Attachment 3
BYE-69319-66
cy 1

PERKIN-ELMER EVALUATION SUMMARY

Evaluation Group Numerical Ratings
(rated on the basis of 0 to 9)

	Rating Category	Rating
I.	Performance Evaluation	6.5
II.	Development Risk	7.0
III.	Design Margin	7.0
IV.	Value Function	9.0
V.	Reliability	4.6
VI.	Operational Considerations	6.2
VII.	Effect on Space Vehicle	7.8
VIII.	Interface Definition	5.8
IX.	Master Program Plan, Design Development Plan, Qualification Plan, Integration Assembly and Checkout Plan	3.6
X.	Fabrication and Delivery Plan, AGE Design Development and Delivery Plan, Mass Properties Control Plan, Reliability Program Plan	3.4

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[redacted]

[redacted]

Albert W. Johnson
Maj. Albert W. Johnson

Leslie C. Dirks
Leslie C. Dirks

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PERKIN-ELMER EVALUATION SUMMARY

Rating Category I: PERFORMANCE EVALUATION — Rating: 6.5

Under the Performance Evaluation rating category, the contractor's proposal is evaluated from the point of view of the adequacy of his proposed design as measured against the design requirements and the completeness of the analysis and data presented by the contractor in support of his proposal.

The numerical rating of 6.5 reflects the Evaluation Group conclusion that the basic design proposed is well matched to the RFP requirements and offers excellent performance potential, but that in many areas the contractor's analysis and his presentation of the analysis and design in his proposal is only adequate. A higher score was precluded by a potential design deficiency in one film transport subassembly and a less than excellent treatment of the over-all systems analysis and focus control areas. However, the thermal design, the optical system, and the structural design and analysis were generally excellent. The following is a critique of the contractor's systems analysis and each of the five major subsystem areas. This critique discusses briefly the major factors which influenced the Technical and Operations Evaluation Group in forming its judgment in the rating category of Performance Evaluation.

SYSTEMS ANALYSIS

Design Concept - The system approach chosen by the contractor is centered around an F/3 optical system with a 60" focal length. The panoramic action is generated by rotating the entire optical system about its long axis. The choice of 120° full scan angle is justified by the contractor on the basis of a maximization of the Value Function defined in Attachment II of the RFP. The focal length and aperture selection rationale is based on a line of reasoning involving both the Value Function and the contractor's assessment of development feasibility. While the over-all contractor discussion justifying the selection of this approach to the systems problem is not presented in as much detail as might be desirable, the basic concept appears sound. The configuration is particularly well suited to the 120° scan angle in that the panoramic action is generated without a consequent impact on optical performance.

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The over-all allocation of the error budget is not rationalized in detail but appears to be based on a general approach which distributes the image degrading errors on a relatively well-balanced basis among the optical system, film, smear, and defocus. The smear and defocus budget allocations are particularly generous and result in a considerable spread between best performance and two sigma low performance. The allocation of the smear budget between the along track and cross track directions is out of balance in that it allows two sigma cross track smears of about twice the two sigma along track smears. However, when combined with the other system errors this effect does not result in appreciable asymmetry in resolution.

The treatment of the optical system surface figure and tilt and decenter tolerances is particularly weak. The contractor allocates an over-all MTF degradation of 0.3 to all of these effects. This 0.3 MTF decrement is then distributed among all the various contributing errors. However, the methodology for combining errors of this type is not well developed in the proposal.

Smear Error Budget - The smear budget developed by the contractor is complete in that no smear contributing sources not explicitly called out by the contractor have been identified. The statistical methodology for combining the different types of smears is well developed in the proposal and is appropriate for the intended purpose. However, the smear rates resulting from four error sources were computed incorrectly. The error sources incorrectly treated are listed below:

a. Camera alignment and pitch.

b. X slit position.

c. Vehicle attitude yaw error.

d. Yaw vibration of the optical bar.

Table I is a complete compilation of the smear error budget. The numbers in parentheses indicate corrections to the contractor's budget.

Defocus Error Budget - The defocus error budget is complete except for the omission of curvature of the plane of best focus along the slit axis.

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However, the contractor treated the focus error budget incorrectly in that he combined both mean and random errors in an RSS fashion. In addition, his manner of treating the impact on over-all focus error due to granularity in the focal plane positioning mechanism is ambiguous and indicates some confusion on the method to be employed in assemblying and focusing the optical system. In addition, the contractor treated defocus due to film plane tilt with respect to the image plane as if the worse case defocus applied uniformly across the field. Table II is a detailed compilation of the defocus budget.

Value Function Computation - The contractor made a major error in his computation of the Value Function. This error appears to result from the contractor having used the resolution computed for mean smear and defocus rather than two sigma smear and defocus as directed in Attachment II of the RFP. In addition, the contractor made a small error in computing the film weight required per day of mission life in that he failed to charge as film wastage the one frame of monoscopic coverage obtained for each camera operation.

Exposure Time Computation - In computing the required exposure time the contractor used a filter factor of 1.4. He states, however, that a Wratten 12 equivalent filter will be used and supplies the proposed filter spectrum. On this basis a more nearly correct filter factor is 1.5.

Performance Over the Design Envelope - After the contractor's performance estimates have been corrected for the errors and omissions in his error budget, the 2.7' ground resolution specified in the RFP leads to a perigee altitude selection of 92.5 nm. In order to meet the performance objectives of the RFP, however, the camera must operate over a range of altitude of 80-240 nm and a range of scene brightness from 200-750 ft. lamberts. Although the contractor does not present a complete discussion of camera performance over this entire operational spectrum, an analysis of the system has not uncovered any unusual performance variations. In particular, the smears resulting from residual image motion do not noticeably increase at the highest V/h corresponding to 80 nm perigee altitude.

Figures I, II, and III present a resolution performance summary. The curves labeled "Evaluation" reflect the revised error budgets of Tables I and II.

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OPTICAL SUBSYSTEM

Basic Optical Design - The optical design proposed by the contractor is a flat field Wright system. It employs a weak aspheric element located about 1.3 focal lengths from the focal plane and shows good performance over the 5.7° field. An analysis of the optical design has verified the correctness of the performance data presented by the contractor. It appears that some improvement in off axis performance might be achieved by a rebalancing of the field corrector group.

Optical System Packaging - The optical system is packaged into a rotating optical bar. This configuration requires the use of a perforated folding flat. The perforation in the flat gives access to the image plane. This mechanical arrangement results in a minimum of optical surfaces and generally excellent structural packaging. In addition, the system is well baffled and presents a low view factor from critical optical elements to the exterior environment.

Tolerancing - Although, as mentioned above, the contractor does not present a detailed discussion of his methodology for treating the optical system tolerancing the basic surface figure and tilt and decenter tolerances are adequate for the performance required (see Table III). The 1/60 wave RMS surface figure tolerances on the folding flat and on the spherical mirror appear to be unnecessarily tight. In addition, the 1/10" radius of curvature tolerance on the spherical mirror could easily be improved on.

Element Materials and Configuration - The contractor has selected a fused silica Heraeus cored structure for the folding flat and the primary mirror. While this structure is somewhat lighter than solid fused silica, it is substantially heavier than fused silica eggcrate structure. The contractor justifies the selection of the Heraeus rather than the eggcrate by the claim that fabrication and handling problems with eggcrate give rise to some added development risk. In any event, the Heraeus structure is certainly a conservative material selection. The perforated folding flat presents a particularly difficult fabrication problem. The contractor claims to have solved this problem by the development of a new polishing technique which he calls "continuous polishing". While this technique has yet to be employed for the fabrication of elements of the 31" size required for this program, the contractor presents considerable evidence leading to a high confidence prediction of the successful extension of the technique to these diameters.

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Element Mounting - The folding flat is mounted by a unique 4 point suspension. This arrangement has been examined by consultants and appears to be a good solution to this mounting problem. The spherical mirror is mounted in a similar fashion. The aspheric corrector plate is potted in a conventional bezel. In general, the contractor's mounting design is good.

Optical Subsystem Test and Assembly - The contractor is aware of the difficult test problems associated with the fabrication and assembly of this high performance optical system. His discussion of assembly techniques is adequate. However, the contractor did not demonstrate that his proposed test techniques would be sufficiently accurate to verify the 1/60 wavelength RMS surface quality he specifies.

FOCUS CONTROL

Design Approach - The basic mechanism for maintaining focus in the contractor's proposed camera is by means of positioning the primary mirror relative to the film plane through three invar metering rods. The effective thermal coefficient of expansion of the metering rods and the associated assembly is tailored so that in principle optical system defocus due to over-all system temperature changes is exactly compensated by the thermal expansion of this structure. The basic concept is excellent and well suited to the type of thermal control proposed by the contractor. In addition, the contractor proposes to mount an active focus measurement device at the focal plane. The general treatment of this device and the rationale for its inclusion and operation are inadequate.

Passive Focus Determination System - The design of the metering rod assembly has been thoroughly analyzed and presented by the contractor. No fundamental feasibility problems with the contractor's approach have been identified. The contractor has budgeted a 10% error in focal plane determination due to variations in the thermal and mechanical properties of the system. While this tolerance appears to be more than adequate, a detailed tabulation of the magnitudes of the various error sources was not presented by the contractor.

Active Focus Sensor - The active focus sensor proposed by the contractor works on the principle of imaging the object scene on a pair of spatial frequency filters and determining the focal plane by nulling the two output signals. While this general approach has been proven workable in other systems, the contractor's understanding of the design problems associated with this device is at best marginal. In particular, his design approach involves converting the optical spatial frequency filters to

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Rating Category I: PERFORMANCE EVALUATION

electrical signals and then comparing these two signals to develop an error signal. This practice, combined with the small grid size apparently necessitated by a mechanical packaging problem, leads to serious signal to noise and stability problems. In order to achieve an adequate signal to noise ratio, the device requires a 100 second integration time. The operational concept proposed by the contractor involves utilizing the focus sensor during non-photographic periods. To make a focus measurement, the optical bar is positioned for nadir viewing and the output of the focus sensor is recorded for later readout. Focus adjustment is then made by ground command. While this "open loop" mode of operation has merit, the inability of the proposed sensor to monitor focus during photography greatly reduces its utility. This limitation coupled with inherent inaccuracy of the device as proposed result in an instrument of doubtful utility. However, the contractor's proposal and error budgets do not require the focus sensor to meet the performance objectives. As proposed, the contractor plans to use this device for diagnostic purposes only.

Image Focus Setting and Tolerancing - The contractor's scheme for setting system focus in ground checkout is not well defined. He has incorporated a device which will permit the adjustment of film plane position and tilt. However, the detailed mechanization of this device results in a $\pm$ 5 micron granularity in focal position adjustment. This granularity appears unnecessarily coarse, particularly since the mechanism as proposed is inherently capable of much finer adjustments. When properly utilized, this capability for film plane adjustment should significantly reduce some of the errors included in the contractor's defocus budget. In addition, the tolerance for platen roller runout of 2.5 microns as proposed by the contractor is unnecessarily large and a tolerance of 0.5 microns is achievable. A revised defocus budget taking into account the above considerations is presented in Table IV. This revised focus budget when examined across the entire film format is at no point worse than the focus budget presented by the contractor (see Table II) and in many places in the format is significantly better. The resulting performance gain is significant. A more careful analysis of the defocus problem by the contractor would appear to have been warranted.

FILM TRANSPORT

039

Design Approach - The basic design requirement for the film transport system is to control the movement of film past the exposure slit in

[redacted]

precise (0.04%) synchronization with the rotation of the optical bar. In addition, in order to avoid wasting film during the 240° of optical bar rotation when the optical system is not viewing the ground scan, the film transport system must recycle film past the slit and bring it back to the required velocity for the initiation of the next frame. The film supply and take-up spools continue at a constant angular velocity during camera operation with intermittent film movement past the slit being accommodated by a looper mechanism. All control systems are mechanized with torque motors and associated servo systems. In general, the film transport system is conservatively designed and appears to be more than adequate for the design requirements it must meet. Mechanisms for control of film tension variations and mechanisms for active steering of the over-all film path are provided. The one electromechanical assembly which has a potential major design deficiency is the oscillating platen. A general criticism of the film transport system as proposed is that it is in many regards over designed in the sense that the required performance can probably have been met with a simpler system consisting of fewer component parts. This design conservatism is a characteristic of the contractor which has been evidenced on other camera programs. The design is conservative in performance as well in that with several minor design improvements the precision film velocity control servo could probably be improved in accuracy by a factor of two or three.

Platen Mechanization and Control System - As mentioned above, a potential design problem has been identified in the platen mechanism and its associated control system. The platen assembly is the critical mechanism for the positioning of the film at the slit. It also provides the means for decoupling the film path from the rotating optical bar between frames. During the exposure of a frame, the platen is positioned with respect to the optical bar through a bearing. As image motion compensation is accomplished by varying the relative position of the platen with respect to the optical bar through several degrees as a frame is exposed, there is a limited relative motion between the two parts. The platen angular velocity profile results in a change of sign of the relative velocity between the platen and the bar at zero scan angle. Since the bearing has a certain amount of Coulomb friction, there will tend to be a discontinuity in the bearing friction torque as the platen cycles through zero relative velocity at zero scan angle. Depending upon the detailed shape of the bearing friction torque level versus velocity, a substantial disturbance could be introduced into the platen control system. A preliminary examination of this question has lead to the conclusion that this disturbance

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could be large enough to cause a serious control system problem. Although the platen mechanical design is presented in some detail, the contractor apparently failed to identify this potential problem area. There are several alternative arrangements which will eliminate the problem if it should prove to be serious, but the contractor was substantially downrated for not having analyzed this critical assembly with sufficient care.

There are a number of additional, less critical problems associated with the particular film transport design proposed by the contractor. The shuttle position is sensed and an error signal fed back to the film recycle control system during interframe operation. This control loop is supposed to maintain average shuttle position in the center of the looper. While some control over looper position is required, this particular mechanization will result in a variation in interframe spacing with undesirable film wastage. A much better design approach would be to feed shuttle position errors back to the supply and take-up spools for corrective action.

As mentioned above, the contractor has provided active steering for film path alignment control. However, between camera operations, film is reversed through the system to eliminate start-up and monoscopic wastage. During this reversing operation, the contractor's proposal calls for deactivating these steering devices. Although the film path may be reversible with the steering mechanisms locked in the position which gives good film tracking in the forward direction, this is certainly not intuitively obvious, and the contractor did not discuss the question. Since alternate sets of film position sensors could readily be included to steer the film during reversal, it would seem wiser to design in this provision until tests have established whether or not they are required.

The contractor's proposal calls for exposing the interframe data block on the film while the film is moving at full velocity. The light source he has proposed is completely inadequate for this purpose. A better scheme would have placed the data block in the system so that it could be flashed when the film is at zero or near zero velocity.

The RFP calls for punching a small perforation in the film between camera operations. The contractor calls for performing this operation immediately after the end of a stop sequence. As this sequence leaves the trailing edge of the last frame back on the supply spool, some alternative scheme must be used for punching the film.

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In general, the alternate modes of camera operation (monoscopic, scan, pitch surveillance) are not adequately treated. The contractor has included only the briefest discussion of these modes and simply states that they can be mechanized as desired. While an analysis of the contractor's design has led to the conclusion that alternate mode mechanization can readily be accomplished the contractor has not been completely responsive to the RFP in this area.

THERMAL DESIGN

The contractor is proposing a completely passive thermal control system. Tailored emissivity and absorptivity coatings on the exterior of the space vehicle, superinsulation on the interior of the space vehicle, and controled emissivity coatings on the optical bar assembly serve to maintain the average temperature of the camera within limits over the range of operating conditions and control gradients within the camera acceptable bounds. The contractor's analysis and presentation of the design of this system is exceptionally complete. The design has been thoroughly analyzed taking into account the extremes of the operating environment as well as the tolerances on the system thermal parameters. Gradients that develop in the optical elements due to energy exchange with the external environment during camera operation have been studied in detail. In addition, temperature gradients due to internal power dissipation and albedo impingement have been considered. The completeness of the thermal analysis and the maturity of the design have led to the conclusion that the design has a high probability of meeting the thermal requirements of the camera system. However, during the course of the evaluation, several potential problems areas were uncovered and examined in terms of their impact on system performance.

An analysis of the range of ambient temperatures to be expected due to thermal properties variations of the system and uncertainties in the external heat sources (solar constant, earth albedo, and earth temperature) has led to the conclusion that the contractor's prediction of a $\pm$ 15° operating range may be optimistic. Two independent analyses of this problem predict $\pm$ 23° and $\pm$ 19°. System performance has been examined from the point of view of sensitivity to ambient temperature changes with the conclusion that about 1.5 microns of additional defocus must be added to the defocus budget for the $\pm$ 23° case. Given the size of the defocus budget, this increase would result in a negligible effect on image quality.

An analysis of the variation in ambient temperature with beta angle indicates that the $\pm 2^{\circ}$ variation with beta angle presented by the contractor may be too small an allowance. However, a redesign of the external thermal coatings can bring this temperature swing down to $\pm 2^{\circ}$.

The only significant omission in the contractor's analysis as presented in the proposal is a treatment of the launch transient problem. As the camera system will be pad-conditioned to some nominal temperature, which in general will not be the equilibrium temperature on orbit, there will be gradients induced in the system as the system moves to thermal equilibrium. The most serious gradient problem is a possible difference between metering rod temperatures and the primary mirror temperature. Supplementary data available to the evaluation indicates that this gradient is unlikely to be large enough to cause any appreciable defocus.

The contractor's analysis of the thermal behavior of the metering capstan was in error. When temperature swings due to ambient temperature changes plus capstan cooling due to film outgassing are properly accounted for, the metering capstan diameter variation will be about a factor of four larger than that predicted by the contractor. However, the contractor's smear budget allowance for metering capstan diameter uncertainty is sufficiently large so that most of this increased variation can be absorbed without added smear. The choice of invar or molybdenum instead of beryllium for the metering capstan material will significantly reduce the magnitude of this effect and result in over-all control system performance improvement over that called for by the contractor's specification.

STRUCTURAL DESIGN

The structural design and design analysis presented by the contractor is adequate. The over-all design is efficient and well packaged. The only error detected in the course of the evaluation is an undersizing of the hardware associated with the pneumatic system which supplies nitrogen to the gas bars in the film path. The contractor was also weak in his treatment of ordnance design. There are several points in the system which use various kinds of ordnance for uncaging of mechanical parts. In general, the ordnance problem both from the design and handling point of view was not well understood by the contractor.

Table V contains a weight and power summary of the contractor's sensor subsystem. The energy requirements presented in the power budget are those required for a 30 day mission. These weight and power estimates are the best estimates arrived at during the course of the evaluation and in some instances are different than those presented by the contractor.

HANDLING

Attachment 3
BYE-69319-66
Category I
Table I

TABLE I

PERKIN-ELMER SMEAR BUDGET

(V/h = 0.054 rad/sec)

(Numbers in parentheses indicate changes made during evaluation.)

A. Worst Location Mean Smear:

Mean	Smear Rate (M rad/sec) Along Track	Across Track
Command Approximations	.068	.21
Optical Distortion	.106	.01
Edge Effects	.345	.075
Platen Rotation	0	.668

B. Worst Location Random Smear

Source	Tolerance - 2 σ	Smear Rate (M rad/sec Along Track	Across Tr
Camera Alignment			
Pitch	10 arc min	.072 (.052)	.079
Roll	5.7 arc min	.086	.013
Yaw	4.9 arc min	.007	.086
Diagonal Mirror Alignment			
Pitch	5.1 arc min	.06	.28
Crab	12.4 arc sec	.21	0
Optical Axis Alignment to Spin Axis			
Pitch	1.5 arc min	.013	.079
Yaw	4.4 arc sec	.072	0
X slit position	.074 in	.053 (.02)	.073 (.02
Y slit position	.074 in	.28	.073 (.04
Vehicle Attitude			
Pitch	.5 deg	.21	.23
Roll	.5 deg	.4	.085
Yaw	.6 deg	.04	.57 (.64)
Vehicle Rates			
Pitch	.015 deg/sec	.29	.013
Roll	.015 deg/sec	.046	.29
Yaw	.015 deg/sec	.25	.065

SPECIAL HANDLING

Attachment 3
BYE-69319-66
Category I
Table I, cont.

Scan Angle Error	14 arc min	.18	.04
Focal Length	.0074 in	.006	.42
Platen Angle	26.8 arc sec	.445	.006
Vibration			
Diagonal Mirror			
Pitch	.00013 rad/sec	.13	0
Crab	.00013 rad/sec	0	.13
Optical Bar			
Pitch	.00013 rad/sec	.13	0
Roll	.00013 rad/sec	0	.13
Yaw	.0024 (.00013) rad/sec	.013 (.107)	.13 (.02)
Film Velocity Sync	.053 in/sec	.013	.885
Film Velocity Modulation	.013 in/sec	.006	.223
$\triangle (V_x/h)$	.00027 rad/sec	.26	.02
$\triangle (V_y/h)$	.00003 rad/sec	0	.033
Lateral film motion	.010 in/sec	.164	0

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Attachment 3
BYE-69319-66
Category I
Table II

TABLE II

PERKIN-ELMER DEFOCUS BUDGET

Random Focus Errors

Platen	
Platen Roller Runout	2.5 microns
Film Plane Alignment to Reference Plane	4.53
Film Thickness	6.0
Film Flutter	2.24
Film Mean Unflatness	2.24
Temperature Variation	2.5
Optical Bar	
Thermal Power	5.0
Metering Rod Uncertainty	2.8

Fixed Unknown Focus Errors

Film Plane Alignment to Image Plane	5.0 microns
Focus Adjustment	5.0
RSS (Random and Fixed Unknown)	12.7 microns

Fixed Known

Object Distance	3.4 microns
Focal Plane Curvature	4.0 microns

Attachment 3
BYE-69319-66
Category I
Table III

PERKIN-ELMER OPTICAL MANUFACTURING TOLERANCES

SURFACE TOLERANCE (RMS)

Corrector Plate	1/30 wavelengths
Folding Mirror	1/60
Primary Mirror	1/60
Field Lens Group	1/30

DECENTER

Primary Mirror	.004 in.
Corrector Plate	.004 in.
Field Lens Group	.002 in. (Each Element)

TILT

Primary Mirror	3 arc sec
Corrector Plate	15 arc sec
Field Lens Group	5 arc sec (Each Element)

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Attachment 3
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Category 1
Table IV

PERKIN-ELMER REVISED DEFOCUS BUDGET

DEFOCUS EFFECTS	
Platen Roller Runout	0.5 microns
Film Thickness Variation	4.0
Film Flutter	2.24
Film Mean Unflatness	2.24
Platen Thermal Effects	2.5
Thermal Gradient in Optics Effects	5.0
Initial Focus Adjustment	3.0
Uncertainties in Metering Rods	2.8
RSS (Random and Fixed Unknown)	8.6 microns
TILT EFFECTS	
Initial Alignment of Film Plane to Image Plane	3.0
Thermal Gradients in Platen	2.5
RSS (Defocus at Edge of Slit)	3.9 microns
FIXED KNOWN DEFOCUS	
Object Distance Variation	3.4 microns
Focal Plane Curvature	4.0 microns

Attachment 3
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Category I
Table V

TABLE V

PERKIN-ELMER SENSOR SUBSYSTEM

WEIGHT & POWER SUMMARY

(30 Day Planned Mission)

Weight

Optical Bars and Film Transport Hardware	1,186 lbs.
Camera Frame	280
Supply and Take-up Spools	636
Film Handling Hardware	140
Thermal Provisions	35
Electronics, Cables, and Connectors	450
Pneumatics	102
Empty Weight	2,829 lbs.
Gaseous Nitrogen	27 lbs.
Film (SO-380) includes 18% wastage	1,682 lbs.
TOTAL	4,538 lbs.

Energy

Optical Bars	1,562 watt hrs
Capstans	2,576
Platen	1,046
Cassettes	5,276
Instrumentation, Solenoids, Data Block	6,576
TOTAL (30 days)	17,036 watt hrs

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Attachment 3
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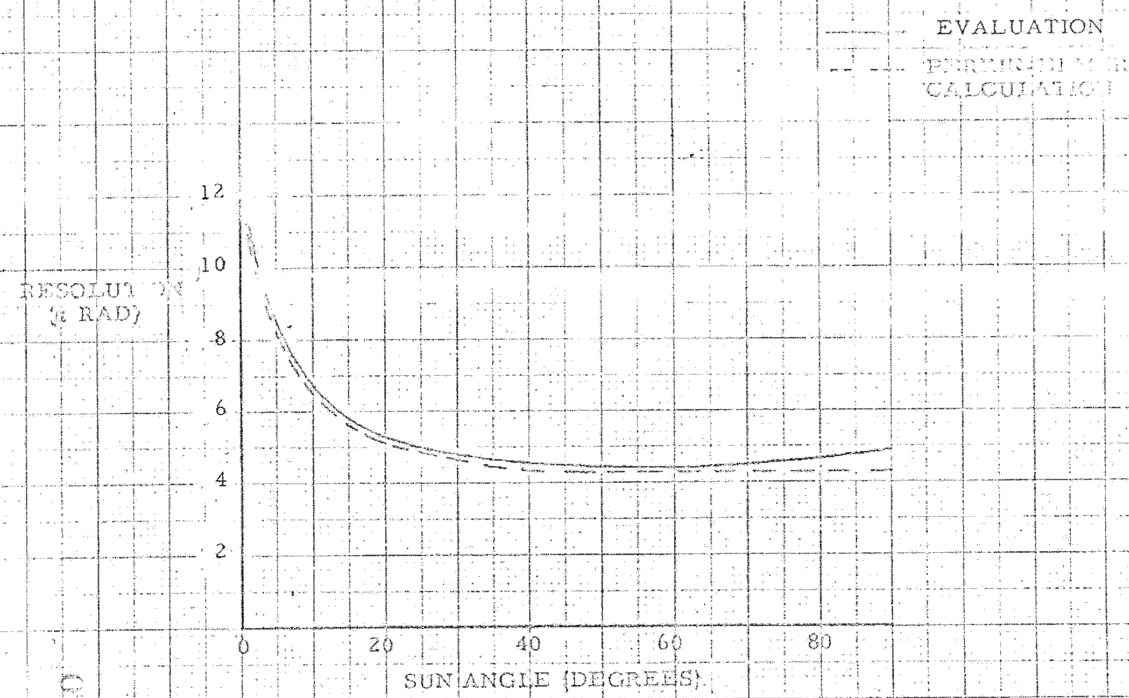
Category I, Figure I

FIGURE I



Attachment 3
BYE-69319-66
Category 1
Table IV

PERKIN-ELMER REVISED DEFOCUS BUDGET

DEFOCUS EFFECTS	
Platen Roller Runout	0.5 microns
Film Thickness Variation	4.0
Film Flutter	2.24
Film Mean Unflatness	2.24
Platen Thermal Effects	2.5
Thermal Gradient in Optics Effects	5.0
Initial Focus Adjustment	3.0
Uncertainties in Metering Rods	2.8
RSS (Random and Fixed Unknown)	8.6 microns
TILT EFFECTS	
Initial Alignment of Film Plane to Image Plane	3.0
Thermal Gradients in Platen	2.5
RSS (Defocus at Edge of Slit)	3.9 microns
FIXED KNOWN DEFOCUS	
Object Distance Variation	3.4 microns
Focal Plane Curvature	4.0 microns

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Attachment 3
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Category I
Table V

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Attachment 3
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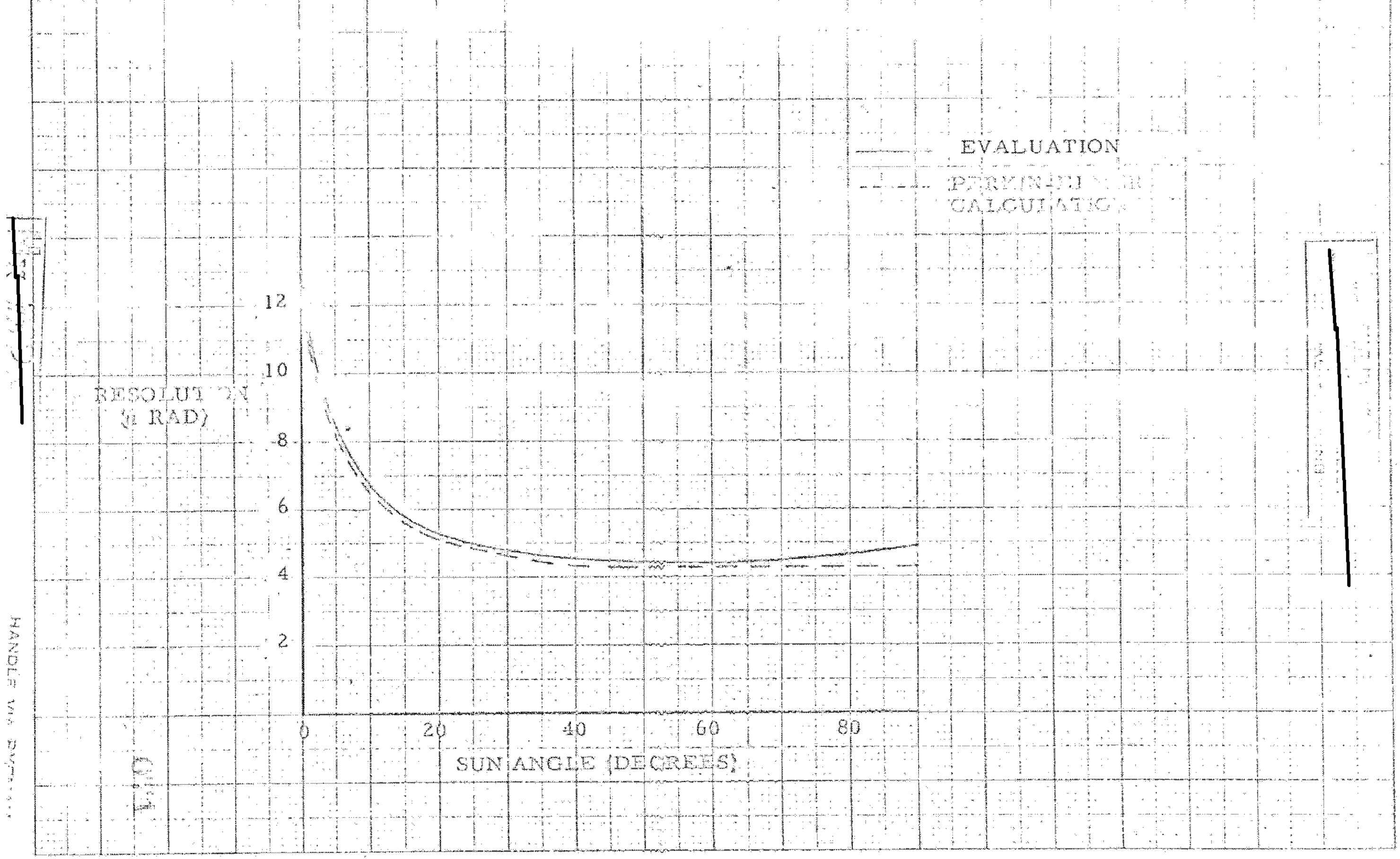
Category I, Figure I

FIGURE I



Rating Category II: DEVELOPMENT RISK Attachment 3
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Both high quality flat mirrors for autocollimation and high quality spherical mirrors for the 420" collimators are required early in the program. While these elements can be made from heavy solid fused silica blanks, their early availability is critical to the fabrication and assembly of the first sets of optics.

While the fabrication and assembly of a near diffraction limited large optical system is always a difficult task requiring experienced optical shop and technician personnel, experience with the GAMBIT optical system (which is similar in configuration to the proposed optical system) lends some confidence to the feasibility of the performance objectives. In order to meet the over-all resolution specifications, the proposed optical system must provide a low contrast, static lens/film resolution of better than 3.7 micro-radians. The GAMBIT system with a physical aperture of 19.5" and a center obscuration about 8% higher than the proposed optical system regularly delivers 3. micro-radians and better. As the GAMBIT performance is achieved with element surface tolerances considerably poorer than the 1/60 wavelength RMS surface control specified by the contractor, this requirement may be unnecessarily stringent.

Focus Control - As discussed in the Performance Evaluation summary, the defocus budget proposed by the contractor contains considerable margin. However, despite the detailed analysis performed by the contractor there remains a residual concern about the behavior of optical performance over the range of average camera temperatures which will be encountered (± 23°F). While the contractor's metering rod design will maintain focus for unconstrained element bending due to thermal expansion, there may be secondary effects caused by mechanical strains induced in the elements by the mounts. Complete confidence can only be achieved by conducting a thorough test program.

Film Transport - The most serious design risk problem in the film transport system as proposed is the schedule risk associated with the redesign of the entire platen assembly and control system. While the performance objectives can probably be met, this critical problem will require considerable engineering attention early in the program and could result in a slip of the Critical Design Review milestone. The platen design problem will be further aggravated by the necessity for careful attention to design of the E core transducer proposed by the contractor as the platen/optical bar relative position sensor. While this type of sensor is an excellent null sensor, the requirement for relative movement between the bar and the platen for IMC leads to off-null operation. The 10 arc sec relative angular measurement accuracy required can be met only with the most careful design practice.

As has been discussed in the Performance Evaluation summary, there are a number of additional secondary redesigns required. While none of these pose any serious difficulties, they will impose further engineering requirements early in the development program and thus, will tend to further aggravate an already critical scheduling problem.

Torque Motor Development - All of the torque motors proposed by the contractor in the film transport system are of the dc brushless type. In this class of motor, the commutation is done by electronic switching and, therefore, eliminates the requirement for brushes. While the elimination of brushes is clearly a step in the right direction and removes the requirement for what could be a difficult qualification program, the brushless type motors are developmental items. Brushless motors have been utilized in the past and the contractor has an operating breadboard motor, but to meet the specific requirements of the film transport system special motor fabrication will be necessary. While no development problems are anticipated, component qualification always represents some degree of schedule risk.

Ordnance - While the contractor proposes to use pyrotechnics for uncaging operations (both primary and back-up) his analysis of the potential effects of shock and debris on the camera system is inadequate. A careful examination of these problems may lead to the conclusion that some redesign is necessary. Again, no fundamental problem exists, but redesign effort constitutes a schedule hazard.

Optical Bar and Platen Bearings - The contractor has analyzed his bearing requirements in considerable detail, and the specifications required on these bearings can be met. Nonetheless, the bearings are large and will require hand lapping of the races and careful ball selection to meet these specifications. While the predicted procurement leadtimes fall within the development schedule as proposed, any initial fabrication difficulties will cause a schedule slip.

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Thermal Control - The thermal control system as proposed is completely passive and requires no heater power; however, there remains the possibility that guard heaters will be needed to prevent heat leakage through the structural mounting points. Unless the thermal model testing leads to the conclusion that guard heaters are not required, the SBA will have to carry a power budget which allows for an additional 3-4,000 watt-hours of energy for the nominal 30 day mission.

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PERKIN-ELMER EVALUATION SUMMARY

Rating Category III: DESIGN MARGIN   Rating: 7.0

Design Margin category covers the evaluation of the proposed system's operational dependability and producibility after the initial flight has been accomplished. The sensitivity of the system performance to variations in tolerances were weighted by the evaluators' judgment of the likelihood of these variations actually occurring together with an assessment of the performance consequences of these variations.

SYSTEM PERFORMANCE

The relatively high rating assigned to the contractor's design for the Design Margin category was strongly influenced by the generally conservative nature of the error budgets as proposed. As discussed under the Performance Evaluation summary, the defocus and smear budgets have the potential of being reduced during the development program. In addition, the analysis of the optical design performed during the evaluation suggests that some off-axis resolution improvement may be possible with a rebalancing of the corrector group. With possible margin in these three categories, the chances of difficulties developing which are sufficiently severe to bring the system below the specified 4.8 micro-radians two sigma angular resolution are substantially reduced.

The sensitivity coefficients for rate of change of resolution with increased smear and defocus about the two sigma performance point are:

$$\frac{dR}{dS} = 0.3 \text{ micro-radians/micron}$$

$$\frac{dR}{dD} = 0.1 \text{ micro-radians/micron}$$

The system is particularly insensitive to defocus as 0.1 micro-radians represents about 2% performance decrease per micron. In order to increase the total defocus by one micron, a random error source of five microns must be added to the current defocus budget.

[redacted]

Rating Category III: DESIGN MARGIN

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CRITICAL SUBSYSTEMS

Despite the optimistic performance picture painted by the above considerations, the camera system is a high precision machine which must be made consistently to exacting tolerances. Fabricating large optics of this precision at the rate of one set per month is a task which should not be underestimated. The platen assembly also must be fabricated to exacting mechanical tolerances. As has been mentioned in previous rating category summaries, the platen and optical bar bearing assemblies must be fabricated to tolerances which are very close to the current state-of-the-art. In addition, the film transport control system is in total, complex and contains a number of critical components. In order to produce these camera systems at the rate of one system every two months, the application of high level engineering skill on the part of the contractor will undoubtedly be required on a continuing basis.

[redacted]

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PERKIN-ELMER EVALUATION SUMMARY

Rating Category IV: VALUE FUNCTION   Rating: 9.0

Points in this category were assigned to the contractor strictly on the basis of the numerical size of the Value Function computed according to the instructions in Attachment II of the RFP. The proposing contractor with the highest Value Function was automatically assigned a maximum rating of 9.0. The other contractor was then assigned a rating in this category using the following formula:

$$R = 9.0 \frac{(V_m)}{(V_m) \text{ max.}}$$

Instructions in the RFP called for computing the Value Function for both winter and summer conditions and for STB and UTB film. For the purposes of assigning a rating to the contractor in this category, only the UTB Value Functions were utilized. An analysis was conducted to determine the proper weighting of the summer Value Function and the winter Value Function. This analysis examined the distribution of sun angles to be expected during the course of a year. Approximately 60% of the target acquisitions occur at sun angles greater than 30^{o} and approximately 40% at sun angles less than 30^{o}. As the contributions to the summer Value Function are almost all at sun angles above 30^{o} and those for the winter Value Function below 30^{o}, it seemed reasonable to weight the summer Value Function 0.6 and the winter Value Function 0.4. Accordingly, the following formula was used in computing a single Value Function for rating purposes:

$$V_m = 0.6 \, (V_m) \, s \quad + \quad 0.4 \, (V_m) \, w$$

where (V_m) s is the summer mission value and (V_m)w is the winter mission value.

As has been pointed out in the Performance Evaluation discussion, this contractor evaluated the Value Function incorrectly. During the course of the evaluation the Value Function had been recomputed using the error budget presented in the Performance Evaluation discussion above and correcting the other errors made by the contractor. Table V presents these recomputed Value Functions for all four cases. In addition, Table V includes the value per day numbers and the nominal mission duration numbers as defined in Attachment II of the RFP.

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Category IV
Table VI

TABLE VI

PERKIN-ELMER VALUE FUNCTION SUMMARY

Nominal Mission Duration:	32.2 days	
Value/day (summer):	3.35×10^6 nm^2	
Value/day (winter):	2.12×10^6 nm^2	
	UTB	STB
Value/Mission (summer):	10.75×10^7	9.51×10^7 nm^2
Value/Mission (winter):	6.82×10^7	6.02×10^7 nm^2

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[redacted]

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PERKIN-ELMER EVALUATION SUMMARY

Rating Category V: RELIABILITY   Rating: 4.6

GENERAL

In this category, the contractor was graded on his understanding of the over-all reliability problem as well as on the numerical failure rate predicted for his proposed system. While the contractor made such statements as "Redundancy, if feasible, will be a strong consideration for areas that cannot meet their reliability" and "Currently, several of the electronic areas would benefit from the incorporation of redundant techniques," he nonetheless neglected to specify in detail the critical subcomponents in a valid failure mode analysis.

DATA PRESENTED BY THE CONTRACTOR

The contractor presented a comprehensive list of parts, together with a Sensor Subsystem mathematical model and the probability calculation of successfully completing the one-shot uncaging operations and of Sensor Subsystem survival per orbital day. He also presented the derivation of his predicted .00279 failure rate per day value in keeping with the .003 failures per day requirement.

TECHNICAL ANALYSIS

The contractor assumed that the optical bar phasing electronics were fail safe--that is, a failure would result in a syncaronous operation of the optical bars but would not cause them to fail. He further assumed that the data chamber was not required for successful operation. Lacking sufficient data to verify the fail safe design and assuming that the data chamber was required for successful operation, they were reinserted in the calculation and, using the same hi-rel values for parts failure, a revised failure rate of .00315 was determined, which was considered as meeting the requirement.

EVALUATION GROUP KEY COMMENTS

a. Failure Rate Analysis

1. Methodology - in error, as stated above.

2. Parts count - complete; in fact, a little high in that 191 integrated circuits for the data block and 102 bearings for a caging device were specified. 082

[redacted]

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Rating Category V: RELIABILITY

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3. Failure mode analysis - no in depth analysis.

b. Program Requirements

1. Parts type - "standard" hi-rel parts (i.e., flight-proven hi-rel parts) were specified.

2. 75% confidence demonstration - not specifically addressed.

3. Life test - contractor stated he would test in accordance with MIL-STD-781A at a 10% customer risk. This is a proper procedure.

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PERKIN-ELMER EVALUATION SUMMARY

Rating Category VI: OPERATIONAL CONSIDERATIONS   Rating: 6.2

Operational considerations include the factors associated with the ease of checkout and launch, the ease of control by the Satellite Control Facility, the mission planning and targeting implications, the film processing requirements, and the photographic interpretation and mensuration.

The supply spool will have its axis of rotation vertical while the system is on the pad. Calculations indicate that the film will remain on the spool; and it will be possible to operate the system in this orientation; but care must be taken to maintain tension on the film at all times.

There must be provisions for easy access to the caging and uncaging mechanisms on the optical bar and the supply spool while the vehicle is on the pad in order to permit camera operations during standby periods and minimize response time.

If monoscopic photography is taken, the total lifetime on-orbit will be reduced.

Increasing the number of individual operations to 1,000 stop-starts as recommended by the SOC would slightly reduce the total lifetime; however, this is compensated by the fact that exposures of small areas would not require large accelerations and decelerations of the film supply and take-up reels. The details of the alternative modes are not well defined at this time, but there do not appear to be any fundamental problems in the mechanization of the short scan and patch surveillance modes.

SPECIAL HANDLING

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PERKIN-ELMER EVALUATION SUMMARY

Rating Category VII: EFFECT ON SPACE VEHICLE

Rating: 7.8

GENERAL

In this category the contractor was evaluated on the impact of his proposed Sensor Subsystem upon the overall design of the Space Vehicle and in each of the critical SBA subsystem areas. The contractor's thermal concept is an entirely passive one, involving only a single external coating pattern for all orbits and for any time of the year, an insulated cocoon, coated baffles in the viewport area, and thermal bulkheads between the aft section of the SBA and between the camera compartment and the R/V's. A single load-carrying door is ejected after launch, the total area of the rectangularly-shaped area being 72 square feet. There is no requirement to remove the door for ground test.

SBA SUBSYSTEM IMPACT

In general, the contractor's proposed camera system packages well into a conventional space vehicle structure and imposes no peculiar requirements on any of the space vehicle subsystems. The following paragraphs summarize the impact on each SBA subsystem.

Attitude Control System - As the camera system is currently configured, continuous monoscopic operation will result in a relatively high expenditure of attitude control system propellant. However, for stereoscopic operation the system is dynamically well balanced and poses no special requirements on the attitude control system. The possibility of slight variation in the supply spool velocity during photography makes it desirable to incorporate a rate roof in the attitude control system.

Power - Although the contractor did not present detailed information on the power transients during camera start-up no special problems are anticipated with the utilization of a conventional high efficiency battery power supply in the SBA.

Telemetry and Command - Although a detailed design of the SBA programmer was not conducted during the course of this evaluation, the camera command requirements are in no way unusual and should present no feasibility problems in the design of the SBA programmer.

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CONTROL SYSTEM ONLY

SPECIAL HANDLING

Rating Category VII: EFFECT ON SPACE VEHICLE

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The camera contractor did not completely define in his proposal the telemetry requirements; but, again, there should be no difficulty in satisfying any reasonable telemetry demands.

Structures - The most difficult space vehicle structural design problem associated with the camera requirements is the large viewport. This viewport will probably have to be covered by a load-carrying door during ascent and separated on orbit without inducing unacceptable shocks into the camera structure.

The space vehicle diameter required by the camera system is 100". As the launch vehicle interface diameter is 120", a conical adapter will be required.

The camera system requires a space vehicle separation plane between the aft SBA section and the center section in order to provide access for supply spool loading. The space vehicle will have to be fabricated in cylindrical sections in any case, so this does not impose any special design requirements.

Table VII gives a weight breakdown of the entire space vehicle.

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Category VII
Table VII

TABLE VII

PERKIN-ELMER SPACE VEHICLE WEIGHT BREAKDOWN

(Expendables sized for a 30 day planned mission)

		Evaluation Group Estimate
Sensor Subsystem		2,856 lbs.
2 Reentry Vehicles		1,620 lbs.
SI Camera		150
Film		1,682
Satellite Basic Assembly		5,069
Forward Section		
RV#1 Cone	215	
RV#2 Cone	60	
Sensor Section		
Primary Structure	575	
Support Structure	95	
Viewport Structural Door	160	
Thermal (incl. coating)	200	
Aft Section		
Primary Structure	300	
Support Structure	80	
OA Hardware	166	
ACS Hardware (propul.)	220	
ACS Hardware (elect.)	50	
TT&C Hardware	175	
Thermal Material	77	
Power & Signal Dist.	93	
Back-up Recovery	31	
Separation	55	
Expendables		
Batteries	1300	
OA Gas	987	
ACS Cold Gas	230	
System Lift-off Weight		11,377
10% Contingency		1,138
Expected Total Space Vehicle Weight (30 day mission)		12,515 lbs.

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PERKIN-ELMER EVALUATION SUMMARY

Rating Category VIII: INTERFACE   Rating: 5.8

1. In this category, attention was focused on the contractor's definition of the interface requirements for the space vehicle. Both the completeness of the definition and the understanding of these interfaces as well as the adequacy of the requirements from the viewpoint of the sensor were examined.

2. Mechanical interfaces were very well defined. The contractor delineated his responsibilities and those of the SBA. In this definition, he made technical errors which the SBA contractor could easily identify and correct. Alignment tolerances for the film chutes and the steering devices were not mentioned although their mounting was assigned to the SBA forward section.

3. The contractor asked for batteries to be provided for operation of the SS equipment only. The satellite will have an integrated power supply since little can be accomplished without both the SS and SBA operating. Further, two separate power sources are less efficient, particularly in view of the high peak current demands of the camera system.

4. The commands required for operation were adequately listed. However, the word length of 11 bits is longer than required considering the accuracy of the data. The proposed commands provided all required SS functions except monoscopic, short scan, and patch surveillance operations.

5. The telemetry interface consisted of listing five functions. Of these, two thermal functions required 196 channels. This indicates their thermal data concern. One vibration function had 12 channels. No caging functions were requested. No telemetry rate was specified for downlink or uplink. No capacity or mode operation was specified for the airborne tape recorder. No impedance value was given for the interface passage of telemetry.

6. There was good AGE definition for checkout at ACF, integrated testing and launch readiness verification.

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Rating Category VIII: INTERFACE

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7. The proposal did not treat the electromagnetic compatibility integrated testing but referred to a previously published Specification Book. Review of the treatment in this book indicated good design and workmanship practices as stated. But no susceptibility or interference levels were defined for the various circuits. MIL-I-36600 was not mentioned.

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PERKIN-ELMER EVALUATION SUMMARY

Rating Category IX: MASTER PROGRAM PLAN, DESIGN DEVELOPMENT PLAN, QUALIFICATION PLAN, INTEGRATION ASSEMBLY AND CHECKOUT PLAN

Rating: 3.6

GENERAL

The plans discussed herein have been evaluated on the basis of technical content only. The criteria applied were:

1. completeness of the information supplied.
2. understanding of system implications.
3. compatibility of plans with requirements.

The comparatively low rating reflects a lack of specific technical data in the various plans. In fairness it must be commented that the RFP is somewhat ambiguous concerning the level of technical detail which is required in these plans.

MASTER PROGRAM PLAN

This plan is responsive in general to the RFP. Some development risks were identified. However, testing was not adequately detailed, nor was there adequate planning for the feedback of test results into the appropriate analyses. In general, test details were inadequate with respect to:

1. definition of parameters to be measured.
2. expected test level.
3. test success criteria.
4. instrumentation requirements (in-plant requirements--particularly for optical testing--were quite well detailed).

Comparatively little attention was directed to interfacing with other contractors.

DESIGN AND DEVELOPMENT PLAN

This plan was presented in some detail. Pacing items were identified (mirror blanks and flats required for production of test collimators).

Rating Category IX: MASTER PROGRAM PLAN, DESIGN DEVELOPMENT PLAN, QUALIFICATION PLAN, INTEGRATION ASSEMBLY AND CHECKOUT PLAN

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Early release dates for long lead time items were given. In other areas, the plan tends to be general rather than specific. An item of some concern is scheduling the CDR at 8 months, rather than at the RFP's 12 months; this suggests a scheduling problem.

QUALIFICATION PLAN

Again, this plan is adequate in broad outline, but the contractor has not defined the plan in sufficient detail to provide a definitive program ensuring that requirements of the RFP will be met. For example, acceleration and acoustic tests of large assemblies are not adequately defined.

INTEGRATION, ASSEMBLY, AND CHECKOUT PLAN

SS/SBA integrated system testing is not adequately defined. The general planning and objectives for integration testing are inadequately defined and detailed. (The magnitude of the integration task requires an early effort to resolve interface problems with confirmed design solutions.) There is little discussion of on-pad and launch operations. There is no consideration of ordnance hazard facility provisions at the factory or ACF, no arm-safe provisions, no ordnance test points, nor safety criteria established. Apparently a light-tightness check of the film path has not been specified at either factory or ACF. Finally, a resolution test at the ACF (in thermal/vacuum chamber) of dubious utility is specified.

On the positive side, the proposed assembly procedure does not require disassembly following performance testing, so that major alignment of the film path and SS to the SBA occurs only once. Also, the contractor has recognized (in general) equipment requirements for on-orbit and post-recovery system evaluation.

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PERKIN-ELMER EVALUATION SUMMARY

Rating Category X: FABRICATION AND DELIVERY PLAN, AGE DESIGN DEVELOPMENT AND DELIVERY PLAN, MASS PROPERTIES CONTROL PLAN, RELIABILITY PROGRAM PLAN

Rating: 3.4

GENERAL

The plans discussed herein have been evaluated on the basis of technical content only. The criteria applied were:

1. completeness of the information supplied.
2. understanding of system implications.
3. compatibility of plans with requirements.

The comparatively low rating reflects a lack of specific technical data in the various plans. In fairness, it must be commented that the RFP is somewhat ambiguous concerning the level of technical detail required in these plans.

FABRICATION AND DELIVERY PLAN

This plan does contain a fair amount of detail. It identifies a number of special tools and equipments to be procured and/or built (with suggested vendors in many cases). Contingency planning of alternate methods to fabricate and test the folding flat are described.

AGE DESIGN, DEVELOPMENT, AND DELIVERY PLAN

This plan is almost totally lacking in detail. There is no consideration of combined SV-SS AGE or of system interfaces.

MASS PROPERTIES CONTROL PLAN

This plan is generally responsive to the RFP, but the detailed work statement simply restates RFP guidelines. No discussion is given of the test equipment required for weight and CG determination, nor of detailed methods for implementing the plan.

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Rating Category X: FABRICATION AND DELIVERY PLAN, AGE DESIGN DEVELOPMENT AND DELIVERY PLAN, MASS PROPERTIES CONTROL PLAN, RELIABILITY PROGRAM PLAN

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RELIABILITY PROGRAM PLAN

This plan mentions the required basic elements, but does not detail technical approach nor describe tests. The failure rate test requirement is not specifically addressed. The life test (properly) references MIL-STD-781A but gives no details.