GAEP
MURAL

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MEMORANDUM FOR : Deputy Director (Research)

SUBJECT : Itek M-2 Proposal

1. I recommend that the M-2 satellite reconnaissance scheme be started at once on a limited basis but comparable to level of effort on Spartan (E-6) by Eastman Kodak for Space Systems Division.

2. Eastman Kodak submitted proposals to SSD on this latter system on 15 March. We are under restraint from receiving data on Spartan proposals direct, but we have had some information via NRO. Unfortunately, information obtained this way is more optimistic on some counts than I had been led to believe. Therefore the following comparisons are subject to uncertainties. I have used what I believe to be the most realistic data in all cases.

3. Both M-2 and Spartan are tied to the TAT Agena D combination so that current TAT uncertainty affects both. I must point out that CORONA suffered through its first year plagued with Thor Agena B problems.

4. In terms of quality the M-2 system with a 39.4" focal length f3.5 lens has an apparent edge over the 36" focal length f4 E-6 lens. However, the M-2 lens remains to be made. Itek expect to reach resolutions comparable to the 24" focal length f3.5 M lens which are reported by Itek to have reached 135-145 l/mm with SO-132 emulsion under dynamic conditions at 2:1 contrast. If this is the case the M lens is capable of angular resolution of 2 arcsecs, and the M-2 lens must be made capable of 1 1/2 arcsecs.

5. Eastman Kodak set 88 l/mm as a criteria for the E-6 lens. Measured quality under conditions supposedly comparable to Itek tests showed a gain from about 80 l/mm to 100 l/mm. This means the E-6 lens is able to reach an angular resolution of about 2 1/2 arcsecs.

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6. The E-6 lens has a large angular field by comparison to M and M-2 lenses (10^{o}-5^{o}-6^{o}). Eastman Kodak expect to reach 125 l/mm or about 2 arcsecs angular resolution by working over a smaller field angle.

7. All of this means that under comparable very best conditions (which never exist) the M system now credited by some with 10' ground resolution should be compared to 7 1/2' for M-2 and 8 1/2' for E-6 (Spartan); or if one insists that M-2 or E-6 can do better the comparison should be 6'-7' for M, 4 1/2' for M-2, and 5' for E-6. I think this means that considering only apparent resolution quality both M-2 and E-6 offer an expected improvement over M and other considerations must be examined to see if the improvement is realizable and to choose between M-2 and E-6.

8. One of the defects of E-6 was poor light transmission characteristics. Eastman expect to realize an improvement from 7.2 to 5.8 in transmission number for E-6. This means that relatively long exposures will not be needed. The longer exposure times needed to produce good image on film call for extremely precise control of system dynamics to prevent smear. Shorter exposures permit more realizable stability. For comparison the following calculations were made:

Shortest Exposure Times to Produce Adequate Images on SO 132 Emulsion

M	1/300 sec. Wratten 21 filter	1/600 no filter
M-2	1/250 sec.	1/500 sec.
E-6	1/150 sec.	1/250 sec.

These numbers can be used only for comparison purposes because actual exposure values used are a compromise considering time of day, season, latitude of most important targets, climatology, etc. For example, a sometimes quoted operational exposure time for MURAL is 1/200 sec. Such an exposure time for 10' ground resolution sets a total image motion error of not over 5 1/2% or a smear rate of about 3 1/2 milradians/sec. or better.

9. The smear rate is caused by uncompensated displacements and rates of motion between ground plane and image plane which are caused partly by vehicle and partly by

camera imperfections. Unfortunately, there seems to be a set of stability data which, in general, match either "present" or "current" or "planned capabilities" with "requirements" almost uniquely for each system showing that stabilization is, or can be made adequate. I should add that Itek and Lockheed do not agree even on method of computation.

10. The rates and displacements quoted for MURAL show that a smear rate of about 2 milradians/sec. is what we should be getting and by a very strange coincidence this just happens to correspond to the acceptable smear rate for MURAL performing at the quoted 88 l/mm and 10' ground resolution. Ergo, in MURAL "capabilities" meet "requirements".

11. Using what I guessed to be most reasonable numbers for vehicle and camera excursions I calculate "up to now" MURAL experience showing a smear rate of about 3 1/2 milradians/sec. or a resolution limitation from system instability of 12'-15' ground resolution at 1/200 sec. exposure time. Since such calculations are of a statistical nature there will be times when either better or poorer performance is shown. This agrees with subjective assessments of MURAL performance.

12. Without the significant system stability improvements claimed to have begun with Agena 1164 lost yesterday and if the above remarks are accurate in general, then any system of better optical expectation than M will be no better than M performance most of the time.

13. Using stability data for "present" Agena (which was to have begun with 1164) the MURAL system turns out to be slightly better than LANYARD in this regard. I do not have "hard" data on LANYARD optical performance, but it appears that even with considerably improved stability to a level of 1-1 1/2 milradians/sec. both LANYARD and MURAL are not matched in optical and system dynamic limitations. The largest source of residual error in MURAL, if the expected stabilization improvements are realized, then stems from inaccuracies in V/H programming. I have asked, and Itek just happen to have, a proposal for an active V/H sensor. The Perkin Elmer sensor ought to be looked at also if it starts to work properly.

14. M-2 is supposed to have about a four times more accurate V/H program selection than M so that, again, a good match is reached in optical and dynamic characteristics. I have no data to enable a numerical look at E-6, but from optical characteristics it appears that M, M-2, and the advanced E-6 will all need about equal stabilization.

15. Conclusions on this seem to be that a theoretical quality improvement of 20-30% ought to be found in MURAL requiring better stabilization and V/H correction; for either M-2 or E-6 to show improvements over M also requires this same improved stabilization and V/H corrections substantially better than past M experience.

16. Lockheed have submitted to SSD a shopping list of Agena improvements including 6 month, 12 month, and 5 year stabilization objectives. As of mid-February these had not been funded and the improvement program consisted of weight reductions and thrust increases only. The ability to loft more weight into orbit is no assurance by itself of better quality as has just been indicated. Improved stabilization should have an immediate effect on M and is necessary for either E-6 or M-2.

17. While it is premature to select between E-6 and M-2 at this juncture, it may be worth setting down a few observations. In bettering the lens to what I have called the advanced E-6 Eastman will have to restrict the field angle and hence the total scan to about 50° unless a new camera is designed. This would negate any lead time advantage they may now enjoy. M-2 has 60° and M 70° scan angle.

18. I see no reason why both M-2 and E-6 could not be used in the dual recovery configuration particularly if the new Agena fuel works out. However, again, unless a new camera design is adopted by Eastman Kodak they will have a severe film limitation in stereo.

19. There are some differences regarding film capacity between Itek and LMSC. This probably stems from extent of liberties taken with present and enlarged recovery systems. My calculations are:

	Present Recovery System	Enlarged Recovery System
M	2 - 20" diam spools 7800' of 70mm film ea. 80 lbs. 7600' stereo	2 - 21" diam spools 8700' of 70mm film ea. 90 lbs. 8700' stereo
M-2	2 - 18" diam spools 6250' of 5" film ea. 115 lbs. 6250' stereo	2 - 20" diam spools 7800' of 5" film ea. 145 lbs. 7800' stereo
E-6	1 - 20" diam spool 7800' of 6.6" film 95 lbs. 3900' stereo	1 - 21 1/2" diam spool 9100' of 6.6" film 110 lbs. 4550' stereo

The "enlarged" version is actually a very minor dimensional change. The dual camera systems are inherently weight limited (parachute) and rocking mirror systems are inherently space limited.

20. There are two points to be made here. First a requalification of the present recovery system would probably be needed for the new higher weights. A new parachute development may be needed also. Therefore an "enlarged" recovery system ought to be looked at as part of either M-2 or E-6 preparations at this stage. Second, if E-6 and M-2 quality turn out to be as competitive as indicated here, then a choice between the two should be made on costs, time of availability, expected total coverage, and operational complications; none of which can be compared now simply because we lack complete data.

21. In summary, the following specific actions seem in order:

a. Approve funding to Itek for small lot lens fabrication, design, and construction of zero tension film transport mechanism, and miscellaneous items. Estimated costs are $250,000.

b. Call in Itek to negotiate specific long lead items in their test facility proposal and possible provision for future improvements with the intent of early partial funding here.

c. Approve funding to LMSC for early design work, mock-ups, etc. Cost estimate is $330,000.

d. Obtain joint views from Itek, LMSC, and GE on limitations of present recovery system on M-2 and trade-offs in minor redesigns to enhance M-2 with the intent of funding at least design studies by GE. This might be well duplicated with Eastman Kodak on E-6. Costs of this unknown now.

e. Present our views to NRO on need for improved Agena stability. This case is not crystal clear because of the several sets of data. However, it is admitted by all that system stability very much better than claimed for M must be shown to gain the potential quality of L, M-2, E-6, and beyond. I feel intuitively that simply because of extent of improved stability claimed to have been incorporated into Agena 1164 is so great by comparison to claims for past M performance, and because we have no flight experience yet to back up these claims, that funding of some extent should be given LMSC by Air Force for improved Agena stability.

f. While the work outlined above can carry beyond a 90 day period at that time certain other dollar committments need be made to keep in balance. Hence, a program review of M-2 should be made in about three months. A selection between E-6 and M-2 may or may not be appropriate at the same time.

22. I have attached a note from yourself to D/NRO to implement the above if you agree.

EUGENE P. KIEFER
Technical Analysis and Evaluation Staff
(Special Activities)

Attachment