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CENTRAL INTELLIGENCE AGENCY

WASHINGTON, D.C. 20505

OFFICE OF THE DIRECTOR

26 JUL 1971

MEMORANDUM FOR: Dr. Edward E. David, Jr.
Science Adviser to the President

SUBJECT : Memorandum to the President on FROG and EOI

I have reviewed your draft memorandum to the President on FROG and EOI and feel it does not reflect the issue as I understand it. I propose the attached draft as an alternative treatment of the subject.

If you and Dave Packard agree with this approach I believe we should have our staff representatives work together on the final document.

Dick

Richard Helms
Director

cc

Honorable David Packard
Deputy Secretary of Defense

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DRAFT MEMORANDUM TO THE PRESIDENT ON READOUT SATELLITES

This memorandum presents an issue for decision concerning our plans for acquiring a readout photographic satellite system for rapid return of images to Washington. Two systems are under consideration involving differences in dates of initial availability, overall capabilities, and levels of immediate and future costs.

The Issue

As you know, the National Reconnaissance Program is supervised by an Executive Committee (EXCOM) consisting of the undersigned (Mr. Packard, Mr. Helms, Dr. David). For a number of years, the Committee, and the Intelligence Community in general, has recognized that a major deficiency existing in our photographic satellite system is their inability to return pictures quickly in times of crisis. Therefore, we have been alert to new technologic developments which might allow us to fill this gap in our program. A little over two years ago, it became apparent that progress in the technology of solid state sensors presented us with a feasible opportunity. As a result, we started a deliberate, well funded technology program to build the Electro-Optical Imaging (EOI) readout satellite that Dr. Land recently discussed with you.

As you may recall, this sytem can send high resolution pictures directly to [redacted] satisfying our needs for crisis reconnaissance, and can significantly enhance the overall capability and quality of our photo reconnaissance program. The EOI system uses a very large telescope and fixed arrays of light sensitive solid state elements to measure light intensity of a ground scene, and sends the picture [redacted] At this point in time we have invested over [redacted] in preparing the technology and the components that would make up this system. We had been planning to start full scale development in December of this year on a schedule which would have put the system in operation in 1975.

However, early this year when an urgency was expressed in having a readout system as early as possible to cover crisis situations that might occur before EOI was ready, we studied a number of systems with varying costs, capabilities, and schedules, hoping to find an interim capability whose costs would have minimum effect on the EOI schedule. In April the EXCOM approved contract studies for the interim system called Film Readout/Gambit (FROG). This proposal would build a new spacecraft and film readout system to use with the telescope of the present Gambit satellite. The system would record the ground scene on film, develop the film in the satellite, scan the film with a laser beam and send this picture information by electrical data link to New Hampshire. Pictures would be available to us in Washington 12 to 24 hours after they are taken.

We tentatively decided to develop FROG concurrently with the EOI system but with the EOI schedule extended to 1976 in order to relieve some of the budgetary impact. Because it would use technology that has been available for several years, the FROG system gave promise of being available sooner -- perhaps by early 1974 -- but it is considerably less advanced technically and would have much less capability and potential than EOI. Since FROG would require $600 to $700M to develop and operate over the next five years, we took this step under the assumption that early availability was the paramount concern.

Events that have occurred since we made this decision now make it clear that a concurrent development and operation of FROG and EOI would have such budgetary impact over a period of five years or more that it seems unwise to pursue this course:

- Senator Ellender has told us that he would not agree to a budget which includes both these programs and that we should choose between them. His letter is enclosed as Attachment 1.

- Even without this specific problem, it has become clear that we are going to have to plan for a reduction in the overall level of the FY 72 intelligence budget and we have a number of high priority programs that we would like to protect.

- Even if we survive the FY 72 budgetary problems, inevitable pressures in FY 73 and beyond would make it most difficult to justify carrying two costly programs. We therefore believe that it may be impracticable to contemplate building both these systems. However, since any other plan would make us either wait one or two years longer for a readout capability until EOI is operational, or give up for the indefinite future the greater capability and long term economies of EOI, we request your decision as to which course of action we should follow.

<u>Alternative Courses of Action</u>

We believe there are four alternatives for you to consider. (The costs of our photo reconnaissance programs through 1980 for each of these alternatives are shown in Attachment 2).

1. <u>Build only EOI on a schedule that would have it operating in 1976.</u> Our planning for the last two years has been based on the assumption that we would proceed along these lines if the EOI technology programs proved successful. The technology has now been demonstrated and we are ready to start this development. This program would give us a system which includes the highest level in current technology and offers growth potential for the future: a system that would satisfy our needs for crisis reconnaissance and indications and warning surveillance, enhance our technical intelligence capability and - after the development is complete - allow an overall reconnaissance program with [redacted] much greater capability. It will also enhance our capabilities to monitor a SALT agreement and can, if desired, support overseas tactical commanders by sending them photos of their local area of interest as the pictures are being taken. In order to keep the reconnaissance budget at a reasonable level we would restrict this development to a maximum of [redacted] in any one year. This funding limitation causes the schedule to be extended from the original June 1975 operational date to mid-1976. It is therefore a higher confidence schedule.

This course of action would mean that we would continue to rely on our present photographic reconnaissance satellites, Gambit and Hexagon, and our aircraft to cover any crisis situation that might occur through 1975.

We recommend this course of action. With Hexagon becoming operational, the current program for Gambit and Hexagon together can provide photographic satellites on orbit about 300 days of the year, and although their low orbits and film return delays will not allow daily access to all targets or quick return of the data, they are vastly superior to what was available last summer during the Middle-East Ceasefire. We would prefer to live with this capability through 1975 than attempt an interim 12 to 18 months improvement which would jeopardize the availability of EOI.

If, however, you consider it important enough to try to get a readout capability for crisis reconnaissance earlier than 1976, the following alternatives are possible:

2. <u>Accelerate the EOI schedule with the possibility of getting it by late 1974.</u>

This course would cost [redacted] more in FY 74 than Option 1 and a total of [redacted] more through FY 77. Dr. Land and his Panel* believe this is a feasible

*The Land Panel report is attached as Attachment 3.

thing to do and would recommend this course. We, however, would prefer to live with the lower budget levels and higher confidence schedule of Option 1. We would recommend this approach to getting early availability over either 3 or 4 below.

3. Initiate both FROG and EOI developments.

This is the plan that we are concerned about from a budgetary standpoint. It would have FROG in operation in early 74 and EOI in operation in 76, thus giving an interim improvement to crisis reconnaissance two years earlier than Option 1 and one year earlier than Option 2. It would, however, increase the reconnaissance budget over the next five years by about [redacted] and in view of the concern of Congressional leaders and our belief that we could not realistically support this budget level over a period of years, we do not recommend this approach.

4. Initiate development of FROG now and hope to start EOI development in 73 for possible operation in 78.

This would give us an interim readout capability in 74 but put off - perhaps indefinitely - the much greater performance and long term economies of EOI.

Under this option, we would have to make a decision in 1973 to start EOI development. At that time, because of the operational costs of the FROG program, the budget levels facing us in the subsequent years would be about as high as those which are now causing us to recommend against building both EOI and FROG today. If these levels seem prohibitively high now, it is likely that they will seem equally so in 1973. Even if we were able to hold to this decision in spite of the high budgets, and launch into the EOI development in 1973, over the five years between FY 72 and 77 the total FROG-EOI program would cost [redacted] more than an EOI only program (Option 1). Through 1980 it would cost [redacted] more and it would delay the time when we could phase out Gambit and realize additional savings.

We think that the selection of this Option would in effect be a decision to postpone EOI indefinitely. In view of the potential of EOI, we do not recommend this course of action.

Summary

In summary then, we recommend Option 1, an EOI development for operation in 1976. We believe that Option 3, the concurrent development of FROG and EOI, is impracticable from a budgetary standpoint and, if started, would inevitably lead to pressures which would cause the termination of one of the two programs in the next few years. Likewise, we do not recommend Option 4, which would defer the start of EOI to 1973, because the budget levels after 1973 are as serious as those we now find prohibitive in Option 3. Therefore, Option 4 would probably have the effect of deferring EOI indefinitely. In view of the improved coverage that we will have in 1974 and 1975 by Hexagon and Gambit, we do not recommend jeopardizing the early availability of EOI in order to get an earlier readout capability by one or two years.

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DEPARTMENT OF STATE

THE DIRECTOR OF INTELLIGENCE AND RESEARCH

WASHINGTON

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July 20, 1971

Dear Dick:

In the past I supported the urgent development of the EOI satellite, and to cover the interim between now and its readiness date, I urged the development of a low-cost, quick response satellite. My letter of September 4, 1970 noted the gap between what policy officers expect and what we can actually deliver at this time. I noted that in the Middle East crisis, the day was saved by your old work horse, the U-2. On January 15 of this year, the Secretary expressed his concern that even with the fastest implementation of plans for the EOI "we probably must wait some 5 years for a satellite system that could give us, on short notice, photographic coverage of areas where activities may be in train critically affecting our international interests and plans". The Secretary urged consideration of an interim system. Recent Congressional statements now force hard decisions on alternative systems.

A strong case can be made to wait for EOI, the Cadillac, particularly since HEXAGON is working so well. The fact remains, however, that target dates tend to slip -- HEXAGON had almost a two year delay. Before EOI is ready we may well be in situations where the decision makers will urgently need more flexible satellite capabilities.

I am concerned that if we go the EOI route its costs may eat into funds available for other satellite and reconnaissance programs and deny flexibility in improving working systems and meeting unforeseen but urgent intelligence needs. I am particularly concerned that its costs might preclude the development of a less vulnerable satellite. We have clear intelligence that the USSR has developed a satellite interdiction capability, so all present and planned systems can operate only with their permission.

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The Honorable
Richard Helms,
Director,
Central Intelligence Agency.

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In view of the foregoing I believe that full consideration must still be given to a relatively inexpensive quick reaction system, less vulnerable than present and planned systems, hopefully available within two years.

A key point is comparative cost. We initially believed an interim system would cost a fraction of EOI. I understand this estimate is now questioned. I believe we need a new look at costs and the time for development of both EOI and the several interim systems initially examined. It was never my intention to urge that we commit ourselves to an interim system so costly as to be feasible only as an alternative to the EOI. I know it is not State's role to determine how intelligence Community money is spent but we do have major concerns over the extent to which various systems meet the needs of our policy people. I would be grateful if you could keep in touch with me as you move toward a decision on these problems.

Sincerely,

Ray

Ray S. Cline

SECRET

30 AUG 1971

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MEMORANDUM FOR: Director of Central Intelligence

To follow-up on Ray Cline's letter to you of July 20 concerning low-cost, quick response satellite systems, I telephoned him last Friday and gave him a status report on the EOI system decision.

In brief, I told him:

(1) That Mr. Laird had sent a recommendation to the President on behalf of the EXCOM and I outlined its contents;

(2) That the option of building a low-cost interim system was still a possibility if the President decided he wants something earlier than 1976 and that you had taken the lead in keeping this option open.

(3) That the conversations Mr. Duckett and I had with Wayne Smith lead us to believe that, on its own initiative, the NSC staff will suggest a low-cost, interim alternative to the President.

I promised to let him know as soon as we know about a decision.

Mr. Cline was pleased to be brought up to date and seemed satisfied that his point of view was represented. I don't think he expects a written reply to his letter and I recommend we consider my telephone call to be a sufficient response.

Donald H. Steininger
Assistant Deputy Director
for
Science and Technology

DD/S&T
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cc: DDS&T

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THE WHITE HOUSE

WASHINGTON

July 11, 1971

Dear Dick:

At the last meeting of the NRP Executive Committee I expressed my judgment that the EOI system could benefit by at least a year and preferably two of continued technology development prior to going into system procurement. That judgment is based on my view that today the film readout system being less exotic is more immediately feasible and available, but that the trend of progress of solid state techniques guarantees that costs will decrease and performance increase rapidly in the application of EOI technologies.

I have sought to test my judgment by having my staff complete at least to some degree the efforts undertaken as a result of Carl Duckett's suggestions earlier this year that we attempt to find measures of effectiveness for the various photographic systems which we have been probing as an answer to the NRT and crisis capability needs. I am attaching a copy of their memorandum relating to "Satellite Photographic Systems Comparisons." An examination of Figures 4 and 5 indicates that the Z systems and all film systems today fit the same trend line but that the Z systems cost about twice as much as the film systems for the same performance. I expect that Z systems can be made to offer photographic capabilities different in dimension from what is attainable with film systems.

I conclude that, if we are interested in a well-organized program with an early result we should aim at a film system today and push the EOI toward an approach that supplies superior performance at the same or even lower cost.

DD/S&T FILE COPY

Sincerely,

Ed

Edward E. David, Jr.
Science Adviser

Honorable Richard Helms
Director of Central Intelligence
Washington, D. C.

Attachment BYE 11950-71

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EXECUTIVE OFFICE OF THE PRESIDENT

OFFICE OF SCIENCE AND TECHNOLOGY

WASHINGTON, D.C. 20506

July 11, 1971

MEMORANDUM

SUBJECT: Satellite Photographic Systems Comparisons

A recent effort sponsored by DDNRO at finding a basis for figures of merit for the comparison of photographic systems provided a large amount of relevant data. These data, which make possible the development of such comparisons at least in a beginning way, are the subject of this memorandum. The motivation for making such a comparison derives from the need to compare systems which display great variation in values of parameters describing them and this in turn derives in part from the variety in the operation of these systems. A second motivation is the need for finding a basis of comparison which provides a context for making assessments of systems' costs, risks and benefits.

The philosophy behind developing this basis for comparison is that commensurate parametric values of the various systems should be developed so that from these, to the degree that it is possible and useful, direct comparison of these system parameters and of associated figures of merit might be made. Some effort has been expended in assuring that numerical values used are accurate, but it is worth noting that results are not sensitive to uncertainties of 10% or 15% in the values used. Where there is potential for larger uncertainty, as for instance in assessing the relationship between ground resolution dimension (GRD) and ground sample distance (GSD) or in variable integration time, these ranges of values are shown explicitly.

Nominally the characteristics of photographic systems are stated in terms of orbit parameters, nadir GRD or GSD, swath width, mission duration, gross area coverage and the like. Because no two photographic satellites operate under similar conditions, comparisons are usually made intuitively if at all, and in any event they are not very satisfying.

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In contrast, this memorandum attempts to use fundamental descriptions of systems capabilities as a basis for comparison. From these fundamentals, figures of merit are developed and compared. Certainly there must be other figures of merit that will seemingly make more clear the value of one system with respect to another, and to the degree that these can be defined they should be developed and applied.

The systems compared in the memo are operational systems, GAMBIT (G) and HEXAGON (H); R&D systems, Electro Optical Imaging (Z) and Film Readout GAMBIT (F); and conceptual systems both modifications of CORONA, referred to as [redacted] and CORONA "Six Pack" (C). Conceptual modifications to each of the two R&D systems (F* and Z*) are presented but the data relating to these have no community standing.[1]

Table 1 presents fundamental data for the several systems treated. The data included are:

1. unit cost of a satellite and booster at a "feasible" procurement rate;

2. angular resolution in microradians -- angular resolution is nadir GRD divided by altitude, both in consistent units, e.g., 1 ft nadir GRD at 165 nm (one million feet) altitude corresponds to 1 microradian (μ rad) angular resolution;

3. total number resolution cells per mission -- which is a function of either mission film load or power constraints on imaging rate;

4. short term average solid angle (field of view) rate -- short term average (STA) solid angle rate multiplied by the square of the altitude gives a rough measure of area (square miles) coverage per unit time averaged over the framing interval for a framing system or at the sweep rate of a scanning system; this is a measure of coverage capability in a given locality.

Given the photographic system parametric values of Table 1, it is possible to develop certain figures of merit which have interest per se but which also permit order of magnitude correlations to be made among systems. The figures of merit developed in this memo and presented in Table 2 are:

[1] Parenthetical letters are reference symbols used in the figures; systems F* and Z* are defined in footnote 1/ of Table 1.

Table 1

Photographic System Parameter Values

System	Symbol	Cost \$M	Angular Resolution 10^{-6} radians	Total Cells 10^{12}	STA Solid Angle Rate Steradians/second
HEXAGON	H	80	4.7	186	$1.1\,(10)^{-1}$
CORONA "Six Pack"	C	21	10	3.8	$6.8\,(10)^{-2}$
GAMBIT	G	33	2.05	8.3	$3.\ (10)^{-3}$
Film Readout GAMBIT	F	35	2.05	6.3	$8.6\,(10)^{-4}$
Film Readout GAMBIT*	F*1/	65	2.05	74	$8.6\,(10)^{-4}$
Electro Optical Imaging	Z2/				
Electro Optical Imaging*	Z*1/2/				

1/ F* and Z* are defined by these entries: F* employs a larger booster and contains two reels each of 176,000 feet o wet process film as opposed to two 15,000 ft reels in F; Z* is defined by a capability to image once each 6.0 sec, i.e., 4.5 sec for imaging and 1.5 sec pointing and settling time, which is taken as a near maximum rate under present designs.

2/ Where two entries are made, the first corresponds to GRD=GSD and the second to GRD=2GSD; the author believes the correct relationship is scene-dependent and lies between these extremes, on the average. Parameters involving time (e.g., Solid Angle rate in Table 1 and Cells/sec in Table 2) assume an integration time of 1 millisecond for the targeting array; if integration time is larger by a factor of two for example, then these parameters are smaller by a factor of two.

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Table 2
Photographic System Figures of Merit

System	Symbol	Total Solid Angle Per Mission Steradians	Cells/Mission Unit Cost 10^6 cells/$	Cost/Frame of $10^3 x 10^3$ cells $/frame	STA Resolution Cells Rate 10^6 cells/sec	Target Resolution Dimension at Swath Edge for 1' Nadir GRD at Altitude ft/nm	Minimum Poss: Target Resolut: Dimension at Swath Edge (feet)4/
HEXAGON	H	4100	2.3	0.44	4800	3/	13.5
CORONA	C	380	0.18	5.55	680	3/	29
[redacted]							
GAMBIT	G	35	0.25	4.00	710	6.0/82	5.9
Film Readout GAMBIT	F	26	0.18	5.55	200	6.0/82	5.9
Film Readout GAMBIT*	F*1/	310	1.14	0.87	200	6.0/82	5.9
Electro Optical Imaging	Z2/	[redacted]					
Electro Optical Imaging*	Z*1/2/						

1/2/ See corresponding footnote numbers of Table 1.

3/ Altitude corresponding to 1 ft nadir GRD is sufficiently below a minimum feasible altitude (≅ 65 nm) of operation as to make this entry meaningless; 2 satellite operation assumed.

4/ This condition occurs for an operating altitude of 152 nm with a corresponding maximum look angle of obliquity of 66° in the flat earth approximation; 2 satellite operation assumed.

1. total solid angle (field of view) per mission -- total solid angle multiplied by the square of the satellite altitude of operation is a gross measure of area (square miles) per mission;

2. resolution cells per mission unit cost; and its reciprocally related

3. cost per frame of 1000 x 1000 resolution cells;

4. short term average resolution cell rate -- which is the average data-taking rate of the system;

5. resolution dimension at swath edge -- based on a one-foot nadir GRD for a [redacted] operation and with swaths abutting at the equator; and for the same operating conditions

6. minimum resolution dimension capability at swath edge.

One measure of system cost effectiveness is gross coverage per unit cost. The measure used is mission total solid angle, which at a reference altitude corresponds to a given number of square miles at varying resolution. A comparison of total solid angle per mission vs. mission recurring (satellite and booster) cost is shown in Figure 1. The figure indicates that for targeting systems such as G, F, Z and Z*, the unit area costs (at varying resolution) form one family and surveillance systems such as H, C and [redacted] form another. It is interesting that F*, the extended version of F, is a kind of transition between surveillance and targeting systems.

Another comparison of photographic systems which gives some insight is that of unit cost of resolution cells and total number of resolution cells per mission. Figure 2 makes such a comparison in which there appears, for well-designed systems of a class, to be a good correlation between cell costs and total mission capability, i.e., an economy of scale. It appears also from Figure 2 that on this basis Z is 50-100% more expensive than film systems. If better response time were possible as with Z* or shorter resolution cell integration time, then this difference might become marginally small.

A third comparison which might give insight to photographic systems is a comparison of resolution cell costs vs. angular resolution and primary optics diameter (data not separately presented). Such a comparison is made in Figure 3. One might anticipate that in well-designed systems the number of cells per unit cost would increase with lessening angular resolution. If such a trend exists it is only marginally apparent in Figure 3 and one must conclude that (1) possibly not all of the systems treated are optically well-designed or (2) that which is obvious: optical systems contribute only negligibly to the unit cost of resolution cells. The near linear dependence between angular resolution and primary optics diameter suggests that at least as among H; F&G; and Z, all systems are equally well-designed optically after optics size was chosen.

A fourth comparison which gives insight to photographic systems is the relationship between the short term average of solid angle (field of view) rate which is a measure of target or area coverage capability on a given satellite pass in a given locality vs. system angular resolution. Such a comparison as in Figure 4 establishes some norms for good design and indicates the tradeoffs which can be made between these two parameters. Figure 4 shows a fifth power dependence between these two variables, implying that for both film and solid state sensor systems, solid angle rate may be doubled by trading with resolution, the resolution being degraded by 15%, i.e., less than 2 inches per foot. Under the present level and exploitation of film and sensor technologies, there are only marginal differences in the resolution and coverage attainable between these two photographic means. Shown also is the system relative area rate capability at fixed nadir GRD as a function of angular resolution in which a cubic relationship is exhibited. Finally, a parametric overplot is shown in Figure 4 of short term average resolution cells per second which is proportional to image data rate in a readout system which had about one frame of storage capability. It appears therefore that changes in technology should aim at points above the trend line, i.e., such changes should offer improving angular resolution and at the same time increasing solid angle rate (area rate).

Because of the correlations demonstrated in Figures 2 and 4, it is possible as in Figure 5A to summarize system capabilities in a single display. Figure 5A gives these various parametric values to a factor of 40% or better, with two qualifications. They are: (1) the cost of Z is reduced by 50% and (2) for C the short term average solid angle rate and the corresponding cells per second are lower by a factor of ten than shown. The import of Figure 5A is shown in Figure 5B. Given one chooses any pair of orthogonal parameters on the chart, e.g., angular resolution and a total solid angle or area coverage, then all other parameters -- total number of resolution cells per mission, the unit cost of resolution cells, the average solid angle and area rates and the data transmission rate (moderately buffered) -- are fixed within the present applications of technology.

A final measure of system capability is the resolution which it can offer under various operating constraints. Figure 6 indicates target resolution dimension[1] for several systems at swath edge (at the equator and at 45^{o} latitude) [redacted] satellite operation and for a 1 ft nadir GRD. Shown also is the altitude at which the various systems must operate so as to give the specified nadir resolution; in some cases altitudes given are clearly infeasible. Given that there is approximately a two-fold increase in diameter of primary optics between H on the one hand and F, F* and G on the other hand, and again a factor of two between these three systems and Z and Z*, it is clear that swath edge resolution is a direct function of optics diameter and operating conditions and that sensor technologies presently contribute little or nothing.

Another system target resolution capability worth noting is the swath edge minimum resolution capability such as shown in Figure 7. As best resolution dimension along a swath edge is a function only of altitude and look angle of obliquity, it is possible to determine an altitude and look angle at which that resolution dimension is as good as can be obtained. This best resolution dimension depends only on the angular dependence law chosen and not on satellite optics. Figure 7 shows for this optimum operating altitude (152 nm) and look angle (66^{o}) swath edge minimum resolution at the equator and at 45^{o} latitude. Again, not surprisingly, the fact of improving minimum swath edge resolution with improving angular resolution and in turn increasing optic size is demonstrated and Figure 7 shows also for the minimum swath edge resolution the corresponding nadir GRD. Both Figures 6 and 7 show as appropriate search and targeting resolution requirements.

[1] Target resolution dimension is defined (in the ordinate of Figure 6) as the geometric mean of resolution capabilities in both the vertical and horizontal planes. It is determined in a way consistent with the analysis that leads to a $\sec^{3/2}\theta$ dependence of ground resolution distance in which θ is the look angle of obliquity. At large angle of obliquity this definition gives a $\sec^{5/4}\theta$ variation with θ which is the geometric mean of $\sec\theta$ and $\sec^{3/2}\theta$ used by different project offices.

Some generalizations ought to be drawn from the foregoing. One can draw, as in Figure 8, a three dimensional plot of average solid angle rate, angular resolution and system size (total cells) or unit cost of resolution cells and find within those three dimensions a "current design plane" which describes with the accuracies stated the present capabilities of both film and solid state sensor systems. Perhaps there is, within this three dimensional space, a new optical and senor technology plane made available by coupling image intensifiers to solid state arrays and through different circuit design choices, reducing switching and amplification noise, decreasing integration time, improving resolution, broadening spectral response and so forth. That is certainly one direction to pursue. Possibly there are film system improvements, but this is not so clear.

However, one need not be restricted by the three dimensions of Figure 8 and at least conceptually, fourth dimensions incommensurate with those shown might be found to give a new "hyperplane" of photographic satellite capability. Some possibilities for these additional dimensions are some or all of [redacted] zoom capability, satellite on-board data storage capability, and imaging surfaces of [redacted] sensitivity. It would appear that the possibility of attaining even a few of these additional dimensions is worth the expenditure of significant amounts of technology funds.

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TOTAL SOLID VIEWING ANGLE PER MISSION VS. COST OF MISSION RECURRING COST.

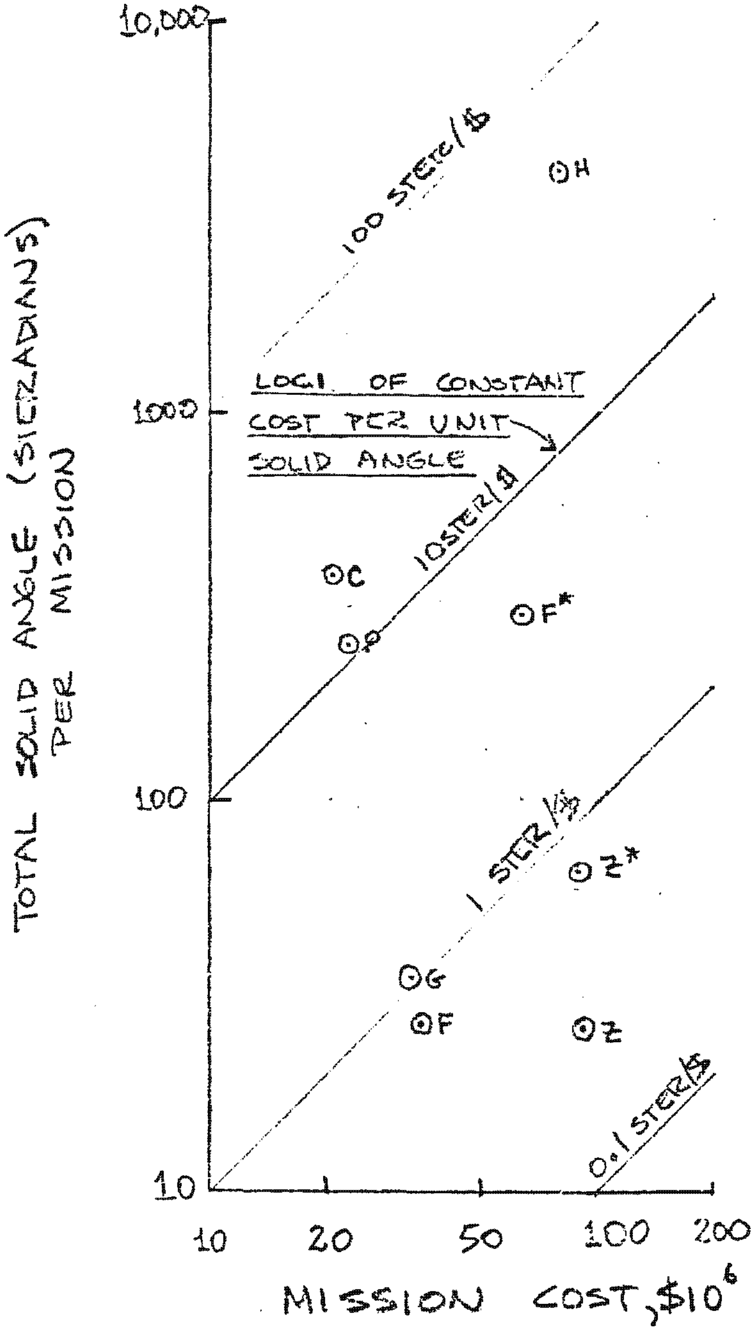
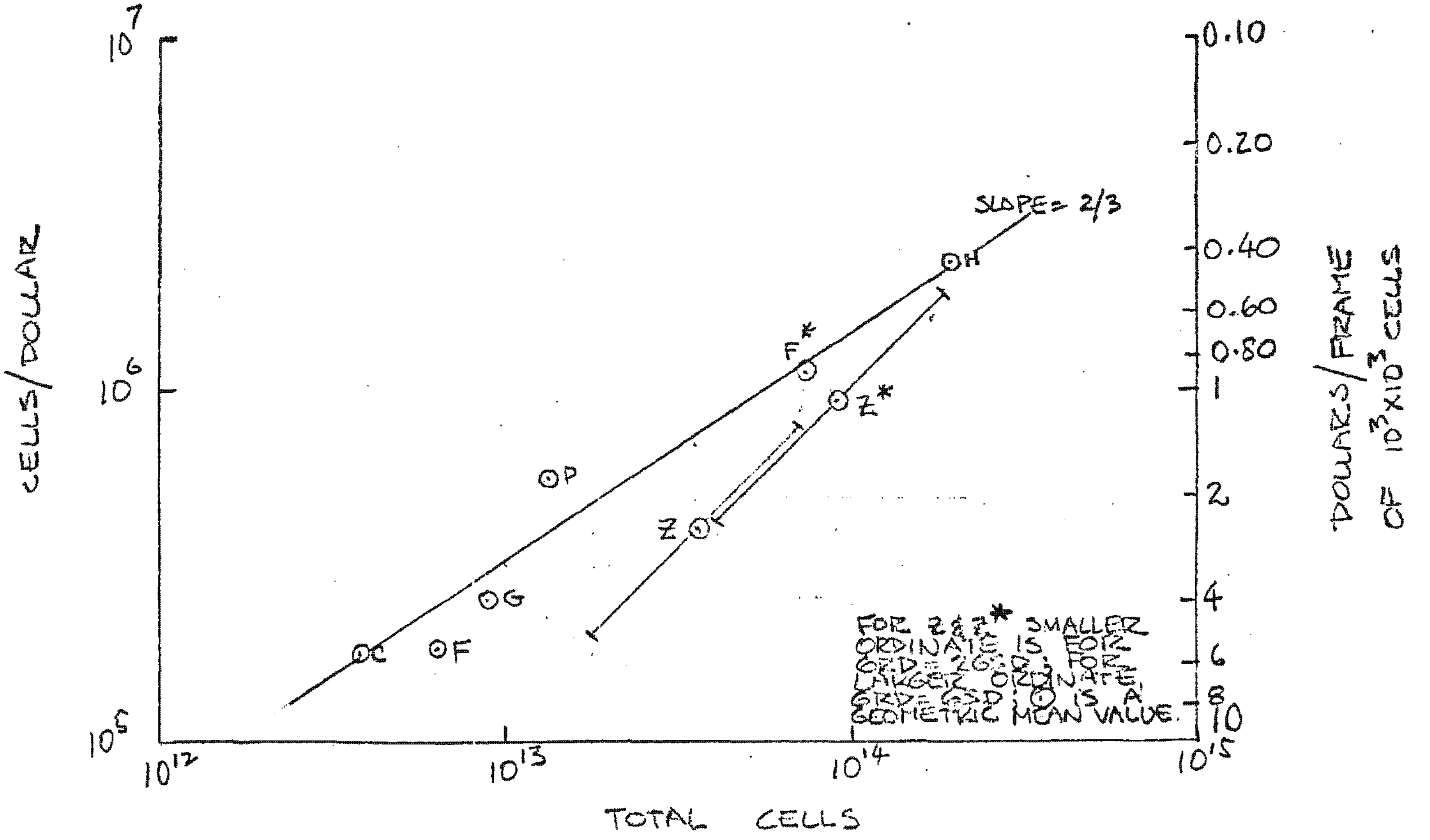


FIGURE 1.

CELL COST VS.
TOTAL CELLS PER MISSION



N.B.-(1) Z IS AT 4 FRAMES/MIN; Z* AT 10 FRAMES/MIN; EACH OF 324 × 10^6 CELLS.
(2) F IS 2 FILM CHANNELS & 30KFT FILM LOAD; F* IS 2 FILM CHANNELS & 352KFT FILM LOAD.

FIGURE 2.

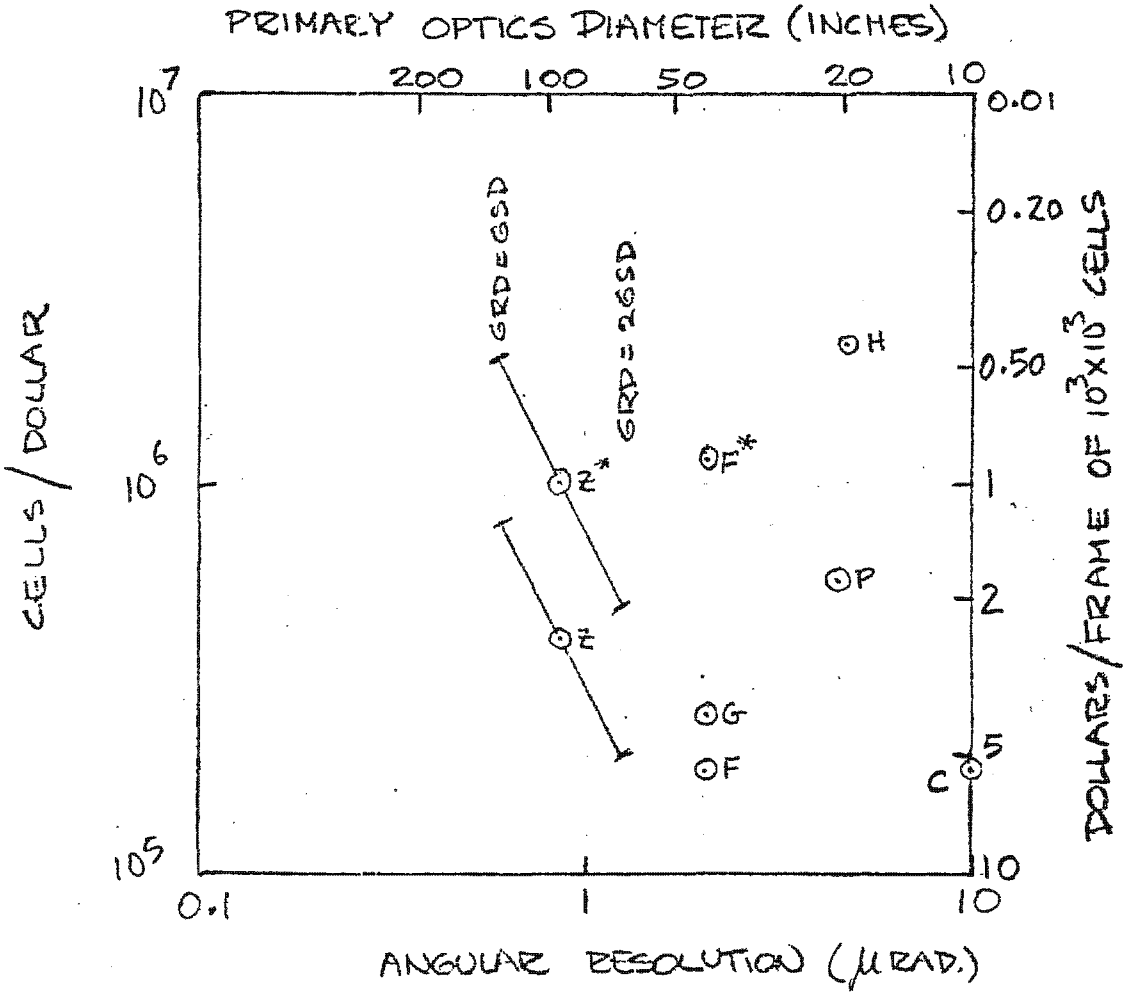


FIGURE 3

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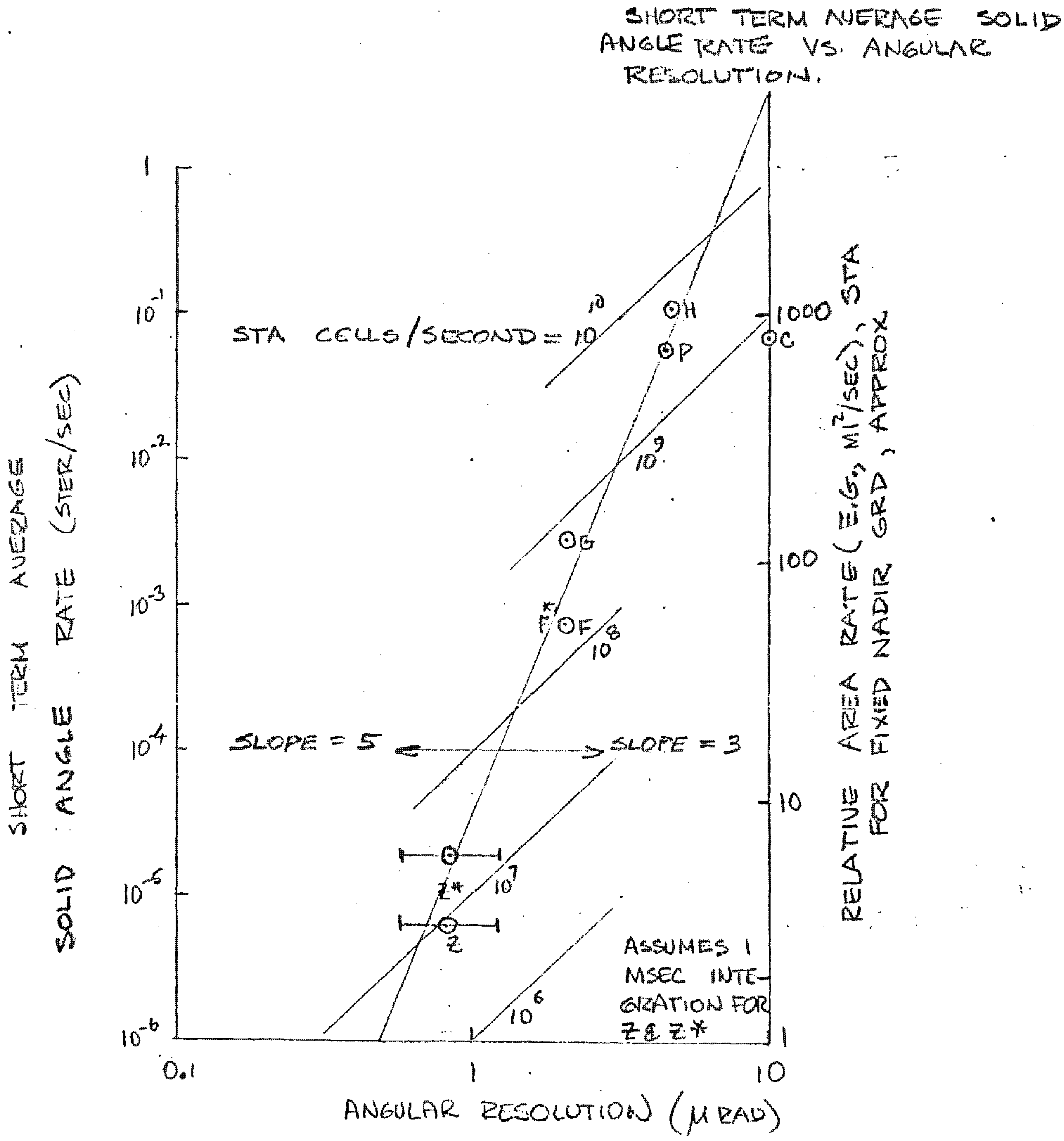
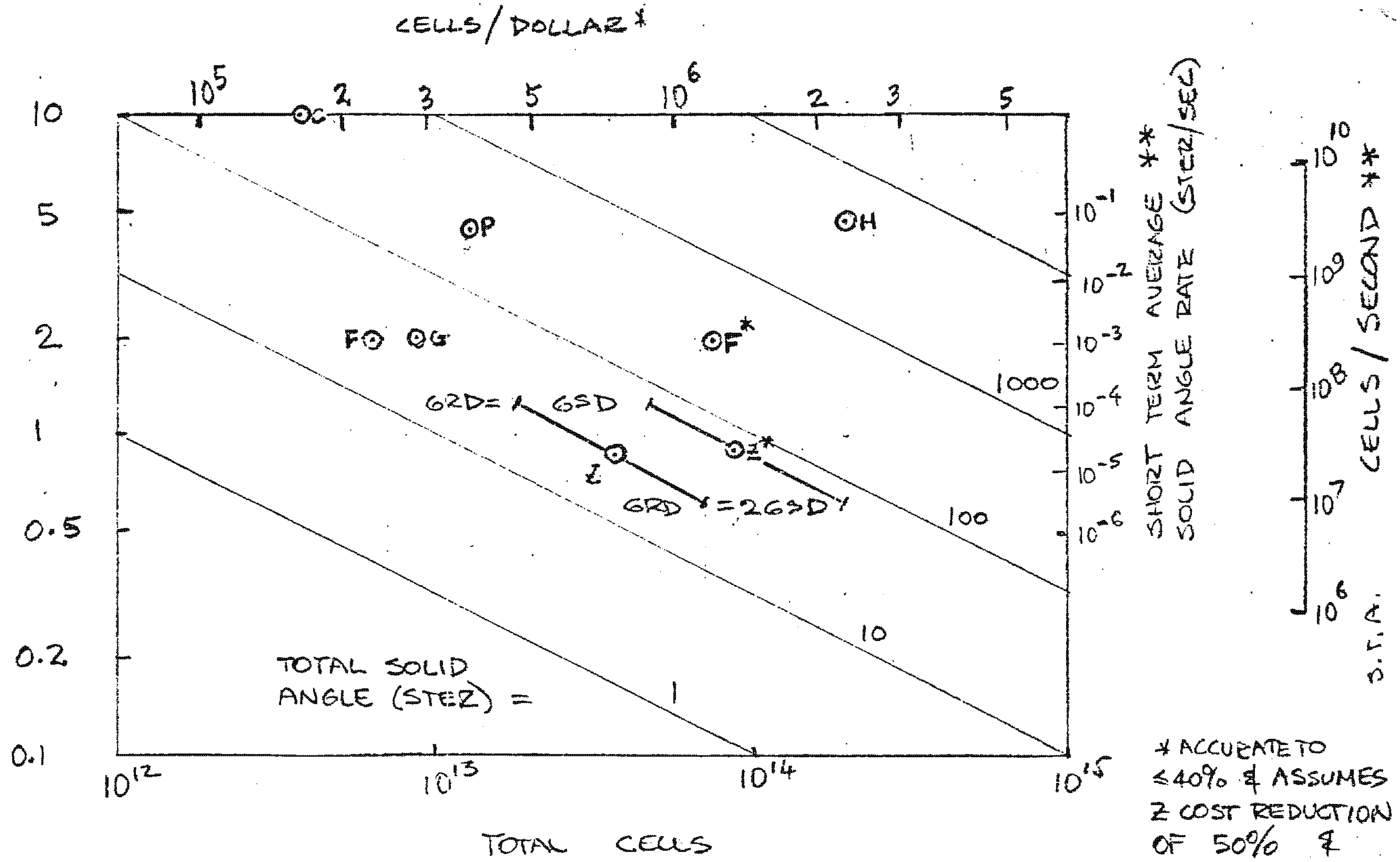


SHORT TERM AVERAGE SOLID ANGLE RATE VS. ANGULAR RESOLUTION.
SHORT TERM AVERAGE SOLID ANGLE RATE (STER/SEC)
RELATIVE AREA RATE (E.G., MI²/SEC), STA FOR FIXED NADIR GRD, APPROX
STA CELLS/SECOND = 10
10
10
10
10
10
SLOPE = 5
SLOPE = 3
H
P
C
G
F*
F
Z*
Z
ASSUMES 1 MSEC INTEGRATION FOR Z & Z*
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
1000
100
10
1
0.1
1
10
ANGULAR RESOLUTION (μ RAD)

FIGURE 4

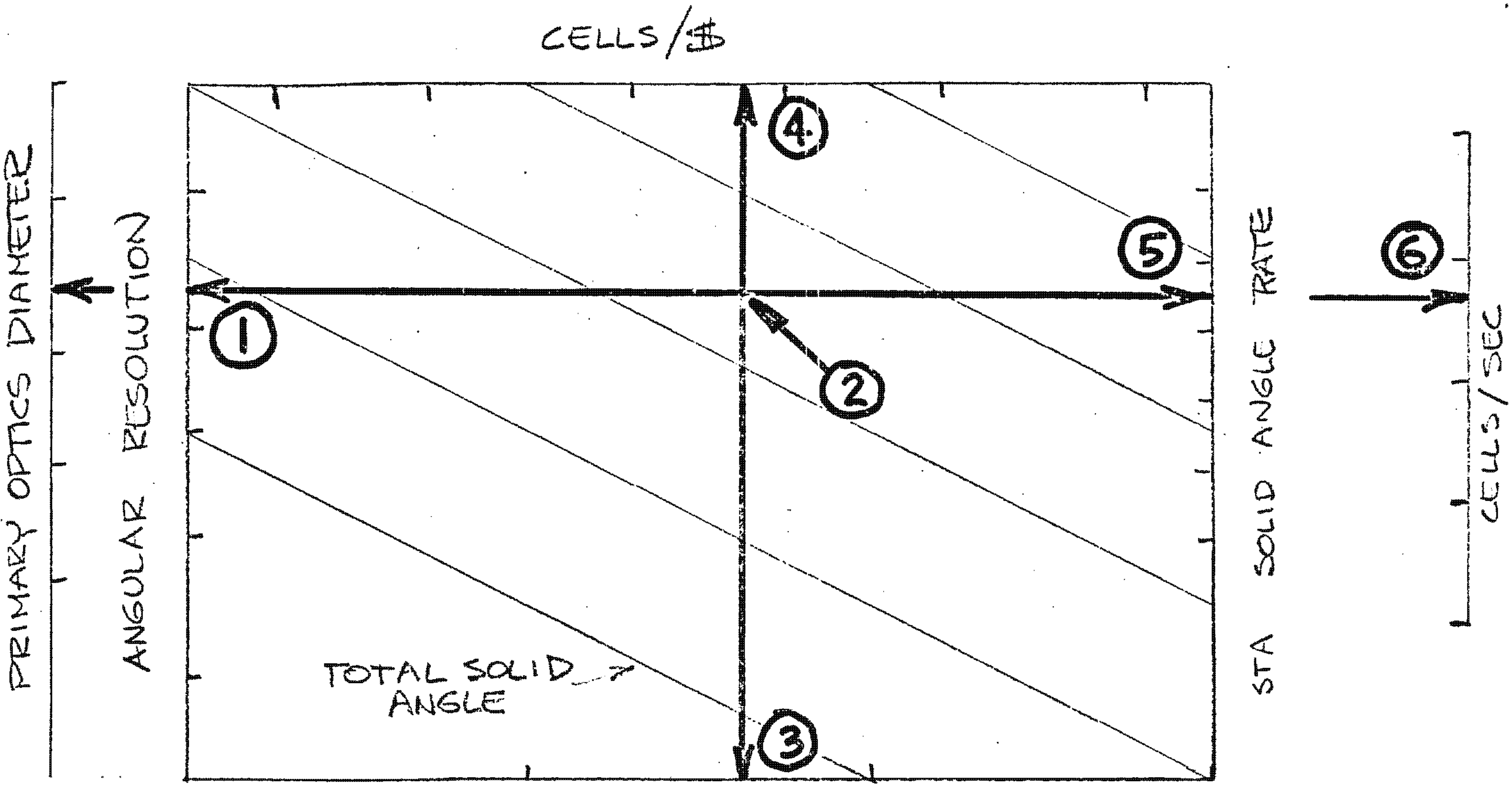
SUMMARY CHART



* ACCURATE TO ≤40% & ASSUMES Z COST REDUCTION OF 50% & 0.001 SEC. INT. TIME

** EXCEPT C WHICH IS 10X LOWER

FIGURE 5A



xample:

1. Choose angular resolution and
2. Choose mission size (total solid angle), <u>then</u>
3. Total resolution cells
4. Cell cost
5. Solid angle rate
6. Cell rate

'e determined.

FIGURE 5B

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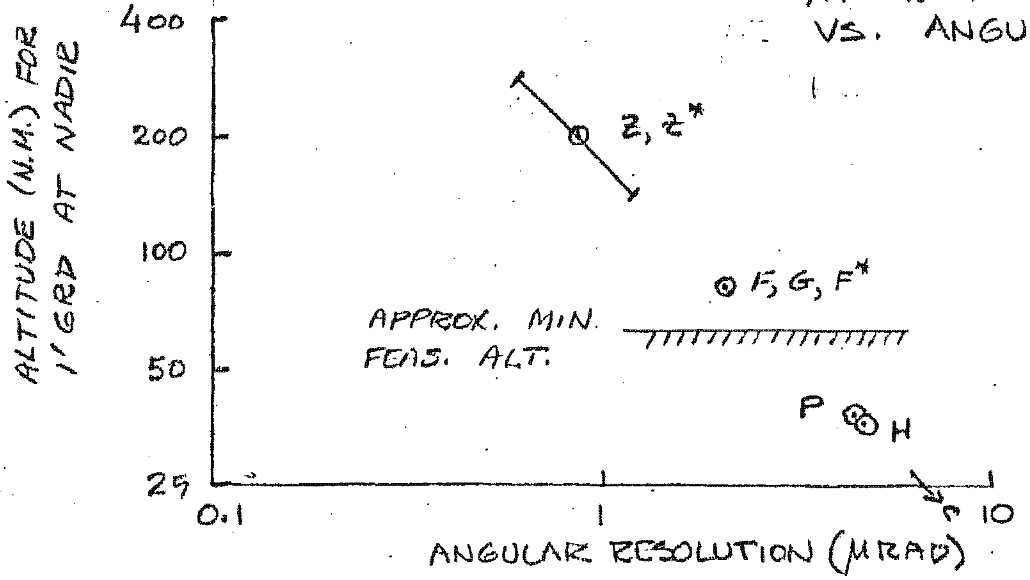
TARGET RESOLUTION DIMENSION AT SWATH EDGE AT EQUATOR VS. ANGULAR RESOLUTION.



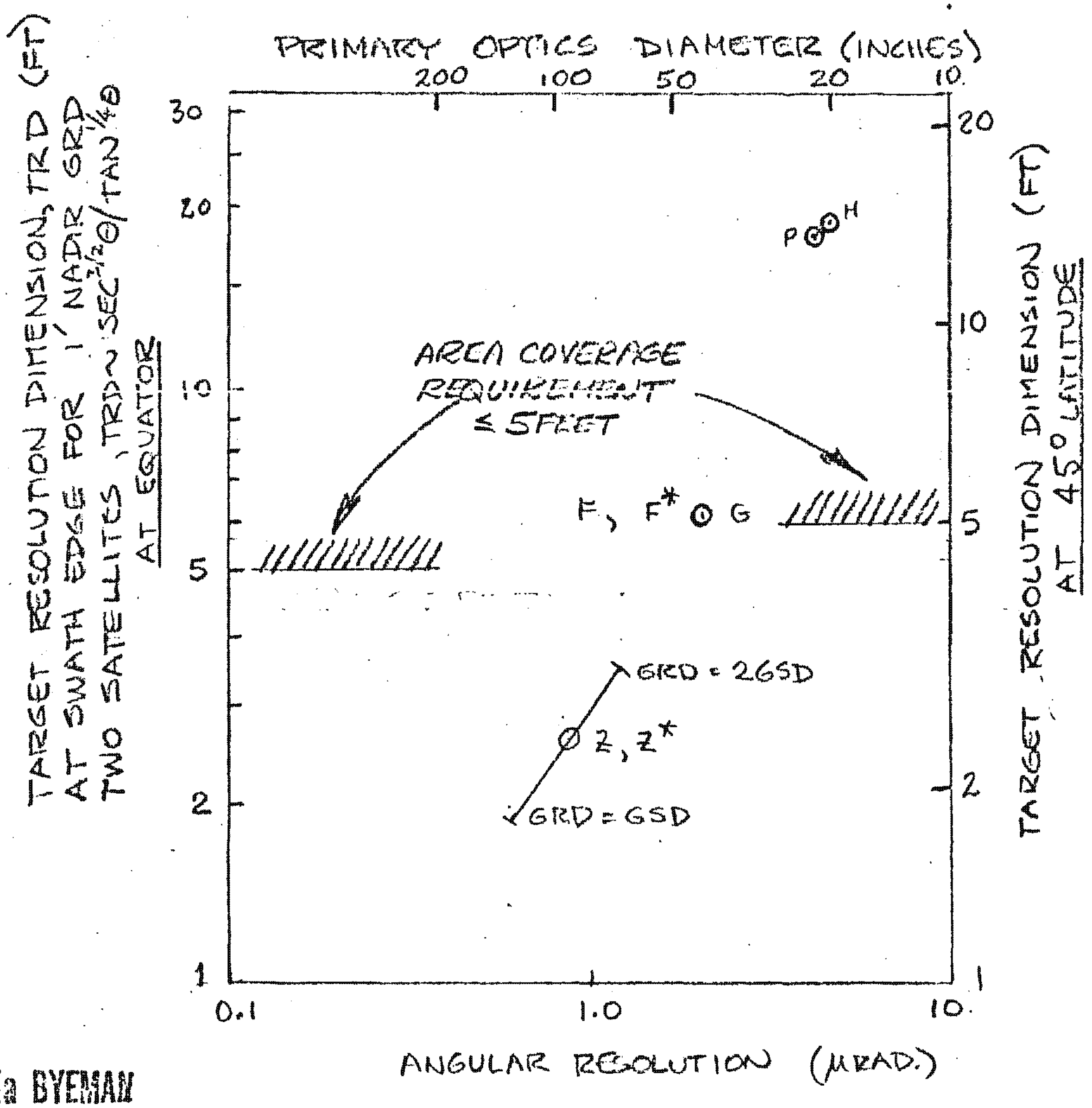
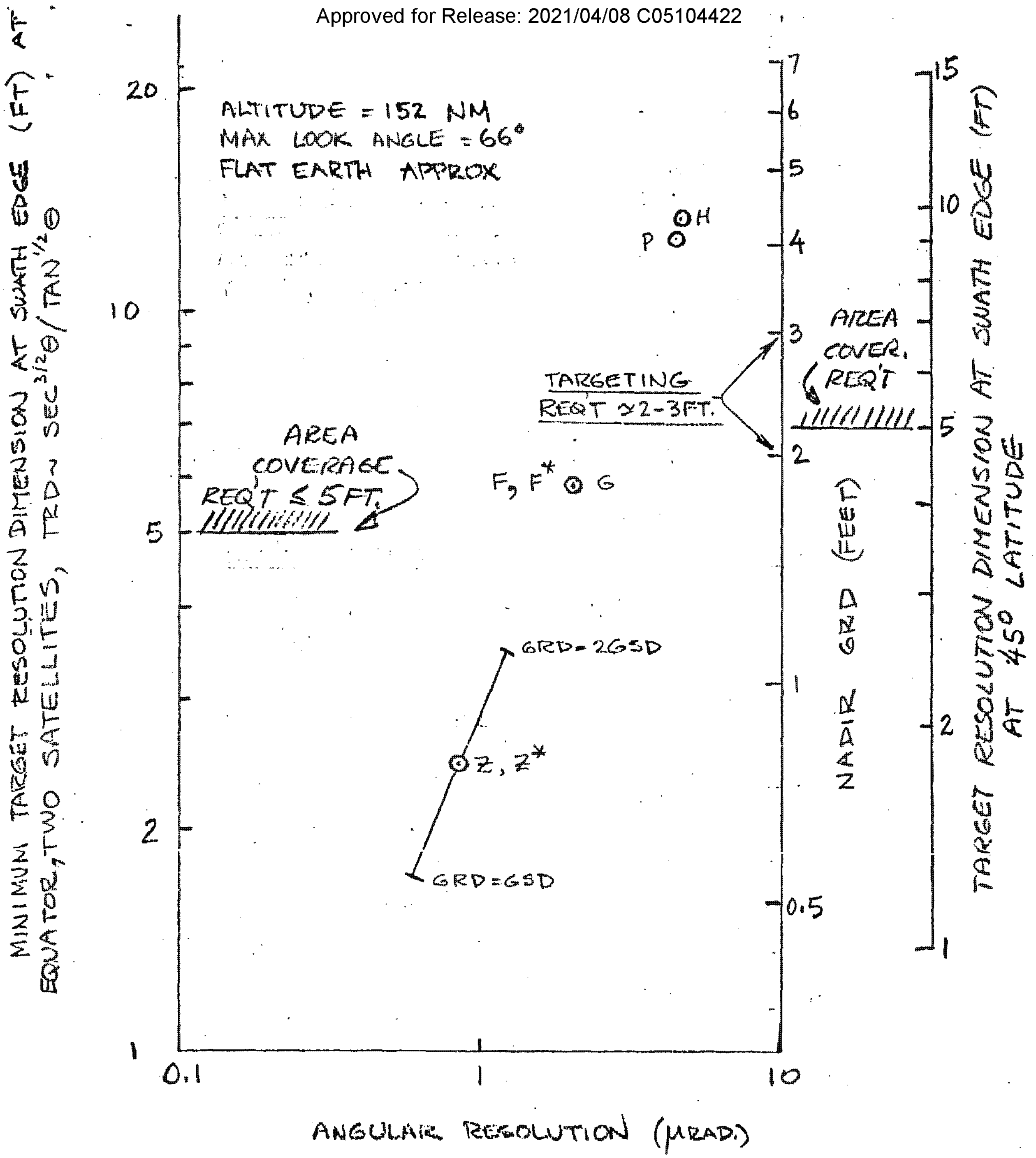
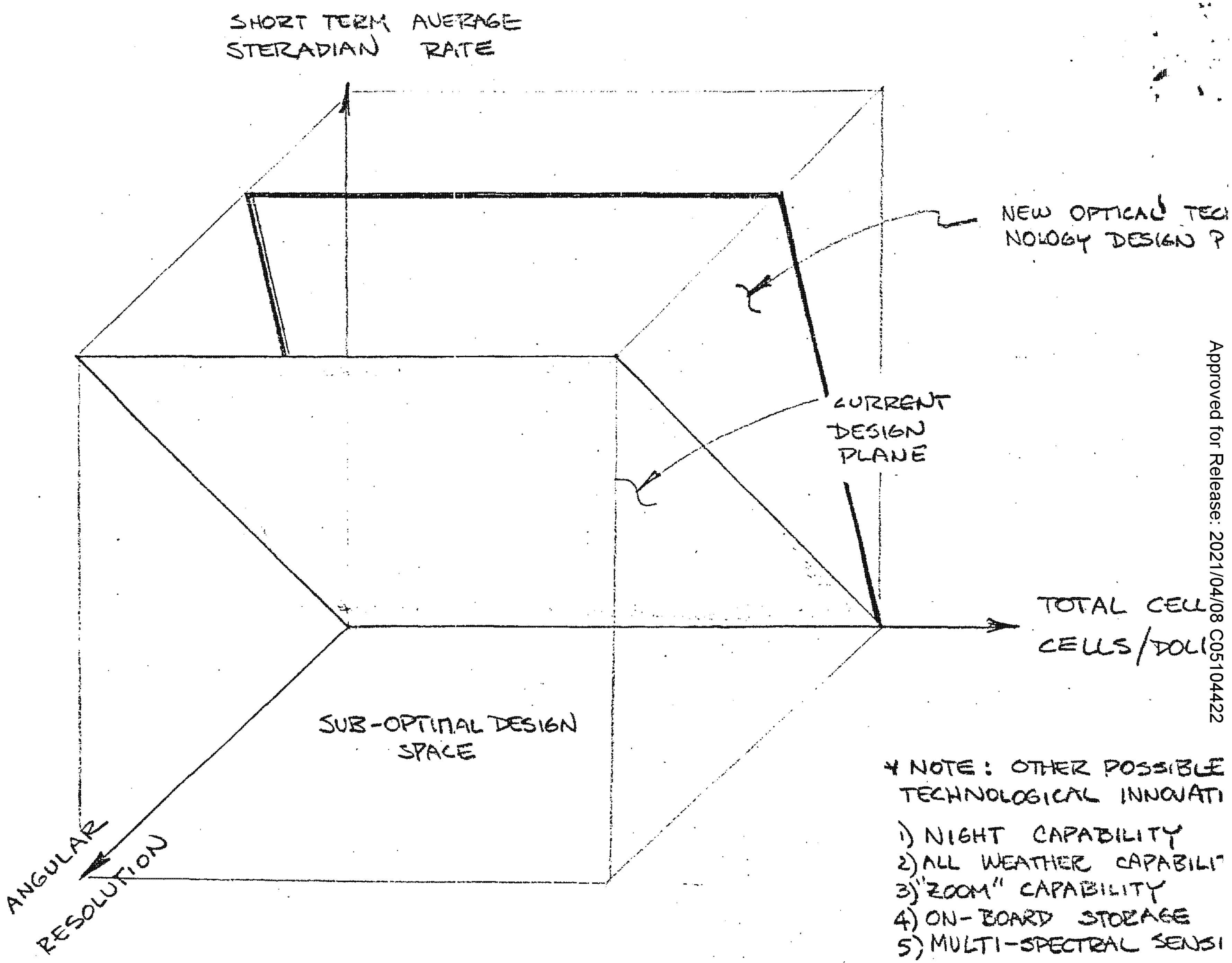


FIGURE 6



MINIMUM TARGET RESOLUTION DIMENSION AT SWATH EDGE AT EQUATOR VS. ANGULAR RESOLUTION

FIGURE 7



* NOTE: OTHER POSSIBLE
TECHNOLOGICAL INNOVATI

1) NIGHT CAPABILITY
2) ALL WEATHER CAPABILI
3) "ZOOM" CAPABILITY
4) ON-BOARD STORAGE
5) MULTI-SPECTRAL SENSI

FIGURE 8

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ndle via BYEMAN
ntrol System

THE WHITE HOUSE

WASHINGTON

July 11, 1971

Dear Dave:

At the last meeting of the NRP Executive Committee I expressed my judgment that the EOI system could benefit by at least a year and preferably two of continued technology development prior to going into system procurement. That judgment is based on my view that today the film readout system being less exotic is more immediately feasible and available, but that the trend of progress of solid state techniques guarantees that costs will decrease and performance increase rapidly in the application of EOI technologies.

I have sought to test my judgment by having my staff complete at least to some degree the efforts undertaken as a result of Carl Duckett's suggestions earlier this year that we attempt to find measures of effectiveness for the various photographic systems which we have been probing as an answer to the NRT and crisis capability needs. I am attaching a copy of their memorandum relating to "Satellite Photographic Systems Comparisons." An examination of Figures 4 and 5 indicates that the Z systems and all film systems today fit the same trend line but that the Z systems cost about twice as much as the film systems for the same performance. I expect that Z systems can be made to offer photographic capabilities different in dimension from what is attainable with film systems.

I conclude that, if we are interested in a well-organized program with an early result we should aim at a film system today and push the EOI toward an approach that supplies superior performance at the same or even lower cost.

Sincerely,

Ed

Edward E. David, Jr.
Science Adviser

Honorable David Packard
Deputy Secretary of Defense
The Pentagon
Washington, D.C.

Cy to Dr. McLucas
Attachment BYE 11950-71

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BYE 11951-71

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United States Senate

COMMITTEE ON APPROPRIATIONS

WASHINGTON, D.C. 20510

July 9, 1971

Honorable Richard Helms, Director
The Central Intelligence Agency
Washington, D. C.

Dear Mr. Helms:

Reference is made to our previous discussions of the necessity of proceeding with the development of two satellite readout systems as proposed in the classified budget for the National Reconnaissance Program.

I want to express again my view that we should proceed with the development of only one of these systems. Judging from the information given me, it would be advisable to proceed with the Electro-Optical Imaging System.

It is my hope that the NRP Executive Committee will review this matter and advise me of the one system that should be developed and the adjustments that should be made in the pending budget requests.

I am addressing a similar letter to Honorable David Packard, the Deputy Secretary of Defense.

With kindest regards and best wishes, I am

Sincerely,

ALLEN J. ELLENDER
Chairman

AJE:W:m

~~TOP SECRET~~

Control System

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The Near Real Time Photo-Reconnaissance Program (EOI-FROG)

Report by the National Reconnaissance Panel
to the
President's Science Adviser
July 14, 1971

At your request we have reviewed the Near Real Time photo-reconnaissance program, both EOI and FROG. The Panel meeting of June 11, 1971 was supplemented by further discussions and visits. We have judged the expected performance and relative program risk of EOI and FROG, as follows:

[redacted]

2. Near nadir, the FROG has very little capability to monitor lines of communication (LOC) and can place only 3 to 4 frames of some 3 miles square along a road of approximately E-W direction, and would be thus limited at times to photographing as little as 10-20 miles of LOC per pass. At large obliquity, FROG has greater LOC coverage, but at substantial sacrifice in resolution.

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GAMBIT-ZAMAN

Handle via BYEMAN

The EOI system, even in its original framing mode, could lay some 20 frames along even an East-West route for a coverage of some 60 miles length (minimum) per pass.

[redacted]

3. EOI gives [redacted] return of imagery to [redacted] with imagery routinely available less than [redacted] after access. FROG with the planned continental U. S. sites will have a 12-hour delay after photographing European Russia, the Suez, or Eastern Europe. Normal sun-synchronous orbits photographing these regions at local noon (about 5 A. M. Washington time) can return EOI imagery in ample time for a full day's review by U. S. Government leadership, with resultant tasking of the next day's take (pictures on the desk at opening of business the following day). A 12-hour delay in return of imagery would lead to a 2-day cycle if the system were to serve directly the needs of Government leaders.

4. The EOI system design now includes an enhanced capability for area and LOC surveillance, achieved by the incorporation in the EOI focal plane of a [redacted] No change in technology was required. Thus the EOI program has demonstrated the performance of the developmental items which have been exposed to critical appraisal for at least the last 2 years. Certain tasks remain to be accomplished, e. g.:

a. Adequate thermal control of the detector array,

b. Choice of the optimum means of continuous calibration of each detector.

c. Demonstration of the vehicle stabilization achievable with the redundant [redacted]

We are confident that this work can be performed successfully on the required time scale.

On the other hand, FROG will require the development or adaptation of <u>many</u> techniques and pieces of equipment new to the program and to the contractors:

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a. Bimat processing with 1 yr. life, involving thermal control to 1°C accuracy at 0°C.

b. Laser scanner-film guide

c. Roll joint modifications

d. Zero-g propellant requirement

e. Flexible solar cell array

f. In general, the many systems responsible for raising the number of "relay-driver pairs" from 220 in the G system to 760 in the proposed FROG.

According to an Air Force spokesman, "every AGENA subsystem is new," as is the film-electronics module. These capabilities appear possible of achievement, no inventions appear to be required, but our experience with analogous development programs (both in this field and in the contexts in which we individually have experience) causes us to regard the successful achievement of all these capabilities on schedule as a substantial risk.

We conclude that the risk associated with FROG on the stated schedule may well be greater than that associated with EOI on its schedule with operational capability one year later.

5. At 17° N latitude, the edge of swath resolution is:

EOI - 26" GSD (ground sample distance, geometric mean)
FROG - 84" GRD (ground resolution distance, geometric mean)

Scaling from the experiment performed by NPIC comparing the best of G^3 photography with simulated EOI photography, FROG would have to show about 30" - 40" GRD to give a product of value to photointerpreters "equivalent" to the EOI 26" GSD product. FROG is thus at least a factor 2 worse in its edge-of-swath resolution.

6. We believe that EOI design will not benefit from operational experience of FROG because such experience will not be available to any significant extent until mid-1975, and to delay the EOI procurement until then would postpone EOI operation to 1978 or 1979.

7. It is true that EOI has substantial growth capability which can be accommodated gradually in the present configuration.

Probably the improved capability of greatest interest is [redacted] This will require substantial improvement in the state of the art and in our opinion would be of relatively small importance compared with [redacted] EOI product. There is some reason to believe that [redacted] imagery can be accommodated in the present EOI configuration, but the relative value of such imagery is not such as to make it advisable to delay the EOI program to determine this technical detail.

Summary and Conclusion

The comparisons (1) through (5) show the performance of FROG to be substantially inferior to that of EOI. The operation of FROG would only be an interim program. The longer EOI is delayed, the longer we will be denied the much superior EOI product, but we shall eventually develop the EOI system. Thus the question is not whether we spend $675M or more (through 1977) to build FROG to fly end 1973 or [redacted] or more (through 1977) to fly EOI end 1974. (The stated EOI program cost does not take credit for a saving exceeding [redacted] annually, resulting from the replacement of G^3 by a very small fraction of EOI observing time). The question is whether it is worth $675M additional to have an inferior product one year sooner (with substantial risk) and with what we regard as probable resulting delay of the superior capability.

The Panel believes that recent decisions have been based on two misconceptions:

(1) that EOI and FROG are sufficiently similar in performance that the two are alternates, and

(2) that the risk in developing FROG is substantially less than that in building EOI.

The Panel is unanimous in its judgment that the FROG program has the higher risk. We respectfully urge that FROG be dropped and EOI acquired on a schedule to result in first flight November 1974.

RLGarwin/fn/14Jul71
Cy 1 File Z
Cy 2 Ling
Cy 3, 4 Land
Cy 5 Goldberger
Cy 6 Martin

RLG -signed- Edwin H. Land, Chairman
National Reconnaissance Panel
RLG -signed- James G. Baker
RLG -signed- Sidney D. Drell
RLG -signed- R. L. Garwin
RLG -signed- M. L. Goldberger
RLG -signed- Joseph Shea

Clarifying remarks added 7/24/71 by R. L. Garwin after discussion with J. J. Martin (keyed to marginal numerals on page 1)

1. Mean mission duration comparable with FROG is 2.6 years.

2. "best of G^3" is usually stated to be [redacted] The MIP frames are commonly judged to be [redacted] These 3 particular frames were estimated to be in the [redacted] range. Since the performance of FROG is simply scaled from G^3, it is more important to recognize that these MIP frames represent the best of G^3 than to assign a numerical GRD to them.

3. This conclusion remains true for any reasonable assessment of GSD vs GRD value. In addition, EOI has the other virtues of intensity resolution as well as spatial resolution, low sun angle, etc.

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