

SUBSYSTEM AND INTEGRAL SYSTEM PERFORMANCE

INTRODUCTION

The generally optimistic technical attitudes expressed in the 1950's engineering analysis reports are felt to be without reasonable substantiation. The extreme sensitivity of the photographic system, in addition to the overall system complexity, raises the question as to whether there is a real basis for such optimism. This portion of the discussion will be limited to those parameters involved in the image forming to image scanning processes, but will also touch itself with the telemetry link, which is covered separately herein.

SYSTEM PERFORMANCE

The I-S system's performance is quoted consistently at 200 lines per MM high contrast of 100 lines per MM. A direct conversion to measurement in object space immediately reveals discrepancies related to the anticipated 20-foot ground resolution. A high contrast target (100:1) at 200 lines per MM yields a detectable dimension of approximately 9 feet on the ground at a scale of 500,000:1 (300 statute miles). It is generally accepted that to recognize an object, it must have from 3-5 times the detectable dimension. Therefore, this 9-foot dimension (detection) will be approximately 30-50 feet in size before recognition level is attained. In view of the fact that occasionally we are dealing with low contrast targets (and accepting the stated figure of 100 lines per MM), the expected ground object recognition level is not less than 100 feet. At this point, it should also be

assumes that the above conditions are based upon a static relationship of camera to ground. The effects of system dynamics during the time of exposure are discussed in the further body of this report, in addition to the effect of weather upon system output.

Further, the above discussion is related to nadir position only, and obviously implies that conditions become worse for increased obliquity.

CAMERA ORIENTATION PROBLEMS

The E-2 camera is basically a strip camera. The slit is, of necessity, oriented such that it is perpendicular to the flight path. The 70 MM film is then fed in a path parallel to the flight line, and at a velocity equivalent to the relative ground velocity. Object and image planes are thereby synchronized, and exposed by means of a slit in the focal plane. The slit width and film velocity establishes the exposure time, with the forward motion of the vehicle providing the "scan" motion. The camera is supported in a 3-axis gimbal system so that the optical axis may be directed to ± 150 miles of the vehicle nadir for preselected target areas.

The preselection function is seriously questioned by virtue of the implicit aiming problem. The transverse dimension of the film represents for this focal length a total angular field of 3.2 degrees. Assuming a safety factor of 50%, a target must, therefore, be angularly determined within a strip of 1.6 degrees from a vertical height of 300 miles! This represents an accuracy of

approximately one part in 50 as related to the accuracy of three camera gimbals, comparable vehicle stabilization control, and accuracy of vehicle location in orbit. As may be seen in Table D-2, page D-6, the maximum tolerances for roll is inconsistent with the desired accuracy, and the suggested tolerance just adequate rather than a safe value. There is obviously a very low probability that the preselected 17x17 mile target area can be photographed.

In effect what has occurred in this design, is that the image motion compensation problem has been simplified and the aiming problem made substantially more difficult. For comparison, the "C" program equipment is more suited for the problem. The "C" camera is properly oriented such that a pendulum sweep occurs across the flight line. The long dimension of the "C" film (wide angle) is then suited to easily satisfy the E-2 aiming problem. With "C" camera, consecutive and overlapping photographs would then virtually insure target area coverage. The "C" configuration is decidedly an improvement over that of the E-2 configuration.

STABILIZATION PROBLEMS

As a further result of the tight control required, the vehicle stabilization demands motion control consistent with the anticipated performance. As may be seen in Table D-2, page D-6 (appendix), the tolerances for roll, pitch, and yaw rates are stated as maximums of $\pm 2.1^\circ/\text{min}$, $\pm 2.4^\circ/\text{min}$ and $\pm 4.4^\circ/\text{min}$ respectively.

is consistent with the fact that from orbit attitude (roll) a roll rate of $1^\circ/\text{minute}$ corresponds to a motion of 126 arc seconds/second, or 1.26 arc seconds in an exposure of 0.01 second. The 1.26 arc seconds represents a ground motion of approximately 9.6 feet which at nominal value already borders on deterioration of resolution, for this represents the blur component along the photographic slit axis. By the same token, the roll axis component contributes to a lack of IAC, which in turn contributes image blur in the film feed direction.

A twenty-(20) foot object on the nadir at an attitude of 300 miles represents an image on the film of 0.0004 inches, or 10 microns. Accepting for the moment the criterion of 60% image motion compensation the residual acceptable blur is but 1 micron. Small motion indeed for exposures of 0.01 seconds time. This means that in 0.01 seconds the stabilization equipment must be capable of maintaining this degree of control. If stabilization control is not closely affected, or, if exposure time increases (longer), resolution of the system is adversely affected.

It is doubtful that this degree of accuracy is presently inherent in the E-2 system, or that this is even presently possible within the current state of the art of photographic equipment and satellite vehicles of these generic types. Vehicular stabilization to the degree required ($0.5^\circ/\text{min.}$) is believed to be most optimistic and incautious.

WEATHER PROBLEMS

Despite the fact that much data exists regarding cloud cover, no true operational level of performance is stated for the E-2 system.

Operational photographic performance does not mention the effect of haze (industrial or natural) which would most certainly effect all performance. The latter is of less significance as compared to the cloud cover problem.

From available weather data, it has been determined that approximately 50% of the area of the USSR is cloud covered most of the time. At least 40% of the remaining areas are determined to be partially cloud covered. Only 20% of the entire area is considered open and clear, and this on a rather sporadic basis as related to moving cloud patterns.

The E-2 system operates on a basis of preselected target areas. There are no sensors aboard which provide remote ground indication for the presence of cloud cover. This is a problem of significance as related to the E-2 photographic system, for the angular field of its film record is but 3.2 degrees square! It is, therefore, not at all inconceivable that cloud cover can completely obscure the full field angle of 3.2 degrees. Moreover, this may occur even when a normally usable condition of 0.2 to 0.3 cloud cover exists. Here again the problems of narrow angle lenses obliquely related to cloud cover is evident. Solar position is important too for the sun at the incorrect angle to the cloud openings will provide undesirable shadow on the ground scene below the opening. Such a situation is at best most difficult, and reduces to approximately zero the probability of overlapping exposures. The low probability of accurately locating a single exposure through the cloud openings is most evident.

The effect of clouds on exposure, comparable with a high acuity system, is also discussed in this report.

CRITERIA

Photographic systems of high resolution are particularly subject to deteriorating performance as a result of motion. The greater the resolution, the more rapid the deterioration in the environment of motion. As the image size decreases (smaller image size) the reduced contrast results also in a lowered performance. The atmosphere plays its usual role as usual represents yet another large undesirable contribution among many others. The slit camera does have one unique characteristic which sets it apart from all other cameras - a dynamic shutter capable of very short exposures. There is no cheaper or more reliable means for minimizing the effects of motion than shutter speed. It is obvious that this markedly useful characteristic of the slit shutter has been forsaken under the attraction of "high resolution", overlooking the complexity of the exacting compensations necessary to make a strip camera useful at exposures of 0.01 second. This represents the penalty purchase of high resolution at the cost of very slow emulsion speed.

This leads next to the problem of camera exposure control. The camera is provided with a glass plate in the focal plane upon which metalized slits are plated. This method was obviously employed as an expedient to the problem of slits which are difficult to maintain in parallelism at narrow separation. The slit plate is capable of indexing a variety of slit widths to provide exposure

(The surface of various materials) and is subject to
control system cannot, however, provide the necessary control
presence of cloud cover. Here it is necessary to deliver
exposure in order to render the image available to the
usable. The present system does not provide this condition
nor does it supply the necessary sensory devices to
possible. It is even questionable as to whether the ground
control system is capable of providing advance data for optimum
exposure which accommodates the normal change of ground reflectivity
encountered on each orbit.

Additionally, the glass base slit plate assembly also introduces
the undesirable light loss by insertion into the optical path.
While the thickness of the plate is not indicated, some light
energy is lost due to surface reflection, and absorption due to
thickness. While the narrow angular field is helpful in certain
circumstances, it is still not preferable where aerial exposures
are already stipulated at 0.01 seconds.

FILM

The film, SO 243, is but another modified version of a very
popular and long standing favorite - microfilm, an emulsion long
known for its inherently high resolution and low speed. It is indeed
surprising that the E-2 system, which represents a decided sophistication
in the state of the art, has been tailored to this low resolution. There is