feel that there will be no unusual problems not commonly encountered by machinery movers in every day life. Each elevator weighs approximately one thousand pounds and rests on a relatively narrow base. It will be relatively straightforward to move these elevators on piano dollies around the area. However, two of the elevators must be installed in relatively congested areas as shown on the site plan drawing number 908 887. It will probably be desirable to install a temporary chain hoist or block and tackle above the elevators to steady them while they are being shifted from the dolly. The details of this moving operation will be worked out later or between Itek and General Electric. Because of the above moving operations, it will not be practical to completely prealign the elevator foundations for final dimensions. We believe it to be desirable for safety sake to check the elevator foundations at the same time as the precise leveling of the main foundation is being carried out. However, it will be necessary to remove elevator foundation during the above installation with the main instrument. Scribe markings will be placed on each elevator and the box frame associated with it so that final dimensions of assembly can be duplicated between Itek and Philadelphia. The adjustment will probably be performed by peel shims under the elevators or the elevator vibration mounts if those are to be used. After installation of the elevators, it will be necessary to complete their assembly by installing the connector frame work at the top of the elevators which is needed to provide a stable structure. This same structure is used to support the skin panels enclosing the box frame and slide handling system. These panels should not be installed until preliminary optical and mechanical alignments have been performed. After the above major mechanical assembly has been performed it will be possible to begin detailed assembly of the system such as installation of cable runs and final optical alignment. These subjects will be treated later in the installation manual as requested.

2. Technical Requirements

Computation Correction Required for the Slide Viewing Subsystem, Problem Description: This paragraph summarizes the results of a preliminary study made to determine the method of applying computation corrections to the SVS. These corrections are made external to the SVS to compensate for deviations from nominal relationships, so that the requirements of TR424 can be met. Specifically, the corrections are applied to the analog voltage servo command signals for the X-Y positioner, spherical zoom lens, cylindrical zoom lens, image rotator, intensity modulator and iris. The desired control parameters for these components are determined from the distortions which are to be applied to the slide being viewed. A modified set of control parameters is generated by the computer such that the modified parameters in combination with component errors result in the desired parameters.

Two general types of corrections are considered. The first is concerned with the relationship between the servo command signal and the parameter which is to be controlled. This relationship is specified to be within a certain accuracy limit which, in general, cannot be met without corrections applied by a computer. In theory, if an exact calibration curve were available, a parameter could be controlled to any desired degree of accuracy by the computer.

The second type of correction is to compensate for lateral image shift. This is a shift of the optical center of the image as seen at the reticle when the various control parameter settings are changed.

For both types of corrections there will be a random error due to the finite limit of precision possible in measurements for obtaining calibration curves and also due to the repeatability of the hardware operation. Since this error is random, it cannot be compensated, and thus it represents the theoretical limit of performance which can be achieved. In addition there will be a fixed residual error due to the finite number of data points taken during calibration and also due to approximations made by the computer.

METHOD OF SOLUTION

The overall approach to providing computation corrections is shown on drawing 140 350. The desired control parameters are:

K	K-mirror image rotation angle	X_{RE}, Y_{RE}	Rhomboid error
α	α-anamorph (1/2X) rotation angle	X_{ZE}, Y_{ZE}	Zoom lens error
X	X coordinate of optical axis	$X_{\alpha E}$, $Y_{\alpha E}$	α anamorph error
Y	Y coordinate of optical axis		
Z	Spherical zoom lens magnification	$X_{\beta E}$, $Y_{\beta E}$	β anamorph error
β	β-anamorph (2X) rotation angle	X_{KE}, Y_{KE}	K-mirror error
		ΔX, ΔY	Desired position of optical axis at film

The computer generates the corresponding modified servo command voltages K', α', X', Y', Z' and β'.

A linear model of the SVS is used where the X, Y coordinates of a point at the output of a component are related to the coordinates of the corresponding input point by the transformation matrix (T_z, T_α, T_β, T_k) for that component. At the output is added the lateral image shift contributed by that component.

Compensation for lateral image shift is accomplished by computing a position offset, Δ X and Δ Y, such that the combination of this offset plus the lateral image shift contributions from the various components will result in zero shift at the reticle. The equation for computing this offset has the following form:

$$\begin{pmatrix} O \\ O \end{pmatrix} \begin{pmatrix} X_{KE} \\ Y_{KE} \end{pmatrix} + T_K \left[\begin{pmatrix} X_{\beta E} \\ Y_{\beta E} \end{pmatrix} + T_\beta \left(\begin{pmatrix} X_{\alpha E} \\ Y_{\alpha E} \end{pmatrix} + T_\alpha \left\{ \begin{pmatrix} X_{ZE} \\ Y_{ZE} \end{pmatrix} + T_Z \left[\begin{pmatrix} X_{RE} \\ Y_{RE} \end{pmatrix} + \begin{pmatrix} \Delta X \\ \Delta Y \end{pmatrix} \right] \right\} \right) \right]$$

$$T_K = \begin{pmatrix} \cos K & \sin K \\ -\sin K & \cos K \end{pmatrix} \qquad T_Z = \begin{pmatrix} Z & O \\ O & Z \end{pmatrix}$$

$$T_\beta = \begin{pmatrix} 2\cos^2\beta + \sin^2\beta & \cos\beta \sin\beta \\ \cos\beta \sin\beta & 2\sin^2\beta + \cos^2\beta \end{pmatrix}$$

$$T_\alpha = \begin{pmatrix} \cos^2\alpha + 2\sin^2\alpha & -\cos\alpha \sin\alpha \\ -\cos\alpha \sin\alpha & \sin^2\alpha + 2\cos^2\alpha \end{pmatrix}$$

Although the specification for lateral image shift applies only to the anamorphic lenses and K-rotator, the correction required for the X-Y positioner (including spherical zoom lens) is also termed lateral image shift because of the similar correction procedures. This correction procedure is complicated by the hardware configuration which places the spherical zoom lens on the rhomboid arm. The runout contribution from the upper bearing joint of the rhomboid arm is functionally separated from the rest of the rhomboid arm by the magnification of the zoom lens. Therefore, the total lateral image shift of the rhomboid arm will be a function of the zoom lens magnification command. Also, the lateral image shift contributed by the zoom lens itself will have to be modified by a rotation of coordinate axes as a function of the angular position of the upper bearing joint.

During final test of the SVS, sufficient calibration data must be taken for storage in the computer so that corrections can be applied to the required degree of accuracy. These data are necessarily in the form of tables which reflect the measurements under a discrete set of parameter settings. However, the computer must interpolate between the data points, and it is desirable that the computer operate on analytical expressions rather than data tables. For these reasons it is necessary to fit analytic expressions to the data. If the form of the expression is reliably known, only a few data points are required to completely define the calibration function. Conversely, if the form of the expression is not known, much data must be taken, and for those components a polynomial approximation seems reasonable. Some of the components have characteristics which are most effectively estimated with exponentials or sine waves with harmonics. Tables 1 through 5 show the type of calibration data that will be supplied.

Two components, the intensity modulator and iris, which also require compensation are not shown on the drawing since they do not enter into the lateral image shift calculation. However, the parameter calibration and compensation procedure for these components is the same as for the ones shown.

In summary, the total correction procedure consists of three basic steps:

1. SVS testing to obtain calibration data
2. Estimation of these data with analytic functions
3. Computer computation as shown on drawing 140 350

X-Y POSITIONER CALIBRATION

X' (volts)	Y' (volts)	Z' (volts)	X_{RE} (inches)	Y_{RE} (inches)
-49.971	-48.993	-49.823	+0.0032	-0.0009
|	|	|	|	|
+50.003	+49.063	+49.876	+0.0007	+0.0010

405 - point table.

9 values of X'

9 values of Y'

5 values of Z'

Estimate with the following functions:

X_{RE} = fifth-order polynomial function of X'

+ fifth-order polynomial function of Y'

+ third-order polynomial function of Z'

Y_{RE} = Same

Table 1

SPHERICAL ZOOM CALIBRATION

Z' (volts)	Z (magnification)	X_{ZE} (inches)	Y_{ZE} (inches)
-50.003	0.090	+0.0015	-0.0010
|	|	|	|
|	|	|	|
|	|	|	|
|	|	|	|
|	|	|	|
|	|	|	|
+49.982	0.700	+0.0020	+0.0005

16 - point table. Estimate with the following functions:

Z = exponential + fifth-order polynomial function of Z'

X_{ZE} = fifth-order polynomial function of Z'

Y_{ZE} = fifth-order polynomial function of Z'

Table 2

K- ROTATOR CALIBRATION

K' (volts)	K (image degrees)	X_{KE} (inches)	Y_{KE} (inches)
-49.997	0	+0.0008	-0.0011
|	|	|	|
|	|	|	|
|	|	|	|
|	|	|	|
|	|	|	|
+49.987	360	-0.0010	+0.0014

16-point table. Estimate with the following functions:

K = third-order polynomial function of K'

X_{KE} = (Fourier components through fifth harmonic) function of K'

Y_{KE} = (Fourier components through fifth harmonic) function of K'

Table 3

INTENSITY MODULATOR CALIBRATION

T' (volts)	T (transmission)
-50.020	0.02
|	|
|	|
|	|
|	|
+49.999	1.00

8-point table. Estimate with the following function:

T = exponential + third-order polynomial function of T'

Table 4

IRIS CALIBRATION

I' (volts)	I (millimeters diameter)
-50.002	2.00
+50.010	4.00

8-point table. Estimate with the following function:

I = third-order polynomial function of I'

Table 5

(1/2 X) ANAMORPH CALIBRATION

(Table for α anamorph will be similar)

α' (volts)	α (degrees)	$X_{\alpha E}$ (inches)	$Y_{\alpha E}$ (inches)
-49.998	0	-0.0010	+0.0010
⋮	⋮	⋮	⋮
+49.972	360	+0.0015	+0.0020

16-point table. Estimate with the following functions:

α = third-order polynomial function of α'

$X_{\alpha E}$ = (Fourier components through fifth harmonic) function of α'

$Y_{\alpha E}$ = (Fourier components through fifth harmonic) function of α'

3. Hardware Description and Operation

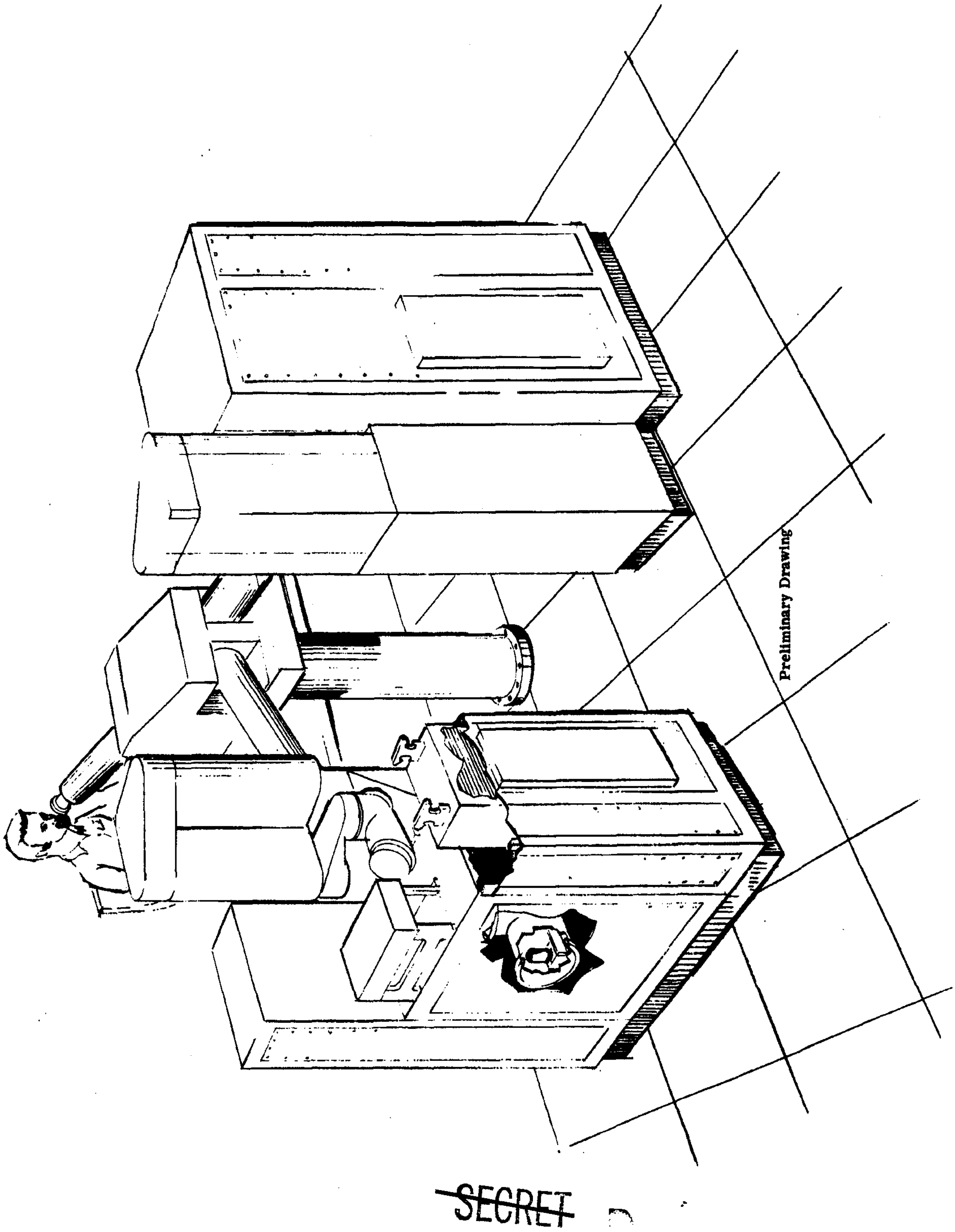
Figure 7 is an artist's concept of one slide viewing system consisting of the eyepiece, pedestal, subassembly and two slide handling subassemblies. The hardware has been completely described in the preceding design reports also many system considerations have been discussed above in Sections 1 and 2. The interface document number 344-68-178 describes all of the input and output conditions of the system. In paragraph 1 the overall system calibration philosophy was discussed. Therefore, only those modes of operation will be described here which have to do with non-computer input. It will be necessary to operate this system off line for servicing, for calibration and during installation before final computer software if connections are available as well as during construction at Itek. For this purpose a test and checkout console will be provided to assist in necessary operations. The operation of this console is described in Reference 1.

4. High Risk Areas

In AGE equipment such as this system areas of high risk should be and are, rare. One potential risk mentioned in the elevator mechanism counterweight has been remedied by means of a reinforced motor housing while the only other hazard existing in the system is that of 110 volt and 28 volt electrical wiring. Standard wiring practices will be followed according to TR424 which will insure no personnel hazard. Conservative design practices have been followed so that risk or failure to accomplish the mission of this system is very low. For these reasons we have regarded the risk areas in the previous design reports to be mostly non-existent.

5. Specifications

Specification TR424, 16 Feb 1968, all paragraphs relevant SDR. DIN 50332-130-1 (9303-68-X39) (Attachments 1, 2, and 3).



Preliminary Drawing

Figure 7

6. Reply to Specifications of Paragraphs

1.0 The slide viewing subsystem has been described adequately in the foregoing documents and satisfies the objectives of the paragraph for scope. Figure 9.

2.0 The applicable documents cited here have been followed in the foregoing design reports with the exception of some details of the illustrations.

3.0 Requirements: The requirements of Paragraph 3 have been discussed in detail in the preceding design reports. Therefore, only those characteristics which have not been previously discussed will be mentioned here.

3.1.1.1.3 Remote Controlled X-Y Linear Positioner - In addition to the parameters discussed in the design report on the X-Y positioner above, it is necessary to budget the planimetric error described in this paragraph among a number of components and physical effects. A preliminary error budget has been drawn up and is shown in the accompanying table and a set of priorities has been assigned for investigating the most prominent errors in this system. As mentioned in the tradeoff analysis, the primary ingredient in attaining the design accuracy in this system is the use of computer correction for systematic errors in this system. Therefore, it becomes the task of the error budget to sort out those effects which are systematic and those effects which are random or uncontrollable. The root sum square of the uncontrollable random effects

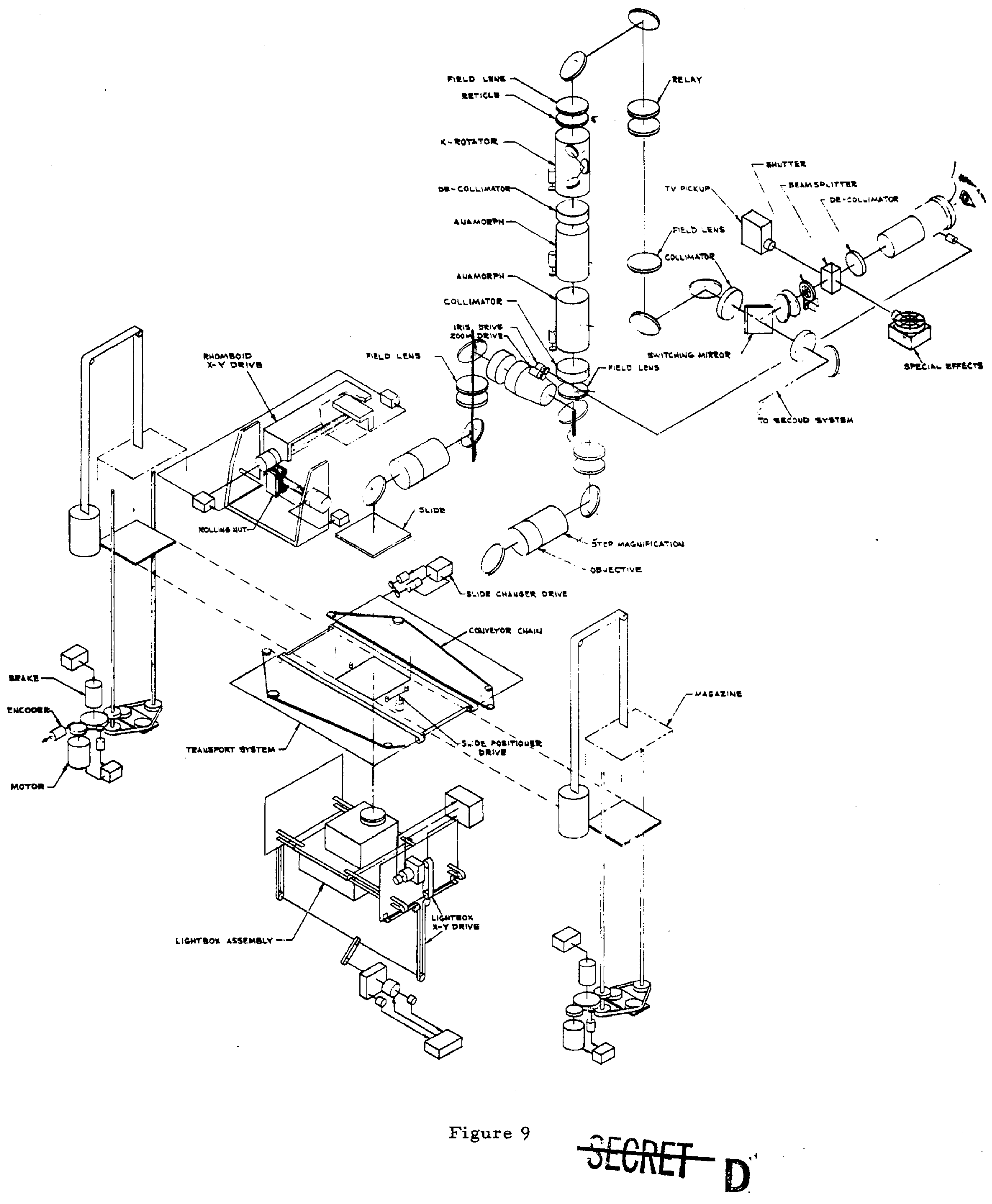

FIELD LENS
RETICLE
K-ROTATOR
DE-COLLIMATOR
ANAMORPH
ANAMORPH
COLLIMATOR
IRIS DRIVE
ZOOM DRIVE
FIELD LENS
RELAY
SHUTTER
BEAMSPLITTER
DE-COLLIMATOR
TV PICKUP
FIELD LENS
COLLIMATOR
SWITCHING MIRROR
SPECIAL EFFECTS
FIELD LENS
TO SECOND SYSTEM
RHOMBOID X-Y DRIVE
ROLLING NUT
SLIDE
STEP MAGNIFICATION
OBJECTIVE
SLIDE CHANGER DRIVE
CONVEYOR CHAIN
MAGAZINE
BRAKE
ENCODER
MOTOR
TRANSPORT SYSTEM
SLIDE POSITIONER DRIVE
LIGHTBOX ASSEMBLY
LIGHTBOX X-Y DRIVE

Figure 9

then, will be applied to the tolerances of this paragraph, the reproducibility of setting in position is to be .0004" over a time span of about 10 minutes root sum square, while the positioning error after computer correction on a long term basis will not exceed .0059" error root sum square. The X-Y positioner may possess many open loop errors such as nonorthogonality of travel, curvature of travel, nutations due to periodic screw errors and so on. However, the X-Y positioner is driven by a CIC film linear potentiometer as a primary distance reference. Because the servo loop is closed through this potentiometer most of the above errors can be compensated by a servo feedback. The computer correction program described previously will correct out the systematic geometric errors to within the observational accuracy of the correction observation plus the ability of the computer digital to analog system to resolve position. Therefore, assuming the above corrections, the principle components of error in the X-Y system are those which are uncontrollable such as temperature gradients within small regions of the system or those which are random such as noise and bearing nutations of the traverse mechanism. Since the key measuring element is the potentiometer itself, its characteristics are the most important ones in determining the properties of this system. For this reason, the behavior of this potentiometer will be investigated experimentally in detail on the X-Y breadboard as well as in oven tests in order to determine the temperature coefficient of position of this potentiometer as installed in the system. If this temperature coefficient is of sufficient magnitude it may be necessary to introduce a systematic temperature correction into the X-Y position commands or perhaps into the X-Y positioner servo loop. High precision observations of potentiometer linearity will be made in order to assess the complexity of the computer correction term for this error. Therefore, the X-Y position error budget with the foregoing assumptions is made up of the components in Table one.

3.1.1.1.3.3 Command Input - See Interface Document 344-68-178.

3.1.1.1.4.1 Holder/Changer - The operation of the holder/changer has been described in the previous design report and in subsequent timing diagrams in the above interface document. The holder/changer has been mechanically designed to be completely reversible for maximum flexibility in operation. However, some internal logic is required to assure correct operation of the slide changer. Current designs of this logic permit recall of the last slide viewed unless the takeup magazine has been indexed, and also permits unloading of the takeup magazine into the supply magazine using a prearranged routine. Present logic does not permit quasi random selection of slides from one magazine to another because the holder/changer has no memory capability nor does the takeup magazine have a position indicator.

3.1.1.1.5 The manual control step magnification has been described above. The entire lower rhomboid arm must be interchanged as well as a pair of condensing lenses in the light source. These items will be

TABLE 1

Potentiometer Linearity	5 microns random (limited by observation means)
Thermal Drift of Potentiometer	25 microns (uncompensated) 5 microns (compensated) (These values to be experimentally verified)
Voltage Drift of Reference Source	4 microns (assuming 1/100 of a percent regulated voltage supply)
Errors due to Contact Potential	4 microns (based on an arbitrary assumption of 1 millivolt)
Line Noise	4 microns (based on an arbitrary assumption of 1 millivolt)
Reproducibility of Slide Positioner	3 microns (based on previous experience with somewhat similar kinematic supports)
Slide Positioner, Wear	3 microns (an arbitrary assumption)
Errors due to Ability to Observe the Calibration Grid Plate	5 microns (based on experience with photogrammetric grid plate observations)
Potentiometer Resolution	1/8 of a micron (Statement from CIC)
Nutations of X-Y Carriage due to Residual Runouts of Individual Ball Bearing Balls	3 microns

If the above error sources are added by means of a root sum square method the short term error in reproducing X-Y coordinate locations will be approximately 12 microns. This is a first cut figure and subsequent analysis will be performed to determine more qualified values of errors with the purpose of decreasing the sum within the budget of ± 10 microns.

color coded and numbered so as to correspond with each slide handling system in order that the integrity of the above system calibration will be maintained for both magnification ranges.

3.1.1.1.6 Remote Controlled Spherical Zoom - The details of the spherical zoom system have been described in the above design report. However, this component has the largest impact on system reliability of any component presently known. The current choice of zoom lens is partly based on availability within the time range of this contract and known minimum or mechanical deficiencies require that the zoom lens be periodically maintained by a factory representative (Angenieux) as well as Itek for assembly into the module. Our present estimate of the service life of the zoom lens between service intervals is approximately three months. This will be verified by an experimental life test investigation.

3.1.1.1.7.3 Lateral Image Shift Tolerances - The above error correction routine using the General Electric computer complex will be used to correct lateral image shifts due to anamorph system and K-rotator nutations to within two arc minutes as viewed by the eye through the eyepiece. Itek will provide primary calibration data tables upon delivery of the equipment while the above mentioned calibration routines will permit easy updating of these calibrations at the General Electric facility when such updating becomes necessary due to replacement of modules or modifications made after delivery of the system.

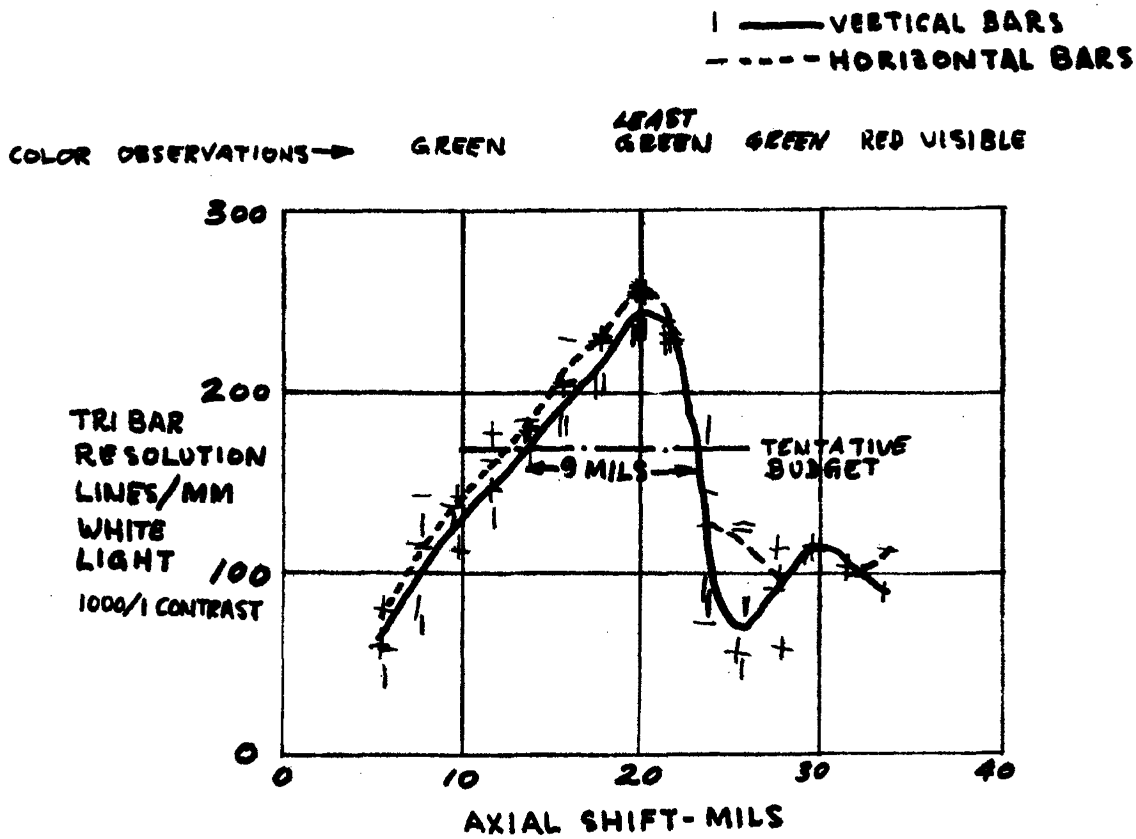
3.1.1.1.8 Quick Change Reticle Manual Controlled - In order to practicably comply with this specification, it is necessary that special AAE tooling be used to center the reticles in their interchangeable mounts.

3.1.1.1.9 Image Combiner - (Attachment 1 - Modification) The image combiner is designed for equal intensities of reflected and transmitted light. In order to satisfy the mirror symmetry of General Electric special effects equipment, it is necessary that the image combiner be able to be assembled in either of two orientations which will be determined by keyways. Access to the image combiner will be through windows in the side of the eyepiece box as shown in drawing number 908 863 which gives principle image and focal data.

3.1.1.1.11 Output Eyepiece - Detailed design of the relay optical system has revealed the fact that in addition to changing from the temporary eyepiece to the AVE eyepiece other optical elements will have to be replaced or shifted in order to accomplish the retrofit operation. The details of this replacement have been described in the foregoing design report.

3.1.1.1.11.2 The exit pupil of this system will be continuously varied from approximately four millimeters to two millimeters in diameter, controlled by means of a motor driven diaphragm on the zoom lens. It is presumed that this iris zoom will be commanded via the interface from the astronaut's control knob and will, therefore, be independent of the actual setting of the zoom lens (needed both for a two to one

~~SECRET~~ D



DEPTH OF FOCUS TEST
2.25x MAGNIFICATION SYSTEM
3 OBSERVERS

Figure 8

~~SECRET~~ D

zoom range and for the correction of variable slant range in photography and mission). The output resolution characteristic as well as other optical parameters will be exhaustively described in the results of the image analysis task to be reported later. It is necessary that the limiting resolution also occur through a useful depth of focus since there is no automatic focusing provisions built into this system. The data shown in Table two describes the preliminary vertical (Z) error budget for the system. The depth of focus is based on experimental observation through the optical system, the data having been taken by three different observers. Figure 8.

3.1.1.1.12 Field Curvature and Focus Adjustment - The field curvature of the slide viewing system will be equal to or less than that observed in the image evaluation test bench.

3.1.1.1.13 - Optical Bench Assembly - All optical components will have high efficiency transmission coatings and all mirrors will use high reflectivity multi-layer coatings for maximum transmission so that the real output intensity will exceed one thousand foot lamberts in the eyepiece.

3.1.1.1.13.6 Image Inversion and Reversion - Because each slide handling system has a different angular orientation with respect to the eyepiece it will be necessary that the servo position of each image rotation device be established on the site by means of a suitable zero offset adjustment. The polarity of the image as seen at the eyepiece is identical with the image seen in the slide holder positive as viewed from above. This polarity is consistent with diapositive prints viewed through their base which are photo-reversal contact prints from second generation positive pictures of targets.

3.1.1.1.14 The secondary image is introduced from a second slide handling system by means of an image selector as described in the foregoing design reports. Specifications for primary and secondary systems are identical.

3.1.1.1.16 Facilities Installation Restraint - The installation of the system in the General Electric facility has been described briefly in Section 1.

3.1.1.2 Secondary Performance Characteristics - Interface characteristics of this system are described in document number 344-68-178, General Electric drawing 7110477 and Itek drawing number 908887.

3.1.1.2.9 All commanded parameters shall be resettable on command to any value in the operating range in less than one second with the exception of the shutters and the image selector. Fast positioning is possible but not required on the intensity modulator anamorphs and the K-rotator. Fast positioning of the present zoom lens will be

TABLE 2

Diapositive Flatness	±2.4 mils
Vertical Runout of Rhomboid Arm and Zoom Lens Focus Tracking	±1 mil
Allowance for Ability to Focus the System	±2 mils
Slide Holder Focus Uncertainty	±1 mil
Temporary (arbitrary) Allowance for Thermal Expansion	±2.8 mils

The root square sum equals 4.5 mils, consistent, therefore, with approximately 180 lines per millimeter at high contrast or something in excess of 90 lines per millimeter, low contrast.

limited by means of a slip clutch and possible also an electric integrator to no faster than 7/10 of a second for a full range command. A two to one zoom setting will be possible within 1/2 second. The reset capabilities of the X-Y positioners are limited to one second by dynamic characteristics.

3.1.1.2.10 Electronic Packaging and Connectors - These items are described in the above design reports and interface document.

3.1.2 Operability

3.1.2.1 Reliability - The system MTBF will be determined by mutual agreement between General Electric and Itek about allowable and practical limits of degradation of functional requirements. In general, it has been assumed that the MTBF can be met by means of a reasonable periodic maintenance schedule.

3.1.2.2 Maintainability - The modulator construction and details of assembly have been described above. It is assumed that maintenance shall be sufficiently rapid so as to satisfy this requirement of three to one.

3.1.2.3 Useful Life - In arriving at useful life estimates consistent with a five year period, it has been uniformally assumed that replaceability maintenance of low life components or modules will be used. The zoom lens module is the most notable example of this practice.

3.1.2.4.1 Normal Operating Environment - The SVS is being designed to operate under ambient temperatures of 75°F plus or minus 10 degrees with ground level laboratory environment humidities and pressures. Structural elements are being designed with natural frequencies of 60 cycles and above which will provide adequate rigidity for both servo mechanisms and normally encountered ambient vibrations. It is not possible to design a complex optical system such as this one to be operable under all possible combinations of the vibration environment described in this specification. However, as a practical matter, it is extremely unlikely that any massive block such as used in this facility is capable of vibrating at 10 to the minus 4 inches double amplitude for all frequencies in this range simultaneously, that is, the slide viewing system would only have difficulty if a structural resonance in it happened to coincide with a similar frequency in the environment. It is believed that a practical solution to this problem (if it should exist later) can be best arrived at on an experimental basis in the General Electric facility, by such means as identifying the source of vibration excitation and reducing or removing it by vibration isolation if necessary.

3.1.2.4.2 Normal Conditions Non-Operating - Exposed surfaces will be coated and all modules will be suitable packed for shipment by means of padded van or air freight for the conditions described.

3.1.2.7.4 Personnel Safety - Details of individual component safety problems have been discussed in foregoing design reports. In general, warning signs will be placed near hazards so service personnel will be warned. Interlocks will be provided so that moving elements will be immobilized during service. However, cheater switches may be needed to be used by service personnel in order to perform some service functions such as bulb changing and rhomboid arm changing. The entire slide handling system will normally be totally enclosed for protection against dust and dirt temperature gradients as well as for personnel safety.

3.2.1 Interface Requirements (Mechanical) - Mechanical interfaces have been described either in individual drawings or previous design reports. The general philosophy on semikinematic mounts have been described in paragraph 1. All adjustments will be positively locked either by counter screws, suitable clamping devices or use of locktite. The principle subassemblies described will be removable independently. These are the light source, the zoom module, the anamorph module, the reticle, the image combiner and the step magnification. As described above, all principle optical elements are fastened to one optical bench assembly which is now called the optical tower because of its vertical orientation. Surfaces near the optical axis or path will be treated by non-reflecting black paint or other surface treatment.

3.2.1.1 Detailed Interface Definitions - System power requirements are described in document number 344-68-178 and previously mentioned in other interface documents.

3.3.3 Materials, Parts and Processes - Materials, parts and processes will be in accordance with DR1165 wherever applicable.

3.3.4 Fungus - It is not possible to protect optical surfaces against attack by fungus when environmental conditions are suitable. As a rule, fungus danger occurs when relative humidity exceeds 80 percent simultaneously with a temperature in excess of $80^{\circ}F$. This combination of environmental variables does not occur with sufficient frequency in Philadelphia or Vandenburg Air Force Base, California, so that fungus attack of optical elements is likely to be a serious problem.

3.3.5 Corrosion Resistance - Exterior surfaces will be painted in accordance with General Electric Specifications ST9026, ST9002, entitled (106 Sub-contractor outside envelope paint specification). Surface treatment for the system, in general, will consist of painting, plating, iriditing, anodizing, and use of corrosion resisting metals in order to satisfy this paragraph.

3.3.6 Interchangeability and Replaceability - Itek standard part numbering procedures will be used to identify interchangeable subassemblies and assemblies and will be marked according to DR1165.

3.3.7 Workmanship - The practices of DR1165 will be followed for workmanship as well as Itek practices, for other mechanical procedures.

3.3.8 Electromagnetic Interference - Memorandum 344-68-112B describes the general practices to be used in system electrical construction in order to avoid electrical magnetic interference.

3.3.9 Identification and Marking - Assembly markings shall be indelible in accordance with Section IV, paragraph A, in DR1165.

3.3.10 Storage - The disassembled system will be capable of performance after one year in suitable storage containers containing desiccant and assuming a sheltered environment. Protective coatings for exposed metal surfaces will be used if storage is required.

4.0 Quality Assurance Provisions - The slide viewing system will be available during assembly at Itek for verification inspection of the following features. Maintainability, transportability, personnel safety, general design features, grounding, shielding, interchangeability, replaceability, workmanship, identification, marking. A file of analytical design data and component data from component manufacturers will be available for review in order to support reliability, useful life, schematic arrangement, selection of specifications and standards, materials, parts and processes, fungus as mentioned above, corrosion resistance and storage, if storage is to be required as a change in scope of this job. Individual modules will be calibrated during assembly and the calibration data will be presented for review for conformance to primary and secondary performance characteristics of this specification.

4.2 Acceptance Test - Acceptance testing shall consist of demonstrations at the Itek facility that performance requirements have been met according to the test plan prepared by Itek and submitted for review by General Electric.

4.2.3 Performance Tests - The philosophy of performance testing will be to generate test inputs in the T & C console which will illustrate that the system is capable of resolving the input commands and performance characteristics of paragraphs 3.1.1.1 and 3.1.1.2 of the specification, as modified by interface document number 344-68-178.

4.3 Measurements and Calibration - Standard Itek calibration procedures conform to MIL-C-45662 calibration system requirements. Calibration data of system modules will be taken in order to support and crosscheck the system calibration procedure which is performed after final assembly.

5.0 Preparation for Delivery - Paragraph 1 described the general procedure of disassembly and assembly to be followed so that the system characteristic will be minimumly altered by the disassembly and shipping process. The system will be broken down into a series of packages which can be handled in padded vans. Detailed descriptions of these processes will be made in the handling and installation procedure manuals.

7. Required Technical Analysis

Data will be made available to General Electric on an "as available" basis for review, covering the topics of reliability, useful life, schematic arrangement, selection of specifications and standards, materials, parts and processes, fungus, corrosion resistence, and storage, as requested in paragraph 4.1.1.2 of TR424. This data will be available for inspection at the Itek facility on an "as available" basis.

8. Mockups and Breadboards

Mockups and breadboards will be or have been made for the following items: The optical bench test set up, slide transport and positioner, the test slide, the 1/10 scale model of the system. A mockup of the X-Y drive, a mockup of the rhomboid arm, an X-Y drive servo breadboard, a low power servo breadboard and miscellaneous electronic breadboards for circuit development purposes.

9. Mass/Power

Current 17 April 1968 estimates of mass for one duplex slide viewing system is 4.5 tons. System input power - 15 kilowatts - peak.

10. Test Data

No data is available at this time.

11. Critical Components Specifications

No critical components or procedures are used in the system.

12. Long-Lead Procurements

Long-lead procurement items have been described in the design reports of slide subsystems. The general approach for this job is that any component whose delivery time exceeds six weeks is designated as a long-lead procurement because of the rapid project schedule. For these reasons such items as lenses, critical electrical components such as potentiometers and motors and gear heads are procured on a long-lead basis. The principle long-lead mechanical components are critical ball bearings and ball screws.

13. Critical Techniques

Paragraph 1 has described broadly the special calibration problems involved in making the system useful for its ultimate mission. The following list shows currently known procedures, standards, and descriptions of system alignment processes which are unique for this system. Standard optical tooling processes used in manufacturing subassemblies will be referred to in the design report index for each subassembly.

14. See Project Schedule

15. Document Index

See attachment

16. Subassembly Layout Drawings and Parts List Data: are submitted with those design reports. The figures included in the preceding paragraphs servo to describe the system.

17. Spare Parts

Spare parts can be specified after a spare approach is determined.

18. Meeting Agenda

See attachment