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CONTRIBUTIONS OF MAN IN THE MOL PROGRAM

MANNED ORBITING LABORATORY PROGRAM OFFICE
WASHINGTON, D. C.

OCTOBER 20, 1967

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CONTRIBUTIONS OF MAN IN MOL

SUMMARY

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MOL Program Office
Washington, D.C.

October 20, 1967

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DORIAN

DEPARTMENT OF THE AIR FORCE
WASHINGTON 20330

OFFICE OF THE SECRETARY

October 20, 1967

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PREFACE

The principal objective of the MOL Program is to secure [redacted] or-better resolution photography of significant targets for technical, strategic, and tactical intelligence purposes.

The objective is to be reached through the development of the necessary high resolution optical technology and flight vehicles for either manned or unmanned use, proceeding toward a reliable capability in the latter as soon as practicable.

The manned system is being developed because this gives a high assurance of meeting the objective at the earliest possible time. The unmanned system is being developed to insure a very high resolution photographic capability should international objections or foreign threats preclude manned operations, or should man prove unable to function effectively for prolonged periods on orbit (this latter concern is diminishing as manned space flight experience accumulates).

This paper presents, in highly summarized form, qualitative and quantitative information on the expected contributions of man during the early development flights of MOL and toward increasing the quantity and intelligence value of the reconnaissance product.

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CONTRIBUTIONS OF MAN IN MOL PROGRAM

The [redacted] length MOL camera, with its six foot diameter main optical elements, is a huge and complex system. Not only must this camera be manufactured with great precision, but several technically difficult-to-achieve functions associated with its on-orbit operation must also be performed with great precision. These functions involve automatic devices many of which either have never before been used on orbit or represent large extrapolations in precision, accuracy, or other capabilities. (b)(1)

The proper functioning of all of these automatic devices (b)(3) is essential to the success of the unmanned system. However, in the manned system, although capable of "hands-off" photography using the same automatic devices, the astronauts can, in most cases, also manually adjust them to peak performance and/or substitute a completely manual mode of operation for failed or grossly malfunctioning subsystems.

It is planned, therefore, to fly the manned system first because this gives the highest assurance of meeting the resolution goal of [redacted] or-better photography; will insure a useful and worthwhile reconnaissance product at the outset; and should contribute to the maturing of the unmanned system at a much earlier date than probably would otherwise occur.

Additionally, once the automatic devices work reasonably well and do not require repeated on-orbit adjustment or extended manual operation, the astronauts are expected to provide significant increases in the quantity and intelligence value of photography acquired over that possible with the unmanned system, and to perform other operational tasks not now practical in the unmanned system.

MAN IN THE DEVELOPMENT LOOP

As indicated earlier, although the manned system includes all of the automatic devices necessary for the camera to operate in a "hands off" mode, the manned system also includes the data displays and controls necessary for the astronauts to fine-tune most of them to peak performance and/or substitute a manual mode of operation for failed equipments. Some examples follow:

1. <u>Alignment</u>: Because of its size and the mass of the optical elements, the camera optical assembly is not a completely rigid structure. The optical elements are clamped down during launch and boost to protect them; released after orbit is achieved; and automatically aligned and realigned as necessary during the course of the mission. Simulations indicate that the astronauts, by observing the light path used to align the optics, can manually set alignment to within the required limits. (The error budget for [redacted] resolution includes approximately 1/4 inch for misalignment. This equates to approximately 20 Arc Seconds of allowable tilt in the primary mirror).

2. <u>Focus</u>: To achieve [redacted] or better resolution, the film platen must be controlled to within $\pm.002$ inches of the plane of perfect focus. Beyond this tolerance, resolution falls off rapidly (another 1/1000 inch focus error degrades the resolution to approximately [redacted]. An automatic focus sensor is provided for this purpose. The astronauts will verify that the best focus position has been selected by photographing a single target several times with the

(b)(1)
(b)(3)

platen in different positions, developing the film in the on-board processor, and identifying the platen position of best photographic resolution. If the automatic focus device is not working properly, the astronauts can manually control the positioning of the platen.

3. Pointing: Because of the small field of view of the MOL camera (9000 foot diameter circle on the ground from 80 miles altitude), and the fact that resolution degrades somewhat from the center toward the edge of the circular format, the tracking mirror must be pointed with considerable accuracy. In the unmanned and manned/automatic modes, the tracking mirror is expected to be pointed with an average accuracy of about 1700-2100 feet on the ground. This much error in a typical photograph of 20 degrees obliquity, with all other devices working properly, will give a resolution of [redacted] at the aiming point. If the across-format image motion compensation device malfunctions, the resolution at the aiming point will be approximately [redacted] Simulations verify that the astronauts can easily control the pointing of the tracking mirror to less than 300 feet aiming

(b)(1)
(b)(3)

error, thus obtaining the best possible resolution of [redacted] in this example, with or without an operative across-format image motion compensation device. (b)(1) (b)(3)

4. Tracking: Since the MOL is a frame camera, the tracking mirror must track the target continuously during film exposure. To meet the [redacted] resolution goal, the mirror must track within an accuracy of 1½ thousandths of a degree per second (about 12 feet per second on the ground). Since ground-calculated estimates of spacecraft height and velocity can only provide inputs which would give about 30/1000 degree per second tracking error rate (which would cause the resolution to degrade to about 19 inches), an on-board image motion velocity sensor is included to provide the final vernier adjustments. Although three different approaches are being pursued, this is a very high risk development. Simulations have verified that the astronauts, by observing the target through the main optics, can manually provide at least as fine a control as the automatic image motion velocity sensor and its associated control electronics when the latter are operating properly.

5. Diagnostics: Many malfunctions, such as those described above, along with the appropriate corrective action, will be quickly apparent to the astronaut and system engineers on the ground (via telemetered data). Other problems may require considerable diagnosis on the part of both parties before even the best course of action for that particular mission is known. However, the astronauts, by virtue of their on-board manual switching and control capabilities, are expected to aid materially in identifying the fundamental sources and causes of problems at a much earlier flight date than normally occurs in unmanned system development programs.

INCREASING THE QUANTITY AND INTELLIGENCE VALUE OF PHOTOGRAPHY

As indicated previously, once the automatic devices are working reasonably well and do not require repeated adjustment or extended periods of manual operation, the astronauts are expected to materially increase the quantity and intelligence value of photography over that possible with the unmanned system. Three means by which this will be achieved are discussed in the following subsections:

1. Weather Avoidance: Targets to be photographed by both the manned and unmanned MOL systems will be selected by the National Reconnaissance Office based upon the requirements of the US Intelligence Board. For manned system operations, alternate targets, where available, will also be designated for each primary objective. The astronauts, by viewing ahead of the spacecraft through their tracking and acquisition scopes (which can be operated slaved-to or independent of the main optics), can observe the weather at both primary and alternate targets and select for photography the highest priority target with the best weather conditions. Numerous analyses and simulations have been conducted to verify the potential of this mode of operation. The results indicate that there is ample time for the astronaut to perform this function with a high degree of accuracy; and that the manned system will average at least approximately 20 percent more cloud-free targets per day on orbit than will the unmanned system. In densely populated target areas with worse than average weather, such as Moscow, the manned system will provide as much as 45 percent more cloud-free

photographs per average day on orbit than will the unmanned system.

2. Verification of Photography: In the manned system, the astronaut will be able to verify to the ground mission director that photography has been accomplished of given targets. This will permit the NRO to then designate another primary target for the next photographic access to the same area (in northern latitudes, the next access will occur only one or two days hence). In the unmanned system, the NRO must either accept a confidence level, based upon weather forecasts, of having photographed a given target, or else wait until the exposed film has been returned, processed, and interpreted (a data recovery vehicle will be returned each week, plus 2-3 days for developing and interpretation) prior to designating a new primary objective for the next access to the same area. Analyses indicate that the manned system, through the immediate verbal verification technique, will be able to photograph from 10-25 percent more targets per day on orbit than the unmanned system. The potential increase is most sensitive to a variety of factors; however, these appear to represent the upper and lower limits.

3. Increased Intelligence Value: Post mission analyses of KH-7 and KH-8 photography indicate that often the targets of greatest intelligence value were not those which were the primary aiming points, but rather were a "bonus" by virtue of the extent of the camera's field of view. Such targets frequently were transitory in nature (for example, a missile being loaded into a silo versus a nearby but closed-up silo). Because of the MOL camera's small field of view, it is most important that the camera be directed at the right target at the right time. Analyses of the various target categories indicate that 70 percent of them have the potential of momentarily increased intelligence value, but that these situations occur only six percent of the time. Simulations and analyses indicate that the manned MOL system, with the astronauts observing both primary and alternate targets through their acquisition and tracking scopes and selecting, as appropriate, those of highest intelligence value, will photograph from 2 to 2½ times as many of these types of targets per average day on orbit as will the unmanned system. In denser than average target areas, the ratio should favor

the manned system over the unmanned by as much as 3-6 times per average day on orbit.

OTHER CONTRIBUTIONS AND CAPABILITIES

The manned MOL system has other capabilities which either are unique to man or not practical for inclusion in the unmanned system at an early date. Three examples follow:

1. Visual Reconnaissance: Appropriate observations of the astronauts, voiced while viewing primary and alternate targets through their tracking and acquisition scopes at 3-30 foot resolutions, will be tape-recorded for later transmittal to the ground. This will supplement the actual photography and provide additional intelligence information on other targets. In the future, when the MOL training simulator is completed, carefully controlled tests will be conducted to ascertain the extent possible for visual reconnaissance and the credence with which it can be accepted.

2. Special Films: The manned system has an alternate camera back, with its own film supply, which was included primarily for the astronauts to make periodic health checks on the system (e.g., by taking test photographs, developing

the film in the on-board processor, and analyzing the results). However, as requested by the ground, special film (color, infrared, experimental black and white, etc.) can be manually loaded in the alternate camera and photographs taken of specific intelligence objectives. Any film thus exposed by the astronauts would be returned by them in the Gemini, along with the normal mission film, for carefully controlled processing on the ground.

[redacted] (b)(1) (b)(3)

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SUMMARY

From the foregoing, it is clear that the manned MOL system gives a higher assurance of meeting the resolution goal; should provide a worthwhile intelligence product at the outset; will contribute to the earlier maturing of the unmanned system than would probably otherwise occur; will provide a significantly greater total quantity and larger numbers of photographs of particular intelligence value per day on orbit than will the unmanned system; and finally, has certain additional mission capabilities either unique to a manned system or not practical in the unmanned system at an early date.

MANNED ORBITING LABORATORY

CONTRIBUTIONS OF MAN IN MOL PROGRAM

October 20, 1967
MOL Program Office
Washington, D.C.

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PREFACE

The Manned Orbiting Laboratory (MOL) Program includes the development of both manned and unmanned space vehicles, each aimed at obtaining very high resolution photography of targets significant to national security.

The manned system is being developed and will be flown first because this gives a high assurance of meeting the objective at the earliest possible time. The unmanned system is being developed to insure the availability of this photographic capability should international objections or foreign threats preclude manned operations, or should man prove unable to function effectively in space for prolonged periods (this latter concern, which was the subject of numerous earlier discussions, has diminished considerably as manned space flight experience accumulates).

This paper explores the utility of man in the MOL Reconnaissance Satellite System. It presents qualitative and quantitative information on the contributions he is expected to make during the early development flights of MOL and toward increasing the quantity and intelligence value of the reconnaissance product.

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I. INTRODUCTION:

The primary purpose of the MOL System is to secure [redacted] or better resolution photography of targets significant to national security. The MOL Program includes the development of the necessary advanced camera/optical technology to meet the resolution goal and systems for either manned or unmanned operational use. (See attachments 1 and 2 for schematics of the manned and unmanned systems.) (b)(1) (b)(3)

The MOL Program presently includes seven launches: two unmanned launches to qualify the Titan IIIM booster, verify structural integrity of the orbiting vehicle, and qualify the Gemini B; plus three 30-day manned/automatic* missions in all all-up photographic configuration; and two 30-60 day unmanned missions in an all-up photographic configuration. At the end of this launch program, it is anticipated that both manned and unmanned systems will be reasonably mature.

The MOL camera/optical system is much more technically advanced and complex than any other system now in use or planned for the future. Not only must the camera/optical system be manufactured with great precision, but several technically difficult-to-achieve functions must also be performed on orbit with great precision. These involve automatic devices which either have never before been

*"Manned/automatic" means that all subsystems necessary to operate the camera/optical system in a "hands-off" mode are included.

used in orbital reconnaissance systems or represent large extrapolations in precision, accuracy, or other capabilities. All of the automatic systems must function within design specifications if the unmanned system is to meet the primary objective; however, in the manned system, although the camera system is capable of "hands off" operation, the astronauts can also apply "vernier" adjustments to those automatic systems not operating within design specifications or substitute a manual mode of operation for grossly malfunctioning or failed automatic systems.

It is therefore planned to conduct the manned system missions first because this gives a considerably higher assurance both of meeting the resolution goal and securing a worthwhile intelligence product at the outset, and also will enhance the maturing of the unmanned system at a much earlier date than probably would otherwise occur.

Once the automatic devices are working reasonably well and do not require repeated adjustment or extended periods of manual operation, the astronauts are expected to make significant increases in the quantity and quality of photography accomplished over that possible with the unmanned system and to provide additional capabilities either not possible or practical at an early date in the unmanned system.

This paper deals with the quantitative and qualitative contributions of man in: meeting the resolution goal, insuring a worthwhile intelligence product at the outset, and compressing the development cycle for both the manned and unmanned systems; enhancing the primary reconnaissance mission through his presence on orbit; and providing other capabilities inherent in the manned system.

The sections which follow touch first upon reliability and vehicle design considerations for a better understanding of the possible areas of crew contributions; and then treat in more depth the astronauts' role in insuring peak-possible camera performance and/or identifying the sources or causes of sub-standard performance; the contributions of man in increasing the intelligence value and quantity of photography accomplished; and additional crew contributions in reconnaissance and other mission areas.

II. RELIABILITY AND DESIGN CONSIDERATIONS:

The manned and unmanned orbiting vehicles each consist of three basic segments: the Gemini B, Laboratory Module, and Mission Module in the manned system; the Support Module (in lieu of the Gemini B) which carries the data recovery vehicles and associated film transport system, a Modified Laboratory Module (life support and manual control systems removed), and the same Mission Module in the unmanned system. The Titan IIIM booster is used for both systems.

Estimates of reliability for the mature manned and unmanned MOL systems are quite high due to the basic design philosophy of incorporating proven hardware and/or redundancies where practical in all sub-systems and components. Desirable redundancies have been identified both from statistical estimates of hardware reliability and detailed analyses of the performance of identical or similar subsystems and components in other satellite systems.

With respect to the Laboratory and Modified Laboratory Modules, a relatively mature system (95 percent or better probability of success for a 30-day period) is expected virtually at the outset. This assertion is based to a degree on the fact that the Laboratory subsystems, for the most part, are derivatives of current hardware technology (for example, from Gemini and Apollo). Additionally, the extensive amount of ground testing in the program instills additional confidence that the Laboratory segments will have an early high level of reliability. The foregoing also applies to the Gemini B and TIIIM segments, and to a lesser degree, the Support Module.

However, the situation with respect to the Mission Payload segment is different. The resolution requirement, plus the problems associated with the 1^{o} field of view, necessarily result in a very complex camera system incorporating, in addition to large and precise optics, many ancillary devices for functions such as image motion compensation, precise pointing, across-the-format image motion compensation, optical alignment, etc. While the statistical estimates of reliability for a <u>mature</u> camera/optical system are high (see figure 3), due to the extensive redundancies incorporated in the design, many of its subsystems represent new technologies or extensive engineering adaptations of current technology and components (see figure 4). It is anticipated, therefore, that there will be numerous instances of out-of-specification performance or failures of these automatic devices on early flights.

The fundamental system design is compatible with the objective of both a manned and unmanned configuration resulting from the program. In addition, the design philosophy is compatible with the concept of crew contribution to the realization of early maturity in both configurations. Since the same camera/optical system will fly in both manned and unmanned configurations, a philosophy of automatic operation, with redundancy where practical has been adopted for the camera/optical system and all Laboratory subsystems associated with both the manned and unmanned configurations. An on-orbit maintenance concept has been permitted on the life-support subsystem only, which is of course peculiar to the manned configuration. The manned configuration does provide for a backup manned switching capability in most instances where subsystem or component redundancies exist, and manual operation where possible. In the camera/optical system, the manned configuration incorporates elements necessary for unmanned missions with the exception of those elements of the film-transport system associated with the multiple data recovery vehicles. That section of the film-transport subsystem is, however, amenable to extensive ground testing.

With respect to diagnosis of failure or out-of-specification performance situations, the basic concept is to accomplish this on the ground during and/or after the mission; to this end, extensive instrumentation and telemetry capability has been incorporated in the basic design. However, since the crew can contribute significantly, as will be illustrated later in this document, to such diagnostic efforts, the manned configuration therefore incorporates certain features to facilitate this function.

First, there is a malfunction alarm system which monitors approximately 100 Laboratory plus 100 mission payload segment parameters and provides aural and visual ques to the crew of out-of-tolerance conditions. In the event of such an occurrence, the alarm system also immediately initiates the automatic recording of telemetry data. Several hundred instrumentation points will be recorded for later transmission to the ground; the crew can have access -- on a selective basis, as desired -- to the recorded telemetry. This feature, in addition to other capabilities provided, will permit the crew in many instances to perform diagnoses and/or take corrective action much more readily than could be accomplished from the ground.

Thus, the anticipated relatively low early maturity of the Mission Payload and the relatively high initial maturity of the Laboratory and Gemini, plus the ability of the crew to diagnose and correct difficulties on orbit, clearly indicated that it was both practical and desirable to schedule the manned flights first.

III. ASTRONAUT ROLE IN SYSTEM DEVELOPMENT

The crew's role in system development can be considered in three general areas. First, they have a basic capability to keep the manned vehicle operating on orbit for the maximum possible duration, thus permitting the obtaining of more operating data and more reconnaissance product. This is facilitated by their ability to operate the system in a degraded mode (thus circumventing many types of failure situations) and/or restore the system to a normal operating configuration often more rapidly than can be done from the ground. Second, the crew can perform health checks on various subsystems -- primarily in the camera/optical system area, but also for the Laboratory segment -- and directly assess performance. Third, in situations of either failures or out-of-spec performance, the crew can perform certain diagnostic functions to verify and supplement the telemetry provided to the ground. As will be discussed later in this section, these diagnostic actions will, in many instances, permit the identification and isolation of the source of off-nominal performance quite rapidly as opposed to the extended analyses frequently required for unmanned vehicles.

Analyses have been performed on many of the Laboratory and Mission Module subsystems to assess situations wherein the crew might respond more rapidly than the ground in restoring a normal operating situation after a failure. In most instances, when an out-of-tolerance condition is sensed on the unmanned configuration, the affected subsystem is put in a quiescent state and telemetry recorded until arrival over a ground station. Upon receipt and analysis of the telemetry data on the ground, appropriate commands are sent to the vehicle. In the manned configuration, while similar deactivations of the same subsystem automatically take place, the crew is alerted and upon analyzing the situation may be able to take the necessary corrective actions prior to arrival over the ground station.

Similarly, the crew can also correct off-nominal situations by operating the system in degraded modes -- in some instances, directly inserting themselves into the system operation loop. This capability is of particular importance with respect to some of the camera/optical subsystems in that, as discussed previously, they represent considerable advancements in technology and hence are relatively high risk development items. For most such devices, a manual mode of operation is possible. For example, if the star tracker (which is the precise pointing reference) malfunctions, the crew manually performs the target centering function. The subsections which follow treat in more detail several such functions.

A. ALIGNMENT:

Because of its size and the large mass of the optical elements, the MOL optical assembly is not a rigid structure as is the case with present (and smaller) unmanned systems. Both the primary mirror (at the aft end of the optical assembly) and the tracking mirror must be protected by being clamped down during the launch and boost phase, and released and aligned after orbit is achieved.

The zero-g alignment of the optical assembly differs sufficiently from the one-g alignment that a means to correct for alignment shifts is necessary. For example, on the ground, gravity-induced factors contribute to bending of the Ross Barrel, deflection of the mirror support structure, stretching or deflection of the Camera Optical Assembly structural shell, etc. On-orbit, cyclic thermal stresses encountered during each revolution also induce structural stresses.

Misalignment from tilt and/or decentering of the primary mirror with respect to the optical axis of the Ross corrector assembly results in a loss of Optical Quality Factor*. This is translatable into lesser static resolution capability. For example (Fig 5), an equivalent primary mirror tilt angle of 20 Arc Seconds equates to a five percent decrease in Optical Quality Factor and approximately the same loss in resolution. (A five percent allowable loss in OQF due to misalignment is the maximum permitted in the error budget).

To correct misalignment errors, three servo linear motors are provided to reposition the primary mirror and three more for the Ross diagonal mirror. Misalignment is measured by light sources which are projected through the optical system, along the optical axis, to two pairs of detectors. The detectors generate electronic error signals which indirectly actuate the servo motors and properly position the mirrors.

The astronauts can read optical misalignment directly and manually control the servo motors in the event of malfunction. Simulations and component tests verify that the astronauts can manually control alignment well within the specified tolerances.

*Optical Quality Factor: ratio of the optical quality of the constructed to a theoretically perfect product.

B. FOCUS:

Resolution is affected not only by optical quality, misalignment, smear, etc., but also by noncoincidence of the film emulsion plane and the plane of best focus during exposure. The mismatch between these two is referred to as the focus error. The allowable tolerance in the MOL camera system for this mismatch is ±.002 inches. Focus errors beyond this limit cause a rapid drop in resolution (For example, another .001 inch out of focus causes a resolution loss of approximately one inch. See Fig 6). An automatic focus system has been incorporated in the MOL camera system which, when operating properly, will keep the focus error well within allowable limits.

The astronaut cannot identify and compensate for focus errors as directly as can be done for mirror misalignment. Periodically, however, to verify that optimum focus has been set, the astronauts will take several pictures of a single target (preferably a resolution measurement target in the USA) at varying focus positions; develop the film on board using the on-board processor; and identify the setting which provided the highest resolution photography. If the automatic focus sensor has not selected the plane of best focus, the astronaut can manually control the positioning of the platen for this purpose.

C. POINTING ERROR:

Accurate pointing is essential to the MOL camera system both because of the small field of view (approximately a 9000 foot diameter circle at nadir and 80 mile altitudes) and the fact that the very best resolution occurs in the center of the picture format.

A small portion of the degradation in resolution outward from the center of the frame is caused by diffraction and the lower illumination at the edges; however, this is relatively small (about 10 percent worse in the outer portions of the frame). The majority of the degradation results from the inability to compensate perfectly for image motion across the entire format during exposure. Figure 7 illustrates the resolution across the format in a typical off-axis oblique photograph both with and without an operative image motion compensator. It indicates that resolution near the edge of the format on this situation, with the IMC operating properly, will be approximately 33 percent worse than at the center. If the cross-format image motion compensation device were not operating properly, the degradation in resolution from center to edge could be as much as 160 percent.

Pointing errors can result from a variety of factors (malfunctioning star tracker; errors in precise location of the spacecraft; geodetic uncertainties with regard to the targets; misalignment between the tracking mirror and the Camera Optical Assembly, etc.). From all such sources, the MOL expects an average pointing error in the automatic mode of about 12-15 Arc Minutes (approximately 1700-2100 feet at 80 miles altitude).

The acquisition and tracking scopes in the MOL are expected to be pointed automatically with average errors of approximately 16 Arc

Minutes (approximately 2200 feet at 80 miles altitude). The astronauts, using their manual centering control, will be able to point the tracking and acquisition scopes to within 2 Arc Minutes (or approximately 280 feet); this capability has been verified in simulators. Thus by slaving the main optics to the tracking and acquisition scopes (or by viewing the target directly through the main optics), the astronauts will easily be able to center the camera field of view on the target with a high degree of precision.

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(b)(3)

D. TRACKING:

Since the MOL camera system is a frame rather than a strip camera, the tracking mirror must track the target continuously during photographic exposure. To achieve [redacted] or-better resolution, with all other essential elements of the camera system and spacecraft operating properly, the tracking rate error must be controlled to within 1.5 thousandths of a degree per second (approximately 12 feet per second on the ground).

Based on altitude and velocity data estimates provided the on-board computer, by ground sources, the tracking mirror rate error can be controlled to an average approximately 30 thousandths of a degree per second (approximately 250 feet per second on the ground). If the tracking rate error were this gross during photography, and all other essential elements of the camera system and spacecraft were operating properly, the resolution could be as poor as 19 inches. Thus, an on-board automatic Image Velocity Sensor is included in the camera system which, when operating properly, will provide the vernier adjustments to control tracking rate error to within the specified limit.

The Automatic Image Velocity Sensor, however, is a relatively high risk technology development. Three different approaches are being investigated -- at least two of which will be carried into prototype hardware.

The astronauts will periodically check the proper automatic functioning of the Image Velocity Sensor by observing actual tracking of the target through the main optics. If the device is not operating properly, the astronauts will inhibit the IVS automatic operation and manually track the target while viewing through the main optics. Simulations have verified that in case of sub-specification performance or complete failure of the IVS, man can provide at least as fine a control.

In the preceding four illustrations of man verification of nominal performance, or adjustment or manual operation of malfunctioning or failed camera sub-systems, the cause and the best possible corrective action will be obvious in many situations. In other instances, considerable diagnosis may be required on the part of the astronaut (in conjunction with ground analysis of telemetered data) prior to identification of the cause and the best possible corrective action for this particular problem. In still other situations, the problem may not be correctible on-orbit; however, the abilities of the astronauts to perform diagnostic functions, and supplement data telemetered to the ground, and assist in the isolation of sources of off-nominal performance is expected to speed considerably the maturing of both the manned and unmanned systems.

The MOL camera/optical system is extremely sophisticated in comparison to systems such as Gambit (KH-7) and Advanced Gambit (KH-8). There are a multitude of possible contributors to off-nominal performance situations which could radically increase the complexities of and time requirements for diagnosis and correction over those of previous unmanned development programs.

Much design effort for the manned configuration was associated with providing crew capability for restoring normal operating conditions and/or degraded mode operations, such that productive reconnaissance operations could be safely maintained for as long a period as possible on a particular flight. Simultaneously, detailed analyses of crew contributions in the area of diagnostics were begun. The discussion which follows illustrates the approach to diagnostics. Although much work remains to be done, the results to date verify that the astronauts will make a significant contribution to the diagnosis process.

By way of illustration, Figures 8 through 12 present diagnostic flow charts for two examples of off-nominal camera system performance, namely: blurred photographs; and targets not properly contained within the field of view. Analyses have been made of the possible steps which crew members might take, in conjunction with the ground, to identify and/or isolate the source(s) of these performance degradations. While the data are presented in flow chart form, this does not imply that these tests would have to be performed in the order indicated. On the contrary, the tests could in most instances be performed in any order, and in whole or in part, depending on the totality of clues available to the crew and the ground as to the possible sources of trouble.

A. POOR RESOLUTION:

Suppose, for example, that poor quality pictures were being obtained. As indicated in Figure 8, the crew would be aware of this by virtue of having processed and inspected photographs. (To indicate the time saving features of this diagnostic approach, the crew would detect this degraded performance on the first day of the mission, whereas in an unmanned system, the degradation would necessarily go undetected for about 10 days until the first data bucket had been recovered and its film load processed.) Their visual inspections of these pictures would indicate whether the loss of resolution was due to smear (directional) or was a general degradation of picture quality (blur). The latter situation might be attributable to an out-of-focus condition.

If the problem were one of smear degradation, possible diagnostic steps are illustrated in Figure 9. The asterisks indicate where telemetry will be available to the ground and the astronauts, though in most cases the crew can significantly augment the information that will be derived therefrom. For example, is the smear across the entire frame or off-axis only? If off-axis only, the across-the-format image-motion-compensation devices would be suspect, and the crew could check the platen and shutter drives. If this were, in fact, the source of the degradation, the crew would manually perform very precise target centering for the remainder of this mission and thus retain maximum possible performance.

If the smear were across the entire format, it could be attributable to an attitude control jet firing during the photographic operation, in turn due to failure of the inhibit signal to be properly transmitted. The crew would readily detect this due to the sound of and motions introduced by such jet firings, and if this were the cause, they would manually inhibit the jets during subsequent photography.

If it were not the attitude jets, the crew might investigate whether all frames of a stereo sequence were smeared or just the early frames. If just the early frames, there could be a situation of an overly long settling transient attributable either to basic vehicle dynamics or a long time constant in the image velocity sensor control loop. The crew could observe the nature and time duration of the settling transient through the main optics eyepiece both with and without the image velocity sensor in the loop, and if the settling time were improved without the image velocity sensor, then its time constant was the problem. If not, the problem might be attributable to vehicle dynamics. In either event, the crew could determine a new and more desirable settling time for the mission planning software.

If all of the frames of a stereo sequence were smeared, then the problem probably would be attributable to the image velocity sensor. The crew could observe, again through the main optics eyepiece, the nature of the discrepancy (e.g., does the scene tend to drift in one direction only, or is the motion of an oscillatory nature?) and for the remainder of this mission would perform the tracking function manually, thus retaining maximum resolution performance.

If the problem were one of a general degradation (blur), similar diagnostic steps, as illustrated in Figures 10 and 11 would be taken. Has the optical alignment drifted out? Is the platen in the best focus position? The crew actions for these situations were described earlier in this section.

The general degradation could also be attributable to an early onset of thermal deformation of the tracking mirror. To investigate this, a series of pictures would be taken with varying door-open times to verify the cause and establish, if necessary, a new maximum door-open time for use in subsequent target programming.

If none of the foregoing were identified as the source of blur degradation, the condition could result from an induced high-frequency oscillation. In Figure 10, the latter possibility is addressed with sequential steps to investigate ringing due to attitude control jet firing, bearing stiction or noise, high-frequency oscillations introduced by the image velocity sensor control loop, or mechanical vibrations somewhere else in the system.

B. POINTING ERROR BIAS:

In another example of possible diagnostic procedures, Figure 12 presents a representative flow chart for analyzing a pointing error in the form of tracking mirror bias. If such a bias existed, targets would either not be contained within the field of view or generally off to the edge. The crew would detect this readily via either acquisition scope observations and/or from film processed on board. This problem could be attributable to erroneous ephemeris inputs from the ground and the flight crew would therefore immediately request the ground to reverify those inputs. Simultaneously, the crew could initiate the steps indicated in Figure 12 to determine whether the errors were due to on-board equipment malfunction, and if identified, to take appropriate corrective action. In any event if the error could not be corrected, the crew would manually perform the centering function for the remainder of the mission.

These analyses of in-flight diagnostic procedures are being extended to more definitive delineation for these and other potential operating problems. This work will also include consideration of the possible utility of special tools or additional data displays to aid in diagnostic procedures.

The main point of this section is that the crew through diagnosis and manual corrective actions can keep the early manned system operative and secure a worthwhile intelligence product in the initial flights. Their in-flight diagnoses, as supplements to ground analyses, are expected to materially assist in the rapid isolation of sources of problems and thus speed the maturing of the automatic devices necessary for the unmanned system.

IV. INCREASING QUANTITY AND INTELLIGENCE WORTH OF PHOTOGRAPHY

As indicated earlier, once the automatic devices are working reasonably well and do not require repeated adjustment or extended manual operation, the astronauts are expected to make significant increases over that possible in the unmanned system in both the quantity of photography taken and in the intelligence worth of certain types of targets. The quantity will be increased via weather avoidance techniques (i.e., photographying a pre-programmed alternate target when the primary is cloud-covered) and also from the positive verification of photography already accomplished (thus permitting the selection from the ground of another target on the next pass over the same target area). The intelligence worth of certain targets will be increased via the selection of an alternate target of the same type but which has a momentary increased intelligence value (for example, a missile on a launch pad at Tyura Tam vs a nearby but empty launcher in the same complex). The sub-sections which follow deal qualitatively and quantitatively with these techniques.

A. WEATHER AVOIDANCE

The MOL Project Office, in conjunction with the NRO, has conducted a rather detailed analysis of the capability of the astronauts to perform a weather avoidance role. By "weather avoidance" is meant that the astronaut may select among pre-designated alternate targets for photography when adverse weather is encountered at the pre-designated primary targets. This sub-section summarizes the pertinent portions of the report of the MOL/NRO study.

The capability of the astronaut to perform as a weather "scout" was analyzed and has been tested in simulations. It was concluded that the astronauts would have little difficulty visually identifying areas of best weather since significant weather differences generally do exist between even relatively close (30-40 miles) primary and alternate targets. The effect of obliquity of viewing angle when the astronaut scanned weather was not considered serious, and the astronauts will have sufficient time (See Fig. 13) to perform the task with a high degree of accuracy.

A representative target deck, based on a mid-1966 GAMBIT/ADVANCED GAMBIT target deck and then-current intelligence community thinking, was used as a basic tool for these manned and unmanned MOL system comparisons. The availability of alternate targets did not particularly favor the manned system (since 51% of the primary GAMBIT/ADVANCED GAMBIT targets had no alternates available, 16% had but one alternate available, 8% had two alternates, and only 25% had three or more alternate targets -- a distribution of one alternate for each primary target would be considerably more favorable to the manned system); however, the locations of target areas are believed to be fairly representative of the environment which will exist when the MOL system becomes operational.

To insure a realistic study and reasonably accurate projections of targets photographed, maximum advantage was taken of NRO operating experience with reconnaissance satellites -- particularly GAMBIT experience operating against forecast and observed weather, GAMBIT software, etc. (in view of the similar characteristics of the GAMBIT and MOL camera sub-systems).

Recognizing the sensitivity of the manned/unmanned system comparison to the weather information employed (it was obvious, at the outset, that the manned system -- given the option of photographing alternate targets -- would appear in a more favorable light in adverse weather situations), a wide variety of weather models and data were utilized, with results as follows:

1. Operating on simulated, identical 30-day duration missions against analyzed March 7-April 5, 1960 weather, the unmanned system would have successfully photographed 2019 primary targets, and the manned system 2533 primary plus alternate targets (an increase of approximately 25% in favor of the manned system). It should be noted that the percentage of targets photographed by the unmanned system in this analysis is about 7% less than GAMBIT experience indicated should be the proper total. This in-effect worse-than-average climatology would bias the results slightly in favor of the manned system.

2. Operating on simulated, identical 30-day duration missions against a weather model derived from the analyses of more than

132,000 frames of KH-4 photography (Fig. 14), the unmanned system would have successfully photographed 2209 targets, and the manned system 2584 primary and alternate targets (an increase of approximately 17 percent in favor of the manned system). This weather model seems fairly representative of Sino-Soviet Bloc climatology, although it may be biased a very limited degree in favor of better-than-average weather conditions. If so, then the manned increase over the unmanned system is slightly less than would ensue in average climatology conditions.

3. Operating on simulated, identical 30-day duration missions against a weather model derived from a cloud-cover count and sorting of 1159 frames of KH-7 photography (Fig. 15), the unmanned system would have successfully photographed 2023 primary targets, and the manned system 2365 primary and alternate targets (an increase of approximately 17 percent in favor of the manned system). Despite the similarity of the percentage increase between this comparison and that for the preceding KH-4-derived weather model, the absolute validity of this answer could be questioned since the results diverge somewhat from actual GAMBIT results and experience.

4. Operating on simulated, identical 30-day duration missions against a weather model derived from the results of 3007 separate GAMBIT operations against primary targets (Fig. 16), the unmanned system would have successfully photographed 2153 primary targets, and

the manned system 2592 primary and alternate targets (an increase of approximately 20 percent in favor of the manned system). This weather model is believed to be reasonably representative of average Sino-Soviet Bloc climatology.

5. Operating on simulated, identical 15-day duration missions against "verified" (i.e., observed) July and August 1966 Sino-Soviet weather for each primary and alternate target, the unmanned system would have successfully photographed 1120 primary targets, and the manned system 1367 primary and alternate targets (an increase of approximately 22 percent in favor of the manned system).

6. Operating on simulated, identical missions against the average weather encountered in the Moscow area target complex (an area which has considerably worse-than-average climatology), the manned system would successfully photograph 45 percent more targets than the unmanned system. Similarly, operating on simulated, identical missions against the Sary Shagan and Tyura Tam area target complexes (which have better than average climatology), the manned system would successfully photograph approximately 15 percent more targets than the unmanned system.

The study led to the following general conclusions:

1. On identical missions against average Sino-Soviet weather, the manned system (with the astronaut providing a weather avoidance function and having the option of photographing only pre-designated alternate targets) can be expected to successfully photograph at least 18-20 percent more targets per day-on-orbit than the unmanned system.

2. Operating against large target complexes, with numerous primary/multi-alternate target combinations available, under average weather conditions, the manned system successful photographic results can be expected to exceed the unmanned system by considerably more than 18-20 percent.

3. When overall Bloc weather is worse than average, the manned system results can be expected to exceed the unmanned system by more than 18-20 percent; conversely, when overall Bloc weather is better than average, the manned system results can be expected to exceed the unmanned system by less than 18-20 percent.

B. VERIFICATION

A limitation to the achievement of maximum productivity with present unmanned satellite photographic systems is NRO verification that a target has been photographed in clear weather prior to examination of the actual photography itself. This, for certain target areas, can be significant. For example, GAMBIT-CUBED, in a typical 8-10 day mission, will have access to most northern target areas 4 or more times (depending on the inclination and orbit flown). For those target areas which are not covered completely with the 5-mile wide swath of the KH-8, the NRO must determine, based only on forecast and/or reported weather, when the highest priority target has been "covered" (with the desired level of confidence) and another target can be used as the primary aiming point on the next pass over the area.

The Global Weather Center provides the NRO daily with so-called "verified" weather of all targets photographed at the time of photography. This verified weather is based on US weather satellite coverage and also monitored Sino-Soviet broadcast weather reports and forecasts. Unfortunately, the US weather satellites generally do not cover the target areas at the precise time of photography, nor do the Sino-Soviet local weather reports always coincide in location or time. Further, in between the extremes of completely overcast or completely clear sky conditions, it is difficult to ascertain whether or not the target was shielded by a cloud or open for photography.

This uncertainty in weather at the time of photography is borne out by the actual results of the KH-7 and KH-8 systems. For example, when GAMBIT operations were conducted against "verified" clear skies, some 9 percent of the targets were actually completely covered by clouds. Another 5 percent found the targets partially obscured by clouds or haze. Conversely, when GAMBIT was operated against "verified" overcast skies, some 7 percent of the targets were actually photographed in the clear, and another 6 percent were partially seen through gaps in the clouds or heavy haze. See Figure 17 for actual KH-7 results against various "verified" sky conditions at the time of photography.

The photography verification problem will be even more acute for the unmanned MOL than for either the KH-7 or KH-8, since a single target for those systems usually breaks down into several MOL targets because of the latter's small field of view. It is planned to return film capsules from the unmanned MOL approximately once each week and target coverage confirmations therefore can be available about three days later. In the meantime, however, the unmanned MOL will have had 4 or more photographic accesses to certain complexes of multiple MOL targets. How many different targets will be attempted will depend on NRO confidence in "verified" weather and the relative priority of the targets involved.

Verification of photography accomplished in the manned MOL system, however, is immediate and, for all practical purposes, with virtually a 100 percent confidence factor. A normal task for the astronaut during each photographic operation will be to assure that the target is centered or contained within the field of view. This will be done by observing the target through the tracking and acquisition scopes or through the main optics. At this point, the astronaut can record the weather conditions and report these to the ground; then, a new target, if appropriate, can be identified for the next photographic access to that same target area. The only possible uncertainty in this astronaut verification process involves the possibility of an undetected momentary camera malfunction during that particular photographic operation.

Using the same target deck and weather analyses described in the previous sub-section "Weather Avoidance", several studies have been conducted in an attempt to determine the number of additional targets which could be photographed by the manned MOL system vs the unmanned as a result of crew verification of photography accomplished. The several calculations involved simulated 30 day simultaneous manned and unmanned flights against the same targets, with film returned from the unmanned system each seven days and results reported three days thereafter.

As might be anticipated, the results of these studies were very sensitive to weather encountered versus target distribution, the distribution of alternate vs primary targets, the relative priority of targets in a given complex or area accessible on a single photographic pass, the required confidence level for the unmanned system that photography of a specific target had been successfully accomplished and a new target could be selected on a subsequent pass prior to analyzing the film, etc. By adjusting these factors and/or analyzing differing situations, the results varied <u>from ten percent to 25 percent in favor of the manned system</u> (i.e., that many more targets photographed per day on-orbit).

Recently, a sample MOL target deck of some 13,000 objectives was completed for use in engineering development activities. The MOL Project Office will analyze man's verification potential, using this deck, when adequate software is available to handle it. It is anticipated, then, that a more accurate accessment will be made of the potential increased photography possible with the manned system. There is confidence, however, that the answer lies somewhere between the results of the initial analyses which now appear to represent the upper and lower boundaries.

C. ACTIVE "INDICATORS"/MOBILE TARGETS

A useful operational technique, that of inspecting targets from orbit for indications or activities of a transcient nature that would yield photography of especially high intelligence value, can and will be employed with the manned MOL system.

A 1966 analysis identified the conditions or activities in various target categories of particularly high intelligence value and the frequency with which they occurred. This same analysis also evaluated the effect of the limited field of view of the MOL camera system on the size, number, and character of such targets, and determined whether the crewmen could detect indications of high intelligence value while viewing the scene through their tracking and acquisition scopes. Recently, simulations were begun to train and evaluate astronaut capabilities in this regard. This sub-section reports on the earlier analyses and the results of simulations in mid-1967.

Of particular significance is the limited field of view of the MOL camera system (approximately a 9,000 foot diameter circle on the ground from 80 miles altitude). This is graphically illustrated in Figure 18 which compares the photographic coverage at Tyruatam attainable by a single strip of GAMBIT KH-7 photography (10 miles wide) versus that attainable by single MOL photographs (represented at proper scale by the small circles).

Experience with both GAMBIT systems indicates that, in many instances, little information was derived from the photographs of the pre-selected target or targets which were the primary aiming point for the center of the frame, whereas other targets which appeared within the frame only by virtue of its length and width yielded considerably more intelligence information. The limited field of view of the MOL camera system denies such "bonus" targets; this fact plus the transitory nature of the objects makes it particularly critical that <u>the MOL camera be directed to the right target at the right time</u>.

Analyses of actual GAMBIT photography revealed that the fraction of targets in the various categories which had potential for active indicators of special intelligence value averaged 70 percent, but that the likelihood of occurrence was only about six percent of the time (Fig. 19).

A special analysis was made of Tyuratam which presently contains more than 60 MOL-size targets, only 2 or 3 of which can be photographed by the MOL on a single pass. Of 159 launch pad photographs analyzed, only 9 percent revealed missiles on the pad; 77 silo photographs yielded 21 percent with doors open. These are much higher incidences than would normally occur with operational systems, which further emphasizes the importance of obtaining technical intelligence data in the early development phases.

Finally, the early analysis determined the resolution with which the astronauts would have to view activity "indicators" to verify them as targets of momentary increased intelligence value. The typical resolutions needed by the crewmen for this purpose ranged from three to ten feet. Figure 20 contains some examples of activity indicators in three target categories and the resolutions needed for their identification.

The analysis of resolutions required to identify targets of momentary increased intelligence value influenced the design of the astronauts' tracking and acquisition scopes. In their lower magnification range, the tracking and acquisition scopes have a circular field of view on the ground of about $6\frac{1}{2}$ miles in diameter with a resolution of about 30 feet. In the upper range of magnification, the tracking scope field of view is approximately 4200 feet (about half of the MOL camera) and the resolution will be about $3\frac{1}{2}$ feet.

The tracking and acquisition scopes can be slaved to the main optics or programmed to aim simultaneously at separate targets. The concept of operations is schematically depicted in Figure 21. While the main camera is photographing the previous target (when the fully automatic mode is operating properly), the astronauts will use the tracking and acquisition scopes to inspect the next primary camera target and its associated alternates (up to 6) and make decisions on the state of each target so inspected (i.e., cloud-covered, clear, clear and "inactive", clear and "active", etc.). The crew determinations are provided to the on-board computer which, based on pre-programmed logic, selects the appropriate target to be photographed. If the astronauts are indecisive for too long a time, the pre-programmed primary target will be photographed automatically.

The mid-1967 simulations, aimed at providing basic engineering data for detailed design of various items in the manned system, largely verified that the flight crews <u>can perform</u> the necessary target inspections at the resolutions which will be provided by the tracking and acquisition scopes and <u>in the time available</u>. Also, refinements to earlier estimates of the number of <u>additional</u> such targets that the manned system will photograph vs an unmanned system were calculated. The next several paragraphs deal with the recent simulations.

A relatively simple static simulator was built in-house for this purpose. Using actual GAMBIT KH-7 film, the simulator provided essentially the same views and resolutions which will be provided the astronauts through the tracking and acquisition scopes. Both monocular and biocular scene presentations were tested to establish any possible difference in performance due to this factor (there was no significant difference). Seven MOL astronauts participated under controlled test conditions, and actual GAMBIT photography was employed as the stimulus material (300 different GAMBIT scenes were available, 60 of which were used only for trial runs). The simulator incorporated a flooding light mechanism to reduce the contrast of the GAMBIT photography (which is specially processed to enhance contrast and maximize intelligence value) to approximate that which would be seen by the astronauts from orbit.

The astronauts were given 2-day training sessions to familiarize them with the types of scenes and types of indicators associated with particular target categories (however, they were not permitted to view beforehand the scenes used in the tests). The astronauts were instructed to identify activity and minimize false alarms (the indication of activity when in fact it is not present), with a maximum time of 12 seconds allotted for evaluating any one scene.

The results of the tests clearly indicated that the astronauts will be very accurate in correctly identifying <u>highly active targets</u> (over 90 percent correct overall average) and also very accurate in correctly identifying <u>absolutely inactive targets</u> (about 2 percent false alarms). Accuracies between these extremes varied depending on the subtlety of the activity indicators (See Fig. 22). Also analyzed was the accuracy of the crew members for those cases wherein responses (i.e., decisions) were made in 6 seconds or less. Here again, very high accuracy on the extremities of the spectrum of activity were obtained (See Fig. 23).

Several statistical calculations have been made to determine, in a quantitative manner, the nature of the mission enhancement of the manned system over the unmanned system attributable to active indicator mode operations. These calculations used as a basis the 1966 study which established 70 percent of the targets as potentially active, with a frequency of occurrence of only 6 percent, plus the results of the 1967 astronaut simulator tests.

The results of one such computation, is presented in Figure 24. Figure 24 depicts mission enhancement factor, defined as the ratio of the number of clear active photographs obtained with a manned system to that obtained with an unmanned system, as a function of the crew performance parameters (% correct detections, % false alarms). These particular calculations involved a simulated 30-day mission, including, within the computational approach, statistics pertaining to numbers of programmed targets per day (devised from runs using GAMBIT software), and to the distribution of alternate targets with respect to programmed main camera targets (i.e., certain primary targets have no alternates available; others have only one, etc.). As seen, if the crewmen were perfect with 100 percent correct detections (i.e., a zero false alarm rate), an overall enhancement factor of 2.75 would result. Superimposed on these parametric curves are the 1967 simulation results presented earlier, and enhancement factors of 2 to 2.5 are indicated. It should be noted that this performance was attained with very little special crew training for this task.

While this overall mission enhancement factor is by itself significant, the effects of active indicator mode operations against representative target clusters are even more dramatic, and of considerable interest when it is recognized that operations against certain, relatively isolated, target clusters offer the potential of significant technical intelligence yield. Enhancement ratios of 3 to 6 are indicated for crew performance levels against such targets.

In summary, the manned system operated in the active indicator mode will provide several times more photographs of targets in which indications of activity are present, and from which considerably more intelligence information will be derived, per day on orbit than will the unmanned system. This is particularly significant in view of the low frequency of occurrence of these transitory activities.

V. ADDITIONAL CAPABILITIES

The crew's presence offers additional unique means of enhancing the reconnaissance product of on-orbit MOL and also the accomplishment of other missions by the manned system. Four of these are briefly discussed in the following sub-sections.

A. VISUAL RECONNAISSANCE:

Intelligence data may be derived for targets not photographed by or included in the field of view of the main camera as a result of the crew observing such other targets through their tracking and acquisition scopes. Their descriptions of their visual observations of these targets will be tape-recorded for later transmittal to the ground, thus providing an additional base of data from which intelligence data may be extracted.

Crew performance to date in the simulators verifies that this can be a worthwhile adjunct to the photographic product. In the future, it is planned, when the Environmental Development Simulator at General Electric is further refined, to conduct a series of controlled tests to determine the extent to which information can be obtained from visual observations and the credence with which the reports can be accepted.

B. SPECIAL FILMS:

The manned MOL configuration incorporates a secondary platen in the camera back with a separate supply of film. Although the primary reason for including this capability is for the astronauts to perform camera health and performance checks on-orbit (by photographing targets with the secondary camera and developing the film

in the on-board processor), the crew can, as requested from the ground, insert a variety of special films (e.g., color, IR, special black and white) into this secondary platen. Such pictures will be returned at the end of the mission, along with the primary film, for refined processing on the ground. (b)(1)
(b)(3)

[redacted]

(b)(1)
(b)(3)

[redacted]

D. ASTRONOMY:

Although not of particular interest to the Defense Department, the MOL Project Office and NASA have investigated the possibilities of using the MOL system to accomplish visible-spectrum photography of the planets or other celestial objectes of comparable brightness. The results of these investigations indicate, depending on the particular planet in question, MOL photographic resolutions 2 to 8 times better than achievable with ground-based telescopes.

The above values were arrived at following simulations of this task which employed MOL astronauts as test subjects. The general concept of operations would be to roll the vehicle to the proper attitude for directing the main camera system at the target planet, and then the astronaut would acquire and track the planet using the main optics visual display.

Calculated required exposure times for MOL planetary photography ranged from 1/1000 second for VENUS to 13 seconds for PLUTO. Although exposure times for SATURN, URANUS, NEPTUNE, and PLUTO all exceed the planned maximum MOL exposure capability of .08 seconds, crew tracking capabilities were tested over the entire range as a necessary input to any possible future considerations of increasing the exposure latitude of the camera. Crew tracking accuracy was verified as adequate for the task.

Utilizing the image displacement data developed from these simulations, modulation transfer function analyses were performed to establish surface resolutions attainable against the various planets. Figure 26 presents the results of these computations and compares these resolutions with those attainable from the ground. Significant improvements are indicated; and, for example, in the case of Mars, the resolution attainable by MOL is essentially equivalent to that achieved by Mariner although a single MOL photograph of Mars would include the entire visible side of the planet.

It should be noted, however, that the present MOL camera and optical system could only be considered an adjunct to a properly designed orbital observatory. Inherent characteristics of the camera limit its use to photography of the near planets.

VI. SUMMARY:

The presence of the crew in the initial flights of the MOL system will, by virtue of their abilities to perform switching, maintenance, manual backup, and in particular, diagnostic functions in situations of failures or off-nominal performance, significantly contribute to an early maturing of the unmanned system. At the same time, the missions will simultaneously be gathering high-resolution photography of significant intelligence value.

The use of the crew in the weather avoidance and active indicator modes can in part circumvent operational limitations introduced by adverse weather and/or the transitory nature of intelligence at particular target sites coupled with the limited field of view of the optical system. By accessing targets other than those programmed for the main camera and making real-time decisions on the relative desirability of photographing the programmed primary or an alternate target, the crew can significantly improve both the quantity and the intelligence value of the take. Additionally, the crew's performance of such functions as target coverage verification, visual reconnaissance, and the use of special films in the secondary camera when appropriate, will further enhance the overall operational effectiveness of the manned system.

(b)(1)
(b)(3)

Finally, the presence of the crew permits the utilization of the MOL system, without modification, [redacted] and/or limited planetary photography

Simulations thus far have provided a high degree of assurance of the crew's basic capabilities to perform all of these tasks. With the additional training to be imparted between now and flight time, it is anticipated that the astronauts' effectiveness in performing these tasks will show marked improvement over the early results.

FIG 1

BASELINE MOL UNMANNED MODE

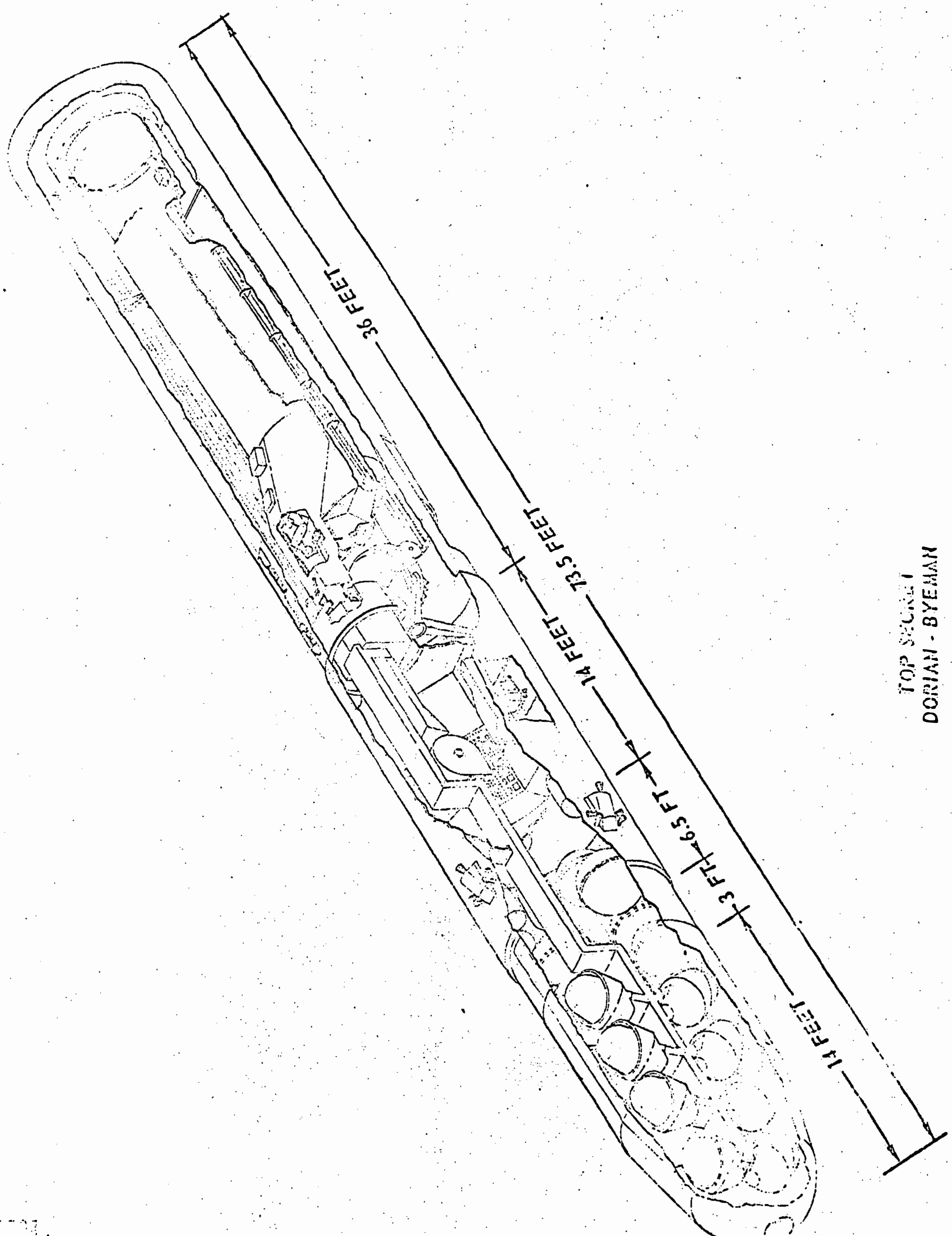

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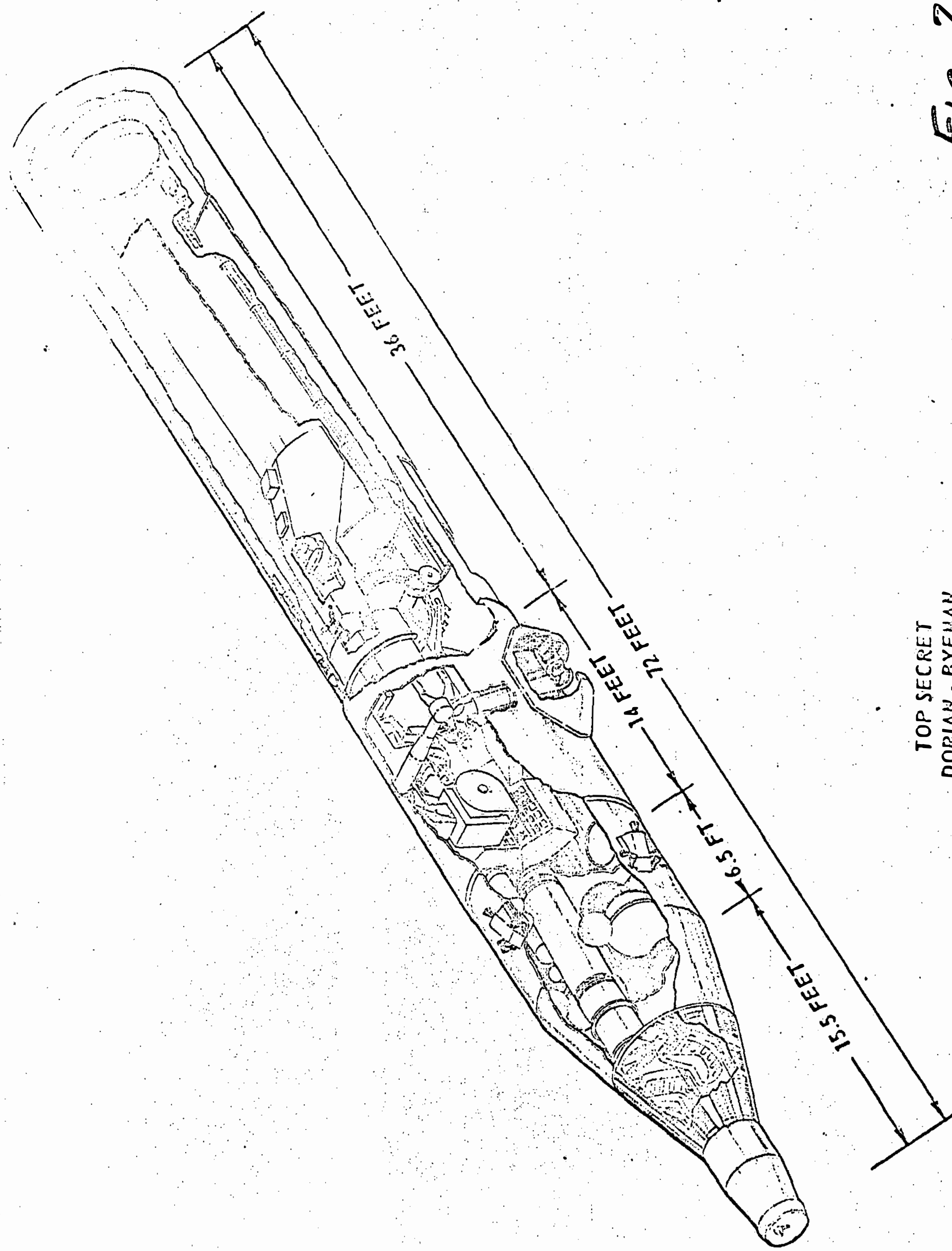
FIG. 2



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UNMANNED MISSION MODULE RELIABILITY ANALYSIS

$(.1 \times 10^{-6}\ \lambda\ /\ AEG)$

	P_R (30 DAYS)
COMPUTER/DAU (R)	.989
STAR TRACKER (R)	.99953
IMU	.9875
ALIGNMENT SENSORS (R)	.99937
FOCUS SENSORS (R)	.99937
ALIGNMENT MECHANISMS (R)	.99753
GIMBAL DRIVES (R)	.998
P&R GYROS (R)	.9998
APERTURE DRIVE (R)	.99984
STRUCTURAL DOOR (R)	.99997
TEMPERATURE CONTROLLERS (R)	.9999
FILM FEED, CUTTERS, ROLLERS, ETC.	.98
RECOVERY BUCKETS, LAUNCHING, ETC. *	.9994
V/R SENSOR (WR/R)	.9542/.9989
MISCELLANEOUS ELECTRONICS	.9640
	.851/.891

ESTIMATED EQUIVALENT AEGS ≈ 12,000 SERIAL

22,220 REDUNDANT

* BASED ON ANY 3 RECOVERY VEHICLES WORKING

FIG 3

MISSION P/L DEVELOPMENT RISK

- ITEMS REQUIRING EXTENSIONS OF CAPABILITIES

  ACROSS FORMAT IMC

  V/H SENSOR

  MIRROR DRIVE SERVOS

  ALIGNMENT MECHANISMS

  MIRRORS

  OPERATING SOFTWARE

- ITEMS REQUIRING ENGINEERING ADAPTATION

  COMPUTER

  STAR TRACKER

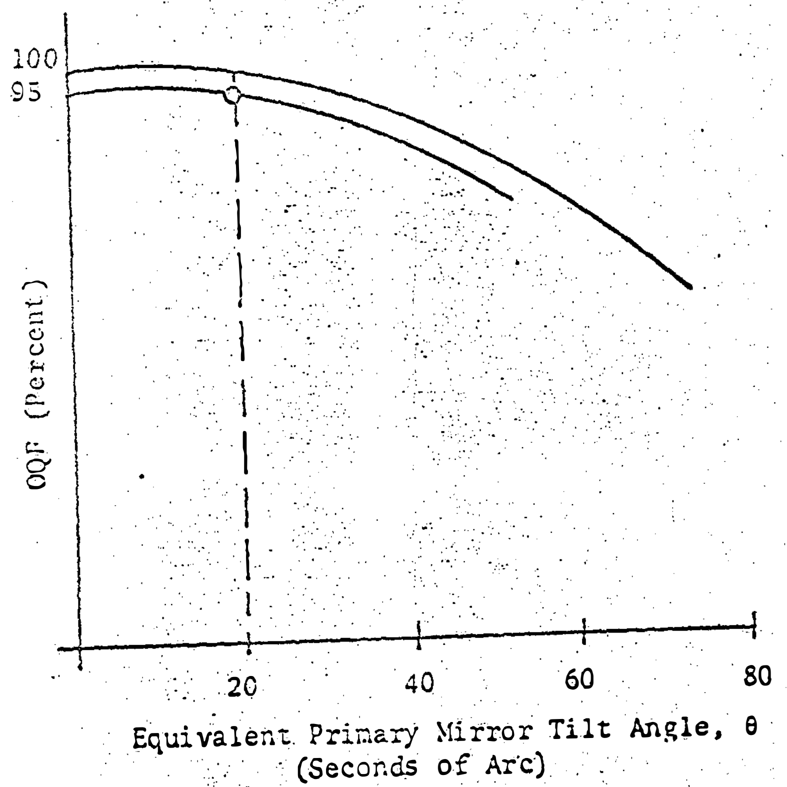
  MULTIPLE RE-ENTRY VEHICLE ARRANGEMENT

  THERMAL CONTROL & DOORS

  MM STRUCTURE

  SENSOR STRUCTURE

FIG. 4



OQF vs Primary Mirror Tilt

FIG. 5

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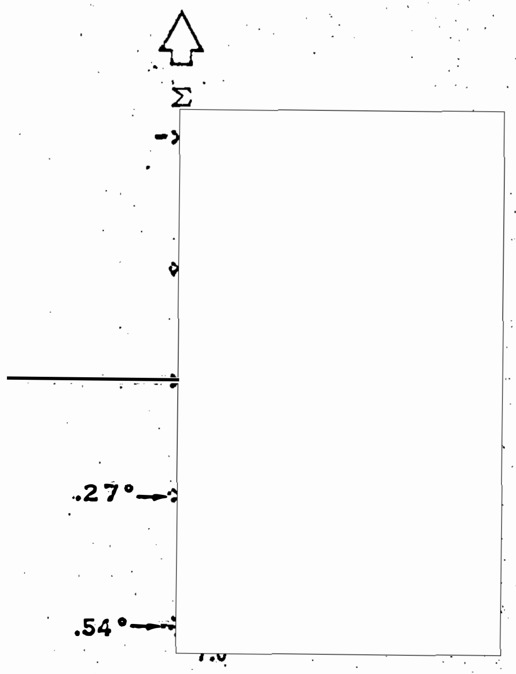
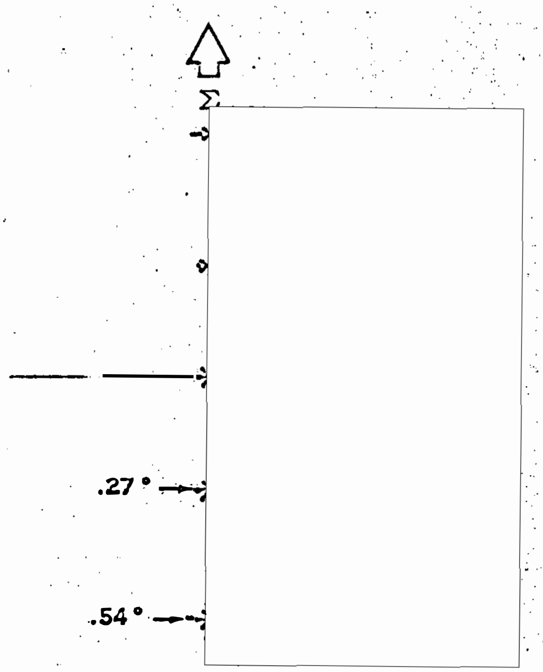


WITH CROSS FORMAT IMC

(b)(1)
(b)(3)



WITHOUT CROSS FORMAT IMC

EXAMPLE:
ALTITUDE: 80 NMI
OBLIQUITY: 20°
FORWARD LOOK: 15°

CROSS FORMAT IMC EFFECTIVENESS

FIG. 7

PROBLEM: POOR RESOLUTION

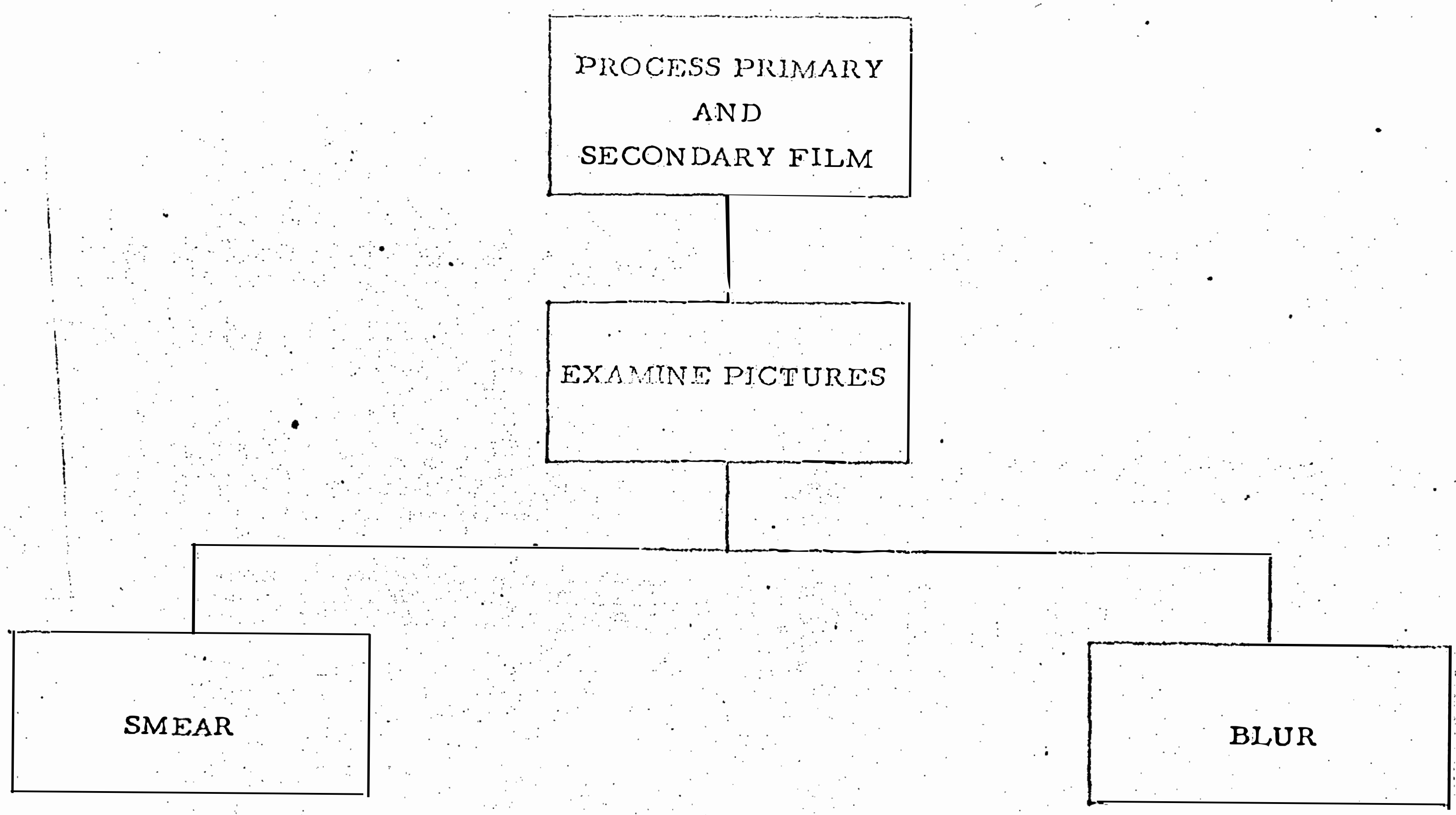


FIG. 8

HANDLE JOINTLY VIA THE BYEMAN/TALENT-KEYHOLE CONTROL SYSTEMS ONLY DORIAN-GAMBIT

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PROBLEM: POOR RESOLUTION (SMEAR)

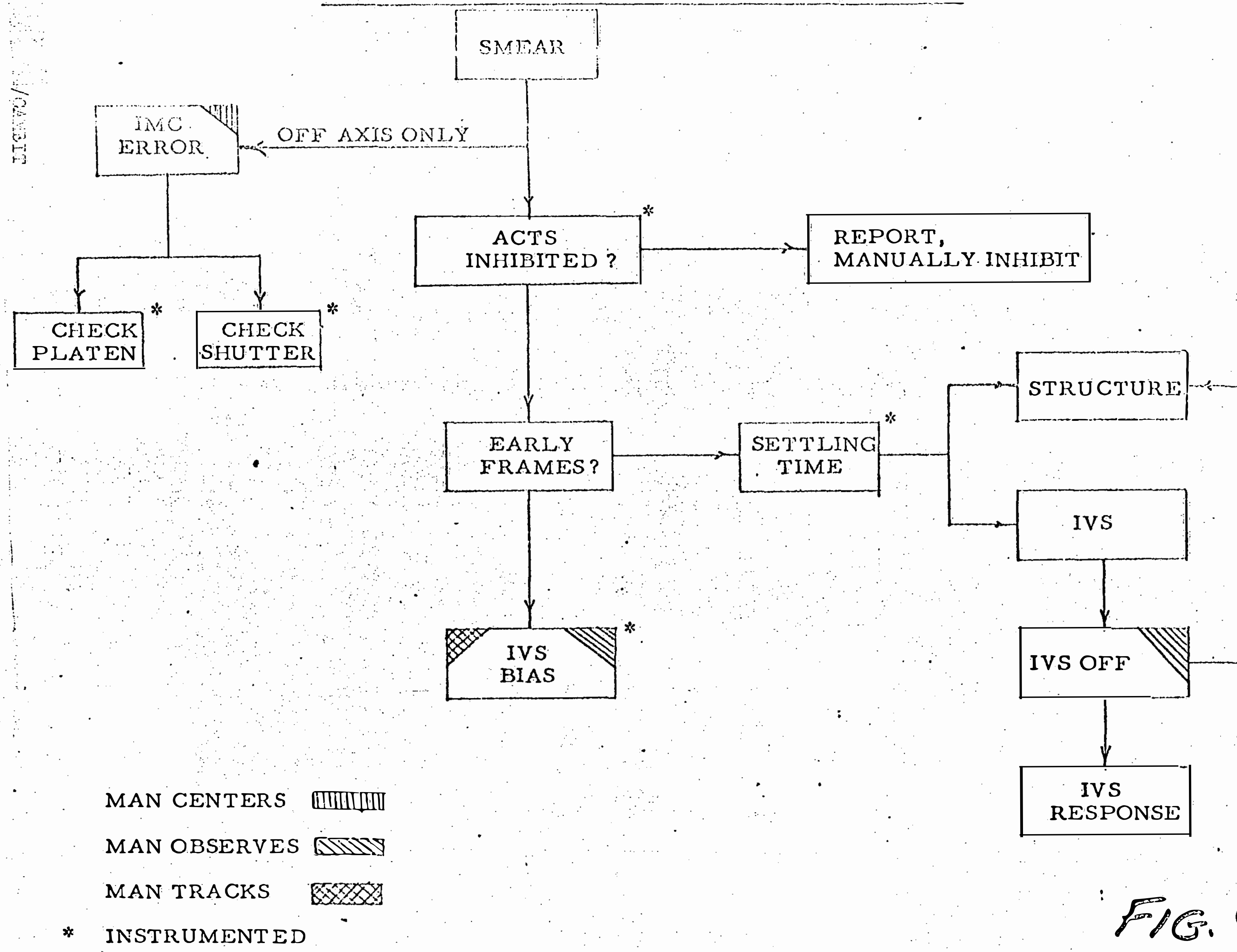

FIG.

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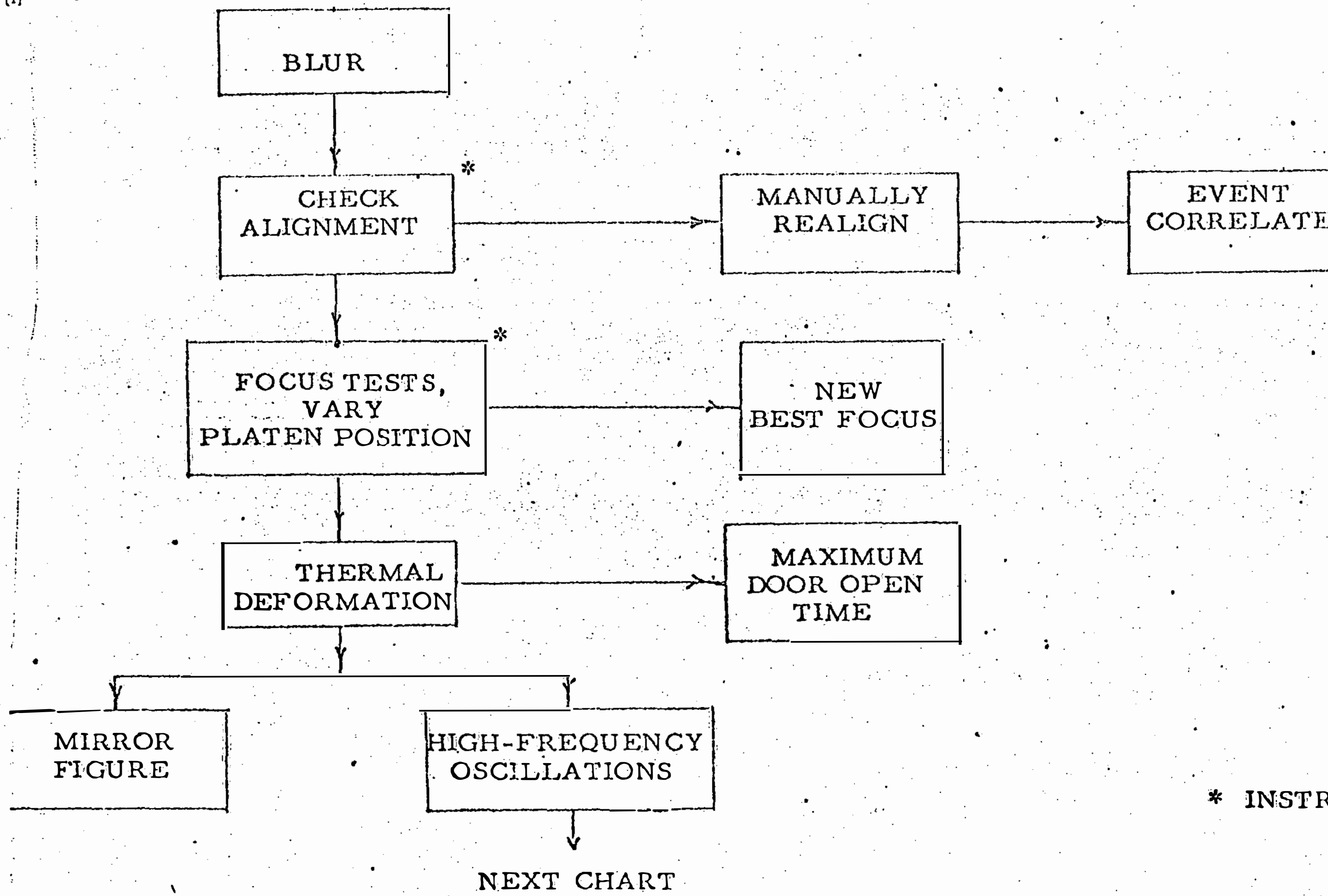
HANDLE JOINTLY VIA THE BYEMAN/TALENT-KEYHOLE CONTROL SYSTEMS ONLY DORIAN-GAMBIT

PROBLEM: RESOLUTION DEGRADATION (BLUR)



* INSTRUMENTED

FIG.

PROBLEM: RESOLUTION DEGRADATION (BLUR) (CONT'D)

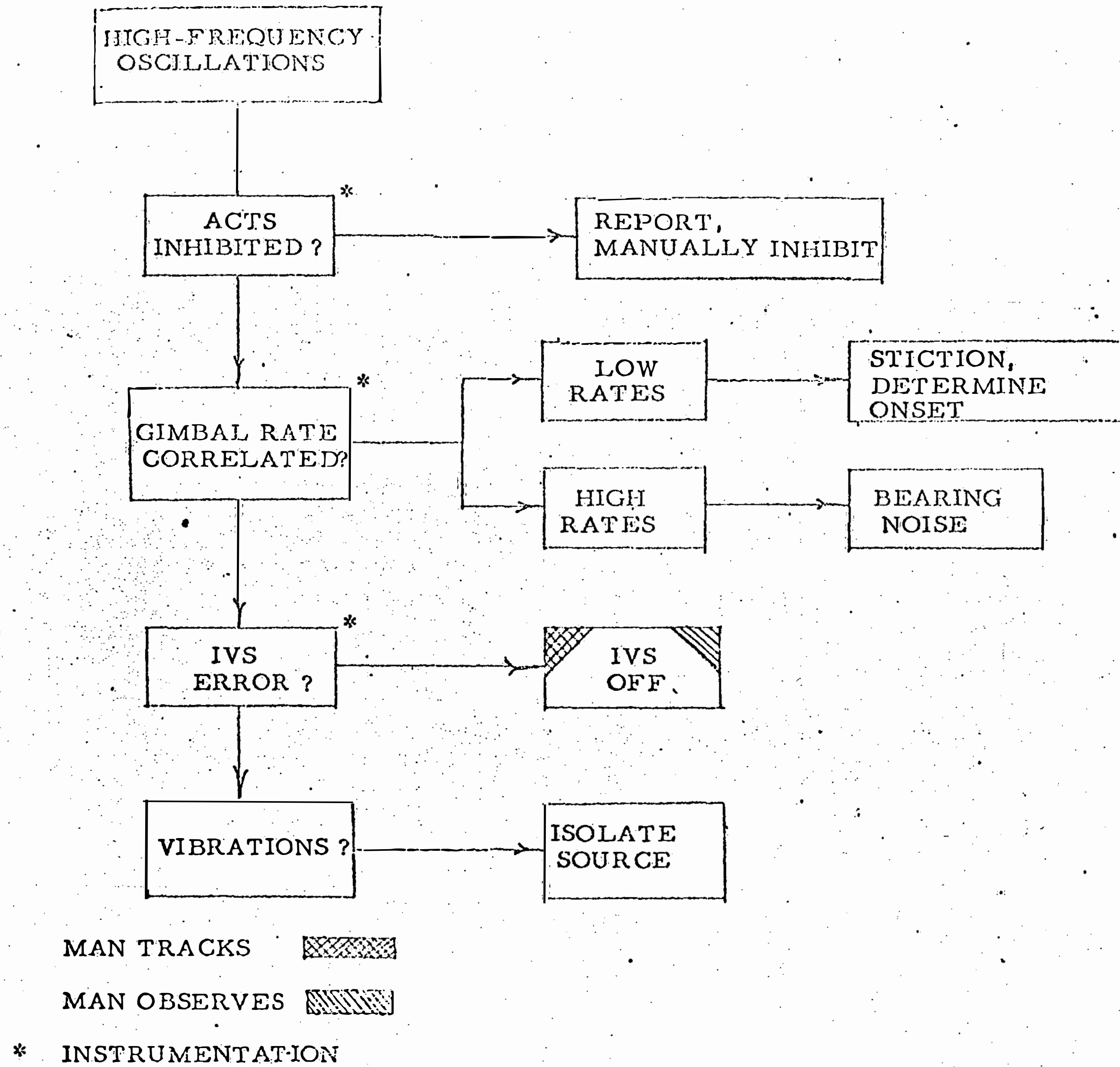


FIG. 11

HANDLE JOINTLY VIA THE
BYEMAN/TALENT-KEYHOLE
CONTROL SYSTEMS ONLY
DORIAN-GAMBIT

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PROBLEM: MAIN OPTICS POINTING ERROR (BIAS)

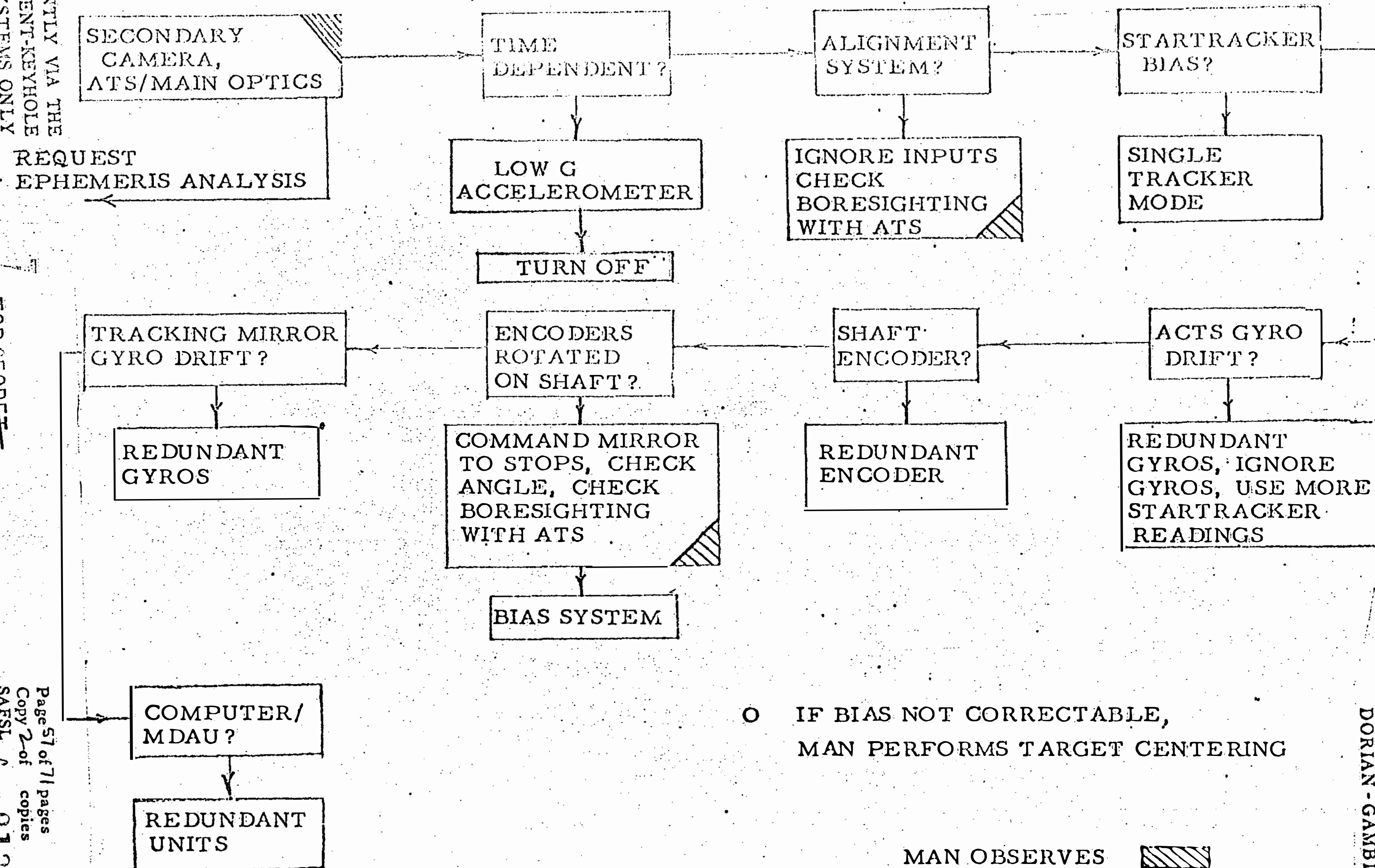

FIG. 11

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HANDLE JOINTLY VIA THE
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DORIAN-GAMBIT

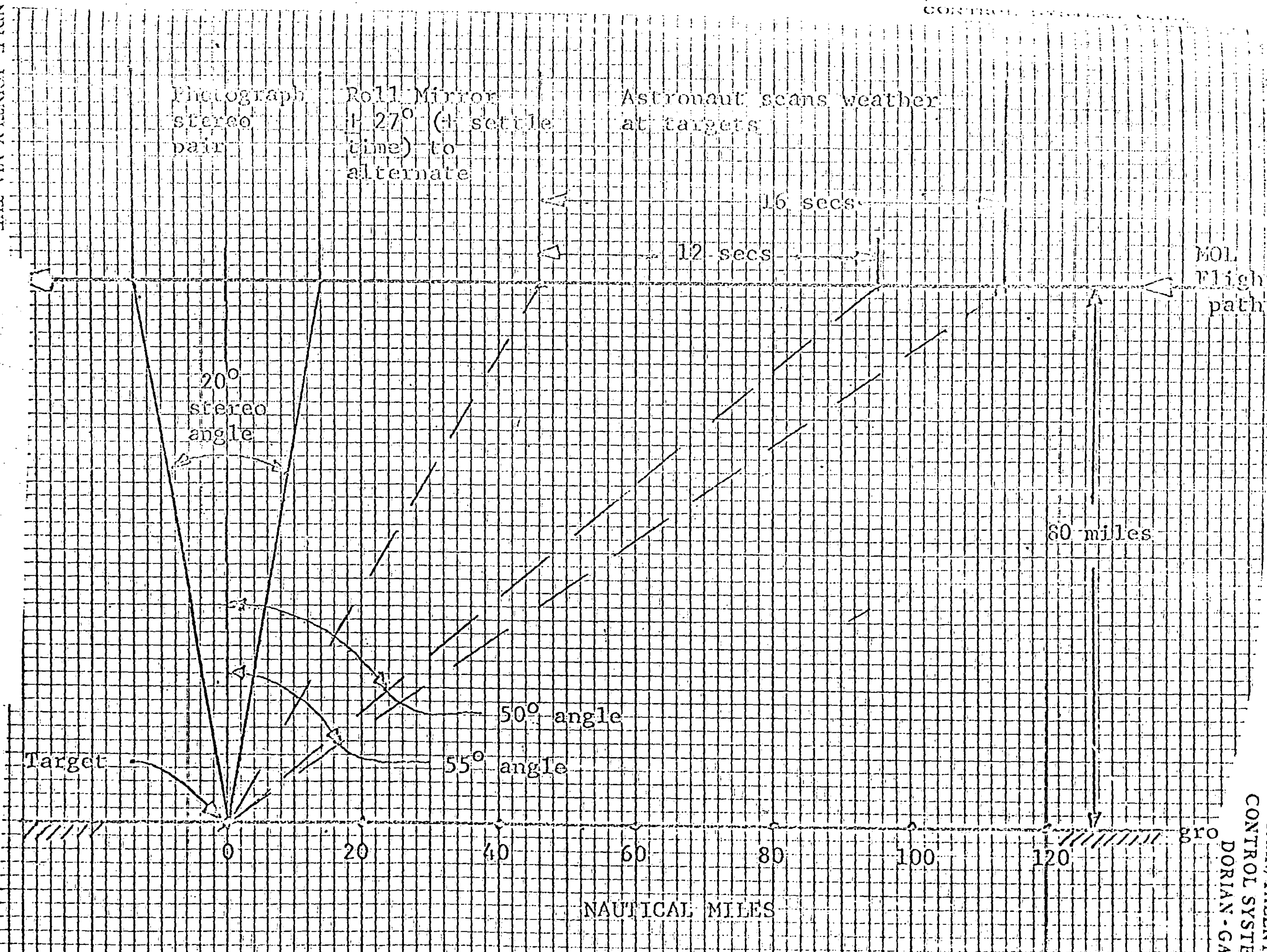
Photograph stereo pair
Roll Mirror ± 27° (+ settle time) to alternate
Astronaut scans weather at targets
16 secs
12 secs
MOL Flight path
20° stereo angle
80 miles
50° angle
55° angle
Target
gro
0
20
40
60
80
100
120
NAUTICAL MILES

FIG 13

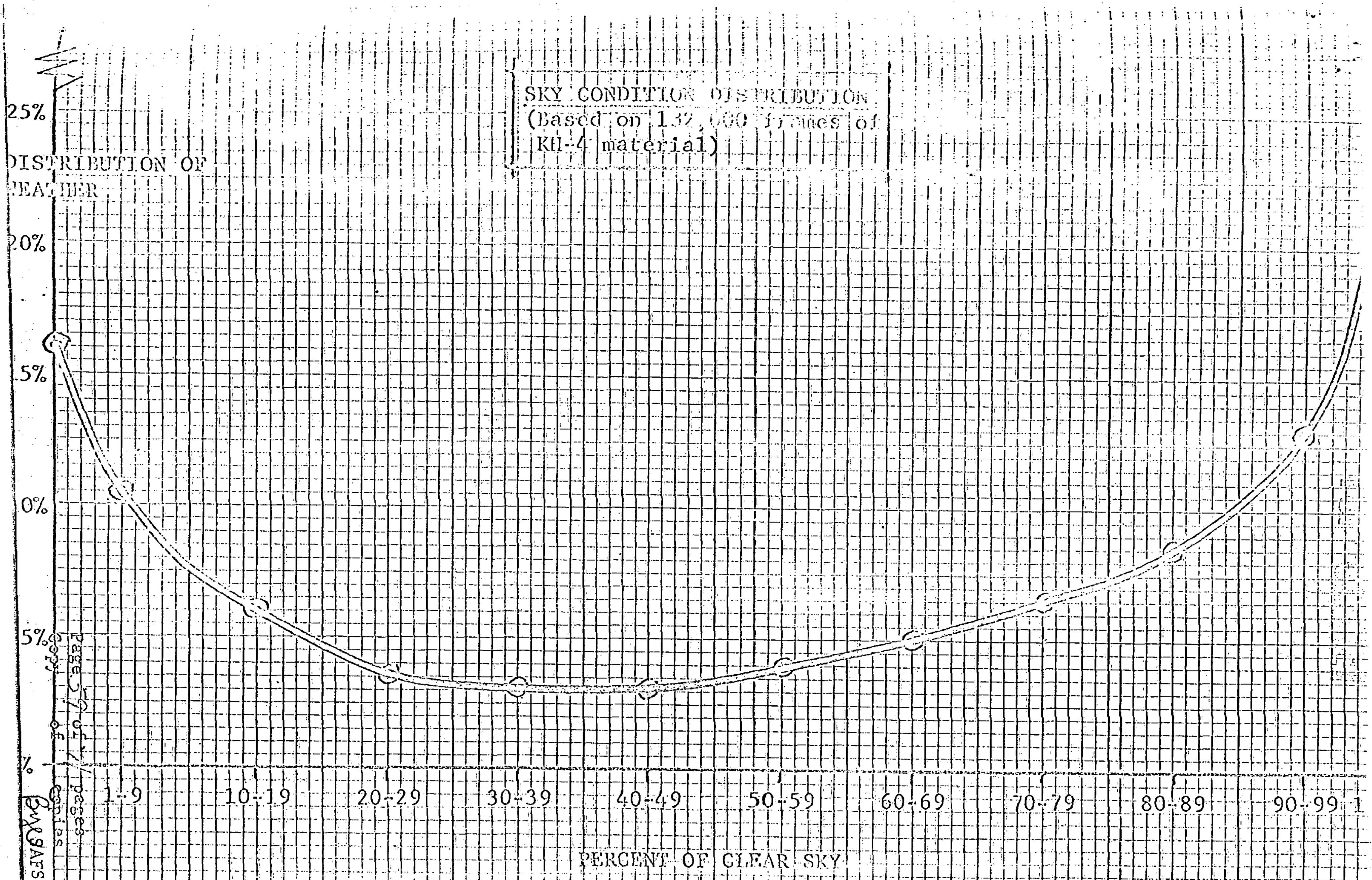

FIG. 14

[illegible]/GAMBIT
HANDLE JOINTLY VIA THE
BYEMAN/TALENT-KEYHOLE
CONTROL SYSTEMS ONLY
DORIAN-GAMBIT

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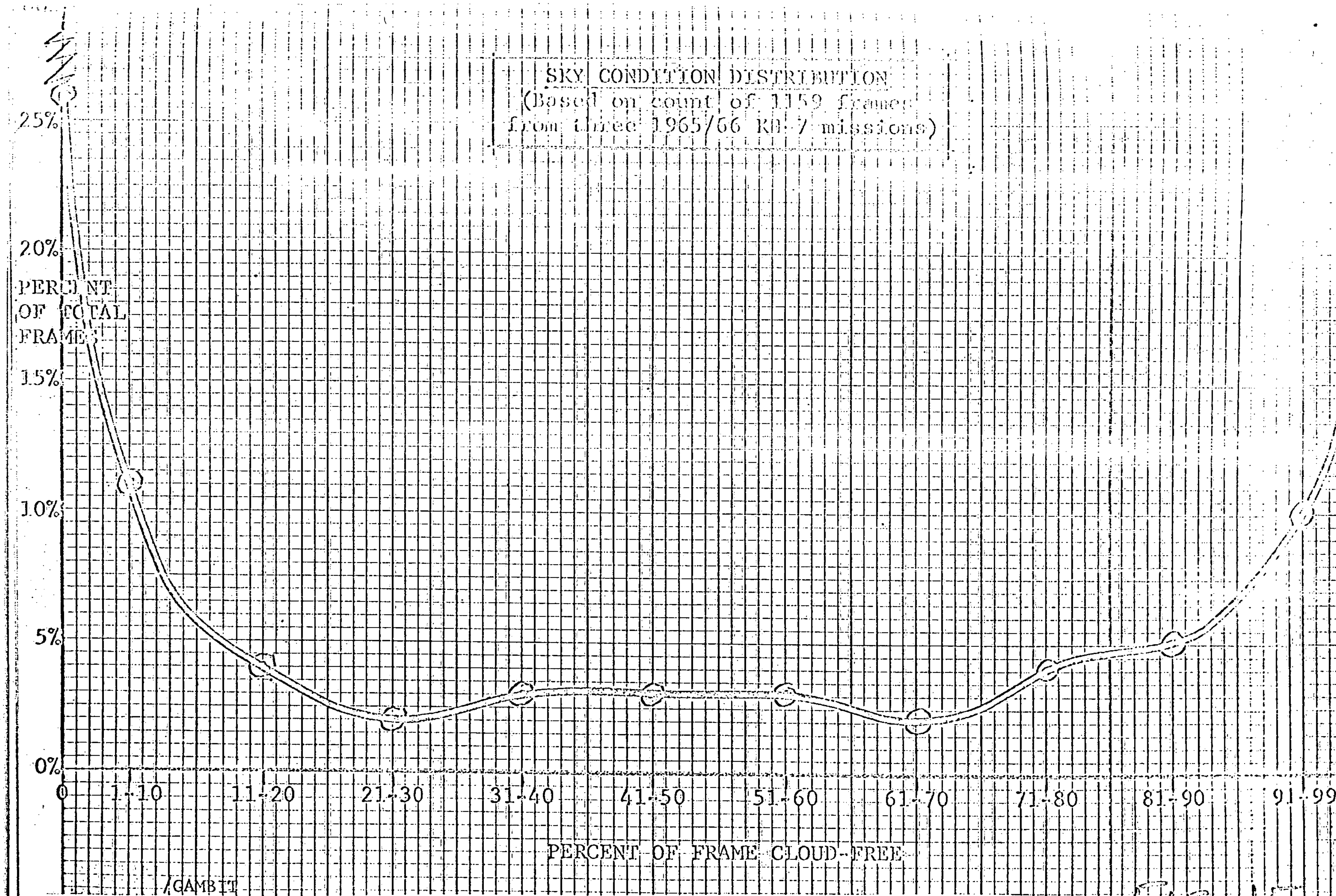

FIG. 15

/GAMBIT
HANDLE JOINTLY VIA THE
BYEMAN/TALENT-KEYHOLE
CONTROL SYSTEMS ONLY
DORIAN - GAMBIT

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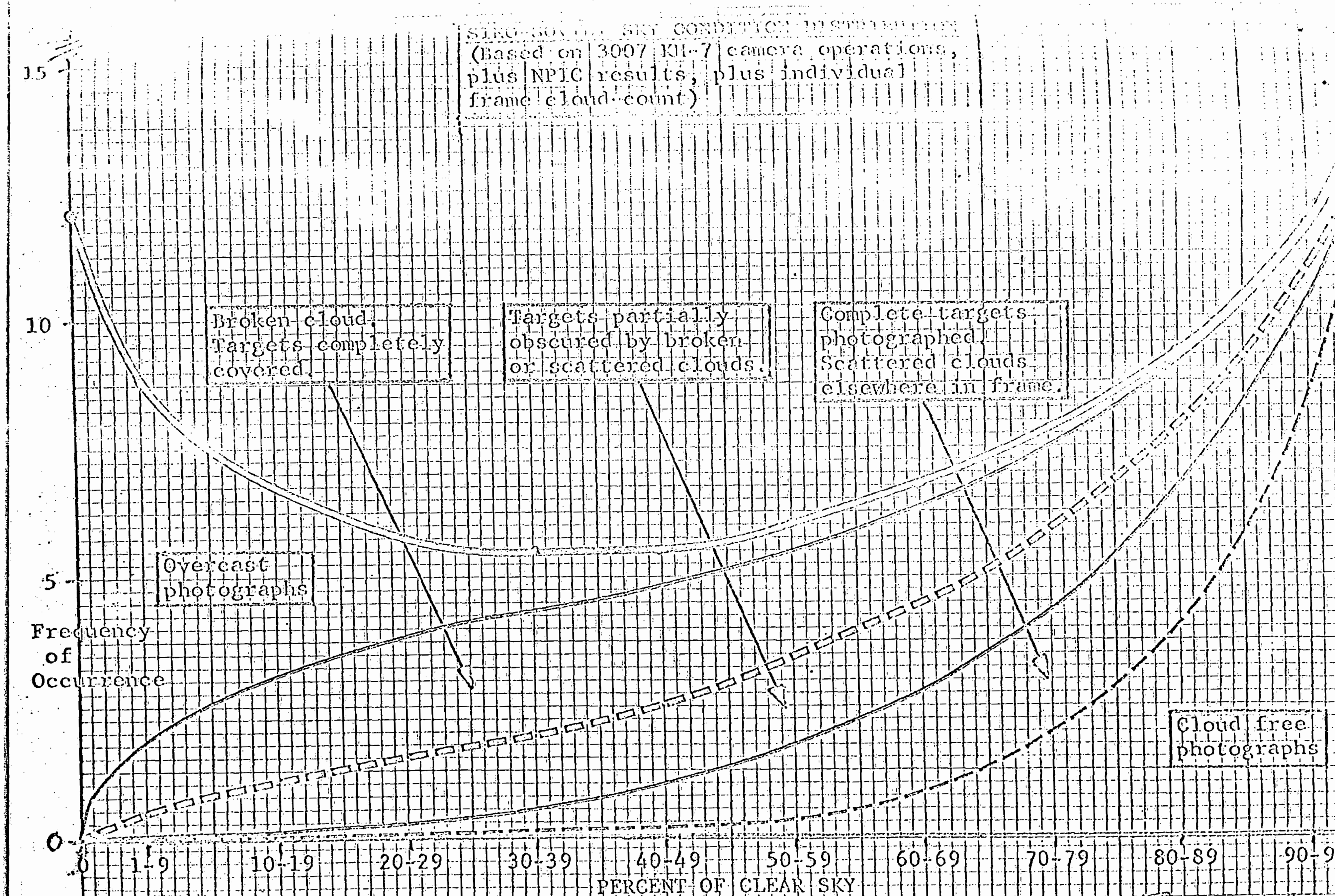

FIG. 16

HANDLE JOINTLY VIA THE
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CONTROL SYSTEMS ONLY
DORIAN-GAMBIT

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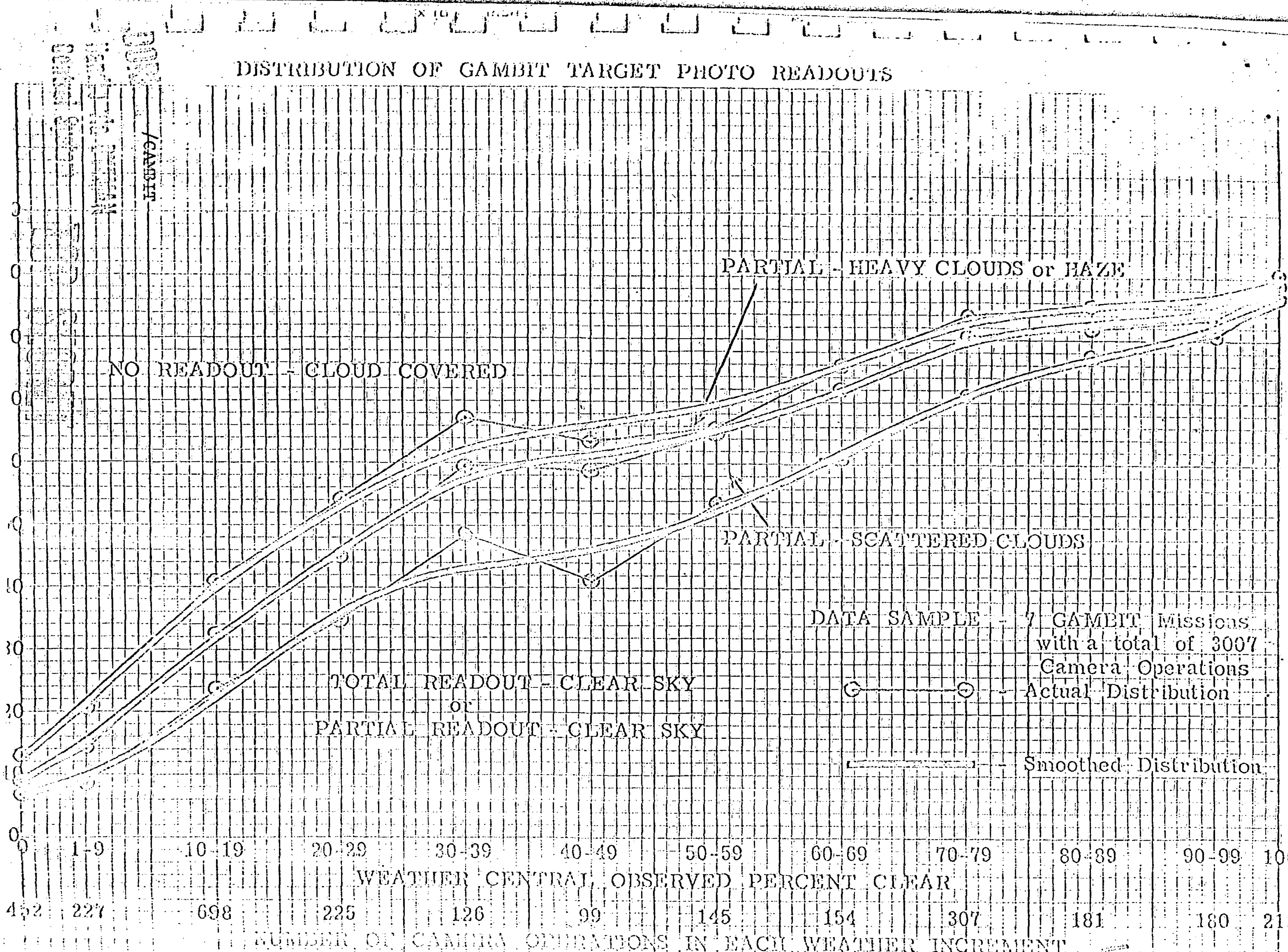

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HANDLE JOINTLY VIA THE
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CONTROL SYSTEMS ONLY
DORIAN - GAMBIT

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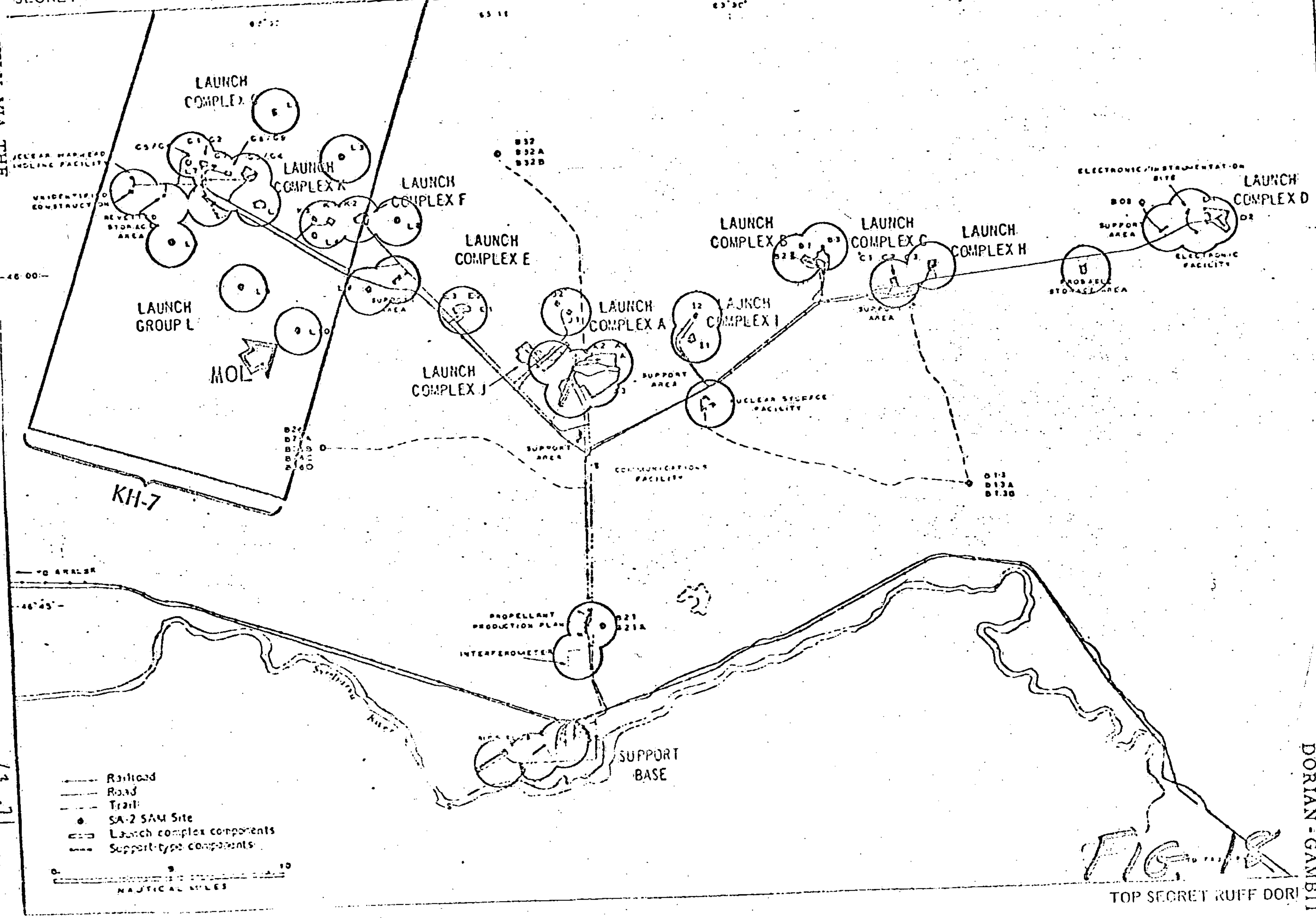
COMPARISON OF KH-7 AND MOL FIELD OF VIEW

SECRET RUFF DORIAN



TOP SECRET RUFF DORIAN

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TOP SECRET

HANDLE JOINTLY VIA THE
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CONTROL SYSTEMS ONLY
DORIAN - GAMBIT

TRANSIENT ACTIVITY INDICATOR PROBABILITIES

Target Categories	Possibility of Occurrence	Likelihood of Occurrence
Missile Development & Test	99%	7%
Ground Forces	35	11
Airfields	75	18
Radar/Communications Deployment	35	4
Industry	5	2
Missile Production & Logistics	65	1
Nuclear Weapons	85	5
BW/CW	85	5
Nuclear Materials	5	3
Aircraft Production	75	24
Naval Activity	65	9
Radar/Communications Major & R&D	100	25
AVERAGE	70%	6%

FIGURE 19

FIG 19

INDICATORS OF TRANSITORY INTELLIGENCE POTENTIAL

PHOTO TARGET	INDICATORS	ESTIMATED DECISION RESOLUTIO[N]
MISSILE SITES (COMPLETED)	MISSILES EXPOSED	10 FEET
	ERECTION/LOADING EQUIPMENT EXPOSED	10
	VEHICULAR ACTIVITY	10
	GSE EXPOSED	5
	SILO DOOR OPEN	5
	SPECIAL VEHICLES	3
	SNOW REMOVAL	10
AIRFIELDS	NEW AIRCRAFT	3-15
	UNUSUALLY CONFIGURED AIRCRAFT	3-10
	AIRCRAFT IN UNUSUAL LOCATIONS	15
	DISASSEMBLED AIRCRAFT	5
	AIRCRAFT/GROUND EQUIPMENT IN WEAPONS LOADING AREA	10
	AIRCRAFT IN MAINTENANCE AREAS	10
	VEHICLE ACTIVITY AROUND AIRCRAFT	5
	AIRCRAFT SUBSYSTEMS IN OPEN	3
GROUND FORCES/ ARMY EQUIPMENT	VEHICLES PRESENT	10
	PARTICULAR VEHICLES PRESENT	3
	VEHICLE ACTIVITY	15

FIG. 2(

HANDLE JOINTLY VIA THE
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CONTROL SYSTEMS ONLY
DORIAN-GAMBIT

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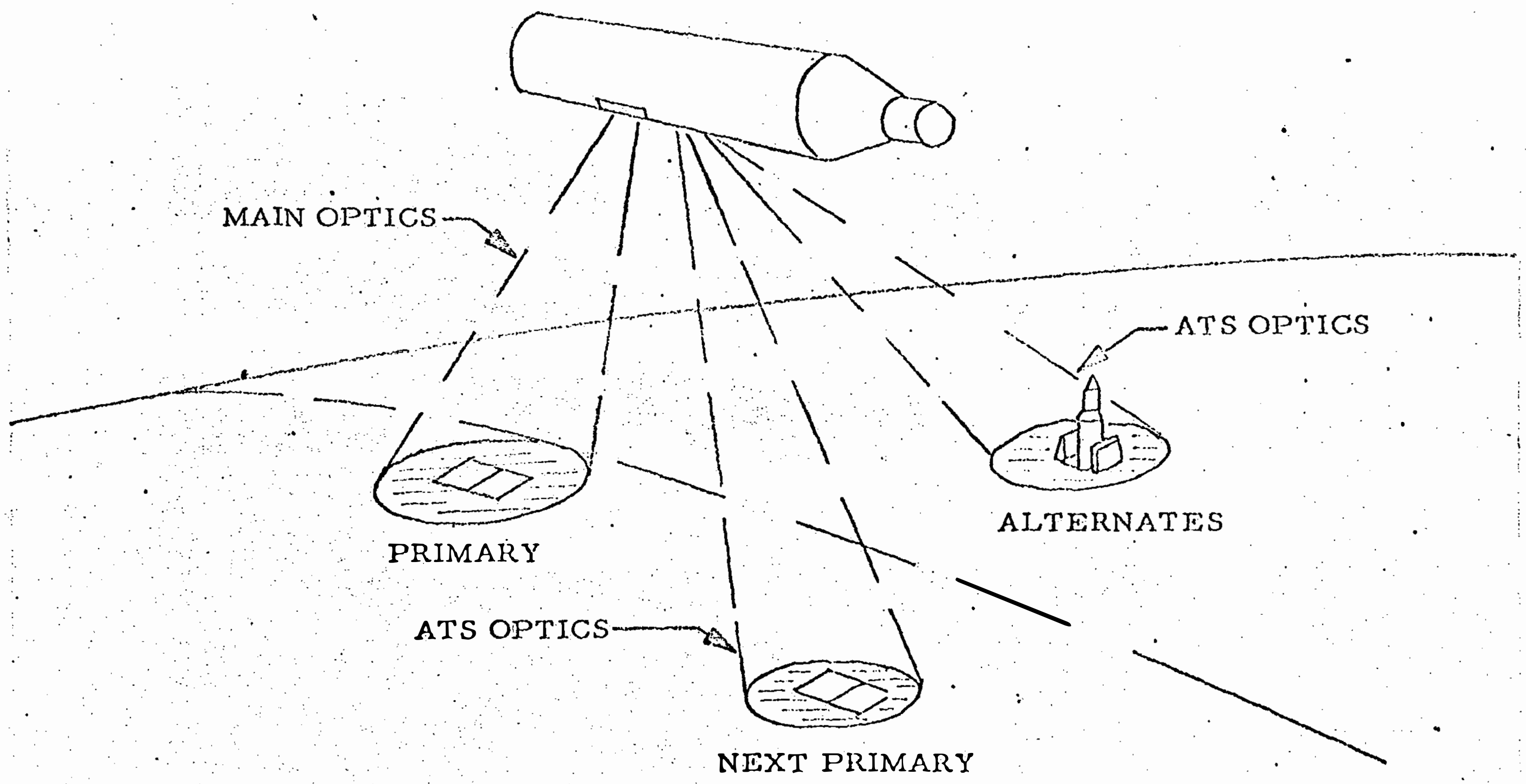
CONCEPT OF MANNED EXAMINATION FOR TECHNICAL INTELLIGENCE INDICATORS/WEATHER



- IF EITHER ALTERNATE HAS ACTIVE INDICATORS, TAKE IT
- IF PRIMARY COVERED AND ALTERNATE CLEAR, SWITCH TO ALTERNATE

FIG. 2

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HANDLE JOINTLY VIA THE
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/GAMBIT

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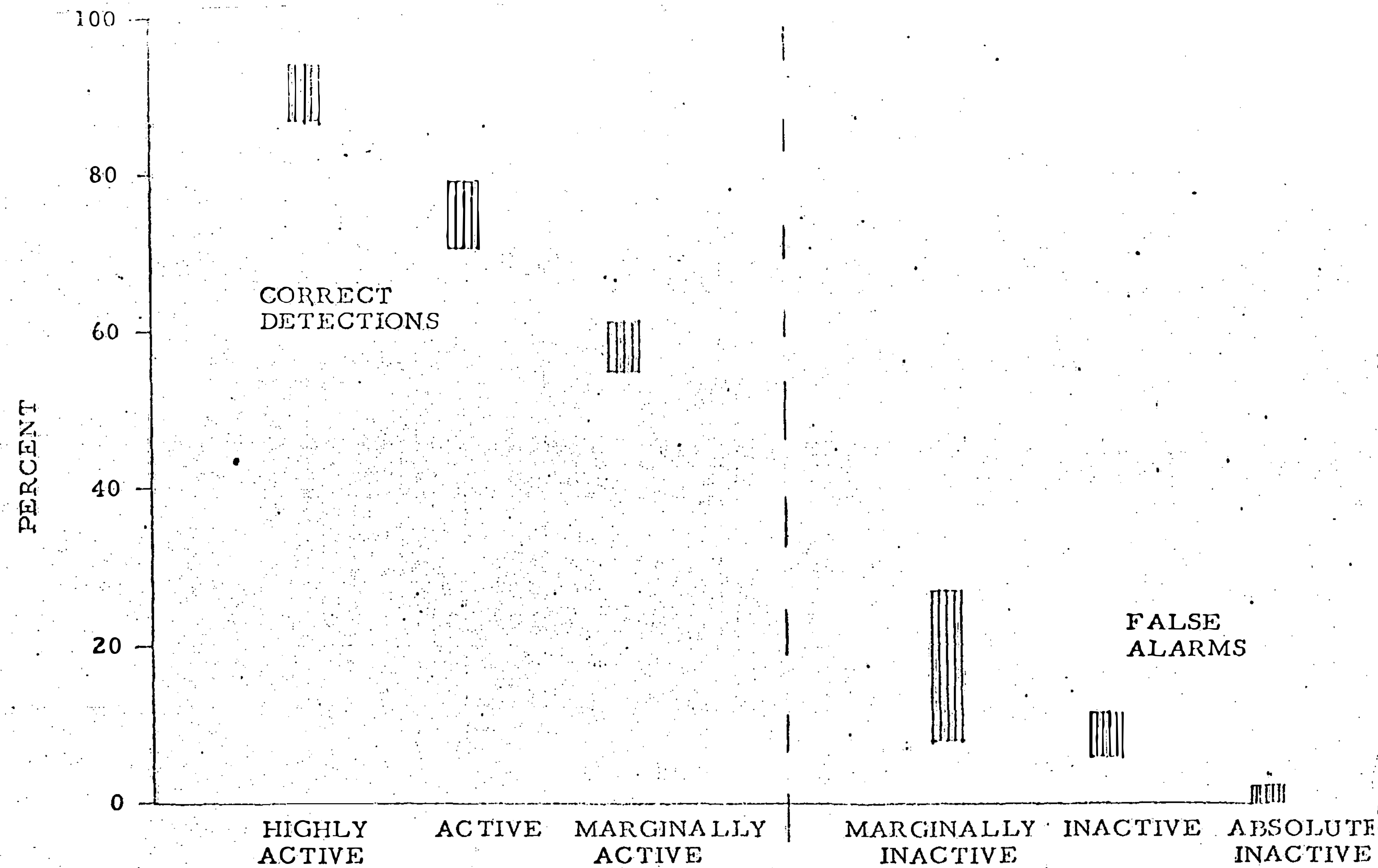
EFFECT OF ACTIVITY LEVEL



PERCENT OF ALL SCENES	8	25	11	17	29	10

FIG. 21

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HANDLE JOINTLY VIA THE BYEMAN/TALENT-KEYHOLE CONTROL SYSTEMS ONLY DORIAN-GAMBIT

ACTIVITY LEVEL VS. SCORES

o RESPONSE TIME 6 SECONDS OR LESS

ACTIVITY LEVEL	CORRECT ACTIVE	INCORRECT ACTIVE	ALLOWED INCORRECT ACTIVE	CORRECT INACTIVE	FALSE ALARM	ALLOWED FALSE ALARM
ABSOLUTELY INACTIVE 12%				92%	0	8%
INACTIVE 3%				67%	0	33%
MARGINALLY INACTIVE 5%				20%	20%	60%
MARGINALLY ACTIVE 12%	84%	8%	8%			
ACTIVE 26%	96%	4%	0			
HIGHLY ACTIVE 35%	100%	0	0			

FIG. 23

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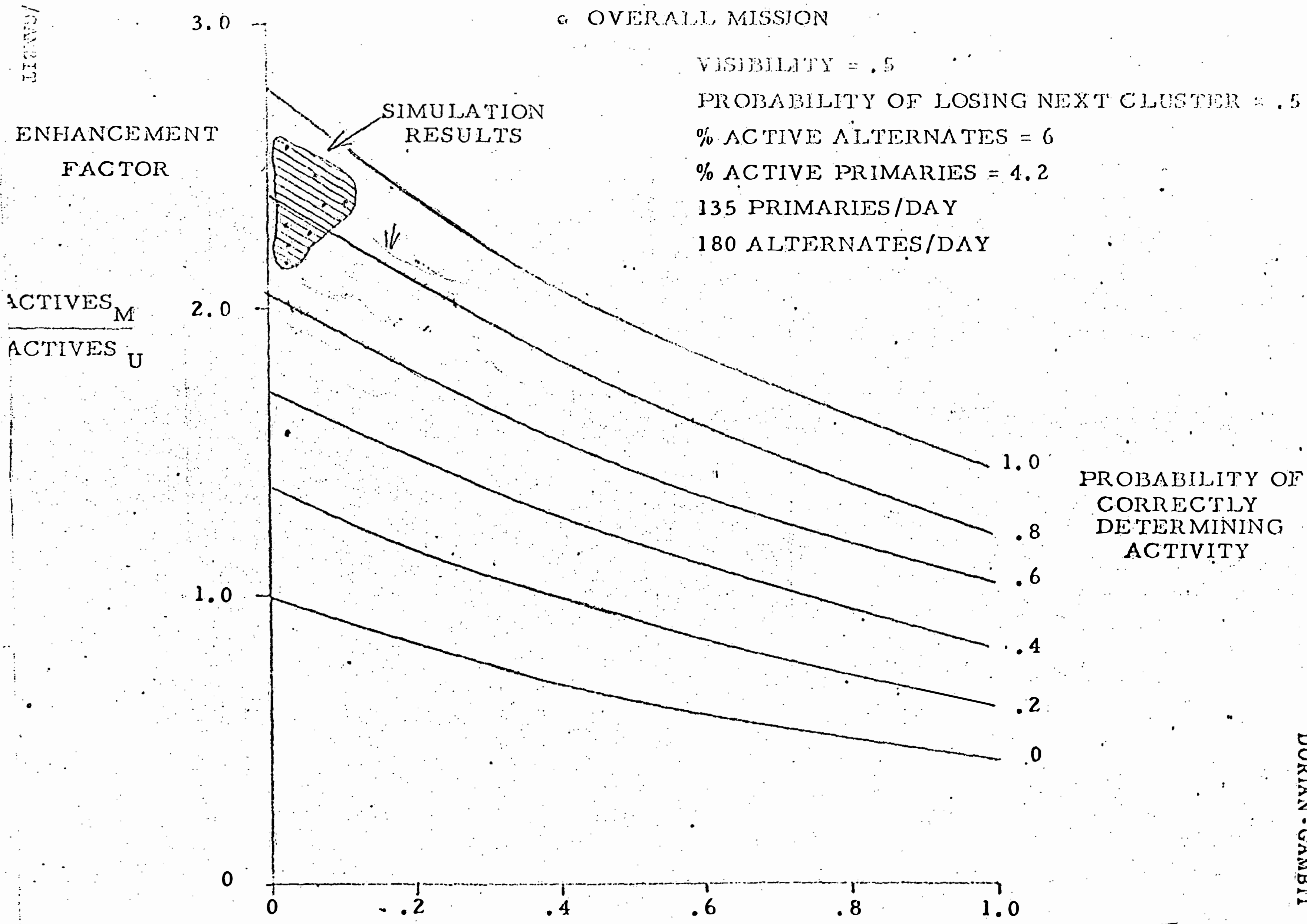
ENHANCEMENT FACTOR VS ACCURACY



FALSE ALARM PROBABILITY

FIG. 2

(b)(1)
(b)(3)

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COMPARISON OF PLANET RESOLUTIONS FROM MOL AND GROUND-BASED SYSTEMS

PLANET	MOL/DORIAN			GROUND-BASED	
	70% OQF(1) (L/MM)	ANG. RES. (SEC)	SURFACE RES. (MI.)	ANG. RES. (SEC)	SURFACE RES. (MI.)
MERCURY ☿	120	.13	52	1	405
VENUS ♀	120	.13	39	1	301
MARS	106	.15	35	1	234
JUPITER	64	.25	440	1	1,760
SATURN (2)	59	.27	975	1	3,612
URANUS (2)	56	.28	2,193	1	7,831
NEPTUNE (2)	54	.29	3,410	1	11,756
PLUTO (2)	32	.50	8,160	1	---

(1) OQF – Optical Quality Factor.

(2) Required exposure times beyond capability of present MOL camera.

FIG. 26