

Rm 602
HANDLE VIA
BYEMAN
CONTROL SYSTEM

~~TOP SECRET~~

~~(S)~~ NATIONAL RECONNAISSANCE OFFICE
WASHINGTON, D.C.

THE NRO STAFF

23 December 1969

MEMORANDUM FOR MR. JOHN CROWLEY, CIA
SUBJECT: Transmittal of Documents

The attached Minutes for the First, Second, and Third Meetings of the Fubini Panel are forwarded for your use.

John D. Regardt
JOHN D. REGENHARDT
Major, USAF

- Attachments
- 1. BYE-13468-69, Cy *12*
 - 2. BYE-13469-69, Cy *12*
 - 3. BYE-13470-69, Cy *12*

HANDLE VIA
BYEMAN
CONTROL SYSTEM

~~TOP SECRET~~

EXCLUDED FROM AUTOMATIC DEGRADING
DOD DIRECTIVE 5200.10 DOES NOT APPLY

CONTROL NO. BYE-13467-69
COPY 7 OF 10 COPIES
PAGE 1 OF 1 PAGES

~~CONFIDENTIAL~~

CONFIDENTIAL
MINUTES OF MEETING OF COMMITTEE ON
IMAGE DATA TRANSMISSION

The first meeting of the Committee on Image Data Transmission was held in the DIA Conference Room on November 13, 1969. The following members were present:

Dr. E. Fubini, Chairman
Mr. J. K. Lewis

[Redacted]
[Redacted]
[Redacted]

Mr. H. Davis, Secretary

Dr. Alexander Flax was present as an observer.

The following members were not present:

[Redacted]
[Redacted]
[Redacted]

Other observers were:

Mr. Les Dirks
Mr. John Crowley
B/G Lew Allen
Capt R. Geiger
Major J. Regenhardt

[Redacted]

Dr. McLucas presented a background of the problem. Briefly, we have technology efforts in progress hopefully to lead to the development and deployment of a system

*Copy 13000000
E. 12*

~~CONFIDENTIAL~~

~~TOP SECRET~~

permitting direct transmission of optical imagery collected from a satellite to the ground. The two leading technology candidates for satisfying the requirements for such a direct reading system are: -- (1) a system based upon a multiplicity of solid-state sensors such as photo-transistors, and (2) a system based upon a device using a photocathode (light-sensitive, electron-emitting surface) and a charge-storage device in the form of a tape having a silicon surface.

Dr. McLucas first observed that there is always a requirements-technology trade off. For this reason he felt the committee should look at the requirements. He recognized the difficulty of the problem. Since we are considering changing from sponsoring technical activities to starting a system, Dr. McLucas felt we need to know the technological status before we answer whether we can firm up on a system specification. Dr. McLucas stated that some people say we are ready. (~~We have a report by Dr. Garwin which gives the reasons for concluding we can start a system development. This report has been distributed~~) Dr. McLucas observed that the committee

~~TOP SECRET~~

should determine whether we are ready now, or whether we would be in a better position in a year or two years.

Dr. McLucas pointed out we are developing a system (HEXAGON) having wider coverage and finer resolution than our presently used CORONA system. It is based on bringing back the buckets with the film in it. We should bear this in mind in considering alternatives of read out. We should also bear in mind a parallel study conducted by a group chaired by [] This group examined the value of high resolution. This report is complete and is being distributed to members of this committee.

Dr. McLucas pointed out the attractiveness of read out -- possibly in situations like Czechoslovakia where we might have had information within 1 hour, 2 hours or 12 hours, depending upon the system. We may wish to look at only a few square miles, and take only what we may want to take. A read-out system may have either high resolution over a small area, or a panoramic low-resolution view of a large area.

[] pointed out that this committee should not address requirements, rather should state what is

~~TOP SECRET~~

possible. He stressed that the words "real time" created an illusion. In a crisis situation, there is no reasonably clear picture of value versus time. Mr. Crowley volunteered the information that this has been studied for six months. In July 1969, the USIB said there was a requirement to have the picture available one hour after exposure.

Dr. Fubini interjected, pointing out that the time required to gain access to a target seemed to be a more important parameter than the time taken after access. There should be some time which represents a plateau -- like a day, or even an hour. Dr. McLucas stated that plateaus like a day appeal to him when factors like clouds, night, or absence of the President is taken into account. If you don't pay much to achieve an hour, it might be worthwhile.

Dr. McLucas also observed that enthusiasm for the solid-state devices has caused us to spend more on it. This may not be bad, but perhaps we should equalize the R&D efforts.

resumed his comments. He pointed out we are in a period of increasing fiscal austerity. This is depressing to those who see new technical opportunities and who recognize that to implement them means killing something else. We must look at technology to see when the time has come to precipitate out a system. We should want to see if the new system could replace one of the existing systems. We might want a decision tree -- showing what work has to be done to allow decisions at the appropriate time. The committee should furnish an understanding as to what work has to be done to reach decision points. We should furnish a consistent description of the two systems. In a vague sense they are in competition. The committee's output should furnish a realistic description of what is available, what plateaus we could expect in timeliness of possible systems, frequency of exposure, and resolution. What is the pace of technology, what benefits, if any, could be expected by waiting. The competing technologies may be different if we wait a year. The delay of one year may

also permit better definition of the requirement.

[] felt the committee could not influence the level of spending in FY 1971. Nevertheless, a report by April would be acceptable.

Mr. Dirks introduced the CIA presentation on the Electro-Optical Imaging System. Mr. Dirks briefly discussed the history of overhead reconnaissance before describing the EOI, solid-state array concept. He then reviewed the key elements of the July 1969 USIB near real-time readout requirement and discussed preliminary design requirements for the EOI system.

Next, Mr. Dirks described a technique for analyzing the performance of a solid-state array, EOI system. In this analysis the ground-sampled distance was given as a function of terms which characterized the scene, the optical system and the solid-state array. The panel asked that an unclassified version of this analysis be made available.

Next, [] discussed the Solid-State Array Program. He reviewed the types of detectors which have been considered and went on to a detailed description

of the two technologies which are presently being funded on a competitive basis -- the phototransistor array work at TRW and the photodiode array work at Westinghouse.

Following the transducer briefing, Mr. Nowinsky described the Sampled Imagery Program. This program is directed at experimentally determining the effects of the sampling process on the reconstructed imagery. Mr. Nowinsky described the apparatus and the results obtained to date. He also pointed out that the early experiments concentrated on the addition of various amounts of noise but that work planned for the future would evaluate the effect of a number of other parameters.

Following the Sampled Imagery discussion, Mr. Roth outlined the development programs for other subsystems and described the overall system configuration.

Mr. Dirks concluded the EOI presentation by reviewing the FY-70 funding, the associated milestones and the overall integrated system schedule.

Colonel Bonner introduced the Tape-Storage Camera presentation with an overview of the various elements of

the Tape-Storage Camera Program. He reviewed the efforts underway at CBS, General Electric and BTL.

Following his remarks, Col Bonner introduced Mr. Stevenson of the Aerospace Corporation who gave a detailed presentation on the various system trade offs which are available with the Tape-Storage Camera (TSC) technology. There was a lengthy discussion of relative sensitivities and the effect of integration on the two sensor types. The chairman terminated the discussion saying that this matter would be looked into in detail in the future. Mr. Dirks was asked to extend his unclassified paper to ^{include the work on the} cover the TSC.

Following []'s presentation, Dr. Cook of CBS described the status of the Tape-Storage Camera effort. Mr. Cook's primary emphasis was on the second-generation laboratory model but he also described other gun designs underway at CBS. The concluding portion of the Tape-Storage presentation was given by GE representatives who discussed the characteristics and performance of the focus project scan work which they

are doing as an alternative to the CBS electron beam
gun work. They also described photocathode work underway
at G.E.

ISSUES

1. TECHNOLOGY - What is known, unknown; gaps, uncertainties.
 - a. Life time, degradation: Photosensors, amplifiers, photocathodes, storage tape, drive mechanism.
 - b. Sensitivity vs dwell time.
 - c. Coarse-Fine vs accurate pointing.
 - d. Bandwidth.
 - e. Producibility, yield, testing methods, problems.
 - f. Technology vs time; status today, one year, two years.
 - g. Attitude control, pointing.
 - h. Sensitivity to environment.
 - i. Optical technology required.
 - j. Photocathode considerations -- sensitivity, poisoning.
 - k. Ground Data Processing.
 - l. Signal-to-Noise considerations.

2. SYSTEMS CONSIDERATIONS
 - a. Size of optical system.
 - b. Storage and play back -- advantages and disadvantages.
 - c. Number of targets per pass.
 - d. Relay satellite considerations.
 - e. System development feasibility -- today, one year, two years.
 - f. Pointing problems - open loop vs closed loop.
 - g. Access time, reporting time.
 - h. Area coverage; resolution; trade-offs.
 - i. Ground Data Processing.
 - j. Signal-to-Noise considerations.

3. SYSTEMS REQUIREMENTS

MINUTES OF THE SECOND MEETING OF THE
COMMITTEE ON IMAGE DATA TRANSMISSION

The second meeting of the committee on Image Data Transmission was held in the IDA building Conference Room on December 3, 1969. The following members were present:

Dr. Eugene Fubini
Mr. Kenneth Lewis

[Redacted]

[Redacted]

Mr. Harry Davis

Dr. Flax was present as an observer.

The following members were not present:

[Redacted]

Other observers were:

Mr. Les Dirks
Capt. R. Geiger
Major J. Regenhardt

[Redacted]

Dr. J. Martin

[Redacted]

Colonel M. M. Bonner

[Redacted]

Mr. Edmond Nowinsky

[Redacted]

~~CONFIDENTIAL~~

The minutes of the first meeting were distributed for a review. Time did not permit this review, so the draft minutes will be distributed at the third meeting.

Dr. Garwin noted an error in the minutes of the first meeting which stated that a report by him gives the reasons for concluding we can start a system development. Dr. Garwin stated his report concluded that an increased level of effort in the technology of solid-state array sensors would permit a reasonably sound judgment within a year on the schedule and cost of a full-scale development of a spotting system using this technique.

Captain Geiger noted that in August 1969 the Executive Committee (consisting of Mr. Packard, Mr. Helms and Dr. DuBridge) had approved an augmented 18-month technology program leading to a possible system start in January or February 1971. Further, by January 1970 a decision was to be made whether additional funds should be added to start system definition.

At the November 25th meeting of the Executive Committee (Ex Com) the additional funds for possible

system definition were slipped to FY 1971, with a start one year later. The NRO had reserved funds for a contingency which would have permitted acceleration and an earlier start in FY 1971, however, the contingency money was deleted in a budget cut. As a result of this action, the technology program has 24 months before system definition. Captain Geiger stated Dr. McLucas needs a review of the program in time for the Spring apportionment exercise.

Dr. Garwin reviewed some of the work of the Land Panel. They had looked at a number of technologies -- Xerox screened thermoplastic recordings, Vidicons, Laser scanners reading from photographic film, Solid State Arrays and the CBS phototape camera. The solid state array looked like it had the longest life possibilities, consequently a sub-committee was set up consisting of [] and R. L. Garwin. The committee prepared a report, as did Mr. []. Both are being distributed.

Dr. Garwin's presentation may be summarized as follows:

1. Chips having 100 sensors and associated amplifiers and switches have been fabricated.

2. Measured S/N indicates about two-foot resolution can be realized.
3. Sensitivity limitations require slowdown of about 20.
4. With four arrays, slowdown of about 5 can be achieved.
5. Continuous strip surveillance is not necessary since width is narrow.
6. Dr. Flax pointed out that continuous surveillance is nevertheless an advantage.
7. Because of slowdown, the system must be a spotting system.
8. A processed wafer should cost about \$50.
9. Yield of $\frac{1}{2}\%$ is not too bad. Taking packaging costs into consideration, about 1% is optimum.
10. At \$100 per wafer, 200 chips/wafer, and $\frac{1}{2}\%$ yield, each good chip would cost \$100. A focal line would cost \$20,000.
11. If TRW can succeed in producing a few chips, other manufacturers can compete to bring cost down.

12. Problem is joining chips -- which has not yet been accomplished.

13. If readout is to be accomplished in 10 seconds there are $(2 \times 10^4)^2$ elements or 4×10^7 amplitudes per second. If 3-bit delta modulation is used, we need 120 megabits/second.

14. Sensor integration time is one millisecond ($V = 1$ foot/ 50 microseconds, which must be multiplied by the factor 20 for slowdown).

15. If one amplifier is to read out 20,000 sensors in a millisecond, the data rate would be 20×10^6 /second. If 100 amplifiers are used, 200,000 samples per second or 5 microseconds each is sufficient.

16. Westinghouse uses diodes clamped to one voltage with leak off. They have to have a very-low-noise amplifier.

17. Fairchild has too large a pitch -- the large stagger introduces problems during roll.

18. TRW has a chip-joining alignment problem. Can they machine close to an active element?

19. Sensor uniformity to a factor of two is achievable. This requires calibration and compensation -- probably on board.

20. Uniformity and death of sensors may create a problem in delta modulation. (Problem -- how much in-flight and how much ground processing is desirable).

21. There is a way of reducing noise by "stroking." The analysis of this is in Dr. Garwin's paper.

22. Cathodes per second, are not a reliability problem, but photocathodes are a severe problem because of poisoning of the surface by contaminants.

At the conclusion of the presentation, Dr. Fubini asked Colonel Bonner to make a computation of the optics size needed by the solid-state array and Mr. Dirks to do the same for the phototape.

presented his views as follows:

1. If sensors can be developed, rest of system can be brought in.

2. The members of the Land Panel were enthusiastic about the significant gain in getting intelligence in a

matter of hours or days. It is difficult to cost this capability.

3. We could have several systems on orbit continuously -- so several looks per day would be possible.

4. The need for as long a life as possible caused the Land Panel to prefer solid-state sensors -- which is inherently simple.

5. The conclusion for solid state being most reliable was intuitive. The fewer the moving parts the better.

6. We could possibly afford redundancies in CMG's and antenna drives.

7. Cost could be estimated to about 3 db.

8. In response to a general discussion of moving parts reliability, [] pointed out how Apollo developed reliability as technology advanced, how redundancy helps testing, qualification and the like. Colonel Bonner observed CMG's only operate a few minutes a day. Nevertheless, bearing wear is always a problem.

[] observed CMG's should be ruled out since

both systems use them. Colonel Bonner pointed out a problem exists when a motor is running in same environment as photocathode (poisoning).

9. In the general discussion comments were made that CMG's can be made reliable, photocathode had a severe problem in poisoning, solid-array sensors degraded gracefully, that other critical elements were computer reliability, TWT's cathodes.

10. As to the optics, stated we are making progress with large sizes -- 72" has been built. We need 96" with an accuracy of $\lambda/50$. New polishing techniques are promising. Even the one g, zero g problem is coming along reasonably well.

11. Communications, too, represent not too difficult a problem. Raytheon has a 50-megabit system and a 200-megabit system in the laboratory. Other companies, too, have high bandwidths in data links.

12. Because of the low current density compared to that in the CBS tube, cathodes in the TWT are not much of a problem.

13. The computer can be realized with necessary reliability by redundancy.

14. Accuracy of pointing is well within state-of-the-art. The smear budget of 50 microradians per second is within the state-of-the-art.

15. Solar cells, mostly body mounted, with a few auxiliary panels, will suffice. Thermal problems are relatively simple.

16. In conclusion, the sensors are the key element, with the glass being the next highest element of uncertainty. The CMG is reasonably encouraging.

Following []'s discussion, Mr. Cook summarized his analysis of the S/N of the two systems. Dr. Garwin did not agree completely pointing out that his stroking technique can be used to reduce the noise of reading out the solid-state array sensors. Mr. Cook pointed out that the primary difference between the two systems is the time of exposure. His analysis has been distributed.

[] presented the status of the CMG development. Some questions were raised on our ability

to analyze five or six CMG's coupled together. Dr. Garwin suggested an open loop method of operation.

The computer required a reliability four times better than the spin computer. This is being explored. To achieve 10,000 hours with 95% confidence, we would need 60,000 hours in a triply redundant configuration.

[] suggested the voting logic be on the ground.

A comparison was made of the two systems using the G³ target deck. The results used different roll rates. Dr. Fubini asked Colonel Bonner to repeat this using identical roll rates.

[] presented considerations relating to the measurement of arrays covering the parameters, sensitivity, uniformity, MTF and spectral response.

Mr. Nowinski presented scene characteristic considerations from which it was concluded that we must obtain data on signal to noise and contrast to determine how pictures effect photo interpretation.

Dr. Garwin stated he would visit TRW on December 8, Perkin Elmer and CBS on December 22, and Westinghouse on the 23rd of December.

The next meeting was scheduled to be held on the West Coast on the 8th and 9th of February.

QUESTIONS

I. TECHNOLOGY

A. Solid State Array

1. What is economical yield?
2. Is there a better (lower noise) readout scheme as proposed by Dr. Garwin (
3. What is the magnitude of the chip joining problem?
4. What is the economics of arrays -- taking into account yield, packaging, low production rate?
5. Can delta modulation be used if chips are not uniform, or sensors fail?
6. How are the sensors calibrated?
7. How is image reconstituted -- how much processing on board, how much on ground?
8. Can gains be realized by wider junctions, showing response toward red where contrast is greater?
9. Are there radiation hardness problems?
10. What is effect of limitation of dynamic range by non-uniformity?
11. Is biasing necessary?
12. What is effect of aging on 5, 6, 7, 8, 9, 10, and 11.
13. Is there any gain by using newer image intensifiers?
14. What are the problems of measuring sensitivity, uniformity, MTF and spectral response.

B. Phototape Camera

1. What is reliability of moving parts in tube? Is tape necessary?

2. What is extent of photocathode poisoning?
What is known, what needs to be known?
3. What is life of cathode in phototape tube?
4. Can new photocathodes be used? Can photocathode be isolated from the rest of the components?

II. SYSTEMS CONSIDERATIONS

A. General

1. What size of optics is necessary for both?
How is this size achieved?
2. What is access time of each, what is the effect on number of targets in the G³ deck?
Is a continuous look desirable?
3. Is a cloud sensor feasible, useful? If so how would it be employed in either system?
4. Is recording necessary or desirable?
5. What is the effect of S/N and contrast on interpretation?
6. Are there disadvantages in moving parts, can moving parts be classified into different categories of reliability?
7. Is the enthusiasm for shortening the intelligence cycle realistic?
8. What density of target capability is desirable?

B. Specific

1. Can CMG's be made redundant?
2. Reliability of CMG's
3. Reliability of antenna pointing mechanism
4. Is Garwin's Open Loop suggestion worthwhile and practicable?
5. What are bandwidth capabilities of Relay Satellites?
6. How many relay satellites are needed?
What is effect on system because of finite reliability?

7. Can computer reliability be achieved? How?
8. What is relative frame time assuming same roll rates?
9. What is feasibility of achieving optics of the size required?
10. Is radiation hardness a serious consideration?
11. Are there other candidate sensors or systems configurations?
12. What flight tests are desirable?
13. What testing programs are needed?
14. Is there an advantage of having a continuous strip?