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Subject: Viewer Requirements: Associated Crew Tasks and Capabilities

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I. Summary

The role of the flight crew in the MOL/DORIAN Program has generally been summed up by the following two statements:

(1) To enhance the quantity and quality of the photographic intelligence derived from the MOL/DORIAN flights.

(2) To aid in the rapid maturing of the system, including both the manned and unmanned versions thereof, while simultaneously gathering high-resolution photographic reconnaissance data.

The basic requirement for the film viewer and its associated optics (microscope, eye loupe) are derived from both items (1) and (2) above, though primarily from item (2). The use of the viewer for initial setup and health checks of the optical system will help to assure maximum useful high-resolution photographic take. The use of the viewer for crew inspection of photography of specialized types of calibration targets may permit the crew, via comparison with reference photography, to isolate certain causes of degraded payload performance. In some instances (e.g., system alignment), the crew could effect a verniering of the system to achieve improved performance for the balance of the flight. In other instances, the results of the on-board inspection, when communicated to the ground, could result in the ground requesting that additional specific types of calibration photographs be programmed to facilitate additional analysis, both during and subsequent to the flight. In effect, the crew's ability to process and inspect the calibration photography and communicate with the ground can lessen the amount of flight time, and perhaps number of flights, expended in the collection of data necessary for diagnostic analysis and subsequent improvement of payload performance.

The MOL/DORIAN Program represents the first opportunity we have had to utilize man in conjunction with a high-resolution photographic system on orbit. Considerable emphasis has been placed on proper definition of man's role, associated hardware, software, and operational concepts in consonance with the objective of enhancing the quantity and quality of the intelligence take. The definition of particular diagnostic tasks, is, however, in an earlier state of development as of this writing; in part because the rather complex physics of the problem requires significant analysis to establish the feasibility and practicality of specific techniques. Additionally, our ability to define, understand and utilize the techniques will improve during the course of the actual flight program. Thus, the extent, and perhaps sophistication, of diagnostic work on the second and subsequent flights may exceed that undertaken on the first flight.

It is the objective of this document to present the current state of our knowledge of these problems. Where uncertainties exist, they will be so identified, providing a basis for the direction of future study efforts in this area. It should also be stated that Eastman Kodak and Data Corporation have study tasks to study and define diagnostic techniques, identify specific types of ground calibration targets which will be required, and produce reference materials for use by the flight crew in performing these diagnostic tasks. Inherent within these studies is, of course, consideration of the particular characteristics of the DORIAN system, and, in the case of the EK effort, crew utilization in these diagnostic tasks.

II. Crew Tasks with the Viewer Microscope

A. Initial Payload Setup and Health Checks

Following initial setup of the optical system, and during an early orbit, a sequence of photographs of a pre-selected target should be taken with intentional stepping of the platen position (focus) over a range covering both sides of the predicted best focus position. This sequence would desirably include a calibration (resolution target) though this may not be mandatory. From this series, the crewmen could qualitatively inspect the processed photos, selecting that photo and associated platen position which appeared to have the best quality. This focus position would be used pending possible adjustments based on subsequent calibration photography or ground analysis of focus sensor telemetry data. For this focus position, photography of ground calibration targets would permit the crew to quantitatively determine the resolution performance of the system. Slant range effects and predictable degradations in the quality of the processed film due to on-board processor characteristics could be taken into account. The results of this examination, if off-nominal performance were indicated, could indicate a need for further exploratory/diagnostic work in addition to, or perhaps in lieu of, planned mission operations.

Examination of this initial photography would provide early indications of system problems resulting in film fogging or scratching. Furthermore, the results of examination of photographic sequences involving manned and IVS tracking, could provide an early indication of IVS performance, again possibly dictating the need for additional diagnostic work; or in this case, and depending on the severity of the problem, necessitating the crew's performance of the backup tracking function.

One other thing which may be derived from this early calibration photography is the validity of the predicted settling time (for damping out of the vibrations induced by tracking mirror slew) a parameter used by the mission planning software in target programming. A low prediction of the settling time could be indicated by poorer resolution on the initial pictures of a stereo sequence, and, if this were indicated, a new settling time could be determined for use in the ground software.

B. Diagnostics

The preceding question discussed representative crew tasks associated with initial setup of the system and with the quantitative establishing of the system (payload) performance. Except in the case of poor IVS performance or inaccurately predicted settling time, no attempts have been made to isolate the causes of degraded performance. For example, while the through-focus tests result in the crew's selection of the platen position for best focus, the resolution determined for the best focus position could be far poorer than spec. The question is why. Assuming that tracking performance has been within bounds, the problem could be attributable to such things as tilt misalignment, decentration or poor mirror figure.

It is obvious that the crew could not examine normal scene imagery and thus isolate the causes of performance degradation. Nor could such diagnosis be done through examination of standard resolution target (bar target) photography. However, the question may be posed as to whether photographs of special types of calibration targets could be utilized for such diagnostic purposes. (We are constrained to utilize photographs because the system design precludes the crew from viewing the aerial image at the film plane, a far more preferable technique. If such crew access were possible, the crew could check the alignment and focus of the system while viewing a star (point source) image, a technique similar to that used on the ground in alignment of optical systems.) This question is, in fact, the subject of the EK and

Data Corporation studies alluded to earlier. Since these studies are in fairly early stages, we have essentially no information as to their progress. However, early this year there was some exploratory work done at Aerospace Corporation on this question of special calibration targets.

In particular, since the point source has historically been used for optical system alignment, a cursory study was performed to determine whether the characteristics of the point images (point spread functions) could be correlated with sources of off-nominal performance, i.e., were these spread functions recognizable and was there some rhyme or reason to their characteristics. The study consisted of making ray-tracing calculations for point sources distributed within the f.o.v. of the optical system (13 points) with the system assumed static, i.e., no smear errors. (Since smear errors would destroy the point images, this implies that the point target should be sufficiently bright to require a very short exposure time.)

Point spread functions were first determined for a perfect system (perfect optical surfaces, alignment and focus) and then, still for perfect optical surfaces, for various situations of misalignment (tilt and decentration) and focus errors alone and in combination.

The results of this analysis yielded several results of interest and several additional questions which should be pursued.

Results:

(1) The dimensions of the point spread functions did not exceed the size of the normal diffraction pattern for the optical system until the magnitude of the errors (alignment and focus) introduced, significantly exceeded spec values on these quantities. This, of course, was expected, for the basis of determining permissible tolerances is no loss in resolution, which means a balance between these errors and normal diffraction limitations.

(2) For errors significantly larger than spec tolerances, the resulting point spread functions could be correlated with the error sources.

(3) The off-axis points tended to yield more correlation information than the on-axis point, implying that an array of point sources would be required.

(4) Such ray tracings, or equivalent laboratory techniques, could be the basis for production of reference imagery for use on board by the flight crew.

(5) Since the flight crew has on-board controls for alignment and focus, "tweeking" of the system to improve performance may be possible.

(6) The point image sizes are such that a high-power microscope (~100X) would be necessary for their examination.

Questions:

(1) How quickly would the ability to correlate point imagery with error sources degrade if the mirror figure were not perfect?

(2) Is the dynamic range of the film sufficient for recording the fine structure of the point images?

(3) What would the point targets be like in order to achieve the short exposures necessary to eliminate smear as a degradation source?

(4) Could the exposure control be at the point source and coordinated with the on-board shutter? Conceptually this is relatively simple, and if so, this would permit simultaneous photography of standard resolution targets with normal on-board exposure settings.

While these questions are, of course, significant, there would appear to be enough promise in such techniques to pursue them further. It might also be mentioned that even if the on-board utility of point source photography were marginal, such photography would still be very useful for post-flight image enhancement/processing techniques--a field in which considerable progress has been made in recent years. This latter point has in general been confirmed by discussions with Dr. S. Q. Duntley and Mr. James Harris of the Visibility Laboratory, University of California, San Diego, who have done considerable work in this field (both have DORIAN clearances and have also done extensive work for NPIC in this area).

It is obvious from the foregoing discussion, that considerably more work needs to be done pertaining to the definition of diagnostic techniques. Still the work done to date indicates the possibility of this additional work being fruitful. To a large extent, this work will have to be done as a part of the EK and Data Corporation study efforts because of limited manpower availability within Aerospace. However, our initial work has provided some basis for the direction of this effort and it is strongly recommended that the contractors' work in this area be followed closely by SO/Aerospace.

III. Derived Viewer/Microscope Requirements

To permit the crew's performance of the tasks discussed in Section II, a film viewer and magnifying optics will be required. The film to be examined will be obtained primarily from the secondary camera, with only a limited amount from the primary camera as only the beginning or end of a primary reel may be accessed for on-board processing. Certainly not all of the secondary film will be processed and inspected on-board for much of the secondary photography is taken for purposes other than health check or diagnostic work; e.g., it is hoped that a large amount of color photography will be obtained with the secondary camera both for intelligence and subsequent crew training purposes. Since the quantity of on-board processing and inspection will be a function of the definition of diagnostic techniques, and, of course, the actual performance of the particular payload being flown, it is difficult to establish exact quantities. However, it is difficult to envision a situation in which more than about 100 to 200 frames would be processed and examined on board for these purposes.

Since considerable information may be derived from off-axis imagery and since it would be operationally undesirable to require the crew to cut out sections of the (sticky) processed film, the viewer should be capable of displaying the entire format of a single frame (including the edge data block) at one time. Sufficient light intensity and variability of light intensity should be provided consistent with the possible range of photographic emulsion densities expected (resulting from variations in ground scene, exposure, etc.) and the demands of the optical viewing instruments.

For cursory inspection and perhaps for some of the qualitative and quantitative health check work, one or more eye-loupes should be provided (~7X and maybe as high as 15X to 20X). However, since more sophisticated diagnostic analysis demands more magnification, a microscope is required. The microscope should provide variable magnifications up to ~100X, with the real f.o.v. on the film commensurate with the image sizes of interest for diagnostic work (1-3mm at highest magnification should be adequate, corresponding to 33 to 100 feet on the ground). The microscope should also provide for viewing of reference diagnostic imagery and comparison with

DORIAN calibration imagery. As a minimum, the reference imagery should be viewable simultaneously in time, though a split-field comparison microscope would be desirable if it could be obtained at minimal weight and cost impact. An image rotation capability (either optical or mechanical) in the microscope optical train viewing the DORIAN photography would be desirable (possibly mandatory) to permit the orientation of this imagery to be aligned to that of the reference imagery. The impact of this rotation requirement should be investigated to facilitate final decision on this design feature.

Hand drive of the film reels will be quite adequate, though the limited f. o. v. of the microscope will demand a vernier positioning capability on the microscope mount.

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