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GRAND TOUR OUTER PLANET MISSIONS
DEFINITION PHASE

Report of the Imaging Science Team
February 1, 1972

Part 2: Minutes of Meetings and Official Correspondence

Team Members*

NGR-03-007-006	Michael J. S. Belton (Leader)	Kitt Peak National Observatory
NGR-09-015-184	Kaare Aksnes	Smithsonian Astrophysical Observatory
NASW-2227	Merton E. Davies	Rand Corporation
NASW-2226	William K. Hartmann	IITRI
NGR-03-003-016	Robert L. Millis	Lowell Observatory
NGR-33-015-149	Tobias Owen	State University of New York
NO	Terrence H. Reilly	Jet Propulsion Laboratory
NGR-33-010-151	Carl Sagan	Cornell University
NGR-50-002-170	Verner E. Suomi	University of Wisconsin
NO	Stewart A. Collins (Experiment Representative)	Jet Propulsion Laboratory

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Tobias Owen	State University of New York
Terrance H. Reilly	Jet Propulsion Laboratory
Carl Sagan	Cornell University
Verner E. Suomi	University of Wisconsin
Stewart A. Collins (Experiment Representative)	Jet Propulsion Laboratory

* Dr. Bruce C. Murray (California Institute of Technology) resigned as a member of the Team on December 2, 1971. We gratefully acknowledge his inputs to the work of the Team especially in the areas of information return and data compression.

TABLE OF CONTENTS

JET PROPULSION LABORATORY

INTEROFFICE MEMO

May 12, 1971

TO: Distribution

FROM: A. Collins Andy

SUBJECT: Minutes, 1st OPGT Imaging Science Team Meeting

Thursday, 6 May, 2:00-5:00 - 169-230
Thursday, 6 May, 7:00-9:15 - 212 Mudd, Caltech
Friday, 7 May, 8:30-12:00 - 186-128

ACTION ITEMS

Assignment	Assignee	Date Due
1. Estimate support needed at home institution during next year	All team members	21 May
2. Recommend Outer Planet systems/ sensors	Sensor committee (M. Davies)	21 May
3. Report of data handling status	Information return committee (B. Murray)	3 June
4. Define scientific objectives and requirements	Planet committee (T. Owen) Satellite committee (W. Hartman)	3 June

Thursday, 6 May

The Thursday afternoon meeting consisted of the following presentations to the Imaging Science Team:

Introduction	E. Smith
Cooperation between Imaging Team and JPL	G. Smith
Trajectories and constraints	P. Penzo
TOPS spacecraft design	R. Draper
Imaging system analysis and baseline system	G. Root
Approach guidance requirements	R. Stanton

In the evening an executive session was held at which B. Murray was chosen Deputy Team Leader.

Friday, 7 May

K. Ando presented an analysis of possible Outer Planet imaging sensors. In the discussion which followed, M. Davies told of an Itek film which required in situ sensitization to permanently store an image. He pointed out that this property would reduce its susceptibility to radiation damage. However, he agreed that film was not as promising as vidicon systems for the outer planets. R. Krauss suggested that, for many applications, a line scanning system might be superior to a vidicon system. He asked that the possible systems be compared on their ability to meet the scientific requirements of the imaging experiment.

A committee was formed to evaluate the possible imaging sensors and to recommend by May 21, a sensor or sensors to be used on the Outer Planets mission. Membership on this committee is: M. Davies (chairman), T. Reilly, V. Suomi, and M. Belton.

M. Davies then told of a "clear aperture" optical design which he suggested the Team consider. Such a design might permit using several secondary mirrors to vary a system's focal length.

An Information Return Committee was established to begin working on the data handling problem. The committee members are B. Murray (chairman), T. Reilly, and A. Collins; and its first report is due June 3.

Two other committees were established to formulate scientific objectives for imaging 1) satellites and 2) planets. The planet committee includes T. Owen (chairman), M. Belton, R. Millis, and C. Sagan; and the satellite committee includes W. Hartmann (chairman), K. Aksnes, and M. Davies. Each committee is to present June 3 a written report stating:

1. Scientific objectives

2. Science requirements - spatial resolution, spectral resolution, coverage, time span, and geometric, photometric and polarimetric accuracy.

W. Hartmann was selected to be the liaison with the Photo-Polarimetry team.

Team members discussed their individual scientific objectives.

Dates for future team meetings are:

June 3 and 4
July 15 and 16
August 12 and 13
September 23 and 24

AC:ldn
Distribution list attached

AURA, Inc.

INTEROFFICE MEMO

June 14, 1971

TO: Distribution

FROM: A. Collins/M. Belton

SUBJECT: Minutes, 2nd OPGT Imaging Science Team Meeting

Thursday, 3 June, 9:00 - 4:30 - 186-128
Friday, 4 June, 9:00 - Noon - 169-230

ACTION ITEMS

Assignment	Assignee	Date Due
1. Submit final proposals.	All team members.	14 June.
2. Organize a meeting to discuss possible dielectric tape camera.	L. Simmons	
3. Organize a meeting to define future optical development.	M. Belton	
4. Define necessary trajectory data and possible analysis strategies.	Trajectory Committee (K. Aksnes)	14 June (15 July)
5. Run IMSYS using lower S/N.	G. Root	15 July
6. Prepare initial draft of Scientific Objectives document.	R. Millis M. Belton	15 July
7. Prepare flow diagram of team activities.	M. Belton	15 July

Thursday, 3 June

Attendees: K. Aksnes, J. Anderson, M. Belton, A. Collins, M. Davies, I. Ghazeil (KPNO), W. Hartmann, R. Krauss, R. Millis, B. Murray, T. Owen, T. Reilly, G. Root, J. E. Simmons (KPNO), L. Simmons, G. Smith, R. Stanton

B. Murray told of the Science Advisory Group which is currently studying a Jupiter Orbiter Mission. The group has tentatively concluded that an orbiter mission should follow, not replace or precede a Grand Tour type flyby. B. Murray suggested that we assume there will be such an orbiter and that we not attempt to perform, on OPGT, studies which are much better suited to an orbiter mission.

M. Belton asked if there were any changes in the preliminary team member budgets he has received.

1) W. Hartmann had revised his budget downward.

2) K. Aksnes proposed a study to define a spacecraft experiment to a) refine satellite ephemerides and b) determine the accuracy available from such an experiment.

Final proposals much be sent to M. Belton by Friday, 14 June.

M. Belton reported on recent SSG activities:

1) Sub-committees may be formed to work with problems common to several experiments. For example, a group has been proposed which would include all instruments on the scan platform.

2) Any team member wishing to receive minutes from another team should contact A. Collins.

3) NASA and Project have established a policy concerning public release of information.

   a) Team members are free to discuss their own experiment and participation in the project, but they should not speak on aspects of the project for which they are not directly responsible.

   b) Proposals and other technical information should not be given to outside contractors. Requests for such data should be referred to T. Bird at JPL.

M. Davies described the report (attachment 1) of the Sensor Committee.

1) R. Krauss distributed a "Critique of Line Scanner Analysis in Grand Tour Science Imaging Team Introductory Data Package".

2) A discussion followed about possible development of a dielectric tape system. It was decided that L. Simmons will set up a meeting (probably with CBS and a representative from the Imaging Team) to review recent progress on such a system and to discuss a possible breadboard development program. Team members Reilly, Davies, Suomi and Belton will attend this meeting.

T. Owen distributed preliminary drafts of the planetary scientific objectives report. B. Murray suggested the inclusion of a figure showing which scientific studies are possible as a function of resolutions. M. Belton requested a similar figure showing the dependence of possible investigations upon the size of single frame coverage. W. Hartmann reviewed the preliminary draft of the satellite scientific objectives. It was decided that M. Belton and R. Millis will integrate these two drafts plus comments into a single document presenting the scientific objectives of the Imaging Experiment. This document would be circulated for review by the next team meeting. Also, M. Belton agreed to generate the required science/resolution and coverage/resolution figures.

B. Murray told of the first meeting of the Information Return Committee with TOPS personnel. From this meeting, he has defined 3 primary areas for further study.

1) Feasibility and desirability of a full-frame buffer.

2) Conflicting S/N requirements for imaging and non-imaging data.

3) Data compression and compressors.

A. Collins presented data from the imaging system analysis program. This data served primarily to illustrate the analysis capability available and to present the tentative conclusion that long focal length (approximately 5 meters) optics may be desirable with the silicon intensifier tube. B. Murray suggested some runs be made using lower S/N to attain higher resolution. G. Root agreed to do this.

Additional attendees at the afternoon meeting were: L. Adams, G. Aumann, A. Goetz, L. Larks, L. Snyder, and J. Watson (ITEK).

John Watson described some clear aperture optical systems which have been developed by ITEK. Following this presentation, there was a discussion of the desirability and feasibility of various optical features:

Topics included

1) Clear aperture and their optical flexibility

2) Long focal length

3) Variable focal length

4) Multi-purpose optics (The WAF on MVM'73 is an example of this)

5) Are thermal IR coatings needed?

6) Multiple Focii. Possibilities for sensor redundancy

7) Are there possibilities of reducing weight?

Mr. Watson pointed out that clear operative systems give a slightly better MTF at 25 lp/mm than regular cassigrainian systems and also have better transmittance. However, the alignment and vibration problems are more severe and the cost is perhaps 25% higher. The flexibility of these CA systems was emphasized and it was estiamted that a 1 to 4 change in magnification was possible in such system. It was implied that CA systems have a greater concentration of light in the central lobe of the diffraction image of a point source.

It was decided that M. Belton would organize a meeting at JPL June 21 to better define possible optical development. Team members Reilly, Owen, Suomi and Belton will attend this meeting.

Friday, 4 June

A movie simulating JSP76 trajectory, Jupiter encounter, and satellite encounters was shown. It was stressed that only one parameter can been chosen with any freedom. It was agreed that the time of arrival at the 1st or 2nd planet was the best choice for this parameter. Following this, A. Collins presented a trajectory analysis for the JSP77 mission. A committee (K.Aksnes, chairman, R. Krauss, W. Hartmann, A. Collins, P. Penzo) was appointed to:

1) Define what specific trajectory data will be necessary for trajectory selection.

2) Recommend several strategies by which this data might best be utilized for trajectory selection.

T. Reilly pointed out that in discussing trajectory diagrams that it was important to bear in mind C_3 and launch window limitations. P. Penzo was asked to include C_3 contours on future trajectory information.

P. Penzo was also asked to provide to the team C_3/weight/booster information to team members. He agreed to do this.

A preliminary report is due June 14, and the final report is due July 15.

A discussion of team progress and operations followed, and M. Belton agreed to draw a flow diagram of future team activities, decisions, and accomplishments.

It was decided by the team to establish no preferential relationships or information channels with scientists not on the team. It was also agreed that discussion of ultimate data distribution was premature.

R. Krauss summarized his critique of the Line Scanner Analysis in the Introductory Data Package. A majority of the team agreed that:

1) The team should no longer consider a line scan system as a current option.

2) University of Wisconsin may propose to NASA, a program for development of an outer planets line scanner. If this program succeeds, the system will once again be considered and evaluated on the basis of the scientific objectives.

3) Such a line scanner development program will be given low priority relative to other team proposals.

MJSB/cmm

Distribution:

K. Aksnes - Smithsonian Obs.
M. E. Davies - RAND
W. K. Hartmann - IITRI
R. L. Millis - Lowell Obs.
B. C. Murray - Caltech
T. Owen - S.U.N.Y.
T. H. Reilly - 168-227
C. Sagan - Cornell University
V. E. Suomi - University of Wis.
T. W. Hamilton - 180-402
D. G. Rea - 180-404
T. H. Bird (10) - 183-301
R. L. Heacock - 180-805
M. A. Mitz - NASA Headquarters
K. J. Ando - 168-227
G. C. Bailey - 168-227
R. F. Draper - 233-307
R. J. Mackin - 186-133
H. M. Schurmeier - 180-805
J. C. Mahoney - 168-227
P. A. Penzo - 156-217
T. C. Rindfleisch - 168-427
G. R. Root - 168-227
L. L. Simmons - 168-227
G. M. Smith - 168-314A
M. I. Smokler - 168-227
R. H. Stanton - T-1152
R. F. Fellows - NASA Headquarters
W. Brunk - NASA Headquarters
S. E. Dwornik - NASA Headquarters
R. Miles - 180-805
L. M. Snyder - 168-227
R. F. Lockhart - 168-227
C. C. Wertz - 233-307
T. Risa - 233-307
G. Cunningham - 233-307
R. R. Bowman - 233-307
E. J. Smith - 183-401

ATTACHMENT 1.

The RAND Corporation

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2 June 1971

Report of the Sensor Committee of the Imaging Science Team (OPGT)

M. Davies (Chairman), M. Belton, T. Reilly, V. Suomi

The Sensor Committee did not meet in the brief period before recommendations were required. However, after many telephone calls, the following proposals emerged and were more or less concurred on by the committee.

1. The committee agrees with JPL that their baseline system, the silicon vidicon or the SIT vidicon, is the most promising sensor for this mission, and its development should be vigorously pursued. However, a one-frame buffer should be incorporated if possible so that some imaging data could be returned to earth if the tape recorder were to fail.

2. Clear aperture optical systems should be studied in detail, and the possibility of changing focal lengths and incorporating multiple imaging systems should be investigated. For a start the following specifications have been suggested:

Aperture: 9 in. or larger depending upon weight
Focal lengths: 1000, 2000, 4000 mm
Spectral region: as wide as possible, preferably an all-mirror system.

3. Investigate methods of putting white reseau marks on the photosensitive faceplates of the silicon and SIT vidicons.

4. Investigate the stability of the properties of narrow band-pass interference filters in the OPGT mission environment.

5. Members of the committee expressed concern over the small format (800 × 800 pixels) of the silicon and SIT vidicons and the reliability of the tape recorder. It is proposed that the feasibility of a CBS tape camera be examined as this camera can have a large format and contains its own storage.

Typical specifications for a CBS camera are:

Format	24 × 24 mm
Scan density	140 lines/mm
Pixel format	3360 × 3360 pixels
Resolution	50 ℓp/mm
Storage (endless tape)	25 frames
Weight	20 - 30 lbs
Root's figure of merit	(S/N = 50) 7.3

There seems to be general confidence in the principle of the CBS camera, as well as in the capability of the components to meet their required performance. However, a breadboard model would be necessary to confirm the design and test the system integration before a prototype could be built. This breadboard would cost about $250,000 and should be built during the next year if this camera is to be available in time for the OPGT missions.

Although this is an untested sensor system, its potential value to the mission could be very great, and the committee feels that this option should be kept open. Some optical systems, such as the clear aperture optics discussed above (2), can be configured so as to feed more than one sensor. Thus both vidicon and tape cameras could be flown on the same spacecraft. The committee thinks that decisions should not be made at this time which would close such possibilities.

JET PROPULSION LABORATORY | INTEROFFICE MEMO

August 5, 1971

TO: Distribution

FROM: A. Collins Andy

SUBJECT: Minutes, 3rd OPGT Imaging Science Team Meeting
July 15, 10:00 a.m. through 4:30 p.m., 186-128
July 16, 9:00 a.m. through Noon, 169-230

ACTION ITEMS

Assignment	Assignee	Date Due
1. Draft recommendation proposing dielectric tape development	B. Murray/M. Davies	7/20
2. Select initial trajectories	Trajectory Committee (K. Aksnes)	7/30
3. Finish "Science Objectives & Requirements"	C. Sagan	7/30
4. Generate S/N/resolution data for silicon tube	G. Root	8/26
5. Define potential spectral problems	L. Simmons/T. Owen	8/26
6. Run SCOUT on initial trajectories	A. Collins	8/26
7. Investigate and propose BER/Data compression simulations	T. Reilly/B. Murray	8/26

Thursday, 15 July

Attendees: K. Aksnes, G. Bailey, M. Belton, A. Collins, M. Davies, R. Klein, R. Krauss, R. Lockhart, R. Millis, B. Murray, D. Rea, T. Reilly, G. Root, C. Sagan, L. Simmons, G. Smith, R. Stanton, C. Wertz

G. Root reported on the signal-to-noise/surface resolution trade-off for the SIT at each planet. He agreed to present, at the next team meeting, similar data for the silicon tube.

M. Belton summarized the "Team Plan", Attachment 3, which he had sent out previously. B. Murray suggested that several systems other than the most promising one be carried through the evaluation. Belton recommended that because of the shortage of time, a thorough analysis of one system be done initially, with alternative systems being evaluated after that. The question was not resolved at this time.

M. Belton then made several announcements:

1. The team's proposals had been accepted by NASA and funds should be available soon.

2. There is currently too much weight on the scan platform. Also, the articulation of the platform is not conducive to post-encounter imaging.

3. TOPS is currently defining and pricing a reduced capability spacecraft for presentation to NASA. Belton expressed his belief that the current baseline imaging system was already minimal, but several team members disagreed with this view.

4. The Space Science Board will meet next month at Woods Hole. At this meeting, several members of the SSG, including M. Belton, will present information about the Outer Planets investigations and instrumentation.

T. Reilly reported on the CBS dielectric tape presentation, June 22, 1971. He concluded that it was a very promising system whose present stage of development precluded its consideration as the baseline Outer Planets imaging instrument. In the ensuing discussion, the team agreed that this camera system had such potential that it was decided to recommend to JPL/NASA that a breadboard be built (within a year) by CBS. B. Murray and M. Davies will draft a recommendation for such a development program.

R. Millis distributed a draft of the "Scientific Objectives and Requirements". It was suggested that the report be expanded to include justification of the studies and more specific information about implemtnation of the investigations. C. Sagan, with the assistance of V. Suomi and W. Hartmann, will amend the report by July 30.

An additional attendee at the afternoon meeting was P. Penzo.

L. Simmons reported on the optics meeting held at JPL June 22 and presented the analysis, by L. Snyder, of the sensitivity of long focal length telescopes to errors in primary-secondary spacing. He recommended, and the team agreed to, considering optical systems whose focal lengths are no longer than 4 meters. The team then discussed the scientific merits of long focal systems and it was agreed to carry a 4m focal length for the SIT tube camera. Murray noted that because of the lower sensitivity of the silicon vidicon, we probably will have to return to a shorter focal length.

M. Davies outlined the need for a wide angle optical system and presented some criteria (Attachment 1) for selecting the focal length of such a system. It was decided by the team that a wide angle system was necessary and that its focal length should be one-tenth the length of the narrow angle system (400 mm).

Friday, 16 July

Additional attendees at this meeting were G. Cunningham and G. Fleischer.

G. Fleischer described the current TOPS attitude control and scan platform pointing capabilities. The following areas were identified as potential problems:

1. The 4 minute settling time.

2. The lack of a planet sensor for guiding the platform pointing.

It was decided that the Imaging Team would define its pointing requirements and work through JPL's Imaging System Design Team (L. Simmons) to communicate these requirements to the spacecraft design team.

A. Collins asked of the team what spectral coverage was desired from the imaging system. L. Simmons pointed out that, in the baseline system, there were several limitations to this coverage. It was decided that:

1. Initially, the $.35 - .9\mu$ region should be considered.

2. Spectral coverage of the wide angle camera is more important than that of the narrow angle system.

3. T. Owen will document the team's spectral requirements.

4. L. Simmons will define, at the next team meeting, potential problems in acquiring wide spectral coverage.

5. IMSYS should continue using the $.5 - .6\mu$ band so that future results will be consistent with current data.

K. Aksnes reported on the trajectory committee meeting held the previous evening. Due to possible trajectory perturbations it was decided to seek no satellite encounters closer than 50,000 Km. C. Sagan suggested, and the team agreed, that emphasis should be placed on satellite encounters at Saturn, Uranus, and Neptune. Jupiter satellite encounter opportunities will probably be readily available from Jupiter orbiter missions and Galilean satellite passes are quite numerous for almost any trajectory. Finally, it was decided that the committee should select preliminary trajectories within 2 weeks and that SCOUT runs should be made for these trajectories before the next team meeting. It was decided that trajectory selection would at present be confined to trajectories with $C_3 \leq 110\ (km/sec)^2$.

B. Murray defined problem areas of the baseline data system:

1. High interdependency among elements. System complexity.

2. Variable line length. Impact of data return on DSN.

3. No real-time capability. Reliance on untested tape recorders. Full-frame buffer appears out of the question.

4. Present compressor scheme is really only conceptual and lacks in versatility. Requires the addition of pixel and word editing schemes.

The team accepted Murray's recommendations:

1. Team should accept the responsibility for defining the requirements for the compressor device.

2. Define and conduct simulations to illustrate the bit error rate/ compression ratio trade-offs. T. Reilly will investigate this second point and will report at the next meeting.

3. Identify alternative data handling performance including at least one back off position.

Finally, it was decided to begin analysis of three possible imaging systems. Attachment 2 shows the characteristics of these systems. M. Belton and A. Collins will define what work is to be included in this analysis.

<u>Next Meeting:</u>

August 26, 10:00 a.m., 186-128

August 27, 9:00 a.m., Noon, 169-230

AC:ldn

ATTACHMENT 1
M. E. Davies

WIDE ANGLE LENS

Justification for WA (not in order of priority)

1. Approach guidance and satellite ephemerides.
2. Simultaneous WA and NA pictures will provide an attitude reference for the NA camera independent of the spacecraft.
3. Nesting of NA pictures in WA frames will improve the interpretability of NA pictures.
4. To provide terminator coverage of Uranus and Neptune.
5. To provide wide coverage for special topics such as Saturn's rings, aurorae, search for new satellites, comets, etc.

Considerations in Selecting WA Focal Length

1. For nesting reference $\frac{NAFL}{10} < WAFL < \frac{NAFL}{5}$

   NAFL = 4 m $\quad$ 400 mm < WAFL < 800 mm

   4 m = $1/4^{\circ}$ FOV $\quad$ 2.5° < WAFL < 1.25°

2. For full coverage of Uranus and Neptune from 200,000 km need $14^{\circ} \times 7^{\circ}$ (72 mm FL) field, from 300,000 km need $8^{\circ} \times 4^{\circ}$ (108 mm) field.
3. At a distance of 1.8×10^{6} km, NA (4 m) camera yields 10 km/pixel. For reference full view of Jupiter requires FOV of $4\text{-}1/2^{\circ}$ in WA and Saturn requires 4°.
4. Field ov view (FOV) required to obtain adequate star references is unknown - perhaps 3°.

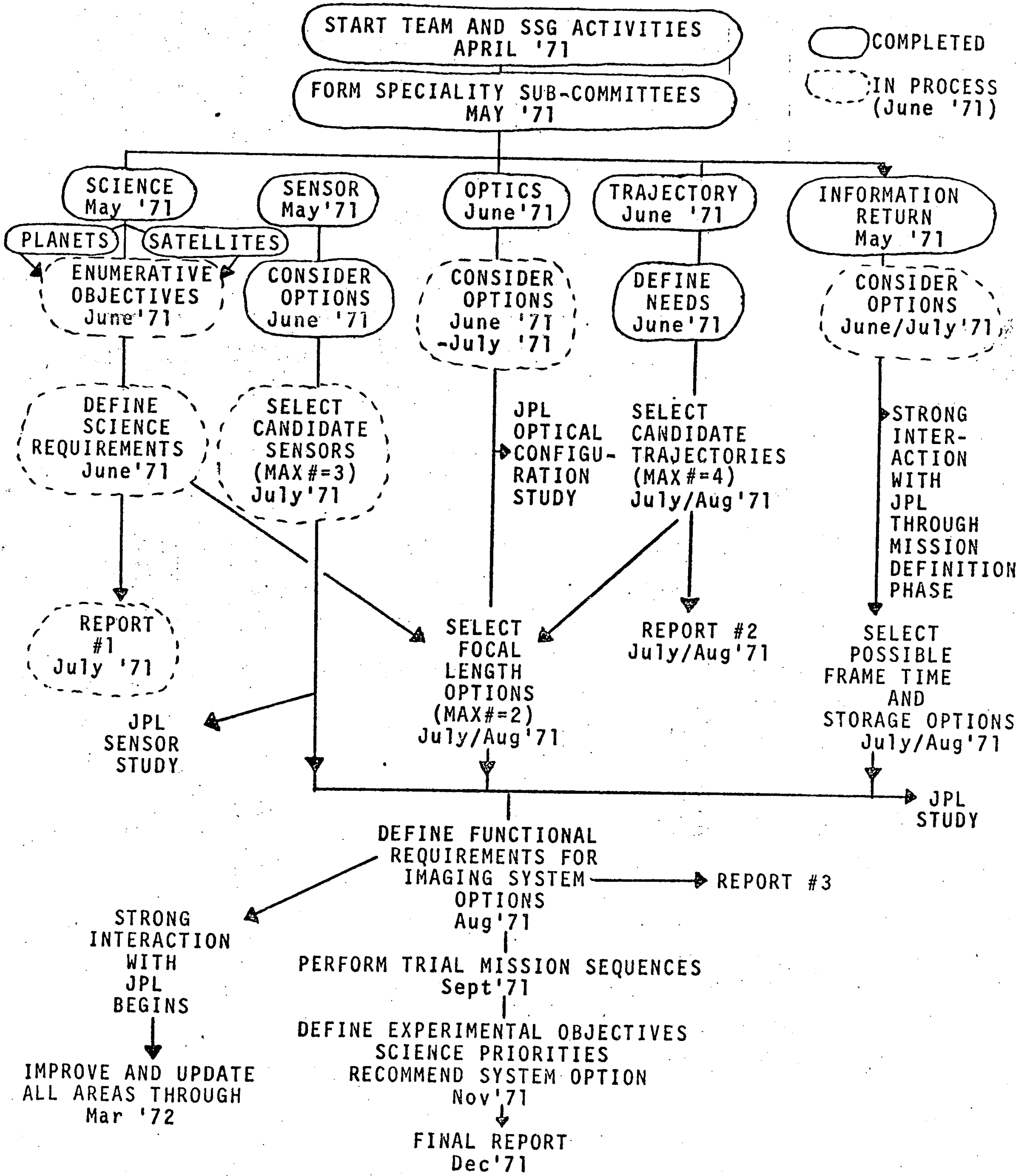
ALTERNATIVE IMAGING SYSTEMS

Priority	Focal Length	Aperture	Sensor	Target Size	Format	Bits/Pixel	Frame Time	Storage Capacity
1	.4M 4M	80 mm 9"	Silicon SIT	18 mmx 18 mm	800 x 800	8	45 sec	390 frames
2	.4M 4M	80 mm 9"	Dielectric tape	24 mmx 24 mm	1920 x 1920	8	2 sec	50 frames
3	.2M 1.5M	100 mm 7"	Selenium	9.6 mmx 12.5 mm	832 x 700	8	42 sec	32 frames

7-20-71

Attachment 3

ROUGH FLOW CHART OF OPGT IMAGING SCIENCE ACTIVITIES



JET PROPULSION LABORATORY INTEROFFICE MEMO

September 9, 1971

TO: Distribution

FROM: A. Collins Andy

SUBJECT: Minutes, 4th OPGT Imaging Science Team Meeting
August 26, 10:00 a.m. through 5:30 p.m., 186-128
August 27, 8:30 a.m. through 1:00 p.m., 169-230

ACTION ITEMS

	Assignment	Assignee	Date Due
1.	Contribute portions of scientific objectives document	All Team members	9/17
2.	Define parameters to be defined for DTC	M. Davies/M. Belton	
3.	Define initial spectral bands for imaging	B. Millis	9/23
4.	Define discriminator polarization requirements	B. Millis	9/23

Thursday, August 26

Attendees: K. Aksnes, J. Anderson, G. Bailey, M. Belton, M. Davies, B. Hartmann, B. Millis, B. Murray, T. Owen, M. Piereson, T. Reilly, G. Root, H. Schurmeier, G. Smith, M. Smokler, L. Snyder, V. Suomi, C. Wertz

H. Schurmeier explained to the team NASA's present budgetary situation. Since Project will not know how large an Outer Planets program NASA plans until about October 1, Project is currently basing the RFP for a system contractor upon the Minimum Science Payload Mission Spacecraft. For this RFP and for the AFO, Project needs from the Imaging Team:

1) Mission plan

2) Spacecraft design requirements

3) Imaging instrument description

M. Belton reported on the Woods Hole meeting of the Space Science Board. While the final report is not completed, the general attitude was that the Grand Tour program was scientifically justified.

G. Bailey described the Silicon (Si) and Silicon Intensifier Tubes (SIT) and told of the RCA contract to develop tubes specifically adapted for an Outer Planets imaging system. Attachment 1 includes his illustrations.

M. Belton reported that Project has responded with interest to the team's proposal to develop a dielectric tape camera. G. Smith explained the material he and L. Simmons had submitted to R. Heacock, Spacecraft System Manager:

1) Preliminary cost and budget estimates.

   a) They felt CBS's budget for breadboard development was significantly underestimated.

   b) There was high probability that a dielectric system would be ready for the '79 launch but low probability for such readiness, without a large funding increase, by the '77 launch.

2) Preliminary reliability and performance estimates - one would have to fly 2 dielectric tape cameras to achieve reliability comparable to a 2-camera vidicon system.

L. Simmons outlined the proposed schedule and decision points:

1) Late CY'72 - early '73: Establish feasibility of a dielectric system.

2) Early '74: Developmental flight model using flight parts and sizes.

3) Late '74: Qualification model - flight configuration without screened components.

4) Since a flight unit (PTM) would have to be delivered in January '75 for a '76 launch, the '76 launch is not feasible with this schedule. However, if the 1st launch slips to '77 then a feasible delivery schedule might be maintained.

5) In mid '74, a decision could be made to build the '79 vidicon systems or switch to a dielectric tape system.

After discussion, the team agreed to continue to pursue the DTC system with a request for an in-house configuration study to see if a DTC system could be designed within reasonable weight/power/volume limitations, and to define its impact on spacecraft design. M. Davies and Belton will pursue these questions.

L. Snyder described an optical configuration which would, using only 1 moving part, allow either camera to be used with either optical system. The team accepted Snyder's proposed contract study with the following addition; that the contractor be asked to compare off-axis and on-axis systems for our applications.

T. Owen presented material describing the investigations possible in various spectral regions and suggested a tentative selection of spectral bands for consideration. R. Millis recommended that a green filter be added to this list. Millis was given the action item to define the requirements for polarization filters. He was asked to be particularly aware of the use of polarizers for identifying cloud heights and testing for the presence of particulates in deep molecular atmospheres.

L. Simmons listed (Attached 2) potential problems in seeking a wide spectral response system. R. Millis received the action item to recommend a specific set of spectral filters for the imaging system.

G. Root distributed data on system component weights and on signal-to-noise vs. contrast vs. resolution relationships. Root's basic conclusion about signal-to-noise was: Except at high exposures, the SIT tube will always give better S/N than the Si tube for a given focal length and aperture. B. Murray pointed out that this would not be true if the SIT tube were found to have a significant noise source which was not present in the Si tube. It was decided that the IPL simulations, which are currently being planned, are needed to resolve this question. Also, the team suggested that satellite data be included in further system evaluations.

Friday, August 27

Attendees: K. Aksnes, J. Anderson, M. Belton, A. Collins, B. Hartmann, B. Millis, B. Murray, T. Owen, P. Penzo, R. Piereson, T. Reilly, G. Root, G. Smith, M. Smokler, V. Suomi

M. Belton suggested the formation of teams to review the S/N question and to determine the ability of several systems to satisfy the science objectives. Members of the planet team are: M. Belton (chairman), T. Owen, C. Sagan, V. Suomi, and T. Reilly. Members of the satellite team are: B. Hartmann (chairman), K. Aksnes, M. Davies, B. Murray, and T. Reilly. G. Root was asked to attend both meetings.

K. Aksnes distributed the preliminary report of the trajectory committee, containing recommended arrival times at Jupiter and Saturn. Data for Uranus is just becoming available and will be included in the next committee report. Further work, relating Jupiter to second planet arrival dates, cannot be done until integrated trajectory data is available. M. Belton told of his intention to present the recommended trajectories at the next SSG meeting.

A. Collins presented a comparison of selenium, silicon, and dielectric tape systems and their performance through the observatory phase.

M. Belton asked for comments on the most recent version of the science objectives. General comments were aimed at the lack of detailed arguments showing why and how specific objectives could be accomplished.

A list of special topics was drawn up, and team members were assigned to write each portion. The list, and assignees, is included as Attachment 3.

The team then agreed upon the following outline for the final team report, due December 1, 1971:

A. Summary/recommendations

B. Science objectives

C. Trajectories

D. Systems

1. Alternative systems

2. Minimum Science Payload system

E. Experimental observations/system analysis

F. Recommendations/rationale

The following 3 types of systems were identified for future study:

A. Modified TOPS baseline

0.4M	Si	1-1/2" tubes; intermediate data system
4.0M	SIT	

B. Minimum system

1. MSPM system

2. DTC - same overall weight, power, and shape on platform as B1

C. Sub-minimal minimum - reduced weight and cost

1. Selenium derived from MVM'73

2. Silicon 1-camera system

AC:ldn

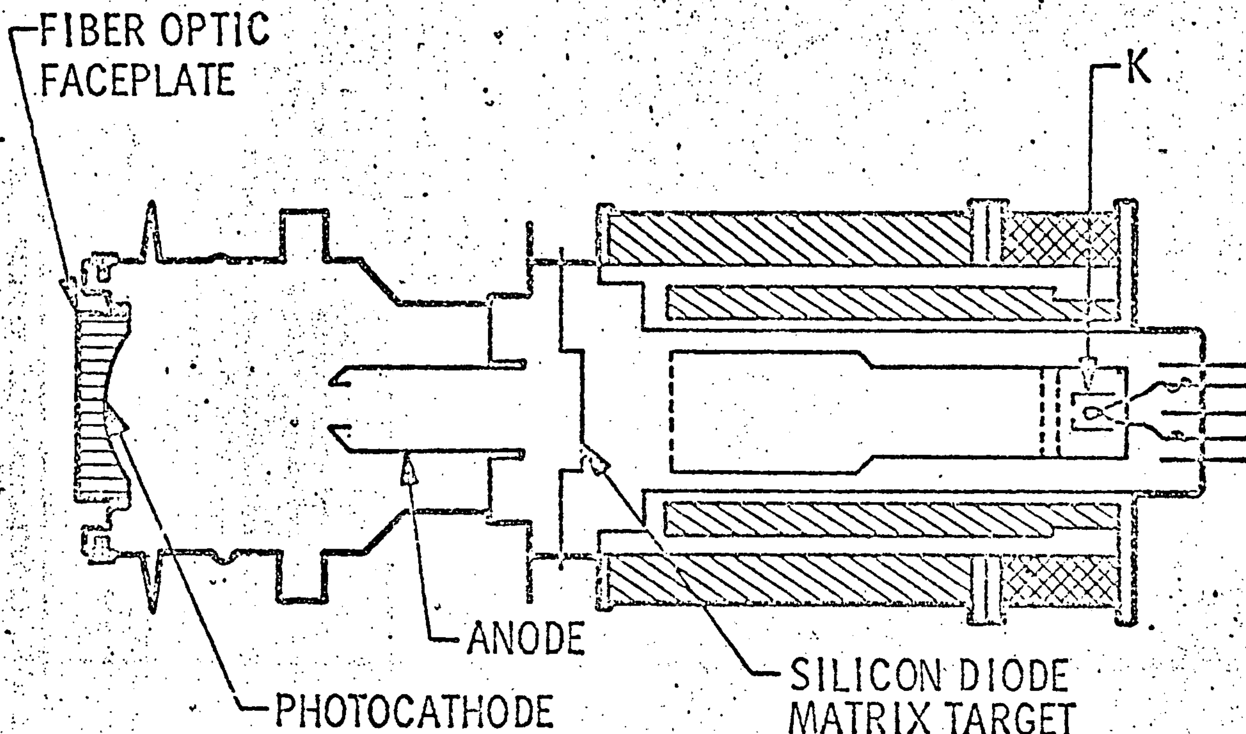
Enclosures

SILICON SENSOR DEVELOPMENT EFFORT

- 1 1/2" SILICON VIDICON
- 1 1/2" SIT VIDICON

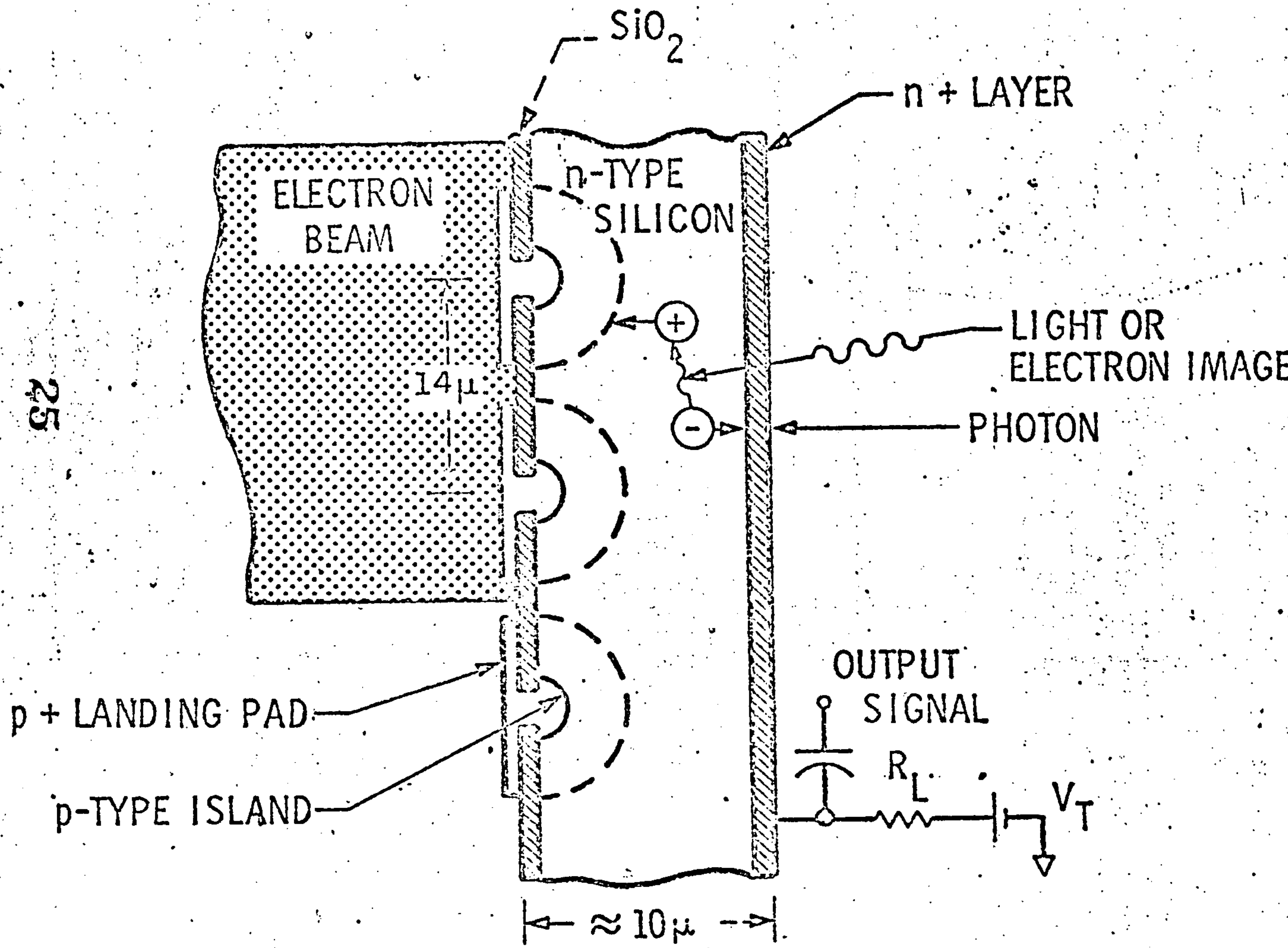
23

ATTACHMENT 1



CROSS SECTION OF A SILICON INTENSIFIER TARGET VIDICON

CROSS SECTION OF SILICON TARGET ILLUSTRATING SUBSTRATE, DIODES OXIDE MASK AND ELECTRON BEAM



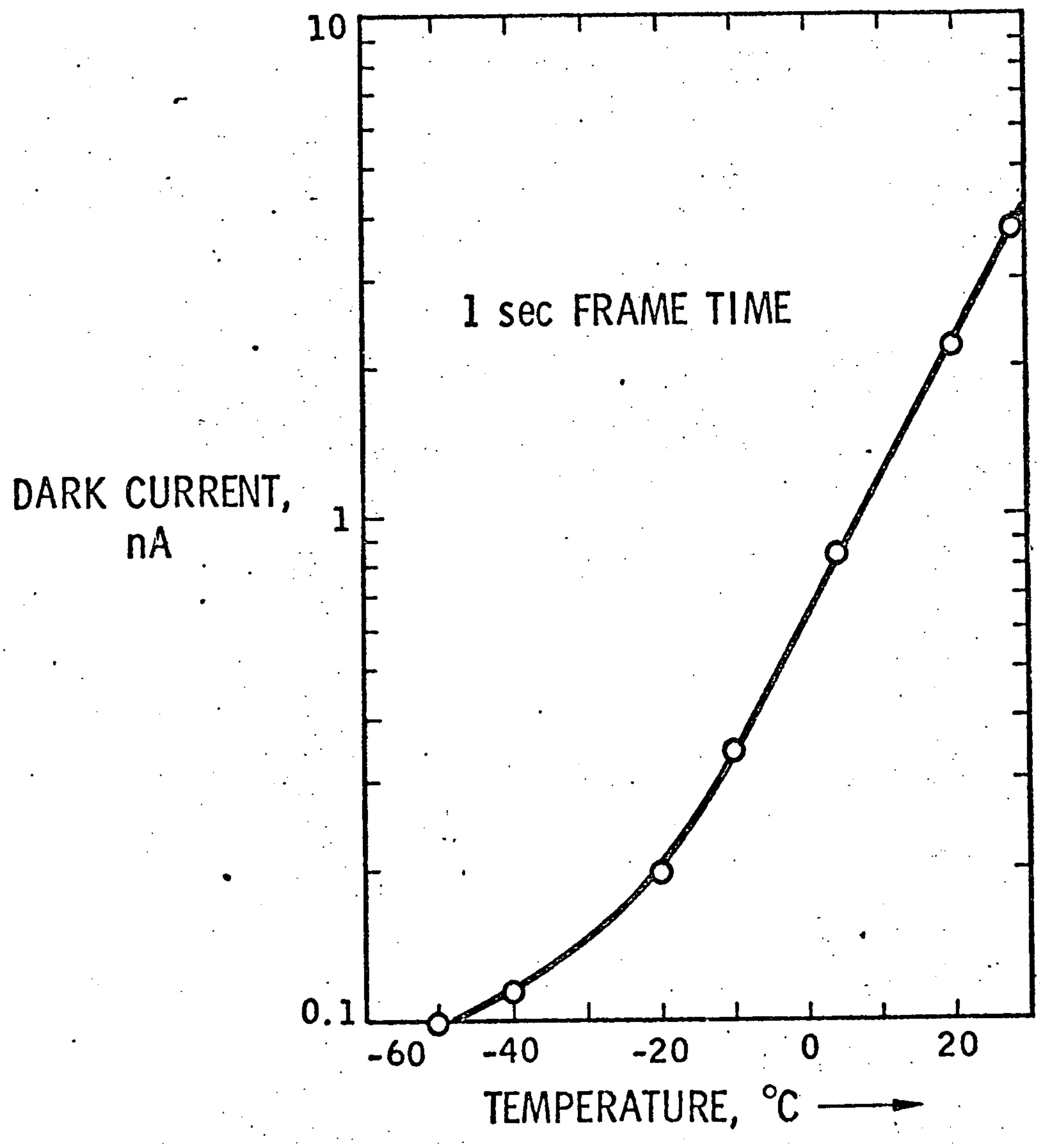
SILICON VIDICON OPERATIONAL CHARACTERISTICS

- Sensitivity And Spectral Response Essentially Independent Of Temperature
- Dark Current Reduced By Cooling
- Signal Current Varies Inversely With Frame Time
- Low Residual Image

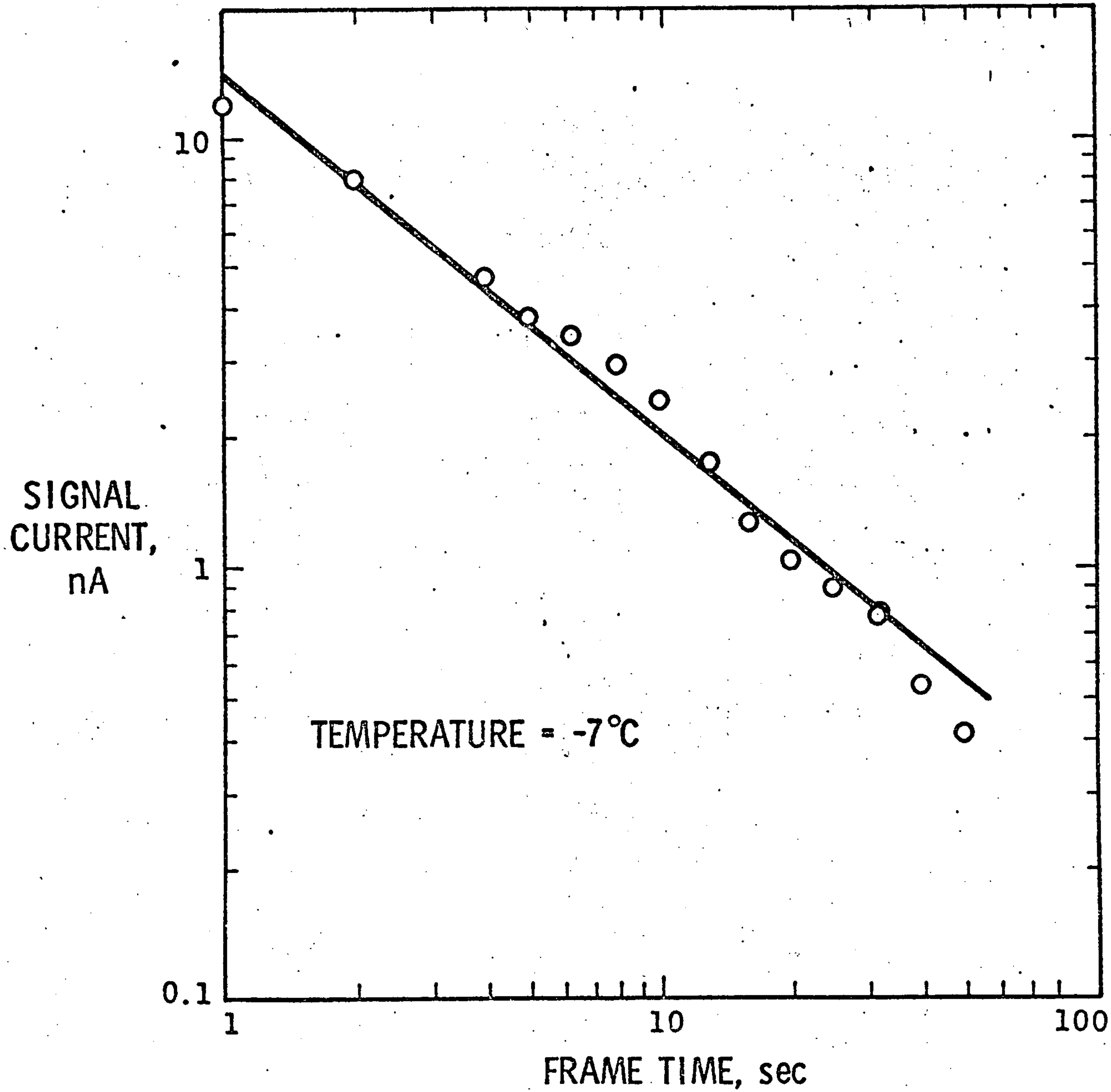
SILICON VIDICON SIGNAL CHARACTERISTICS

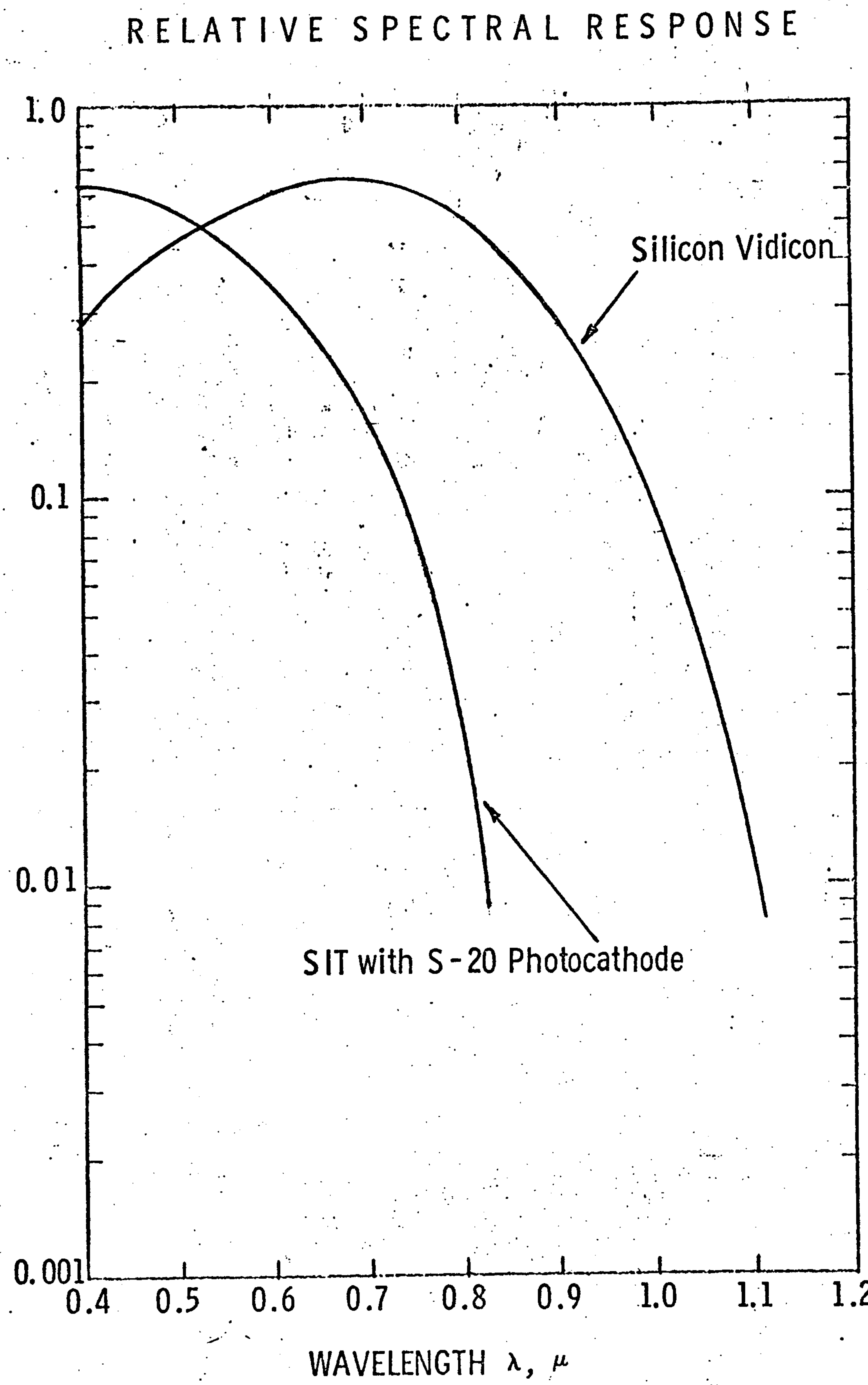
- Low Signal Currents At Slow Scan Rates
- Shading Due To Beam Landing Errors Expected To Be Poorer Than Normal Vidicon
- Corner Resolution Fall Off Expected To Be Poorer Than Normal Vidicon

DARK CURRENT vs TEMPERATURE



SIGNAL CURRENT vs FRAME TIME





RELATIVE SPECTRAL RESPONSE
1.0
0.1
0.01
0.001
Silicon Vidicon
SIT with S-20 Photocathode
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
WAVELENGTH λ, μ

MAJOR DEVELOPMENT TASKS

- Improved Slow Scan Performance of Silicon Target
- Improved Cathode Life
- Design and Ruggedization of 1 1/2" Silicon Vidicon and 1 1/2" SIT Vidicon

DEVELOPMENT STATUS

32

- Fabrication of Targets Using 1, 5, and 10 Ω-cm Silicon in Progress.

- Design of Electron Gun Incorporating Dispenser Cathode in Progress.

7/15/71
G.C.B.

SILICON SENSOR DEVELOPMENT CONTRACT

MILESTONE DATES

- 1 December 1971 -- Design Freeze On Silicon Target Processing.
- 1 March 1972 -- Design Freeze On Both SIT Tube And Silicon Vidicon.
- 30 June 1972 -- Delivery Of Three Prototype SIT Tubes And Three Prototype Silicon Vidicons.

ATTACHMENT 2

L. L. Simmons

26 August 1971

POTENTIAL SPECTRAL PROBLEMS

1. Airy disc size decreases optics MTF at 9000 Å in NA camera.

2. The possible need for a refractive field-flattening element with the WA camera may cause problems in the UV.

3. The SIT photocathode cuts off at long wavelength.

4. UV transmission of current fiber optics is not good in UV.

5. UV response of silicon tube is very poor.

6. Good red response in an intensifier tube causes problems in developing a good electronic shutter.

7. There is evidence that the spectral properties of photocathodes vary over small areas.

A. Collins
8-31-71

ATTACHMENT 3

Science Objectives Topics

Saturn rings - detail phenomenon	Aksnes
Satellite ephemeris/mass	Aksnes
Why cloud physics?	Belton/Sagan
Uranus & Neptune - clouds, belts	Belton
Weather centers	Belton/Millis & Sagan
Vertical structure	
Limb photography	Belton
Solar Occultation & illum. satellite occult.	Belton
Stereo	Murray
Polarimetry	Murray
Cloud shadows	Murray
Terminator structure	Murray
Absorption photography	Owen
Spin axis	Davies
Shape	Davies
Exploratory photography	Hartmann
Aurorae/night glow/flux tube	Hartmann/Belton
New satellite search - dynamical evolution	Hartmann
Why Pluto?	Hartmann
Moon comparison with satellites - Lewis	Owen
Itemize anomalies in planets & satellites	Owen
Satellite atmospheres - absorptions & frosts	Reilly
Hydrodynamics	Suomi/Belton
Importance of spectrum and scale of motions	Suomi
Importance of time coverage & resolution	Suomi

JET PROPULSION LABORATORY

INTEROFFICE MEMO

September 29, 1971

TO: Distribution

FROM: A. Collins *Andy*

SUBJECT: Minutes, 5th OPGT Imaging Science Team Meeting
September 23, 10:00 a.m. through 5:00 p.m., 186-128
September 24, 9:00 a.m. through 1:00 p.m., 169-230

ACTION ITEMS

Assignment	Assignee	Date Due
1. Contribute portions of scientific objectives document	All Team members	Immediately
2. Define analysis to be performed on candidate systems	A. Collins/M. Belton	10/1
3. Present preliminary compressor simulation results	T. Reilly	10/18
4. Determine relationship between far encounter satellite ephemeris improvement and near encounter satellite position knowledge	K. Aksnes	10/18

Thursday, September 23

Attendees: K. Aksnes, J. Anderson, M. Belton, T. Bird, A. Collins, M. Davies, B. Hartmann, B. Krauss, B. Millis, B. Murray, T. Reilly, C. Sagan, L. Simmons, G. Smith, R. Stanton

The following dates were selected for future team meetings at JPL:

October 18-19
November 22-23
December 16-17

M. Belton told of recent SSG work:

A. With the development of the minimum scientific payload capability, emphasis has been placed on the potential value of flying different payloads on different missions. Belton described some sample payloads suggested by V. Eshleman. Because of the substantial technical problems involved, the team decided to not seek common optical systems with other experiments.

B. The team agreed that, if additional weight were available, they would endorse including planetary probes on the spacecraft. However, such probes should not be carried at the expense of the current flyby payload.

C. The SSG has established a preliminary set of non-fields and particles priorities:

1. Mass, size, shape, spin axis, B-field, rotation, ephemeris - satellites and planets equal priority,

2. Energy balance, atmospheric composition and structure, satellite surfaces,

3. Atmospheric motions, particulate matter (Saturn's rings),

4. Upper atmosphere, clouds.

While the team disagreed with the priorities, they felt it was not detrimental to imaging.

M. Belton and B. Hartmann reported on the recent planet and satellite committee meetings and presented the alternate minimum imaging systems which had been proposed.

Additional attendees at the afternoon session were A. Eisenman and J. Westphal.

J. Westphal told of his current use of silicon vidicons for astronomical applications. He reported success in reducing dark current (and thereby increasing potential frame time) by cooling with dry ice.

G. Root presented the information necessary to evaluate an imaging system's theoretical approach guidance performance. He also concluded that selenium and line scan systems are both incapable of satisfying the current TOPS approach guidance requirements.

M. Belton told of a discussion he had held with B. Schurmeier and of a memo he had written to G. Smith, both on the possibility of developing a dielectric tape system. L. Simmons reported that JPL hopes to let a 3-month study contract, by early or mid-November, to CBS to perform functional design and preliminary analysis of such a system. The source of funding for this contract has not been identified. Project is currently committed to prepairing a Request for Proposal (RFP) for the system contract and is unable to study the impact of a dielectric tape system on the spacecraft design.

The team decided to limit its current analysis to 3 systems:

Baseline	2 meter	1-1/2" SIT	9" aperture	
	.2 meter	1-1/2" SiV	3" aperture	
Minimum	1 meter	1" SIT	7" aperture	
	.3 meter	1" SiV	3" aperture	
	1 meter	Dielectric tape	7" aperture	40 lp/mm
	.3 meter	Dielectric tape	3" aperture	

A. Collins and M. Belton will define the analysis to be performed on these systems.

T. Reilly described his proposed program to simulate an imaging/data system. The team accepted this proposal with the additional requirement that Reilly plans to have preliminary results from phase 2 (compressors) by the next team meeting, be it at the expense of thoroughness.

Friday, September 24

Attendees: K. Aksnes, J. Anderson, M. Belton, A. Collins, M. Davies, B. Hartmann, B. Krauss, B. Millis, P. Penzo, T. Reilly, C. Sagan, L. Simmons, G. Smith, R. Stanton

P. Penzo described the characteristics of JSUN missions. B. Hartmann suggested that with reduced focal length and mission set, the team should place greater priority on single close satellite encounters than on multiple distant encounters. The team was very interested in JSUN missions but saw no clear preference between them and JSP and JUN missions.

B. Millis distributed his reports on spectral and polarization requirements. L. Simmons cautioned that the assumed UV response of the tube was probably too great, and C. Sagan expressed dismay that the UV response was so poor. Simmons also asked the team to identify the specific filter/sensor/optics combinations they are most interested in. The team concluded that with two polarizers (wavelength unspecified) a vidicon would probably have the following limitations and capabilities:

1. No negative branch detection
2. Can identify frost surfaces
3. Can identify deep Rayleigh atmospheres
4. Can, under certain viewing conditions, be used as a discriminator to enhance the appearance of limb hazes and cloud layering by minimizing molecular scattering.

L. Simmons described the proposed optics contract which he hopes to negotiate within the next 2 weeks. It will probably begin in mid-November. The team agreed with the proposal but asked that the 4 meter focal length be elminated and that the effects of smaller apertures be studied.

M. Davies presented the following conclusions relative to "essential accessories" to an imaging system:

1. The current attitude control system will not require a far encounter planet sensor with focal lengths shorter than 4 meters.

2. A mechanism will probably be required to protect the optical surfaces during cruise.

3. Some means of automatic exposure determination will be required.

4. In-flight calibration will be required.

M. Belton questioned the first conclusion: It may be necessary to have a body-centered tracking system if, during the observatory phase, it is not possible to refine a satellite ephemeris enough to accurately predict its position during a later close flyby. K. Aksnes accepted the task to define, by the next meeting, the relationship between far encounter ephemeris improvements and near encounter position knowledge.

A. Collins described the current baseline attitude control and pointing requirements and the criteria behind them. The team agreed to these requirements and criteria.

B. Krauss presented a scheme whereby a line scan system could be used on a TOPS-type spacecraft. This topic was tabled until V. Suomi could be present.

AC:ldn

JET PROPULSION LABORATORY

INTEROFFICE MEMORANDUM

October 27, 1971

TO: Distribution

FROM: A. Collins Andy

SUBJECT: Minutes of 6th OPGT Imaging Science Team Meeting
October 18, 10:00 AM through 4:30 PM, 169-230
October 19, 9:00 AM through noon, 180-102

NEXT MEETING: November 22, 10:00 AM through 4:30 PM, 169-230
November 23, 9:00 AM through noon, 169-230

ACTION ITEMS

Assignment	Assignee	Date Due
1. Define sequences for three candidate imaging systems	M. Davies & Committee	11-22-71
2. Prepare and distribute data sheets for three systems	A. Collins	10-26-71

Monday, October 18

ATTENDEES: K. Aksnes, M. Belton, A. Collins, M Davies, B. Hartmann, R. Krauss, B. Murray, T. Owen, R. Piereson, T. Reilly, T. Rindfleisch, G. Root, C. Sagan, L. Simmons, G. Smith, R. Stanton, C. Wertz.

M. Belton communicated the conclusions of the Physical Sciences Committee which recommended that the OPGT Imaging Team should consider systems that have a resolution of 50 μrad/line, and he expressed concern over the amount of science weight being budgeted for Imaging. At a recent meeting with Project, it was decided to drop the present baseline because of weight limitations and to consider the present minimum system as baseline and, also, further systems which are reduced in weight from the minimum.

The Team tentatively decided that further reduced systems should sacrifice redundancy rather than performance. It was decided to consider several one-camera systems which would have performance similar to the original baseline (2-meter) system. L. Simmons was asked to describe, the following day, the relative cost of various systems.

T. Reilly presented the following initial simulation pictures:

1. 5 uncompressed MVM targets - Earth clouds and lunar
2. 4:1 delta compression of these frames
3. 2:1 delta compression
4. 2:1 delta compression with a telemetry channel bit error rate of 5×10^{-3}
5. 2:1 delta compression with a telemetry channel bit error rate of 10^{-5}
6. 2 targets imaged through a MM'71 system at various exposures (S/N's)

It was immediately clear that great care will be required in selecting a Telemetry BER compatible with this type of compression scheme. (Reilly's original proposal is included as Attachment 1.) The Team decided that operationally one should not increase the exposure (and smear) until the single pixel S/N reached about 5:1. B. Murray suggested that future IMSYS data should include this criterion for determining exposure. T. Reilly was asked to further study alternative methods of achieving compression ratios of 4:1 with several bit error rates. R. Piereson was asked to describe, the following morning, the bit error rates and data rates associated with various telemetry coding/decoding methods.

Additional attendees at the afternoon session were B. Millis, P. Penzo, J. Randolph and P. Thiesinger; R. Stanton was absent.

P. Penzo described the "standard" trajectories he planned to recommend to the Mission Design Team. These trajectories were selected for $C_3 < 109$ (1460-lb spacecraft):

JSP77	Jupiter	4-24-79	Imaging Team's 2nd choice
	Saturn	11-13-80	Imaging Team's 1st choice
JUN79	Uranus	4-19-87	good satellites
	Jupiter	6-01-81	Imaging Team's 1st choice

B. Hartmann reported that, by trying to outline a Saturn encounter sequence, he had concluded that a 1-meter focal length was totally inadequate to obtain geological data for Saturn's satellites (Attachment 2). R. Krauss outlined a sequence (Attachment 3) for Uranus and concluded that mass storage of 100-200 frames was necessary. M. Davies described the use of a dielectric tape camera during a Saturn encounter (Attachment 4).

B. Murray recommended an alternative imaging/data system which was further discussed the following day.

Tuesday, October 19

ATTENDEES: K. Aksnes, M Belton, A. Collins, M. Davies, B. Hartmann, R. Krauss, B. Millis, R. Piereson, T. Reilly, G. Root, C. Sagan, L. Simmons, G. Smith.

R. Piereson presented a block diagram of a proposed data system. Concern was expressed over the variable line length for compressed non-imaging science data. Also, Piereson described the relative data rates for various bit error rates and coding/decoding schemes:

Bit Error Rates

	Compressed (10^{-5})	Uncompressed (5×10^{-3})
Block Coded	4.5 kbps	10.0 kbps
Convolution/Viterbi	8.8	11.0
Convolution/Sequential	10.0	10.0

K. Aksnes presented a report (Attachment 5) in response to an action item from the last meeting. His principal conclusion was that, to accurately point at and image a satellite from a close distance (10^5 km), it is necessary to either use a far encounter planet sensor or to improve the satellites' ephemeris accuracy to about 400 km using observatory phase imaging.

M. Belton appointed a Sequencing Committee: M. Davies (chm), B. Hartmann, R. Krauss, B. Millis and A. Collins. The committee is to develop detailed imaging sequences for the following three systems and to report at the next meeting. A. Collins was asked to prepare and distribute data sheets for these three systems.

MSP	1M 7" Optics	17 lbs	
	.3M 3" Optics	8	
	1" SIT	18	
	1" SiV	12	
	2 10^8 bit tapes		104 lbs
	1 5 X 10^5 bit buffer		7
	Electronics	10	
		65 lbs + 111 lbs = 176 lbs	
BCM	2M 6" Optics	19 lbs	
	.3M 3" Optics	8	
	1" SIT	18	
	Electronics	5	
	Data Conditioning Unit	15	
		65 lbs	
MJSB	2M 9" Optics	25 lbs	
	.3M 3" Optics	8	
	1" SiV	12	
	Data Conditioning Unit	15	
	Electronics	5	
		65 lbs	

The Team decided to pursue the possibility of conducting the imaging experiment without using the tape recorders. Removal of the tapes offers a great weight savings.

AC:st

Attachments

Attachment 1

JET PROPULSION LABORATORY INTEROFFICE MEMO

September 20, 1971

TO: Distribution

FROM: T. H. Reilly THR

SUBJECT: IPL Simulation of OPGT Imaging Systems

I. INTRODUCTION

The OPGT Imaging Team is presently studying several camera and data system options for possible use on the outer planet missions. The goal of this study is to identify a practical imaging system which will return the greatest number of pictures with adequate quality from these flights. To determine the practicality of an imaging system, reliability, weight, power, cost, etc. are assessed. The question of adequate quality, however, is more subtle.

The easiest approach to achieving adequate image quality is simply to maximize quality within the limits of existing technology. However, when we consider the concurrent requirements for practicality and large picture return, it may become desirable to compromise on quality. This is a difficult trade-off to make, primarily because there is no consensus on what constitutes adequate quality. Some of the factors which complicate the analysis of picture quality are listed below:

1. The parameters which determine adequate picture quality are numerous, and are all interrelated in a complex manner. The prime considerations appear to be angular resolution, picture format, signal-to-noise ratio, and the character of the scene to be photographed. Other factors include photometric accuracy, geometric fidelity, and the range of spectral response.

2. Several types of scenes are to be photographed on these missions, and the lighting conditions will change with time. The overall trend, of course, will be toward lower illumination levels as the mission progresses.

3. The ultimate measure of adequate picture quality is the amount of information which can be extracted by the eye/brain of the scientist who will use the photographs. Models exist which attempt to describe the psychophysical process by which a trained observer looks at an image. Of necessity, these models are very crude. In addition, there are several empirical studies which report the image quality required for reliable detection of specific features. However, these studies are only partly relevant to the present problem, due to the special nature of the

Attachment 2

Routing:

1	2	3
4	5	6

IITRI **Inter-Office Memorandum**
IIT Research Institute

Date: October 15, 1971

To: Mike Belton, Outer Planets Grand Tour Imaging Team

From: W.K. Hartmann

Subject: JSP 77 Saturn and Saturn Satellite Encounters

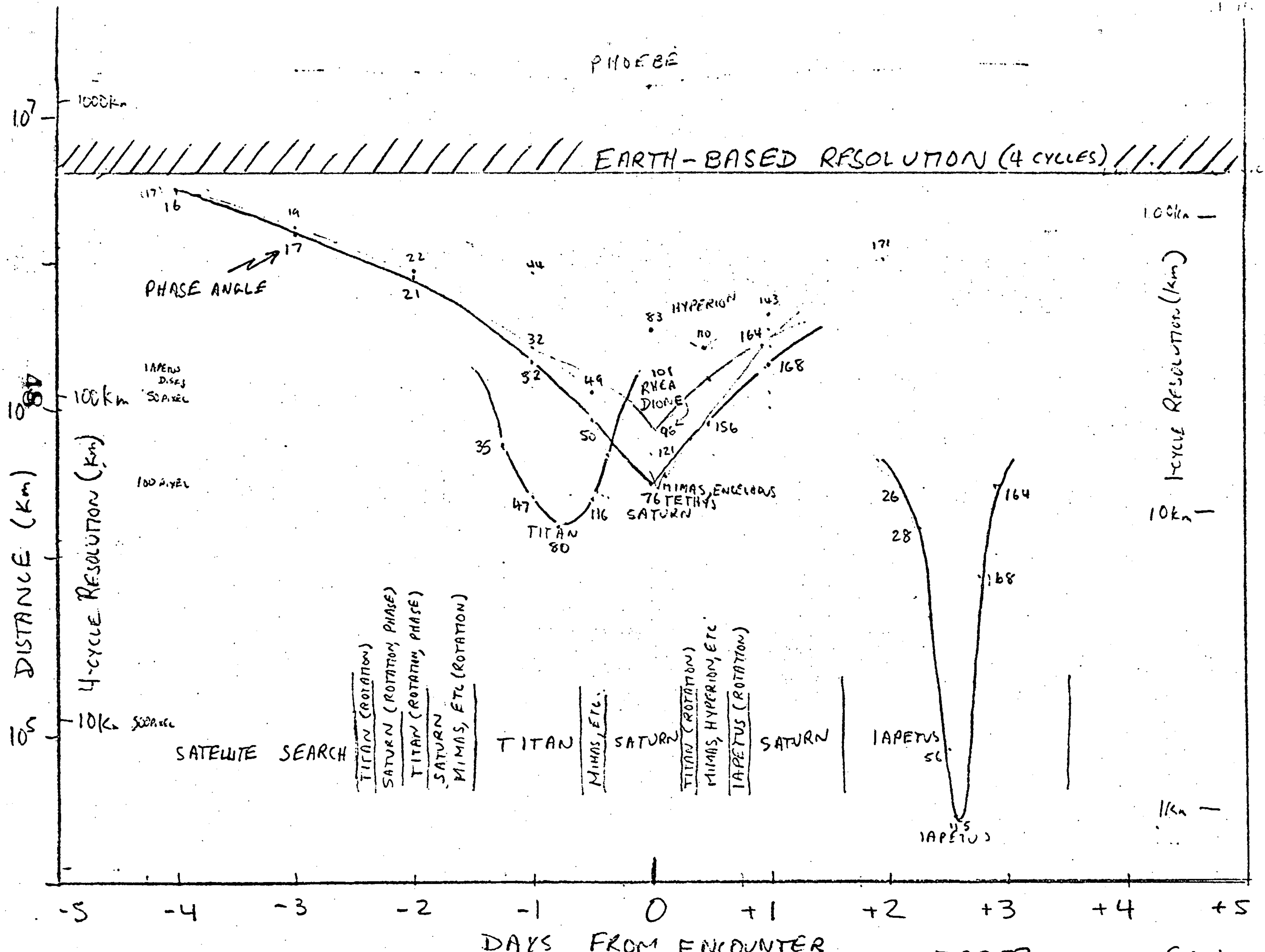
My general conclusion is that the spacecraft imaging system outlined in the system data sheet of October 13, 1971 yields very disappointing results for the planned JSP 77 encounter with Saturn. This results primarily from the 1-m focal length. If we assume an earth-based resolution of 600 km at the Saturn system, the distance at which the 1-m focal length camera matches earth-based resolution is 6.7 million km (assuming a resolution element of 4 scan lines or 89 micro radians).

One disappointing result of this low resolution is that the time interval during which earth-based resolution can be exceeded is now limited to only a few days on either side of Saturn encounter for Saturn and most of the satellites. For the two satellites, Iapetus and Titan, where a very close fly-by is planned, very high resolutions are obtained only on Iapetus and only for an interval of a few hours. All of these time intervals are much too short to give a good baseline for rotation determinations. Also, they are so short that they are effectively instantaneous in the sense that the satellite does not move or rotate during the encounter and therefore, continuous coverage is limited to only one hemisphere for any given phase angle. To put it another way, we cannot switch on the camera at very far encounter distances and then watch the satellite rotate.

Another disappointing result is that time is utilized very inefficiently for the imaging system during the Saturn fly-by. Because the resolution is so low, there are intervals, for example, between the Saturn encounter and the Iapetus encounter at which only poor resolutions of a few hundred kilometers can be obtained on any objects. Therefore, even while we are flying through the Saturn satellite system, there are time intervals which are very inefficiently used. In effect, this means that the opportunity which is presented by the Grand Tour -- a spacecraft flying through the satellite systems of the outer planets -- is, to a degree, wasted because the resolution carried on board is too poor to give extraordinary advances over earth-based or earth-orbital telescopic equipment.

A third disadvantage of the chosen optical system is that the wide-angle camera is scarcely utilized at all. Although the wider-angle format is useful for satellite searches, the silicon system proposed for it is less sensitive than the SIT system proposed for the narrow-angle camera is not maximized. Wide-angle imagery of specific satellites during fly-bys is virtually useless.

A fourth illustration of the disappointing performance of this optical system comes from the diagram proposed for our science objectives document showing contiguous coverage vs spatial resolution. This diagram shows a band defined by features of different scale ranging from small features such as small volcanic craters and lineament systems up to large craters, mare regions, and features that allow determination of the spin axis. Only one satellite encounter, that of Iapetus, extends from the region now covered by earth-based imagery into this "band of optimum performance". The only other satellite encounter, Titan, extends from the region now covered by earth-based imagery only marginally up to "band of optimum performance", but falls below the level of performance which we had considered as truly fruitful for the outer planet mission. All other satellites of Saturn can only be photographed with resolution of a few hundred kilometers and such images will only tell us what we already know: mainly that the satellites of outer planets have dusky markings and, for the most part, rotate in synchronous fashion.


PHOEBE
EARTH-BASED RESOLUTION (4 CYCLES)
1000Km
100Km
10Km
10^7
10^6
10^5
PHASE ANGLE
DISTANCE (Km)
4-CYCLE RESOLUTION (Km)
1-CYCLE RESOLUTION (Km)
HYPERION
RHEA
DIONE
MIMAS, ENCELADUS
TETHYS
SATURN
TITAN
IAPETUS
SATELLITE SEARCH
TITAN (ROTATION)
SATURN (ROTATION, PHASE)
TITAN (ROTATION, PHASE)
SATURN
MIMAS, ETC (ROTATION)
TITAN
MIMAS, ETC.
SATURN
TITAN (ROTATION)
MIMAS, HYPERION, ETC
IAPETUS (ROTATION)
SATURN
IAPETUS
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
DAYS FROM ENCOUNTER

JSP 77

FIG 1

SATELLITE SCIENCE OBJECTIVES

IAPETUS – { DIAMETER 1150 KM
REV. PERIOD 79 DAYS

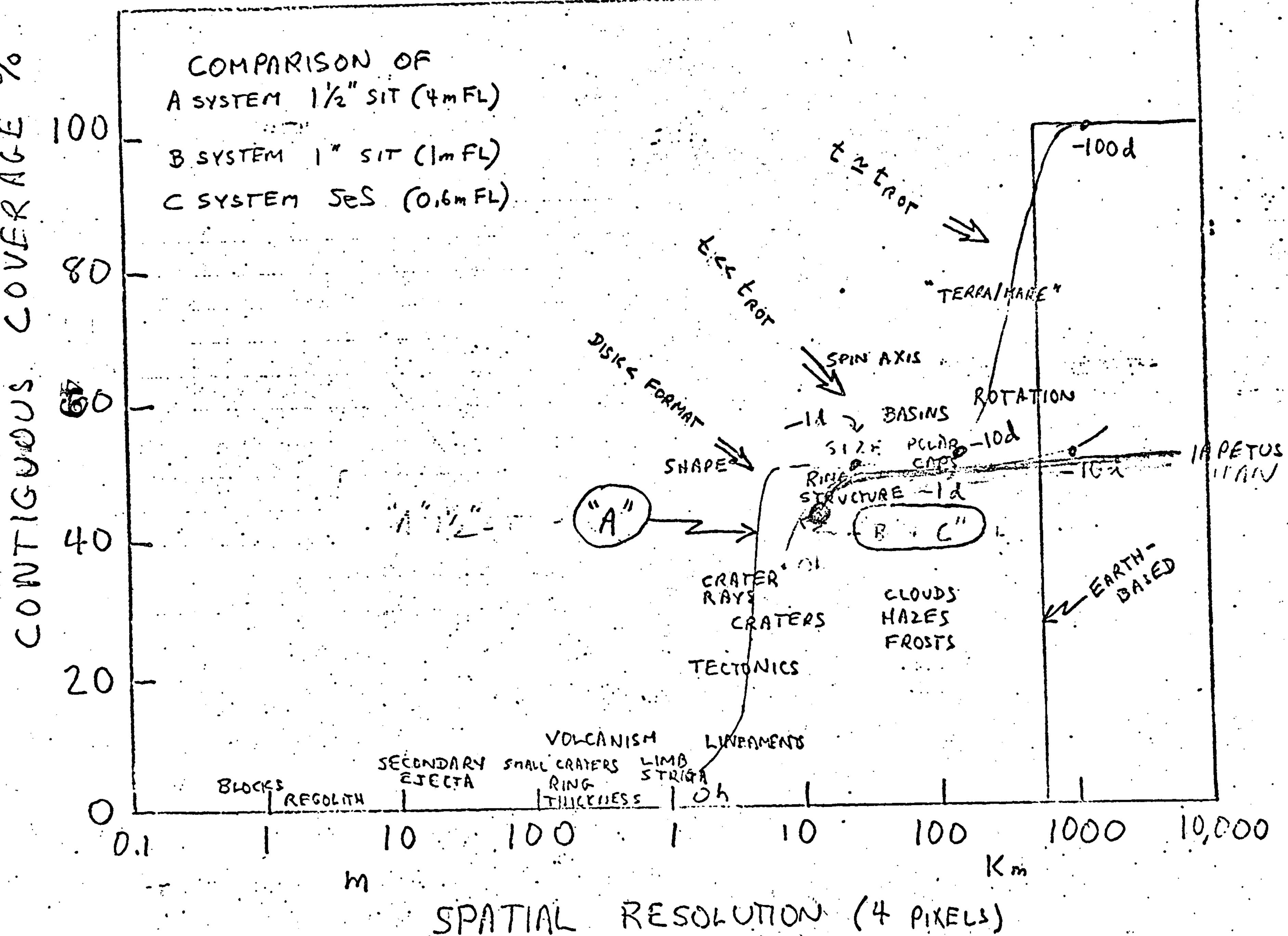
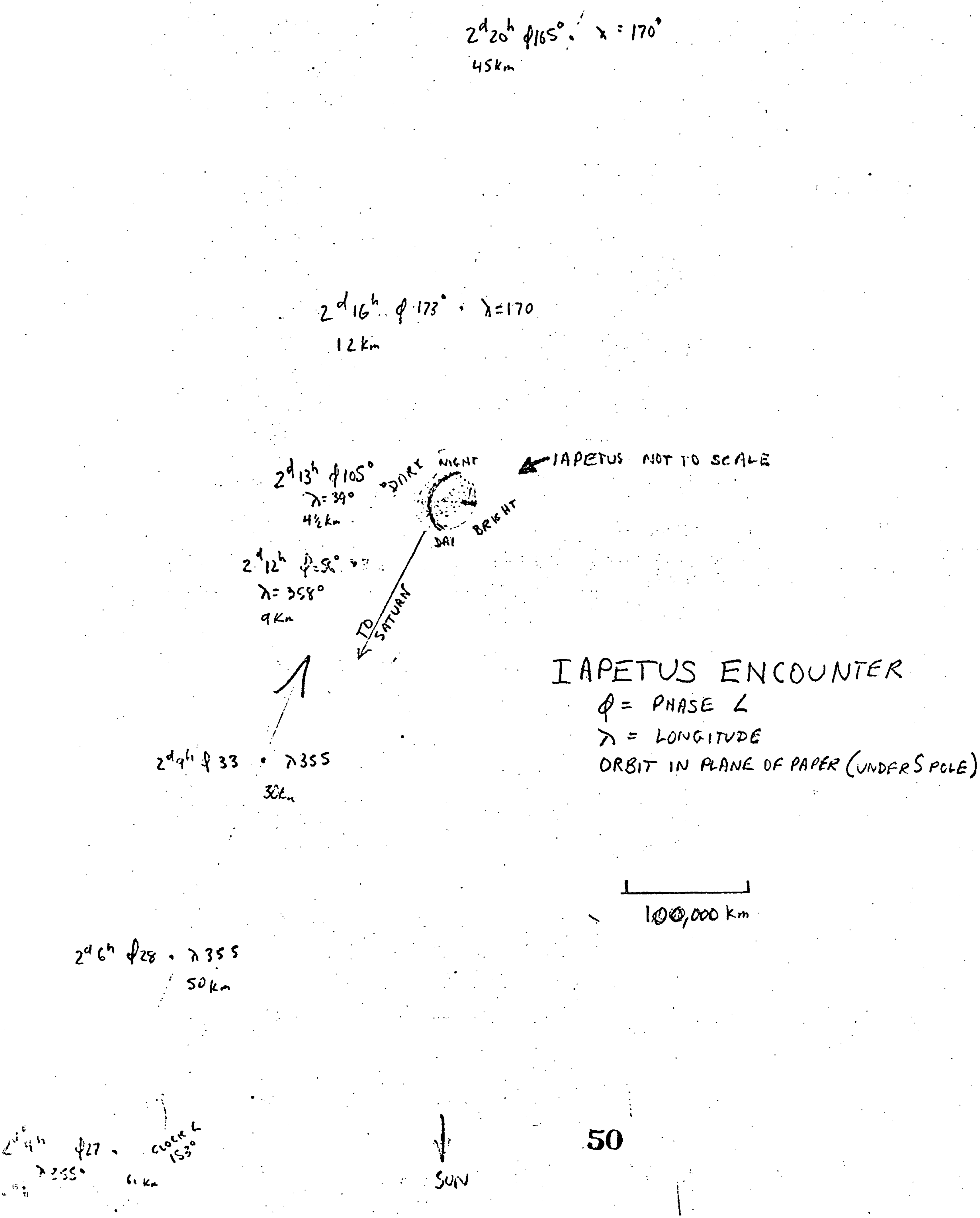


FIG. 1



2d20h φ165° λ = 170°
45km
2d16h φ 173° λ=170
12km
2d13h φ105°
λ = 39°
4½km
DARK
NIGHT
IAPETUS NOT TO SCALE
DAY
BRIGHT
2d12h φ=56°
λ= 358°
9Km
TO SATURN
IAPETUS ENCOUNTER
φ = PHASE ∠
λ = LONGITUDE
ORBIT IN PLANE OF PAPER (UNDER S POLE)
2d9h φ 33 λ355
30km
100,000 km
2d6h φ28 λ355
50km
φ27
CLOCK ∠ 153°
SUN

R. Krauss
10-22-71

Attachment 3

URANUS SEQUENCE

W/A 2.5^{o} X 3.3^{o} N/A $.75^{o}$ X 1^{o} 45 μr/cycle

GROUND RULES:

1. Planets and satellites of equal priority--each get 100 of near encounter 200 picture tapeload.

2. No partial tapeloads.

3. Far encounter pictures of poor ground resolution are of little use except for navigation or study of time dependent photometric variations.

4. Earlier photography has determined the use of proper color filters; filter sequence is omitted.

5. Approach from sunlit side; leave from dark side. Split pictures, 80 on approach, 20 on departure.

6. No satellite ever fills N/A camera field of view, so W/A camera is never used.

7. With so few pictures, coverage versus ground resolution plots are unimportant. One takes the pictures as close to target as orbit and desired phase angles permit.

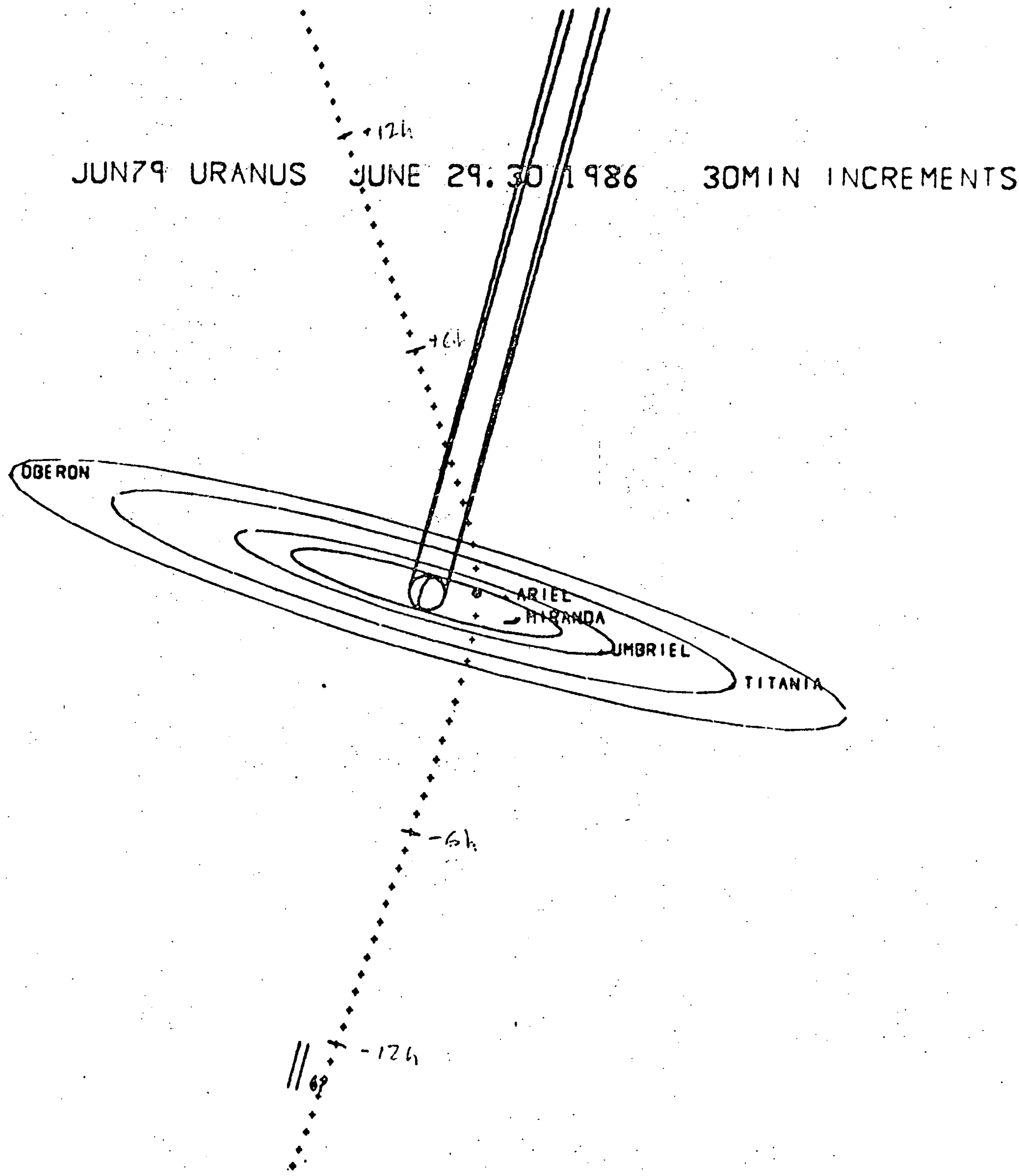
8. Even though almost everything is closest at encounter, the limited picture load and 13.4 second frame time should prevent pointing conflict.

SATELLITES:

Desire coverage of each from at least three phase angles in each of six filters, or similar combinations.

E-12h	30 pix	N/A	~300 km/cy		
E+0h	30 pix	N/A	TITANIA	~16 km/cy	
			UMBRIEL	~8.5 km/cy	
			MIRANDA	~3.4 km/cy	
			ARIEL	~8 km/cy	
			OBERON	~27 km/cy	(pass better after encounter)
E+12h	30 pix	N/A	~300 km/cy		
E+6h	10 pix	N/A	~150 km/cy		

Last set of ten used for intermediate phase angles, stereo coverage, etc.


JUN79 URANUS JUNE 29,30 1986 30MIN INCREMENTS
+12h
+6h
OBERON
ARIEL
MIRANDA
UMBRIEL
TITANIA
-6h
-12h

CASE 1

URANUS:

One can use 25 W/A frames to mosaick most accessable 2/3 of illuminated disc near periapsis--a worthwhile endeavor, but one needs nearly 300 N/A frames to do the same job. The tradeoff is thus the ratio of W/A to N/A frames within the 100 frame limit, not coverage versus resolution. The N/A frames should not be used for maximum ground coverage, but rather for spot investigations of limb and terminator fine structure, observable connective elements, wave phenomena, or other targets or opportunity as they present themselves. In this way, the few high resolution frames will yield greater science return.

E-12h	3 pix	N/A	~ 25 km/cy	mosaic leftmost 1/3 of illuminated disc
E-2h to E+0	25 pix	W/A	~ 15 km/cy	mosaic right 2/3 of illuminated disc
E-2h to E+½h	25 pix	N/A	~ 5 km/cy	limb, terminator targ. of opportunity
E-1h to E+½h	20 pix	W/A	~12 km/cy	additional term. coverage to study motions & structure in stereo
E+2h	6 pix	W/A	~15 km	limb mosaic ¼ forward scattering photometry
E+3h	6 pix	W/A	~ 20 km	for limb forward scattering & mosaic
E+12h	15 pix	N/A	~25 km	sunlit crescent at large phase angles

Due to 35-minute frame transmission rate, a full tapeload takes five days. The use of partial tapeloads in far encounter is mandatory to maximize resolution. One does not want to be playing back a tapeload the entire five days before encounter, but rather a half dozen pictures every 3-4 hours when about one day out.

In addition, use of a single long focal length camera would severely limit closeup coverage of the planet to isolated spots when the lighting conditions are best to view upper layer structure over the whole illuminated disc. A wide-angle camera is essential to interpret larger scale organization and flow patterns which may not be visible in zero phase angle views of the lighted pole.

M. Davies
Attachment 4

Saturn Encounter
Dielectric Tape

SYSTEM DATA SHEET

	12×12mm Format	12×18mm Format	12×24mm Format
Sensor	DTC	DTC	DTC
Format	960×960×7	960×1440×7	960×1920×7
Focal length	1 meter	1 meter	1 meter
Aperture	178mm	178mm	178mm
Pixel size	12.5 μrad	12.5 μrad	12.5 μrad
Bits/PIX	6,451,200	9,676,800	12,902,400

Full-frame transmission time (PIX/day)

	12×12mm Format	12×18mm Format	12×24mm Format
Jupiter (13.1 Kbps)	493 sec (175) 8min 13sec	739 sec (116) 12min 19sec	985 sec (87) 16min 25sec
Saturn (3.1 Kbps)	2081 sec (41) 34min 41sec	3122 sec (27) 52min 2sec	4162 sec (20) 1hr 9min 22sec
Uranus (.84 Kbps)	7680 sec (11) 2hr 8min 0sec	11520 sec (7.5) 3hr 12min 0sec	15360 sec (5.6) 4hr 16min 0sec
Neptune (.4 Kbps)	16128 sec (5.3) 4hr 28min 48sec	24192 sec (3.5) 6hr 43min 12sec	32256 sec (2.6) 8hr 57min 36sec
Pluto (.36 Kbps)	17920 sec (4.8) 4hr 58min 40sec	26880 sec (3.2) 7hr 28min 0sec	35840 sec (2.4) 9hr 57min 20sec

RANGE FROM WHICH THE DIAMETER OF THE PLANET OR SATELLITE FILLS THE FORMAT (12 mm, 18 mm, 24 mm)

Outer planets & their satellites	Diameter (km)	Range (km) 12 mm	18 mm	24 mm
Jupiter	141,700	11,808,000	7,872,000	5,904,000
Io	3,500	292,000	194,000	146,000
Europa	3,100	258,000	172,000	129,000
Ganymede	5,550	463,000	308,000	231,000
Callisto	5,000	417,000	278,000	208,000
Saturn	120,000	10,000,000	6,667,000	5,000,000
Tethys	1,200	100,000	67,000	50,000
Rhea	1,300	108,000	72,000	54,000
Titan	4,850	404,000	269,000	202,000
Outeredge Ring B	235,600	19,633,000	13,089,000	9,817,000
Uranus	50,800	4,233,000	2,822,000	2,117,000
Ariel	600	50,000	33,000	25,000
Oberon	800	67,000	44,000	33,000
Titania	1,000	83,000	56,000	42,000
Neptune	49,500	4,125,000	2,750,000	2,063,000
Triton	3,770	314,000	209,000	157,000
Pluto	6,400	533,000	356,000	267,000

Camera focal length = 1 meter.

Attachment 5

October 18, 1971

SATELLITE FINDING PROBLEMS WITH THE OPGT CAMERAS

Kaare Aksnes

Two fundamentally different methods have been proposed to aiming the TV cameras accurately enough not to miss a satellite during a close approach to it. The simplest and most direct method calls for the use of a planet/satellite sensor that can lock on a target planet or satellite. This method has the disadvantage of adding weight and complexity to an already overloaded spacecraft. In the second method, camera pointing is achieved solely by feeding the predicted ephemeris position of the target satellite into the coordinate encoders of the scan platform, to which the cameras are rigidly attached. It is much harder to evaluate the performance of this method. While not requiring the addition of any new instruments, the major flow of the method is that it places very strong demands on the accuracy of the satellite ephemerides.

The feasibility of the second method will depend mainly on (1) the field-of-view (FOV) of the camera (2) the spacecraft - satellite distance, (3) the satellite radius, (4) the satellite ephemeris error, and (5) the camera pointing error. Figure 1 illustrates the relationship between these five parameters for the narrow angle (NA) and wide angle (WA) baseline cameras (2 m and 0.3 m focal lengths, 1-1/2" sensors) and "minimum" cameras (1 m and 0.3 m focal lengths, 1" sensors) which are currently being considered by the Imaging Team. For this study, it will further be assumed that the scan platform and its encoders allow the cameras to be pointed to within $\pm 0^{\circ}.05$ of any point in the sky, defined in terms of its celestial coordinates. It should be safe to assume that the satellite ephemerides have a geocentric uncertainty of not greater than 1 arc second, corresponding to position errors between 4000 Km to Jupiter's satellites and 20,000 Km for the satellites of Neptune. (These estimates are probably too conservative for most satellites, especially for Jupiter 1-4 whose positions are supposed to be known to better than 1000 Km.)

It can be seen from Figure 1 that satellite finding on the basis of an ephemeris of, say, 5000 Km uncertainty becomes hazardous for distances less than 1,000,000 Km with the NA cameras, and 200,000 Km with the WA cameras. By comparison, the adverse effect of a camera pointing error of ± 0.05 is much smaller, especially since this effect decreases with decreasing distance to the satellite. Since it may be desirable to pass within 50,000 Km or less of a satellite, (the preliminary trajectory data indicates that a flyby distance of 40,000 Km of Iapetus is possible), ephemeris errors of only about 200 Km for the NA cameras, and 1000 - 2000 Km for the WA cameras, can be tolerated if the center of the satellite is to be kept within the FOV, according to Figure 1. But the finite sizes of the satellite radii, that vary from a few hundred kilometers for Uranus' satellites to about 2500 Km for the most massive satellites, will set lower limits for the required ephemeris accuracies. Obviously, if a satellite's radius exceeds the ephemeris error, at least a portion of the satellite will be seen by the camera, regardless of its FOV. In order to miss the satellite entirely, the angular measure of the ephemeris error minus the satellite radius has to be greater than 1/2 FOV. However, if this inequality is close to an equality, there will be no control over the aiming of the camera within the visible disk of the satellite.

It can now be estimated that an ephemeris accuracy of about 400 Km is required to provide accurate enough pointing information for the NA cameras during satellite flybys closer than 100,000 Km. This would demand a drastic improvement over currently available accuracies, which are not even sufficient for pointing the WA cameras during very close approaches. Although it is likely that the ephemeris errors can be reduced by a factor of two or three by means of earth-based optical observations stretching over several years prior to the satellite encounters, it is clear that only on-board observations can meet the required accuracy. If it is assumed that, by means of the science cameras or a special approach guidance camera, the position of a satellite can be measured relative to neighboring stars with a precision of 15 arc seconds, a resolution of 400 Km would result at a distance of 5.5×10^6 Km. The spacecraft would attain this distance roughly 4 days before encounter. If the observations are started, say, 20 days before encounter and discontinued 1 day before encounter to allow time for processing the observations and planning a camera sequence, enough precise observations ought to be available for the orbit improvement. This would be considerably simplified by the fact that over the short time intervals of interest here, most of the ephemeris error of a satellite is likely to manifest itself as a constant timing error that can be removed by a simple longitude correction.

In conclusion, it appears entirely feasible to achieve a sufficient camera pointing accuracy by means of the second method, especially since the on-board measurements presumably will be available anyway for the spacecraft navig... and the satellite ephemeris/mass experiment. Nevertheless, it is doubtful whether this method can achieve the same reliability as the other method using a planet/satellite sensor.

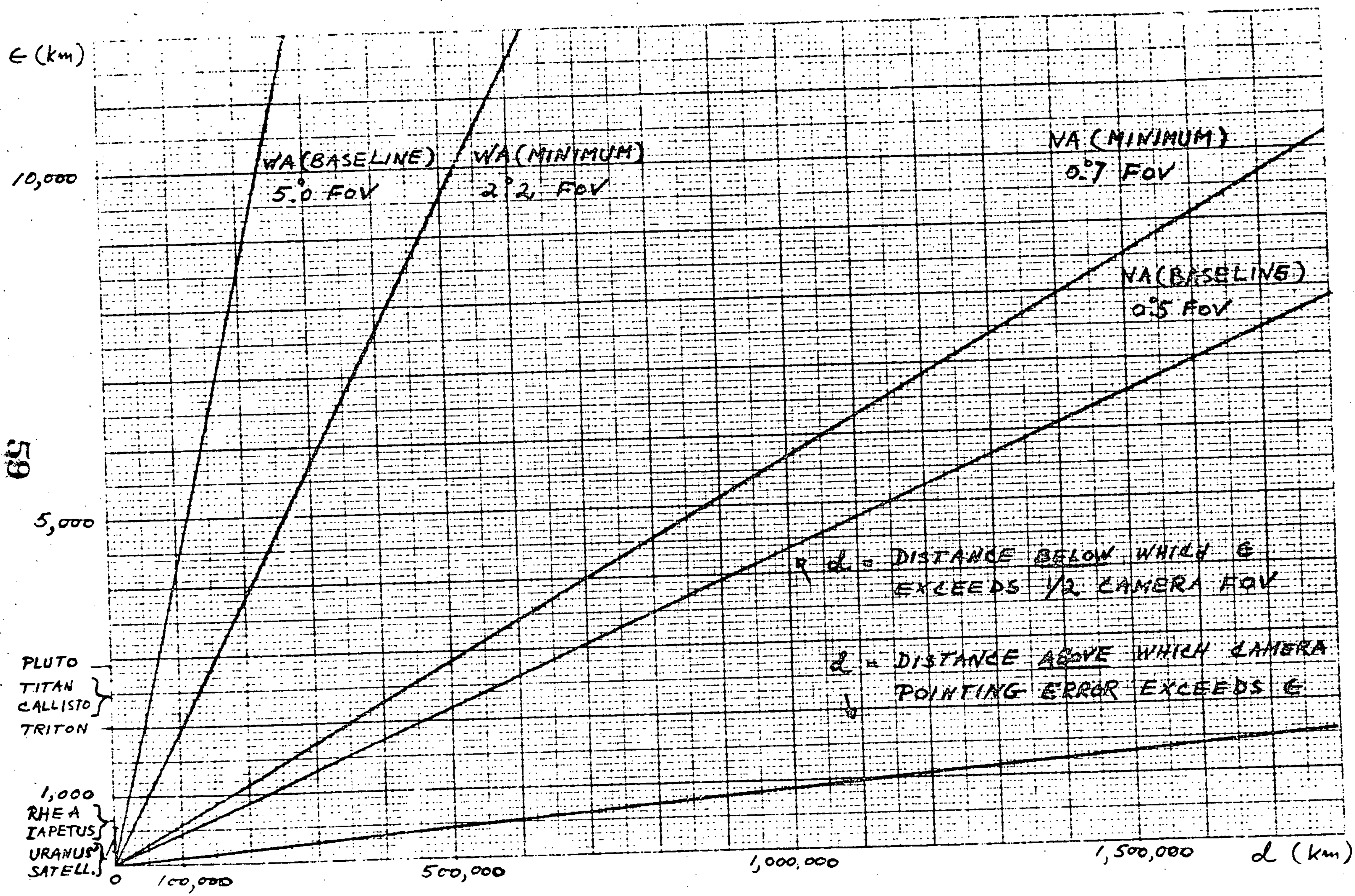


FIG. 1 RELATI[illegible] SHIP BETWEEN CAMERA FoV, SATELLITE DISTANCE (d), SATELLITE RADIU[illegible] [illegible]R EPHEMERIS ERROR (∈), AND CAMERA POINTING ERROR (0.°05).

JET PROPULSION LABORATORY

INTEROFFICE MEMO

1 December 1971

TO: Distribution

FROM: A. Collins Andy

SUBJECT: Minutes of 7th OPGT Imaging Science Team Meeting
November 22, 10:00 AM through 5:00 PM, 169-230
November 23, 9:00 AM through 1:15 PM, 169-230

NEXT MEETING: December 16, 10:00 AM through 4:30 PM, 183-328
December 17, 9:00 AM through 1:00 PM, 186-128

ACTION ITEMS

	Assignment	Assignee	Date Due
1.	Review scientific objectives document	Team Members	12-1-71
2.	Prepare draft of final report sections	Team Members	12-16-71
3.	Define preliminary ground data processing requirements.	Collins/Suomi	12-16-71
4.	Analyze compression/editing schemes.	Reilly/Hartmann	12-16-71
5.	Collect together previous team minutes and official correspondence for team report.	Collins	12-16-71
6.	Prepare a list of systems previously considered by the team.	Collins	12-16-71

Monday, November 22

Attendees: K. Aksnes, J. Anderson, J. Ashlock, M. Belton, A. Collins, M. Davies, R. Draper, P. Henry, R. Miles, B. Millis, B. Murray, T. Owen, T. Reilly, G. Root, L. Simmons, V. Suomi, R. Wallace.

M. Belton passed out the following preliminary documents to be reviewed by the team members and discussed the following day: Final Report (outline the science and objectives), Management Plan, letter to M. Mitz in response to PSC recommendations. He then asked A. Collins and V. Suomi to specify the real-time processing and data reduction requirements for use in budgetary estimates. Belton reported that he had asked Simmons and his group to look into line scan systems to see at what system resolution a line scan became competitive with a frame camera. Simmons reported that they had not been able to do this other than to note the results of a previous evaluation of line scan systems.

V. Suomi re-emphasized the need to evaluate the capabilities of a line scan camera to meet the scientific objectives. He also suggested that careful consideration be given to the techniques available for reconstructing a geometrically accurate raster for a line scan picture. It was pointed out that a linear array of sensor elements working in a line scan mode would provide a low cost, low weight, back up in a single sensor TV system.

R. Miles explained that Project could not now consider an imaging system whose performance exceeded that of the MSP. This upper limit on performance had resulted from a NASA Headquarters decision in response to non-project advisory group recommendations. It was suggested that the team seek clarification from NASA of the relative positions and functions of the Imaging Team and these other advisory groups. R. Draper described (Attachment 1) the data systems currently being considered by Project.

G. Smith described the work being done by the Imaging System Development Team (ISDT) to functionally design a data system for the OPS (MSP spacecraft). M. Belton expressed concern that this design did not include possible cameras other than the baseline (MSP), and Smith agreed to include other camera options previously specified by the OPGT imaging team in future ISDT work.

Following lunch, an executive session was held.

Tuesday, November 23

Attendees: K. Aksnes, M. Belton, T. Bird, A. Collins, M. Davies, B. Hartmann, P. Henry, B. Millis, M. Mitz, B. Murray, J. Naugle, T. Owen, P. Penzo, I. Rasool, T. Reilly, G. Root, C. Sagan, L. Simmons, E. Smith, G. Smith, R. Stanton, V. Suomi.

L. Simmons reported the following progress and decisions on current OP imaging contracts:

1. RCA has been instructed to continue development of only 1" silicon and SIT tubes.

2. CBS has begun a system definition study for a dielectric tape camera.

3. ITEK is about to begin design and analysis of switchable optical systems. Initial work will use 1 meter and .3 meter focal lengths, but they will later describe parametrically the implications of a 2 meter focal length. The money intended for a filter study may be put into the optical study.

Simmons also explained that total system costs don't depend strongly on focal length and instrument performance. Rather, a large part of expenses is incurred in relatively fixed items such as test equipment and personnel. A cost estimation is planned for the MSP within the next two weeks. The team asked that similar estimates be made for alternative systems. Belton agreed to request such estimates from Project and Simmons agreed to provide them although perhaps not in such detail as the MSP estimate.

T. Reilly presented IPL pictures simulating the following compression/transmission situations:

Compression	Edition	Bit Error Rate
1:1	1:1	0
4:1	1:1	5×10^{-3} and 10^{-5}
2:1	2:1	5×10^{-3} and 10^{-5}
1:1	4:1	5×10^{-3} and 10^{-5}

He tentatively concluded that compression of 4:1 was not acceptable, even as a backup, and that therefore, some editing would be required. Reilly and B. Hartmann agreed to analyze the pictures in greater detail before the next meeting.

B. Murray announced his resignation from the Imaging Team. J. Naugle and I. Rasool agreed to try to eliminate the involvement of various advisory groups in the design of the Imaging System.

The Team held an executive session.

M. Belton distributed a draft of the science objectives portion of the final report. Team members are to review the draft and send comments to Belton. The following assignments were made for preparing the final report. M. Davies briefly reported on the activities of the Mission Analysis Group. A further meeting will be held in Tucson on 10 December to discuss sequencing.

1. C. Sagan - Scientific objectives (3A and B)
2. V. Suomi - Scientific priorities (3C)
   Incorporation of a line scanner (5A)
3. K. Aksnes - Trajectories (4)
4. A. Collins - Alternative systems (5A)
5. R. Krauss - Optics (5B)
6. M. Davies - Mission profiles (5C and D)
7. T. Reilly - Data handling (6)
8. B. Hartmann - Data handling (6)
9. T. Owen - Accessories (7)

OP SPACECRAFT MASS SUMMARY
JUN 79 MISSION
19 November 1971

	Kg.	Lbs.
STRUCTURAL SUBSYSTEMS	125.5	276.1
TELECOMMUNICATION SUBSYSTEMS	63.2	139.2
POWER	144.0	313.6
ATTITUDE & ARTICULATION CONTROL AND ATTITUDE PROPULSION	54.5	120.0
PROPULSION & PYROTECHNICS (275 m/sec)	105.6	231.8
CONTROL COMPUTER, COMMANDING AND TIMING	23.8	52.5
MEASUREMENT PROCESSOR	5.9	13.0
DATA STORAGE	40.0	88.0
CONTROL & CONDITIONING LOGIC	7.0	15.4
RADIATION SHIELDING FOR SCIENCE	7.0	15.4
SCIENCE	59.1	130.0
TOTAL SPACECRAFT	635.6	1395.0
ADAPTER	17.5	38.5
LAUNCHED MASS	653.1	1433.5
LAUNCH VEHICLE CAPABILITY	700.0	1540.0

DATA STORAGE OPTIONS

TWO TAPE RECORDERS AND 1/4 FRAME

- STORAGE CAPACITY SIZED TO MEET MISSION REQUIREMENTS.
- BLOCK AND FUNCTIONAL REDUNDANCY.
- REQUIRES 4:1 COMPRESSION OR EDITING OR DATA WHEN USING MEMORY.

ONE TAPE RECORDER AND 1/2 FRAME

- STORAGE CAPACITY SIZED TO MEET MISSION REQUIREMENTS.
- FUNCTIONAL REDUNDANCY ONLY (DEGRADED MODE POSSIBILITY).
- REQUIRES 2:1 COMPRESSION OR EDITING OF IMAGE DATA WHEN USING MEMORY.

FULL FRAME ONLY

- STORAGE CAPACITY LIMITED.
- NO REDUNDANCY - DEGRADED MODE OPERATION ONLY.
- TIME BETWEEN IMAGES OF SEQUENCE CONSTRAINED TO BE AS LARGE AS TRANSMISSION TIME.
- MAXIMUM TV READOUT RATE LESS CRITICAL.

DATA STORAGE OPTION PARAMETERS

DATA STORAGE CONFIGURATION	WEIGHT	POWER	COST	CAPACITY
2 TAPE RECORDERS AND 1/4 FRAME MEMORY	88	60	1330K	2×10^8
1 TAPE RECORDER AND 1/2 FRAME MEMORY	68	60	1150K	10^8
FULL FRAME MEMORY	25	11	880K	1.76×10^6

MM71 TAPE RECORDER AND OP MISSION

TWO YEAR SHELF LIFE

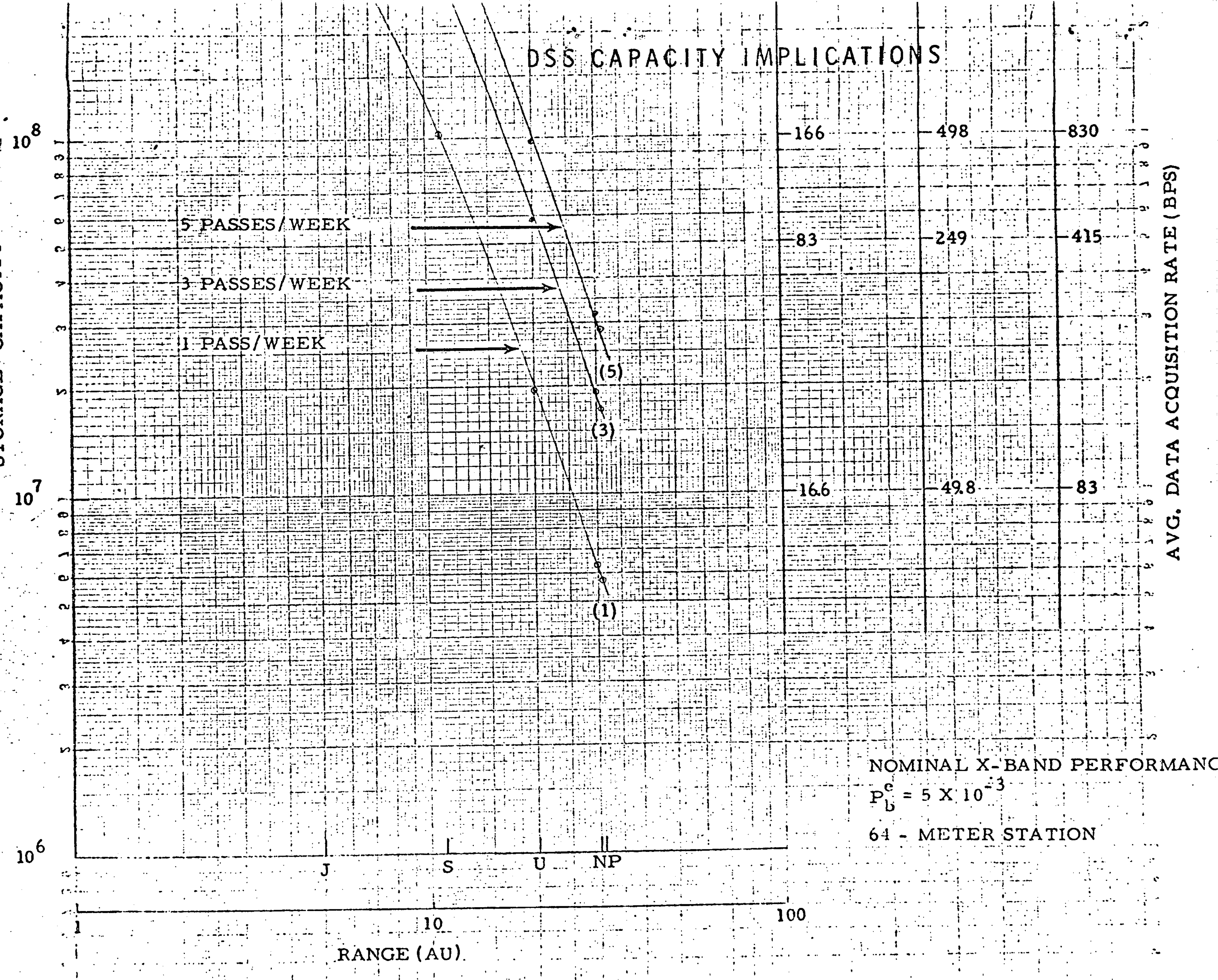
RECORD/PLAYBACK RANGE 131:1
FOR OPGT REQUIRE 655:1

300 RECORD/PLAYBACK CYCLES

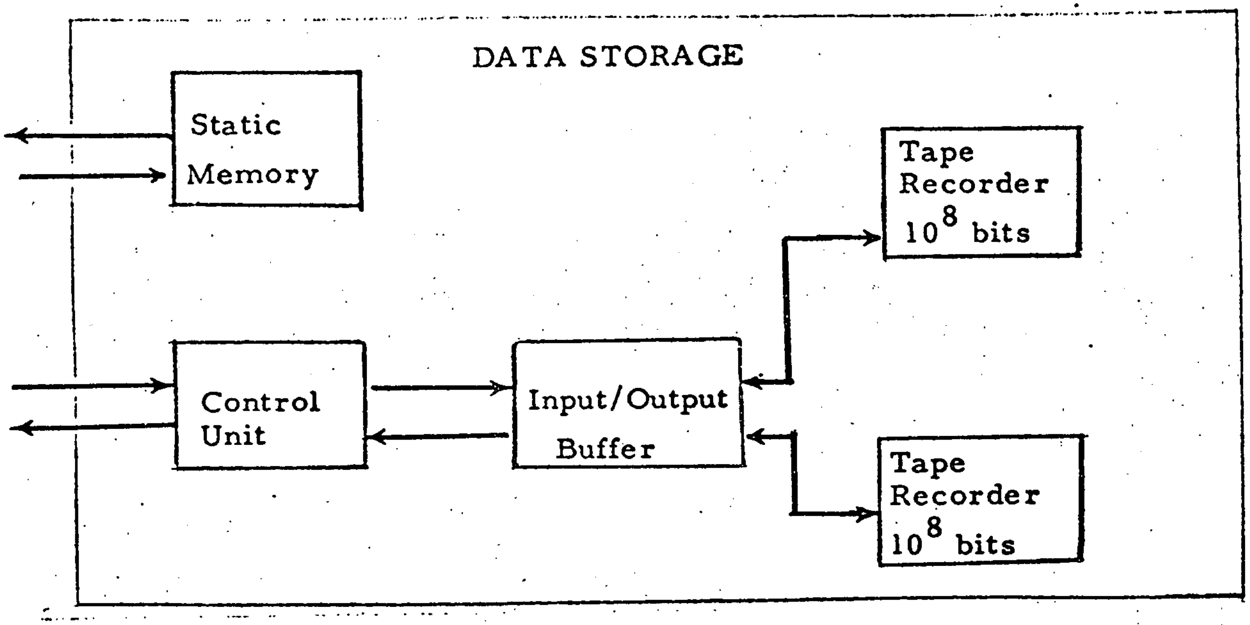
COMPLEX ELECTROMECHANICAL DESIGN WITH
MANY KNOW WEAR OUT MECHANICS.

DSS OPTIONS & IMAGING CAPABILITIES

	JUPITER	SATURN	URANUS	NEPTUNE PLUTO
TAPE RECORDER AND STATIC MEMORY				
IMAGE FRAMES	37/hr+100	7.4/hr+100	1.4/hr+100	0.45/hr+100
NON IMAGE	---	---	---	---
NON IMAGE	18,097 bps	3620 bps	675 bps	220 bps
IMAGE FRAMES	100	100	100	100
MEMORY ONLY				
IMAGE FRAMES	31/hr	7.2/hr	1.4/hr	0.45/hr
NON IMAGE AVG. RATE	1760 bps	46 bps	2.25 bps	0.18 bps


DSS CAPACITY IMPLICATIONS
STORAGE CAPACITY (BITS)
AVG. DATA ACQUISITION RATE (BPS)
10^8
10^7
10^6
5 PASSES/WEEK
3 PASSES/WEEK
1 PASS/WEEK
(5)
(3)
(1)
166
498
830
83
249
415
16.6
49.8
83
J
S
U
NP
1
10
100
RANGE (AU)
NOMINAL X-BAND PERFORMANC
$P_b^e = 5 \times 10^{-3}$
64 - METER STATION

DATA STORAGE DESIGN KIT



		WEIGHT	POWER	COST: UNIT	COST: DEVELOPMENT
STATIC	1/4 FRAME	7	4	220K	
MEMORY	1/2 FRAME	13.5	6	440K	522K
	FULL FRAME	25	11	880K	
CONTROL UNIT		20	16	150K	-
I/O BUFFER		10	3	160K	Included in static Memory
TAPE RECORDER (each)					
FLUID		26.5	37	400K	1240K
DRY		22	37	400K	730K

JET PROPULSION LABORATORY

INTEROFFICE MEMORANDUM

January 4, 1972

To: Distribution

From: A. Collins Andy

Subject: Minutes of 8th OPGT Imaging Science Team Meeting
December 16, 10:00 AM through 4:30 PM, 169-230
December 17, 9:00 AM through 12:30 PM, 186-128

Attendees: K. Aksnes, G. Bailey, M. Belton, T. Bird, A. Collins, M. Davies, B. Hartmann, P. Henry, R. Krauss, R. Millis, T. Owen, P. Penzo, T. Reilly, G. Root, C. Sagan, L. Simmons, G. Smith, L. Snyder, R. Stanton

The Team chose the following dates for future meetings:

Monday, January 10, 10:00 AM - noon, 169-531
Monday, January 10, 1:00 PM - 5:00 PM, 169-230
Tuesday, January 11, 9:00 AM - noon, 169-230

Thursday, February 17, 10:00 AM - 5:00 PM, 169-230
Friday, February 18, 9:00 AM - noon, 169-230

Thursday, March 16, 10:00 AM - 5:00 PM, 169-230
Friday, March 17, 9:00 AM - noon, 169-230

M. Belton told of recent developments regarding the PSC recommendations. He also reported that, at the last SSG meeting, representatives of some non-imaging experiments expressed great reluctance to operate without a tape recorder to accumulate cruise data.

L. Simmons described the imaging systems he proposed to evaluate and the analysis which would be performed. The Team accepted his recommendations (Attachment 1) but asked that the single camera system include an option for an unintensified silicon sensor. The Team considers the extended spectral response of this tube to be of great merit. Simmons accepted this request with the stipulation that analysis would include no cost estimates and performance estimates only on request.

G. Root explained his reliability analysis (Attachment 2). L. Snyder reported that the optics contract, which should be signed within a week, would cover both 1 meter and 2 meter options. The final report is due in early May, and an interim report will be submitted in early March. Snyder also described the optical filter contract which is being negotiated. T. Owen suggested the study include two narrow band (200 Å) filters centered at 6200 Å and 8900 Å. It was agreed to replace two wide-band filters with the recommended ones. G. Bailey described the current work to develop white reseaus in silicon targets (Attachment 3). A. Collins presented the proposed dielectric camera configuration (Attachment 4) from the CBS interim report. A synopsis of this report is included in Attachment 4.

It was agreed that, at the next Team meeting, L. Simmons would report the status of the system analysis efforts he had proposed.

The afternoon of December 16 and the morning of December 17 were devoted to the preparation of the Team's report in executive session.

AC:pb

Attachments

OPGT IMAGING TEAM DISTRIBUTION LIST

K. Aksnes - Smithsonian Obs.
K. J. Ando - 168-227
G. C. Bailey - 168-227
M. J. S. Belton - Kitt Peak
T. H. Bird (10) - 183-301
R. R. Bowman - 233-307
W. Brunk - NASA Headquarters
G. Cunningham - 233-307
M. E. Davies - RAND
R. F. Draper - 233-307
S. E. Dwornik - NASA Headquarters
R. F. Fellows - NASA Headquarters
T. W. Hamilton - 180-402
W. K. Hartmann - IITRI
R. L. Heacock - 180-805
R. Krauss - University of Wisconsin
R. Lockhart - 168-227
R. J. Mackin - 186-133
J. C. Mahoney - 168-227
R. Miles - 180-805
R. L. Millis - Lowell Obs.
M. A. Mitz - NASA Headquarters
B. C. Murray - Caltech
T. Owen - S. U. N. Y.
P. A. Penzo - 156-217
R. Piereson - 156-142
D. G. Rea - 180-404
T. H. Reilly - 168-227
W. B. Green - 168-427
T. Risa - 233-307
G. R. Root - 168-227
H. M. Schurmeier - 180-805
C. Sagan - Caltech
L. L. Simmons - 168-227
E. J. Smith - 183-401
G. M. Smith - 168-314A
M. I. Smokler - 168-227
R. H. Stanton - T-1152
V. E. Suomi - University of Wisconsin
C. C. Wertz - 233-307

Attachment 1

LLS 12/15/[illegible]

Outer Planets Imaging Exp.

Instrument Options

Improved MSP

- 2 M, 7" Narrow Angle Optics
- .3 M, 3" Wide Angle Optics
- Optical Switch
- Automatic Exposure Control
- Sensor Thermal Control
- MSP Cameraheads & Electronics

MSP

- 1 M, 7" Narrow Angle Optics
- .3M, 3" Wide Angle Optics
- MSP Cameraheads & Electronics

Reduced MSP

- (2) .5M, 5" Optics
- (2) MSP Si Cameraheads & Electronics

Imaging Team Inst

- 2M, 6" Narrow Angle Optics
- .3M, 3" Wide Angle Optics
- (1) MSP SIT Camerahead & Electronics

Dielectric Tape Camera

LLS 12/10/71

Outer Planets Imaging Experiment Options Description

Budget Estimate

Characteristics (weight, power, interfaces, etc.)

Preliminary Performance Analysis

Preliminary Reliability Analysis

Approach Guidance Capability

Attachment 2

WHITE RESEAU STUDY AT RCA

GOALS

TO DEVELOP A METHOD OF PRODUCING A WHITE RESEAU PATTERN ON THE SILICON TARGET

TO EVALUATE THE RELATIONSHIP BETWEEN RESEAU SIZE (ELECTRICAL) AND THE NUMBER OF MODIFIED DIODES IN THE TARGET STRUCTURE

TO DEVELOP COMPATIBILITY OF WHITE RESEAU PROCESSING STEPS WITH SILICON TARGET FABRICATION

G. Bailey
12/16/71

STUDY PROGRESS TO DATE

EXPERIMENTAL WHITE RESEAU MASK FABRICATION COMPLETE

FIRST WHITE RESEAU TARGET UNSUCCESSFUL BECAUSE OF MASK MISREGISTRATION DURING INTERMEDIATE PHOTOLITHOGRAPHIC STEP.

NEW WHITE RESEAU TARGET STRUCTURE FABRICATED AND READY FOR DEMOUNTABLE EVALUATION.

G. Bailey
12/16/71

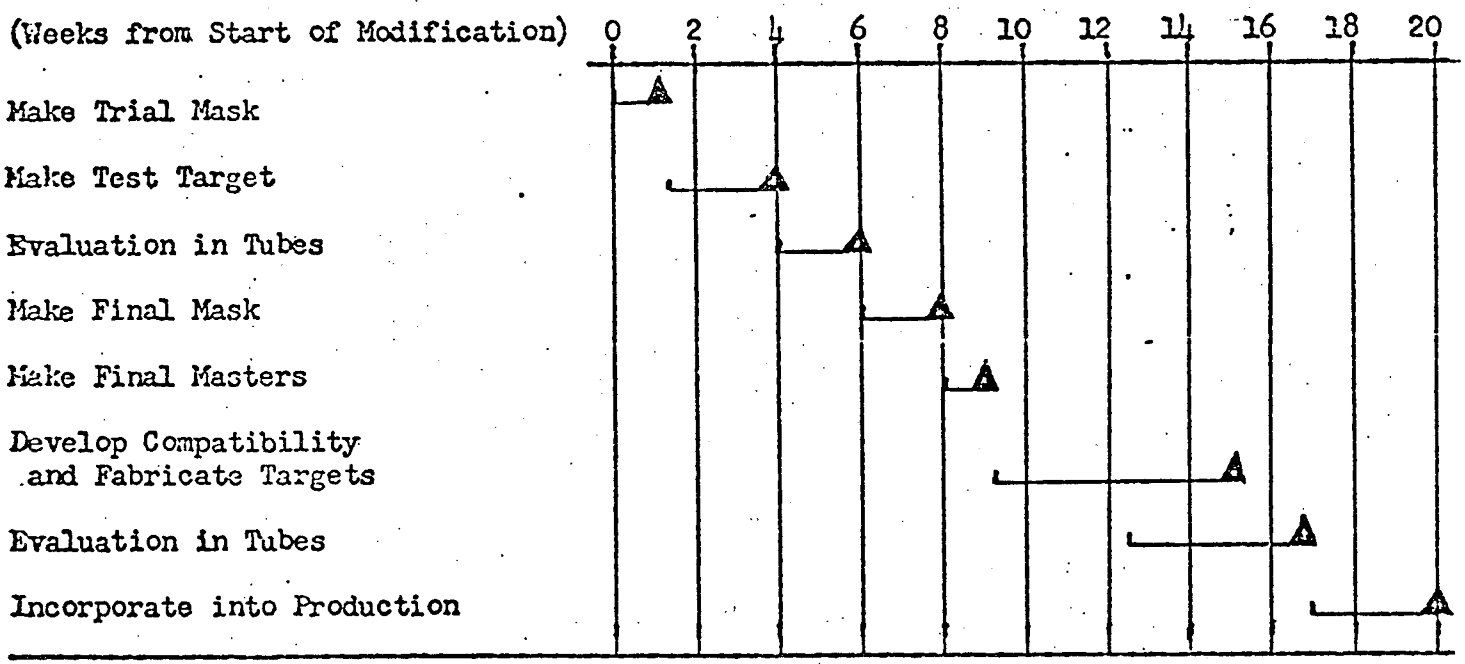
FUTURE PLANS

EVALUATE THE ELECTRICAL PROPERTIES OF EXPERIMENTAL WHITE RESEAU TARGETS FABRICATED.

DEVELOP COMPATIBILITY OF WHITE RESEAU PROCESSING STEPS WITH COMPLETE SILICON TARGET FABRICATION

G. Bailey
12/16/71

WHITE RESEAU STUDY SCHEDULE



November 1

G. Bailey
12/16/71

ASSUMPTIONS IMPLICIT IN STANDARD RELIABILITY ANALYSIS

NO NON RANDOM FAILURES

NO FAILURES DUE TO ENVIRONMENTAL FACTORS, e.g. RADIATION

NO FAILURES DUE TO PARAMETER DRIFT

NO WEAR OUT

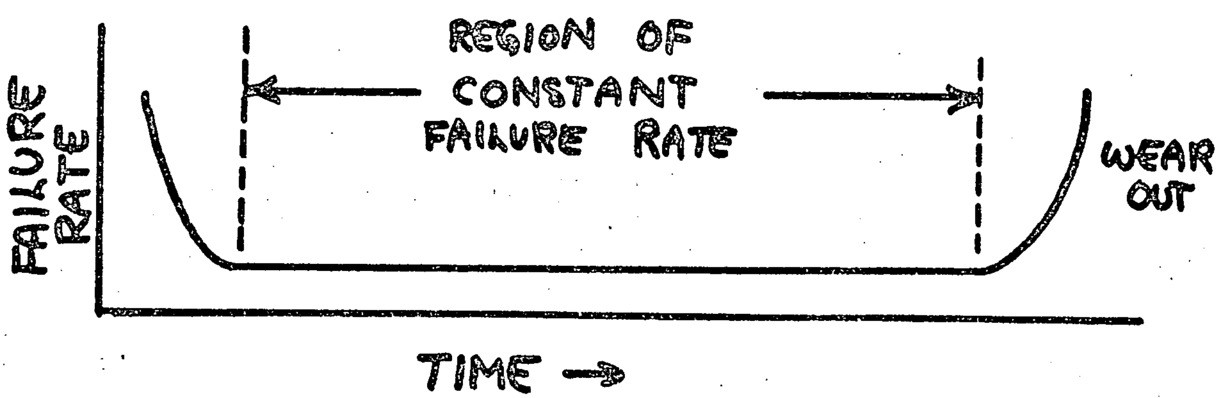


FIGURE 1

ESTIMATED OPGT SINGLE CAMERA FAILURE RATE

PART TYPE	NUMBER USED M'71	EST NUMBER OPGT	EST NUMBER /CAMERA	PART CLASS	EST % OF TOTAL	TOTAL PER CAMERA	TOPS FAILURE RATE (% /1000 HR)	TOTAL CLASS FAILURE RATE
CAPACITORS	478	574	287	MICA	25 %	72	0.0002	0.0144
				TANTALUM	75%	215	0.0003	0.0645
DIODES	483	580	290	SIGNAL	75%	217	0.0002	0.0434
				POWER	15%	44	0.0008	0.0352
				ZENER	10%	29	0.0004	0.0116
IC's	131	262	131	BP LINEAR	50%	66	0.009	0.5940
				BP LOGIC	50%	66	0.005	0.3300
RESISTORS	1260	1512	756	COMPOSITION	100%	756	0.00003	0.0227
TRANSISTORS	272	326	163	Sm SIGNAL	90%	147	0.0003	0.0441
				POWER	10%	16	0.001	0.0160
OTHER	12	14	7	-	-	7	0.001*	0.0070
CONNECTIONS	-	-	3300	-	-	3300	0.00001*	0.0330

TOTAL SINGLE CAMERA FAILURE RATE 1.216 (%/1000 HR)

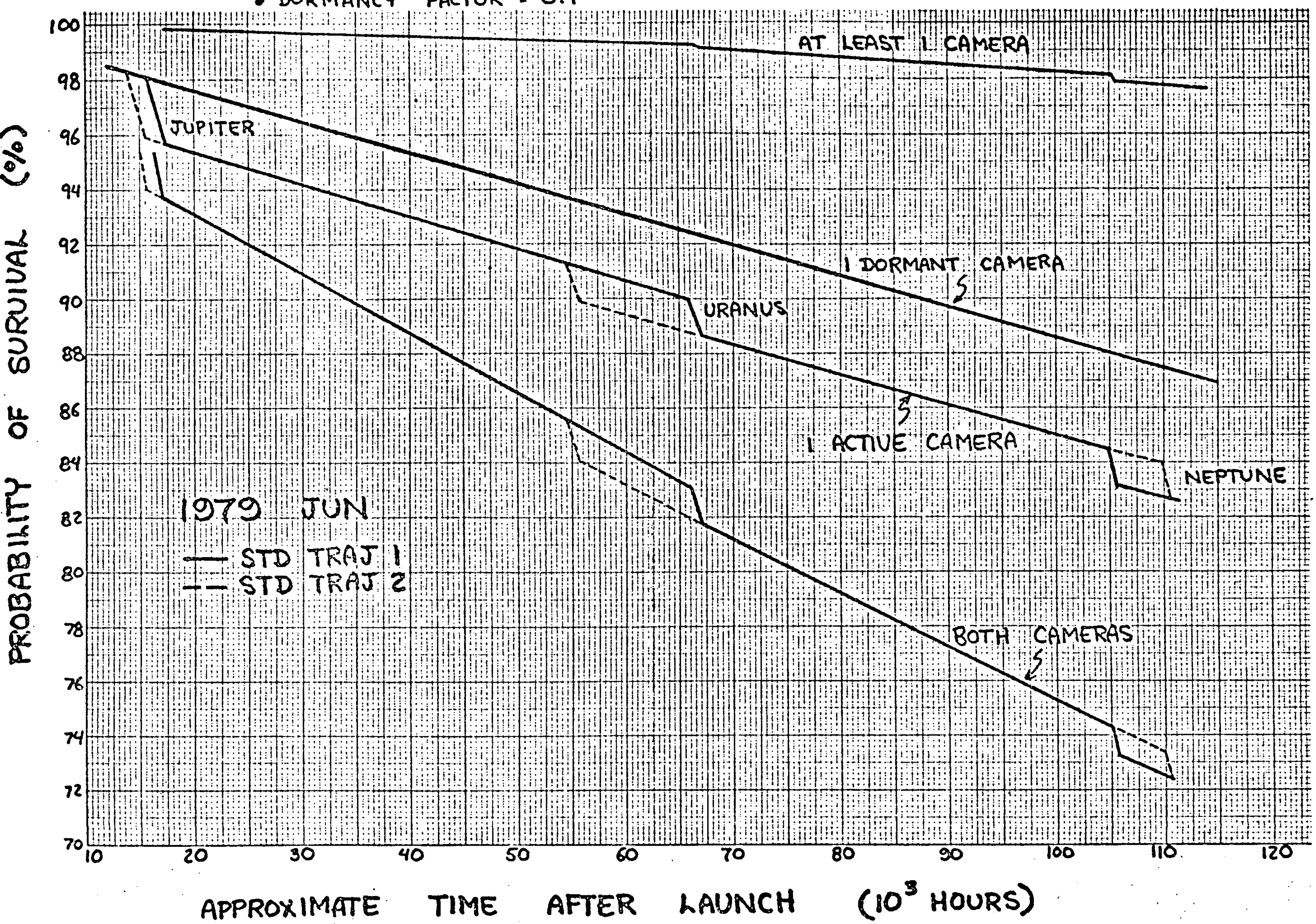
* ARBITRARY SELECTION

GRR
11-15-71

FIGURE 6

ESTIMATED PROBABILITY OF SURVIVAL FOR TWO CAMERA OPGT IMAGING SYSTEM

- SINGLE PART FAILURE CAUSES CAMERA FAILURE
- CONSTANT FAILURE RATE = 1.216 % / 1000 HOURS
- DORMANCY FACTOR = 0.1



Attachment 4

W. Porter

SUMMARY OF INTERIM REPORT ELECTROSTATIC CAMERA

FUNCTIONAL DESIGN STUDY

INTRODUCTION

The interim report describes the status of the electrostatic camera design study as of 5 December 1971. It is the purpose of the study to prepare a functional design and analysis for an electrostatic camera system. The technical effort to date has mainly been directed towards the identification of system functional block diagrams, functional block analysis, and the preparation of configuration drawings.

FUNCTIONAL BLOCK DIAGRAM

Work on the functional block diagram is 70% complete. As conceived, the basic camera tube fits previous descriptions, with the exception that the prime/erase gun has been eliminated. The prime/erase function will now be performed by the readout electron gun.

The video signal processing chain is a base band video system chosen because of the narrow bandwidth necessary for data transmission rates. An alternative to be considered will be a pulse amplitude modulation system as used on Mariner Mars 1971.

A single power supply will be used for the image section and another for the readout section, with all voltages obtained by dividers or methods that insure tracking of the tube voltages.

The scanning system involves a digital process utilizing a counter and digital to analog converter. As the counter counts up, the D/A converter converts the counter output to a ramp suitable for driving the deflection circuits. The scan rates may be varied to accommodate the various data transmission rates by varying the clock frequency supplied to the counters. In the prime/erase mode, the clock frequency will be increased to reduce the time required to erase the frame, but the rate will be limited by the deflection power requirements.

A simple storage drum with multiple-facets was selected for the storage section. A film transport with supply and take up reels was not required for only 30 frames of information. Several alternative storage drum drive mechanisms have been designed. An internal solenoid drive which activates an indexing ratchet mechanism when pulsed was chosen. The mechanism is similar in operation to the wide angle shutter mechanism used in Mariner Mars 1969. An alternate drive mechanism considered utilizes an external stepping motor.

One method under consideration for determination of drum position is a photo detector circuit consisting of photo transistors positioned opposite light emitting diodes. The storage drum which contains a series of coded holes will be interposed between these detection elements and position will be indicated by the alignment of the holes with the light emitting diodes.

Several alternative automatic exposure control systems have been considered. The method used on Mariner Mars 1971 suffers from the limitation that the exposure is set during the previous frame. The alternative under consideration sets the automatic exposure during exposure of the frame between recorded. During exposure, the photocathode current is sensed, integrated, and compared to an exposure reference. When the integrated photocathode current equals the reference, the shutter is closed.

The method of calibration has not yet been selected. Use of an extended source has not been rejected as a reasonable method.

FUNCTIONAL BLOCK ANALYSIS

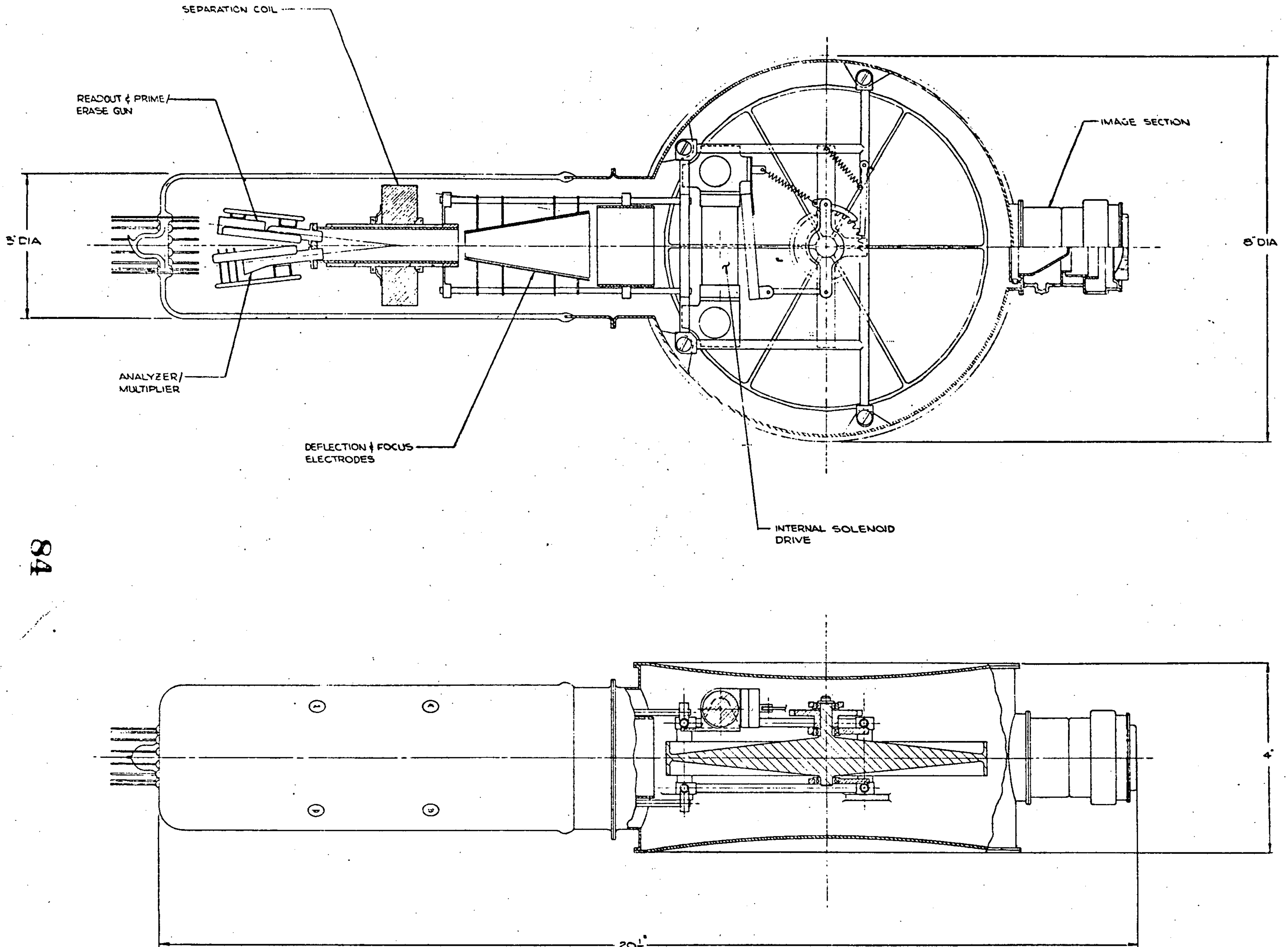
Work on the functional block analysis is 50% complete. Values for the various camera operating parameters are being selected on the basis of the SNR, exposure, storage and readout requirements.

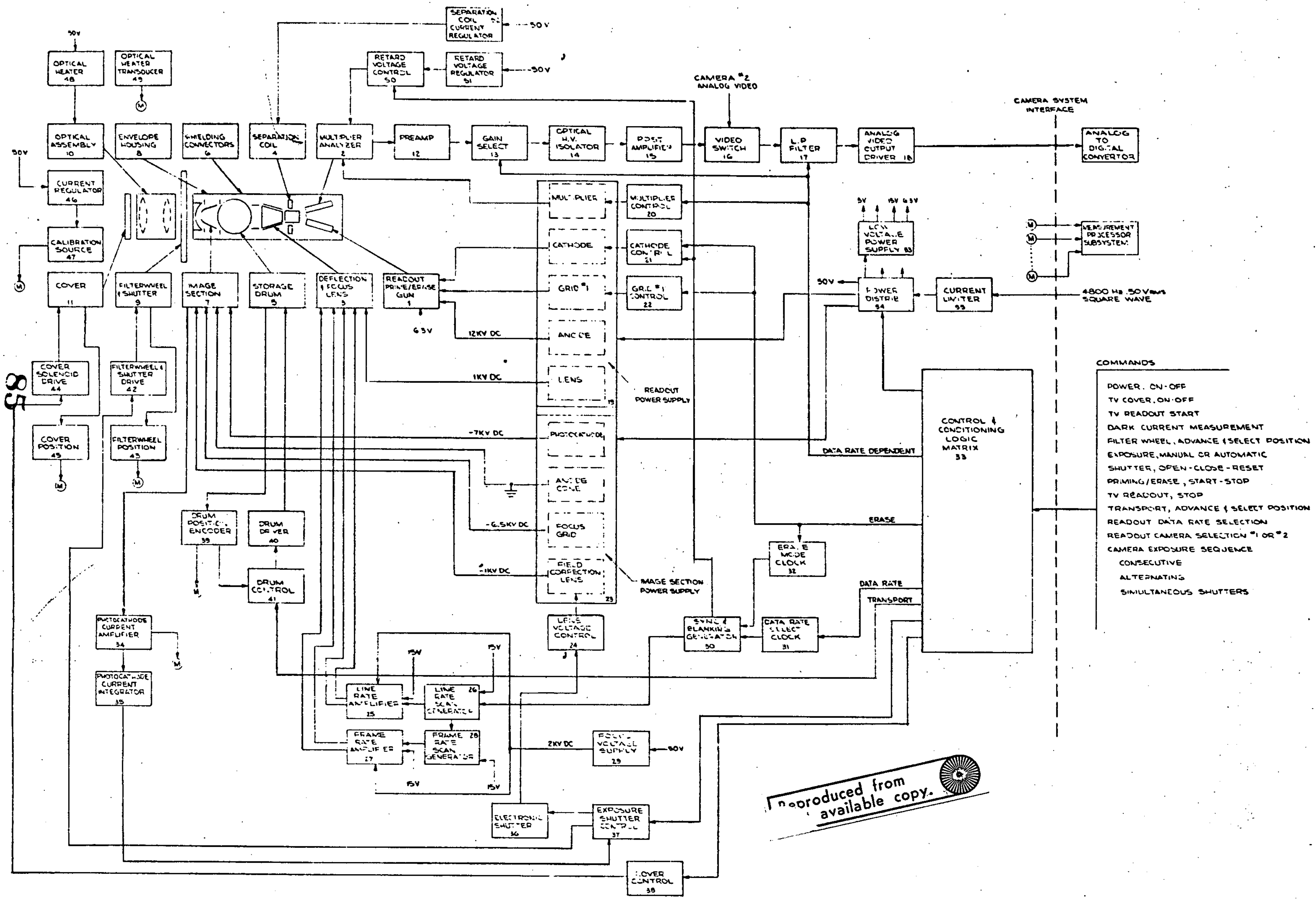
The corresponding exposure requirements have been established. Results show that for a photocathode having an average sensitivity of 200 μA/lumen (4800°K), exposures of 3.8×10^{-2} ergs/cm^2 and 1.5×10^{-1} ergs/cm^2 are needed for SNR's of 50:1 and 100:1 respectively. (In these calculations, a quantum efficiency of 7% was used and the mean photon energy was associated with a wavelength of 600 nanometers). These exposure values assumed 100% light transmission through the fiberoptics faceplate. Transmission data on fiberoptics faceplates indicate, however, that transmission losses of $\sim 1/3$ are typical. In addition, the sensor response will decrease the effective signal and there will be additional noise sources. In practice, therefore, the required exposure will be longer than the values stated above.

Use of an electromagnetic image section in the electrostatic camera would reduce the exposure requirements, because a fiberoptics faceplate would not be required. The exposure values stated above would then apply.

CONFIGURATION DRAWINGS

Preliminary configuration drawings of the camera system are being prepared. Work is 50% complete. The basic camera tube has been designed and is shown in drawing #457723. Designs for the camera housing, shielding, mountings, and electronics package have not yet been configured. The functional block analysis of the electronic circuits must be completed before configuration drawings of the system's electronic package can be accurately defined.


SEPARATION COIL
READOUT & PRIME/
ERASE GUN
IMAGE SECTION
3" DIA
8" DIA
ANALYZER/
MULTIPLIER
DEFLECTION & FOCUS
ELECTRODES
INTERNAL SOLENOID
DRIVE
4"
20½"


SEPARATION COIL CURRENT REGULATOR
50 V
OPTICAL HEATER 48
OPTICAL HEATER TRANSDUCER 49
RETARD VOLTAGE CONTROL 50
RETARD VOLTAGE REGULATOR 51
-50V
CAMERA #2 ANALOG VIDEO
CAMERA SYSTEM INTERFACE
OPTICAL ASSEMBLY 10
ENVELOPE HOUSING 8
SHIELDING CONNECTORS 6
SEPARATION COIL 4
MULTIPLIER ANALYZER 2
PREAMP 12
GAIN SELECT 13
OPTICAL H.V. ISOLATOR 14
POST AMPLIFIER 15
VIDEO SWITCH 16
L.P. FILTER 17
ANALOG VIDEO OUTPUT DRIVER 18
ANALOG TO DIGITAL CONVERTOR
50V
CURRENT REGULATOR 46
CALIBRATION SOURCE 47
MULTIPLIER
MULTIPLIER CONTROL 20
CATHODE
CATHODE CONTROL 21
GRID #1
GRID #1 CONTROL 22
ANODE
LENS
READOUT POWER SUPPLY
19
5V 15V 6.3V
LOW VOLTAGE POWER SUPPLY 53
MEASUREMENT PROCESSOR SUBSYSTEM
POWER DISTRIB 54
CURRENT LIMITER 55
4800 Hz 50 Vrms SQUARE WAVE
COVER 11
FILTERWHEEL & SHUTTER 9
IMAGE SECTION 7
STORAGE DRUM 5
DEFLECTION & FOCUS LENS 3
READOUT PRIME/ERASE GUN 1
6.3V
12KV DC
1KV DC
COVER SOLENOID DRIVE 44
FILTERWHEEL & SHUTTER DRIVE 42
COVER POSITION 45
FILTERWHEEL POSITION 43
-7KV DC
PHOTOCATHODE
ANODE CONE
-6.5KV DC
FOCUS GRID
-1KV DC
FIELD CORRECTION LENS
IMAGE SECTION POWER SUPPLY
23
DRUM POSITION ENCODER 39
DRUM DRIVER 40
DRUM CONTROL 41
DATA RATE DEPENDENT
ERASE
ERASE MODE CLOCK 32
DATA RATE
TRANSPORT
CONTROL & CONDITIONING LOGIC MATRIX 33
COMMANDS
POWER, ON-OFF
TV COVER, ON-OFF
TV READOUT START
DARK CURRENT MEASUREMENT
FILTER WHEEL, ADVANCE & SELECT POSITION
EXPOSURE, MANUAL OR AUTOMATIC
SHUTTER, OPEN-CLOSE-RESET
PRIMING/ERASE, START-STOP
TV READOUT, STOP
TRANSPORT, ADVANCE & SELECT POSITION
READOUT DATA RATE SELECTION
READOUT CAMERA SELECTION #1 OR #2
CAMERA EXPOSURE SEQUENCE
CONSECUTIVE
ALTERNATING
SIMULTANEOUS SHUTTERS
PHOTOCATHODE CURRENT AMPLIFIER 34
PHOTOCATHODE CURRENT INTEGRATOR 35
LENS VOLTAGE CONTROL 24
SYNC & BLANKING GENERATOR 30
DATA RATE SELECT CLOCK 31
15V
LINE RATE AMPLIFIER 25
LINE RATE SCAN GENERATOR 26
FRAME RATE AMPLIFIER 27
FRAME RATE SCAN GENERATOR 28
2KV DC
FOCUS VOLTAGE SUPPLY 29
ELECTRONIC SHUTTER 36
EXPOSURE SHUTTER CONTROL 37
COVER CONTROL 38

JET PROPULSION LABORATORY | INTEROFFICE MEMO

June 28, 1971

TO: Distribution

FROM: T. H. Reilly

SUBJECT: Minutes of the OPGT Optics and Sensor Committee Meetings, June 22, 1971, JPL.

OPTICS

Attendees

M. J. S. Belton - Kitt Peak
M. E. Davies - RAND
R. Klein - JPL
L. Larks - JPL
R. Lockhart - JPL
T. Reilly - JPL
G. Root - JPL
L. Simmons - JPL
G. M. Smith - JPL
L. Snyder - JPL
V. Suomi - University of Wisconsin
A. T. Young - JPL (for T. Owen)

Science Requirements on Optics

M. Belton reviewed the conclusions reached by the OPGT Science Committees in their draft report:

1. The scientific objectives fall into three categories: Major Planets, Satellites (including Rings and Pluto), and Other (asteroids, approach guidance, etc.). The various categories levy different performance requirements on the imaging system.

2. The camera performance required to meet the Major Planet objectives is a combination of resolution, single frame spatial coverage, and "contiguous" temporal coverage.

3. The camera performance required to meet the Satellite objectives is a combination of high resolution and coverage of a significant fraction of the satellite surface.

4. The several missions offer an opportunity to do comparative studies of planets and satellites, leading to a more profound understanding than would an encounter with a single object. The multiple encounters require a flexible imaging system.

5. Although a large amount of data on the outer planets is available, this data has not led to an understanding of these bodies. This is due to the fact that earth-based data falls below the threshold of resolution, spatial coverage, and temporal coverage needed for scientific measurement.

Charts summarizing the science requirements on imaging system performance were distributed. These indicated that a large picture format is needed for Major Planet studies, and very high resolution (= long focal length) is needed for satellite pictures.

It was recognized that the science requirements must be applied to the combination of sensor and optics, i.e., the optical system will be optimized differently for various types of sensor.

Focal Length Limitations

In view of the need for a long focal length (FL) telescope, an effort was made to determine if there is an upper limit to available FL's imposed by engineering constraints. Three types of limit were identified:

1. Tolerance Problem - L. Snyder distributed the results of a study on the performance of long FL Cassegrain telescopes (ATTACHMENT 1 of these minutes). Plots of diffraction - limited MTF were compared with the MTF resulting from small longitudinal displacements of the secondary mirror. Snyder estimated that secondary mirror displacement due to temperature changes will be on the order of 0.001 inch. He concluded that at very long FL (> 8 m), even diffraction - limited telescope performance would not be sufficient due to the high f/numbers which result. At shorter FL, there is a trade off between the tolerance which must be held and the physical length of the telescope. For shorter barrel lengths, the tolerances get very tight. Snyder cautioned that most of his plots were calculated for λ in the middle of the visible spectrum. The performance will fall off linearly with increasing wavelength.

   M. Davies proposed the use of active focusing, i.e., the secondary mirror would be moved to compensate for dimensional change due to temperature. The major difficulty with such a system is the need for an automatic sensor to control the movement. The experimenter could not expect to participate in the focusing operation because of the long round trip radio time to the spacecraft.

2. Pointing Problem - M. Belton estimated that we would want a field of view (FOV) at least three times greater than the pointing uncertainty of the scan platform. At present, it appears that the TOPS pointing uncertainty is a little greater than 0.1 degree. For the sensors in the TOPS baseline camera, the FOV is given by

$$\text{FOV}\begin{pmatrix}\text{full angle}\\ \text{in degrees}\end{pmatrix} \approx \frac{1}{\text{FL (in meters)}}$$

Thus, the pointing uncertainty restricts us to FL's shorter than 3 meters.

There are some ways to get around this problem. First, it may be possible to refine the pointing of the scan platform through hardware changes. Second, if a sensor with format larger than the 18 mm square baseline vidicons could be used, the above relation would not apply, and the pointing problem would be eased. Third, pointing error could be reduced through use of some auxiliary device such as a rather sophisticated far encounter planet sensor (FEPS) or even a wide angle camera.

3. Field of View Problem - Apart from the pointing problem, there are scientific reasons for having an adequate FOV. Again, this can be achieved by shortening the FL or using a sensor of wide format.

M. Belton concluded that, from an engineering point of view, there are a lot of reasons not to exceed 3 meters FL. On the other hand, the resolution required for the science argues for nothing shorter than 4 meters. These numbers will require some study and refinement, and eventually a compromise will be reached. However, the Imaging Team will be required to assume some focal length and some sensor when doing trajectory studies and planning picture sequences, so we must settle on some nominal numbers for this purpose. At the last Team meeting, it was agreed that the TOPS baseline sensors would also be the Imaging Team baseline sensors, at least until some better choice became available. Belton now proposes that the nominal FL be set at 4 meters for the narrow angle camera. This number is reasonably consistent with the science objectives, and with some engineering effort, might prove to be workable.

Imaging System Configuration

The science objectives report indicates that most of the science will be done with the narrow angle (NA) camera. This leaves open the question of whether a wide angle (WA) camera is needed. In choosing a system configuration, the matter of redundancy must also be considered.

The major argument for a WA camera is based on the likelihood that the NA camera will have a small format. High resolution pictures of cloud structure will not be very useful if the format is too limited. Both Suomi and Belton feel it may be necessary to have the high resolution pictures nested in pictures of lower resolution but greater coverage.

Use of a wide angle camera also affects the redundancy. The WA camera requires a less sensitive image tube than does the NA. Thus, there could be redundancy in sensor type as well as number.

Four possible camera configurations were sketched by Belton:

1. One on-axis NA telescope feeding two identical sensors (presumably SIT's).

2. One NA and one WA telescope, two different sensors, either sensor usable with either telescope.

3. One clear aperture telescope with interchangeable secondaries to provide variable FL. The one telescope operates with two or three sensors.

4. One NA telescope feeding one sensor. Attached to the front of the NA telescope, a very simple WA mirror focused on a second sensor.

Belton's enthusiasm was for System 3 because of its obvious flexibility. JPL engineers leaned toward System 1 because it is less complicated, or even System 0 which was not sketched, but which consists of the traditional NA-WA arrangement.

Optics Study

It was concluded that the optics problems were such that we could benefit from the separately funded optics study discussed at previous Team meetings. The work would be done by a contractor under JPL supervision. The exact nature of the study was not determined. L. Simmons agreed to accept the task of defining the study. He expects to have a rough definition of the tasks by July 15 for the Imaging Team review. A detailed statement of work would follow in August.

SENSOR

DIELECTRIC TAPE PRESENTATION

Attendees

K. Ando - JPL
G. Bailey - JPL
M. J. S. Belton - Kitt Peak

R. Bottacelli - CBS
F. Cook - CBS
M. E. Davies - RAND
R. Klein - JPL
R. Lockhart - JPL
T. Reilly - JPL
G. Root - JPL
R. Rutherford - CBS
L. Simmons - JPL
G. M. Smith - JPL
M. I. Smokler - JPL
L. Snyder - JPL
V. Suomi - University of Wisconsin

Presentation by CBS

The meeting was given over to a presentation by CBS Laboratories on the dielectric tape camera system. Material used in the presentation is included in these minutes as ATTACHMENT 2. Page 2 of the handout compares the TOPS BASELINE camera with the dielectric tape Image - Data Storage Unit (IDSU).

The major advantages of the dielectric tape camera are as follows:

1. Larger format and higher scan line density than the TOPS baseline cameras. The format could probably be extended to a 3000 x 3000 frame. The higher line density results in higher resolution for a given focal length than is available with the baseline television system.

2. The dielectric tape system provides its own storage, thereby obviating the large rate buffer and at least one of the tape recorders on the spacecraft.

3. The system could provide for variable resolution readout and non-destructive readout. This would permit low resolution scans of all the stored data followed by high resolution readout of selected frames.

4. The tape can be read out at variable data rate. Thus, the camera can match its data rate to the telemetry system at any point in the mission without an intermediate buffer.

The major disadvantages of the dielectric tape camera system are as follows:

1. The camera itself does not exist; only the key components have been built. The same can be said of the baseline television system, but the TV is a much smaller departure from the existing systems than is the dielectric tape camera.

2. The dielectric tape system requires moving parts (motor, rollers with bearings) inside the vacuum envelope.

3. No life, vibration, or radiation data of any substance.

4. Weight, power, and size of a flight model unknown, even approximately.

Participants at the meeting generally agreed that <u>if</u> the budget and the schedule permitted, it would be desirable to pursue this system. CBS indicated that a breadboard camera could be built in one year, and the cost of doing this was discussed.

No attempt was made to reach a conclusion on the matter. L. Simmons and T. Reilly were asked to assess the performance and the feasibility of building the dielectric tape camera on schedule. They are to report at the next Team meeting. If the system still looks attractive, we must then address the budget question.

CBS was asked about a modification suggested by B. Murray, namely, a tube with a single fixed dielectric tape target. CBS thought that such a device could be made by depositing the dielectric on a transparent (to electrons) substrate. However, they thought it would not be much more difficult to go the whole way and use movable tape.

THR:ldn

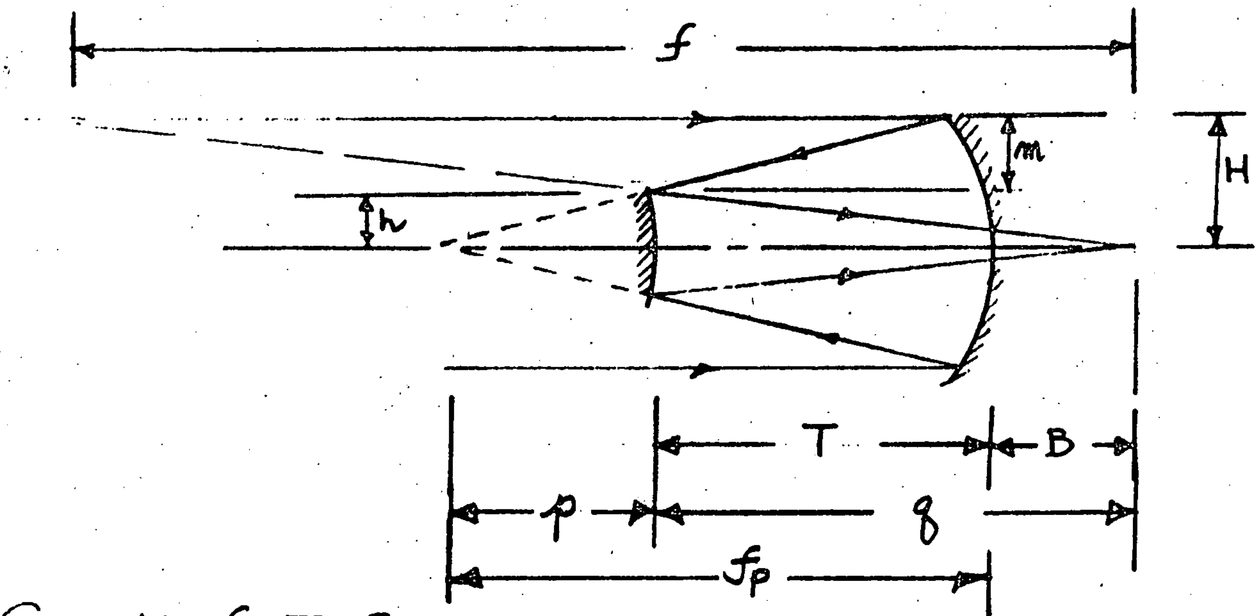
Distribution:

OPGT Imaging Distribution List I
OPGT Imaging Science Team

OPGT OPTICS REVIEW

ATTACHMENT 1

22 JUNE 71



GIVEN: f, T, B

LET p AND q BE UNDIRECTED SEGMENTS

$$q = T + B \qquad (1)$$

$$\frac{f}{H} = \frac{q}{h}$$

$$\frac{h}{H} \triangleq OBS = \frac{q}{f} \qquad (2)$$

$$\frac{p}{h} = \frac{T}{m}$$

$$p = \frac{Th}{m}, \quad m = H - h$$

$$p = \frac{Th}{H-h} = \frac{T}{\frac{H}{h} - 1} = \frac{T}{\frac{1}{OBS} - 1} \qquad (3)$$

$$\frac{1}{f_s} = -\frac{1}{p} + \frac{1}{q}$$

$$f_s = \frac{pq}{-q+p} \qquad (4)$$

$$R_s = 2f_s \qquad (5)$$

$$e_s = \frac{q+p}{q-p} \qquad (6)$$

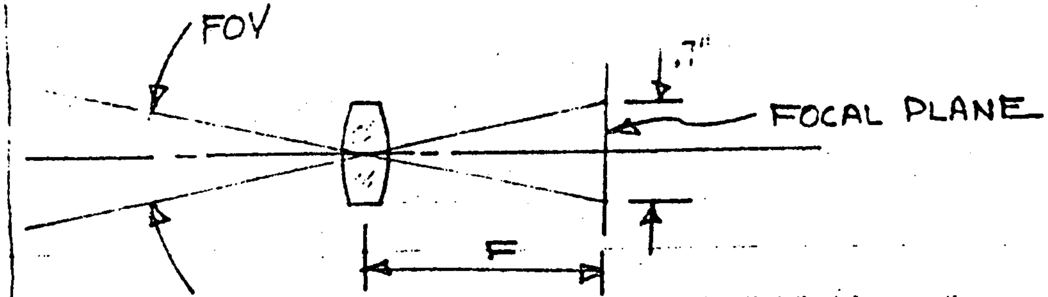
$$e_p = 1 \qquad (7)$$

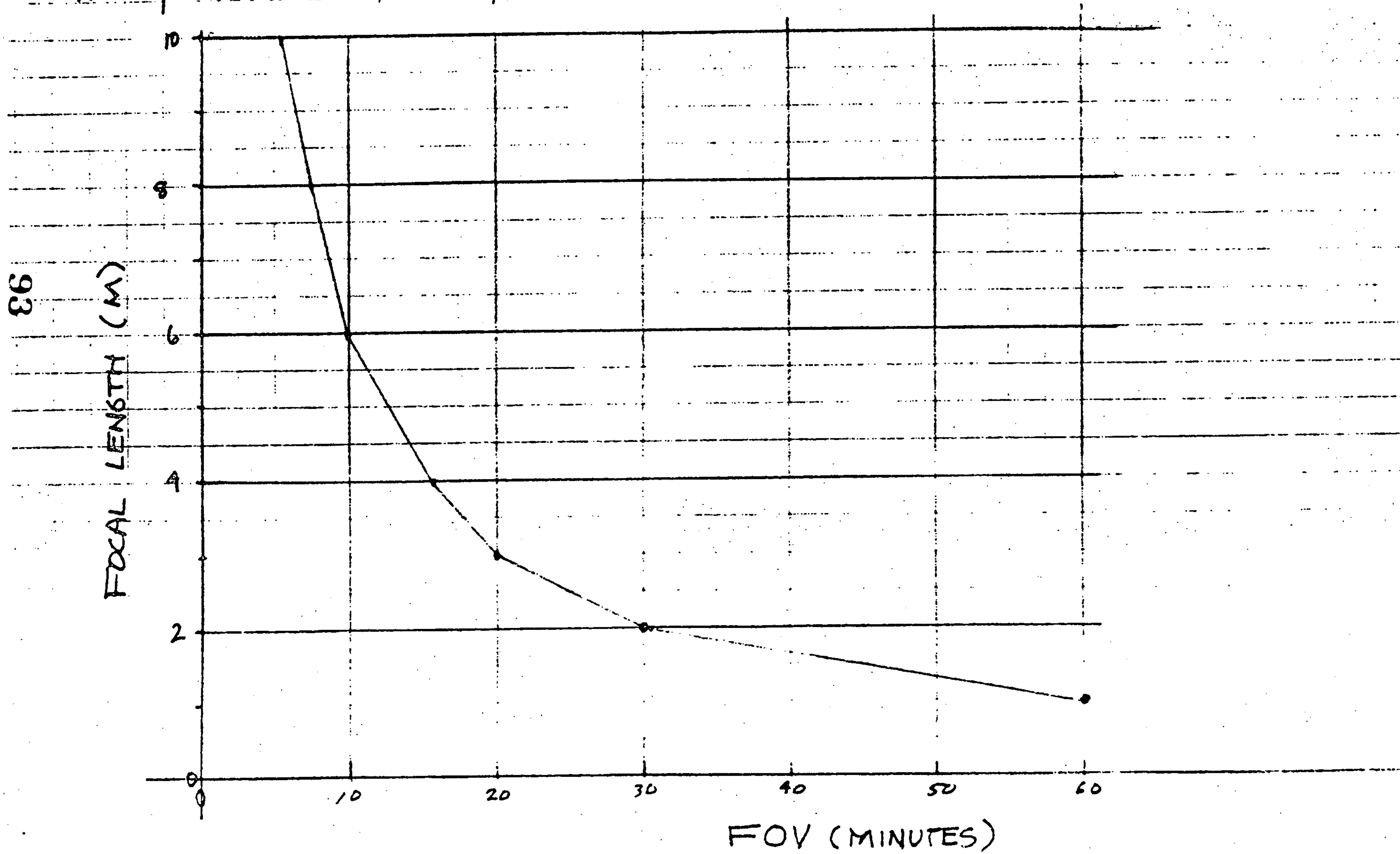
$$f_p = T + p = \frac{T}{1 - OBS} \qquad (8)$$

$$R_p = -2f_p \qquad (9)$$

$$\frac{q}{p} = \frac{f}{f_p} = m \qquad (10)$$

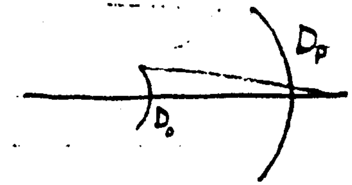
		tan FOV	FOV
1 M	39.4	.01776	1°
2 M	79	.00886	30'
3 M	118	.00593	20'
4 M	157	.00445	15.3'
6 M	236	.00296	10'
8 M	315	.00222	7.5'
10 M	394	.00177	6'





6-15-71

Cen'l Obscuration $\frac{D_o}{D_p}$ assuming 3" back f. ls



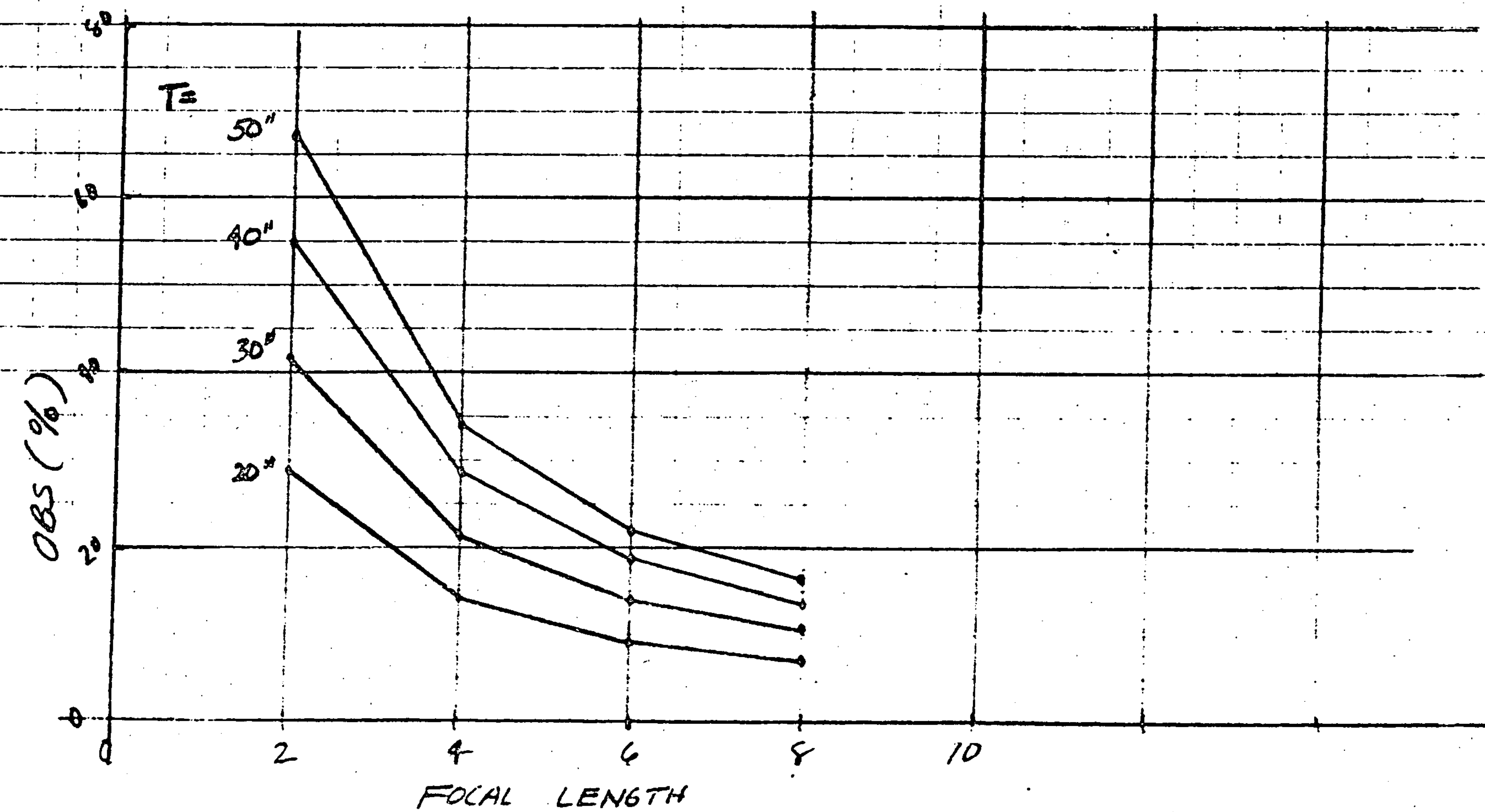
Diam / Obsc

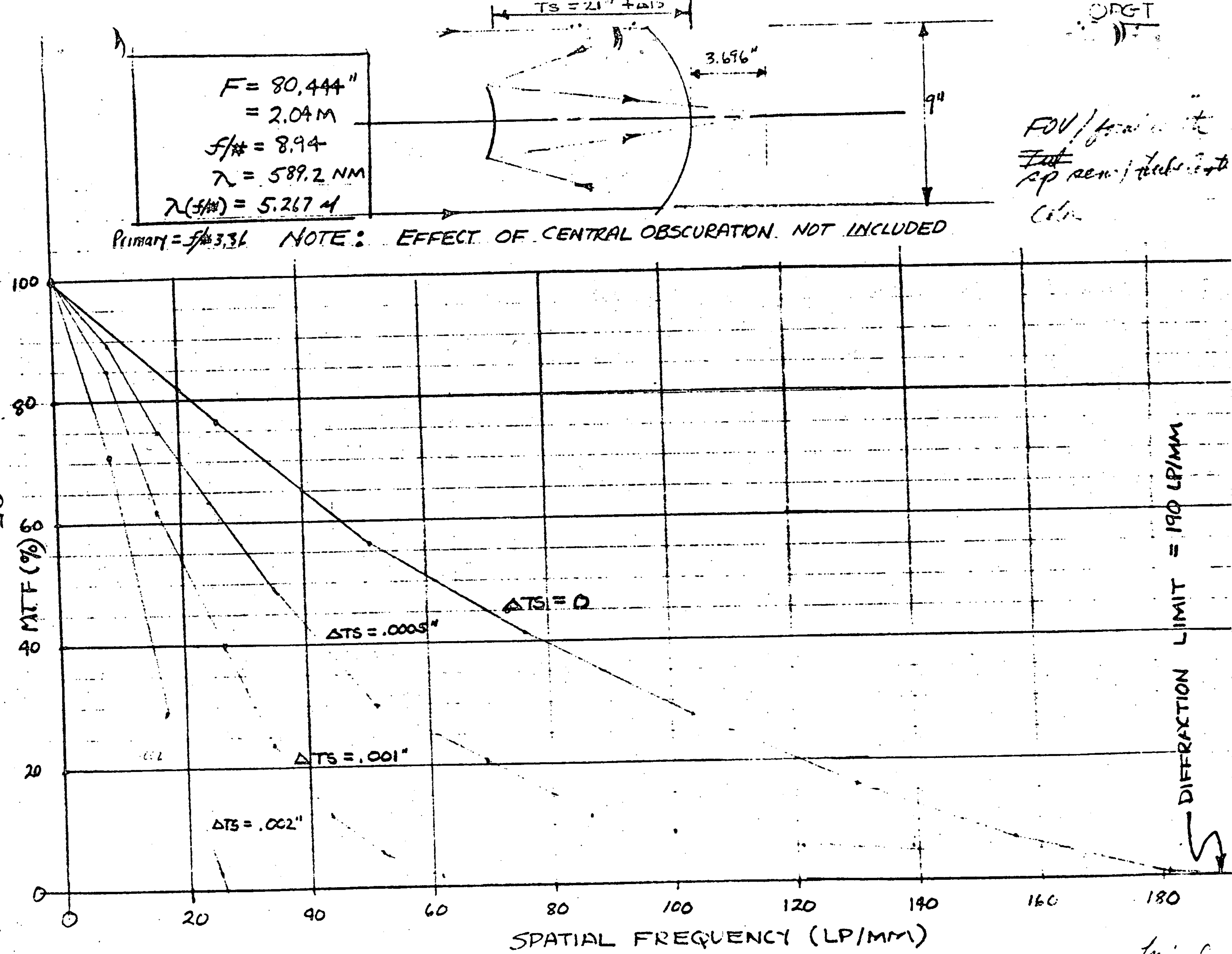
$q = T + B$

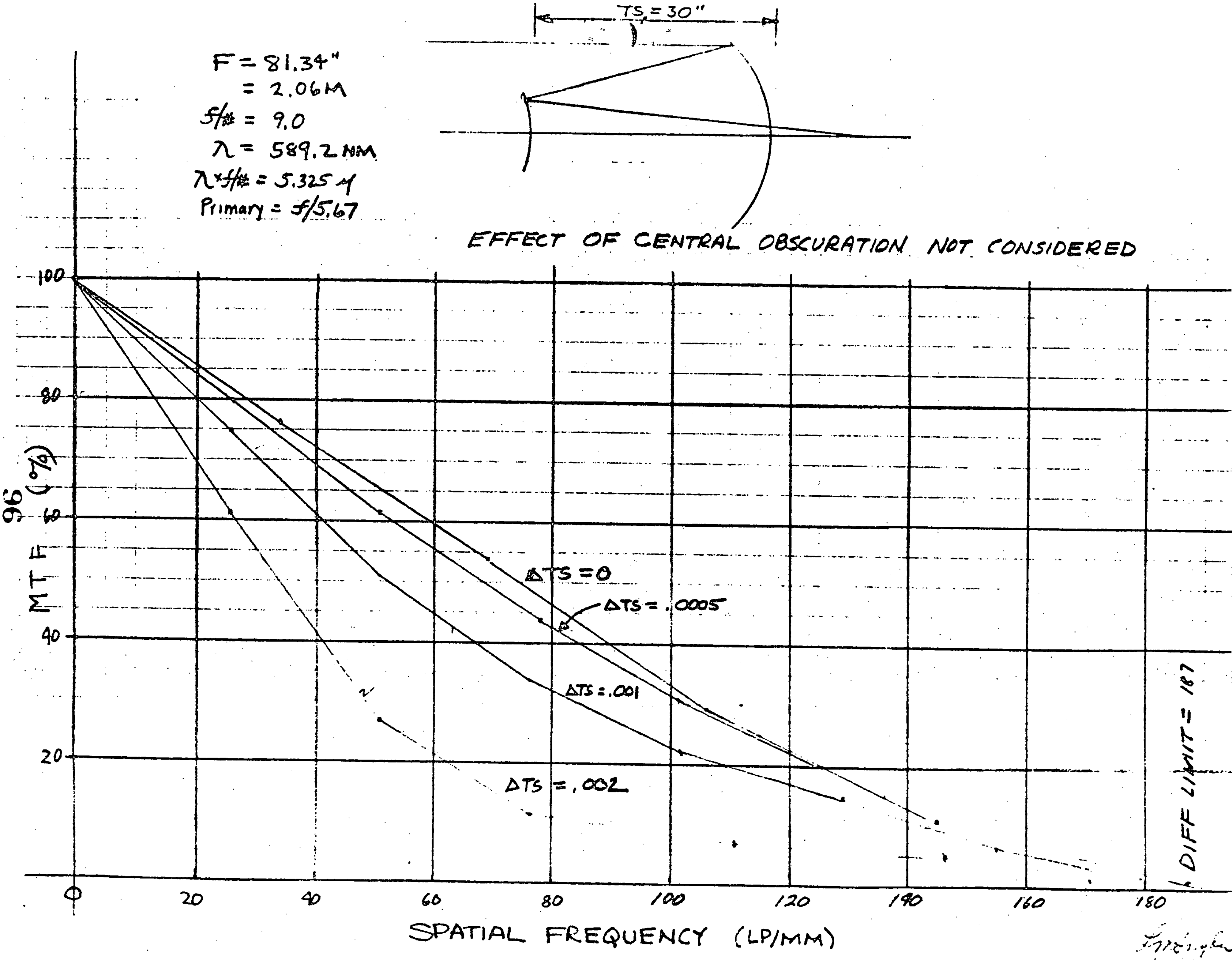
$obs = q / F$

let T = 20", q = 23" = .585 M: F	OBS	let T = 30", q = 33" = .84 M: F	OBS	let T = 40", q = 43" = 1.08 M: F	OBS	let T = 50", q = 53" = 1.35 M: F	OBS
2	29%	2	42%	2	55%	2	67%
4	14.5	4	21%	4	27%	4	34
6	9.7	6	14%	6	18%	6	22.5
8	7.3	8	10.5%	8	13.6%	8	17

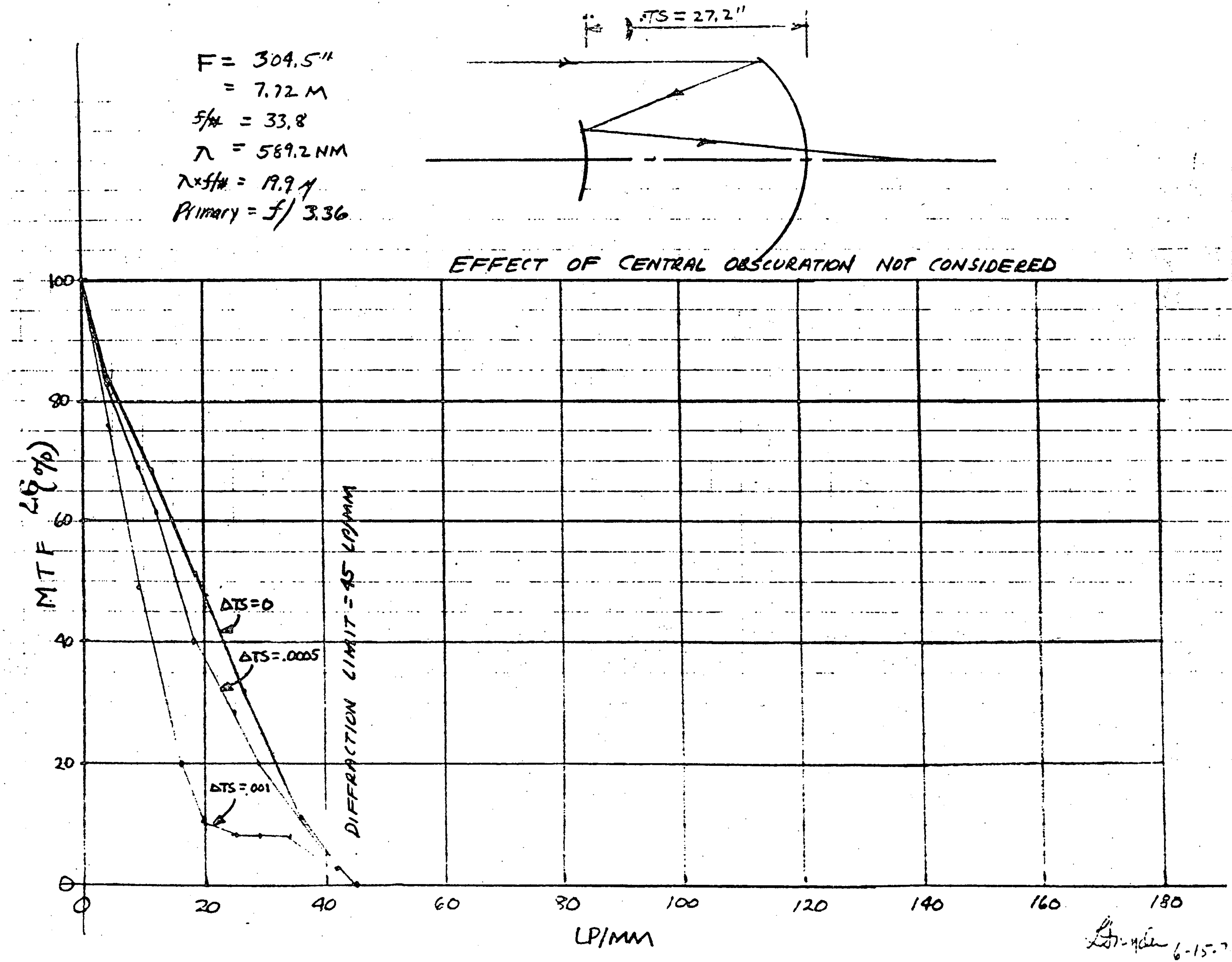
94




TS = 21" + ΔTS
3.696"
9"
F = 80.444"
= 2.04 M
f/# = 8.94
λ = 589.2 NM
λ(f/#) = 5.267 μ
Primary = f/# 3.36
NOTE: EFFECT OF CENTRAL OBSCURATION NOT INCLUDED
ΔTS = 0
ΔTS = .0005"
ΔTS = .001"
ΔTS = .002"
MTF (%)
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
180
SPATIAL FREQUENCY (LP/MM)
DIFFRACTION LIMIT = 190 LP/MM

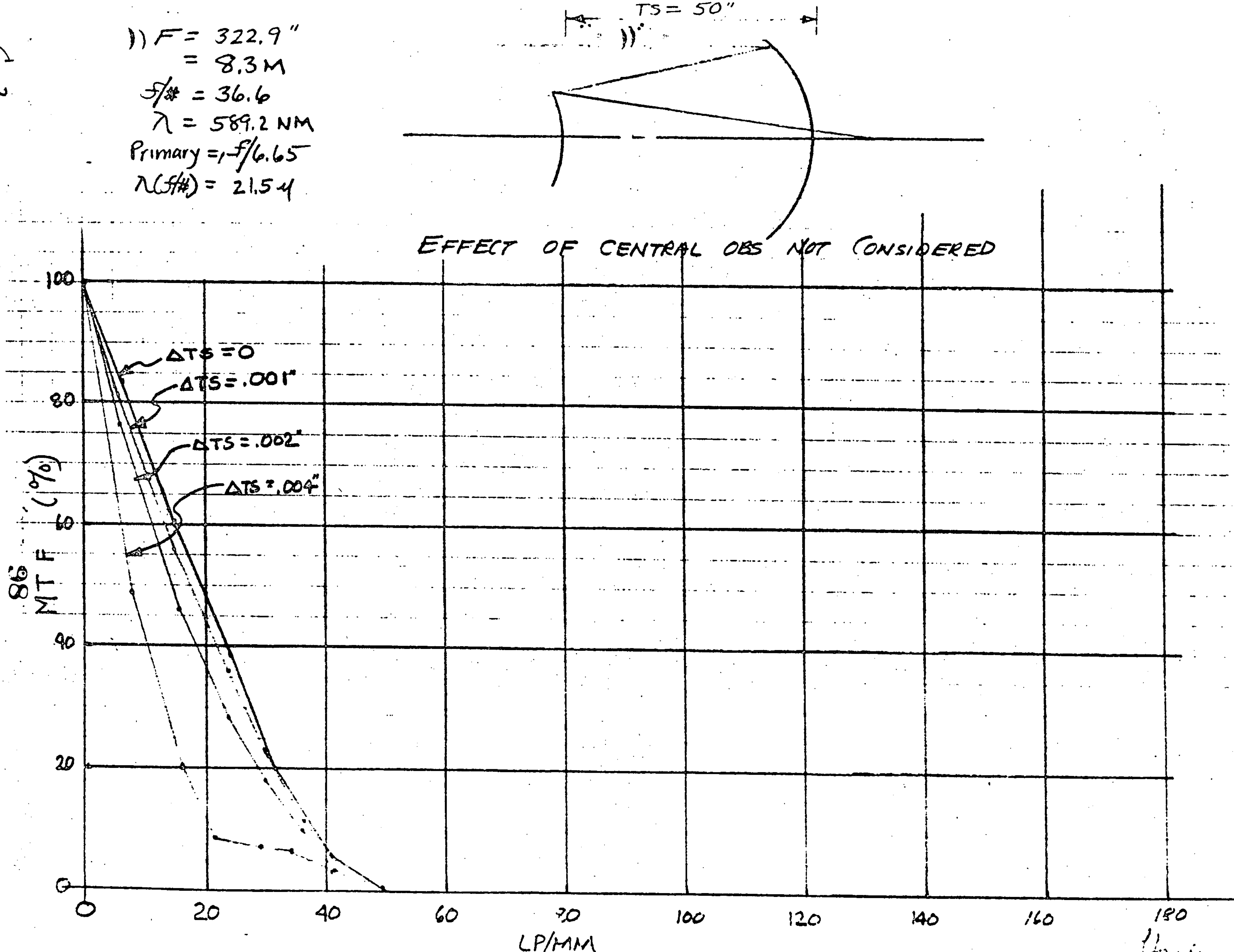


TS = 30"
F = 81.34"
= 2.06M
f/# = 9.0
λ = 589.2 NM
λ×f/# = 5.325 μ
Primary = f/5.67
EFFECT OF CENTRAL OBSCURATION NOT CONSIDERED
MTF (%)
100
80
60
40
20
ΔTS = 0
ΔTS = .0005
ΔTS = .001
ΔTS = .002
DIFF LIMIT = 187
0
20
40
60
80
100
120
140
160
180
SPATIAL FREQUENCY (LP/MM)

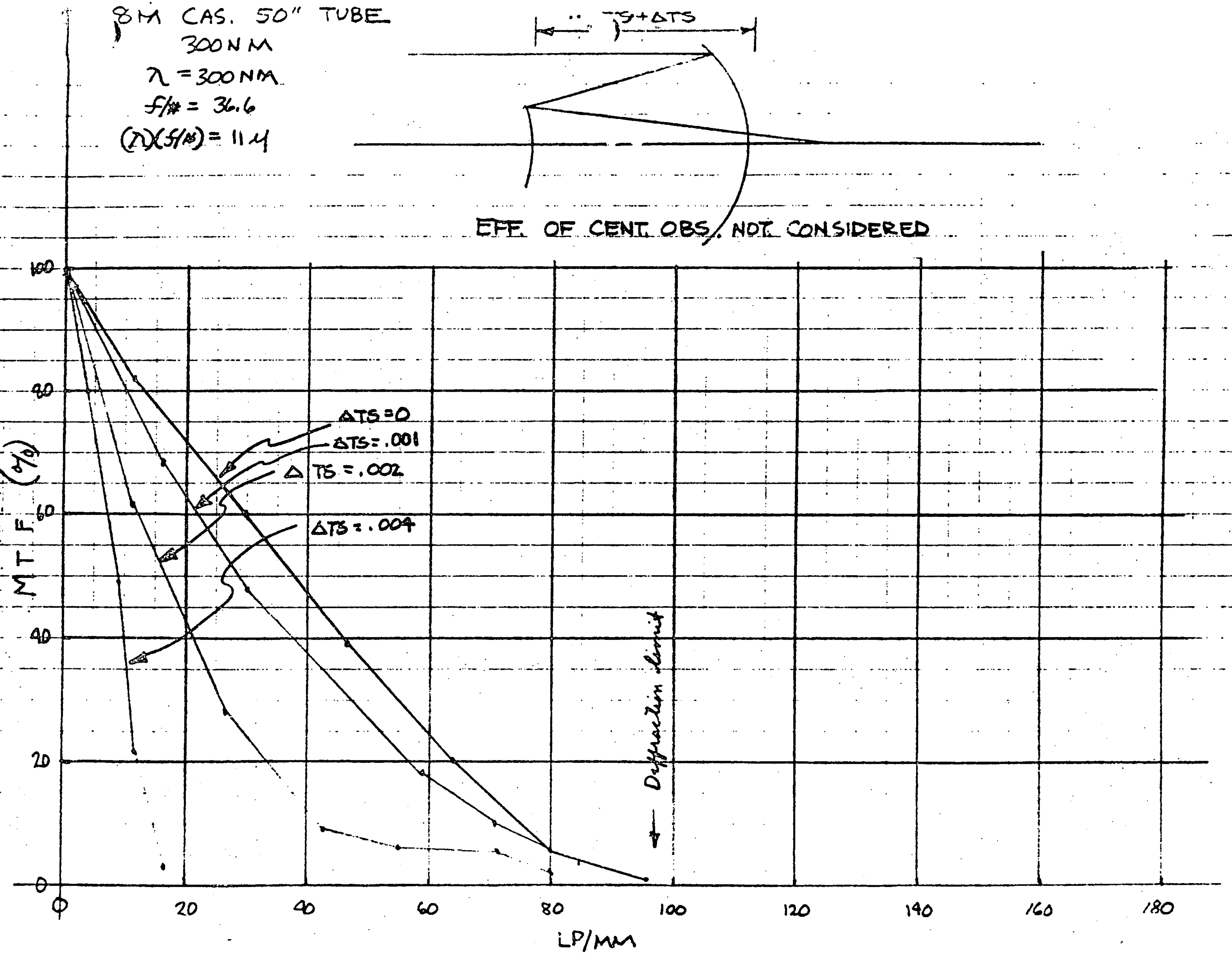

F = 304.5"
= 7.72 M
f/# = 33.8
λ = 589.2 NM
λ×f/# = 19.9 μ
Primary = f/3.36
TS = 27.2"
EFFECT OF CENTRAL OBSCURATION NOT CONSIDERED
MTF (%)
100
80
60
40
20
0
ΔTS=0
ΔTS=.0005
ΔTS=.001
DIFFRACTION LIMIT = 45 LP/MM
0
20
40
60
80
100
120
140
160
180
LP/MM
6-15-7

2

F = 322.9"
= 8.3 M
f/# = 36.6
λ = 589.2 NM
Primary = f/6.65
λ(f/#) = 21.5 μ



86


8M CAS. 50" TUBE
300 NM
λ = 300 NM
f/# = 36.6
(λ)(f/#) = 11 μ
TS+ΔTS
EFF. OF CENT. OBS. NOT CONSIDERED
ΔTS=0
ΔTS=.001
ΔTS=.002
ΔTS=.004
MTF (%)
LP/MM
Diffraction limit
0
20
40
60
80
100
120
140
160
180

at 20 LP/MM

2M, 21" TUBE

$\Delta TS = .001"$ reduces MTF from 82% to 55%
or $\frac{27}{82} = 33\%$ reduction

$\frac{.001}{21} = .5 \times 10^{-4} = 5 \times 10^{-5}$

2M, 30" TUBE

$\Delta TS = .001$ reduces MTF from 86% to 80%
or $\frac{6}{86} = 7\%$ reduction

$\frac{.001}{30} = .33 \times 10^{-4} = 3.3 \times 10^{-5}$

8M, 27" TUBE

$\Delta TS = .001$ reduces MTF from 47% to 10%
or $\frac{37}{47} = 79\%$ reduction

$\frac{.001}{27} \approx .37 \times 10^{-4} = 3.7 \times 10^{-5}$

8M, 50" TUBE ($\lambda = 589$)

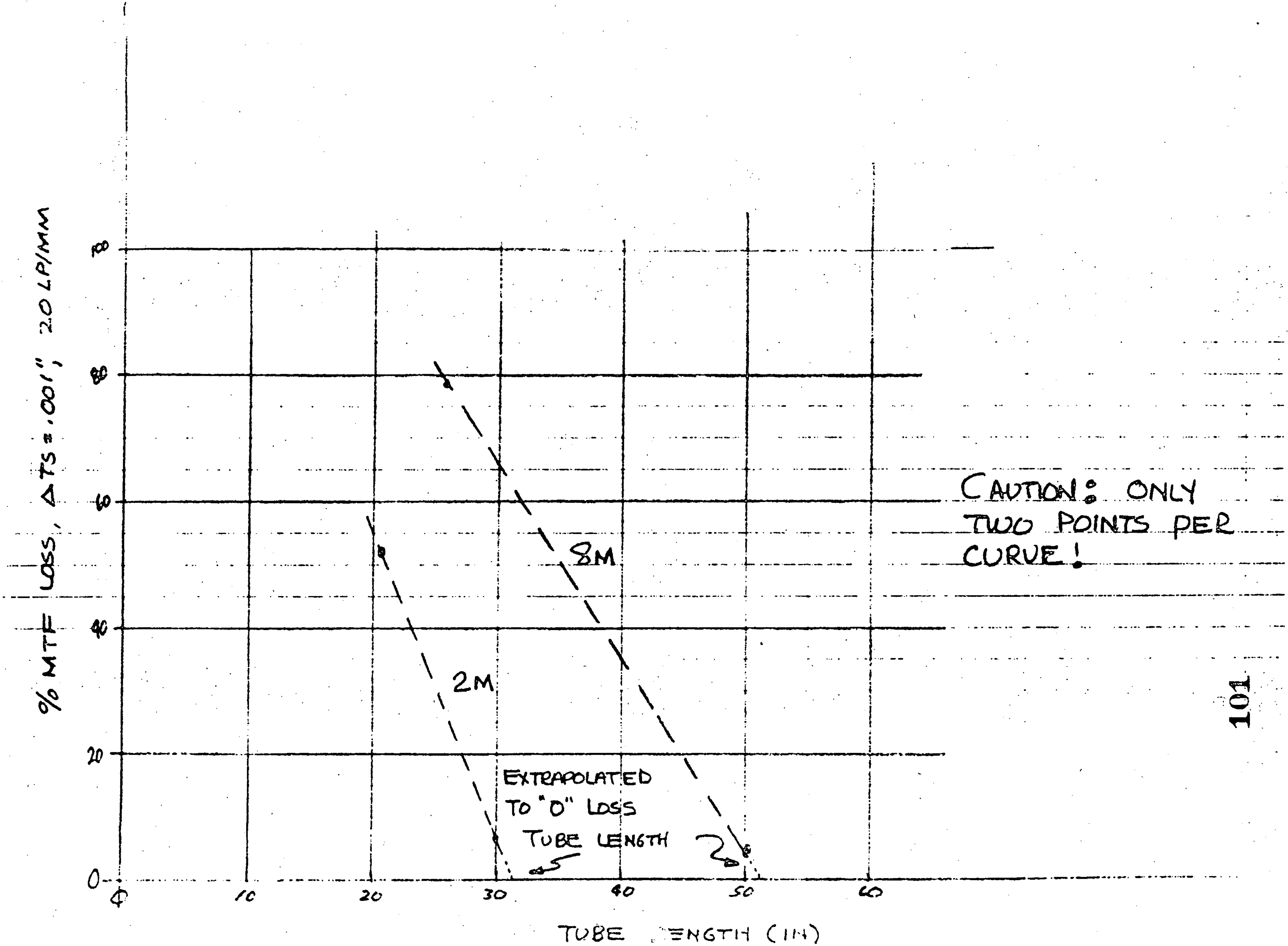
$\Delta TS = .001$ reduces MTF from 47% to 45%
or $\frac{2}{47} = 4\%$ reduction

$\frac{.001}{50} = 2 \times 10^{-5}$

8M 50" TUBE ($\lambda = 300$)

$\Delta TS = .001$ reduces MTF from 72% to 63%
or $\frac{9}{72} = 12.5\%$ reduction

MTF Cal. at 587 NM



Super Invar

Expansion

0° F	0 EXPANSION
25°	−.006 ×10⁻⁴
50°	−.0132
75°	−.019
100°	−.026
125°	+.007
150°	+.082
175°	+.157
200°	+.273
225°	+.430
250°	+.627

UNIT/UNIT/×10^{-4}

INVAR HAS IRREVERSIBLE PHASE CHANGE AT -30°F (?)

Super invar has irreversible phase change (-30°F ?)

consider ceramic?
cermet ?
graphite composition?
— outgassing?
— compressive strength ?

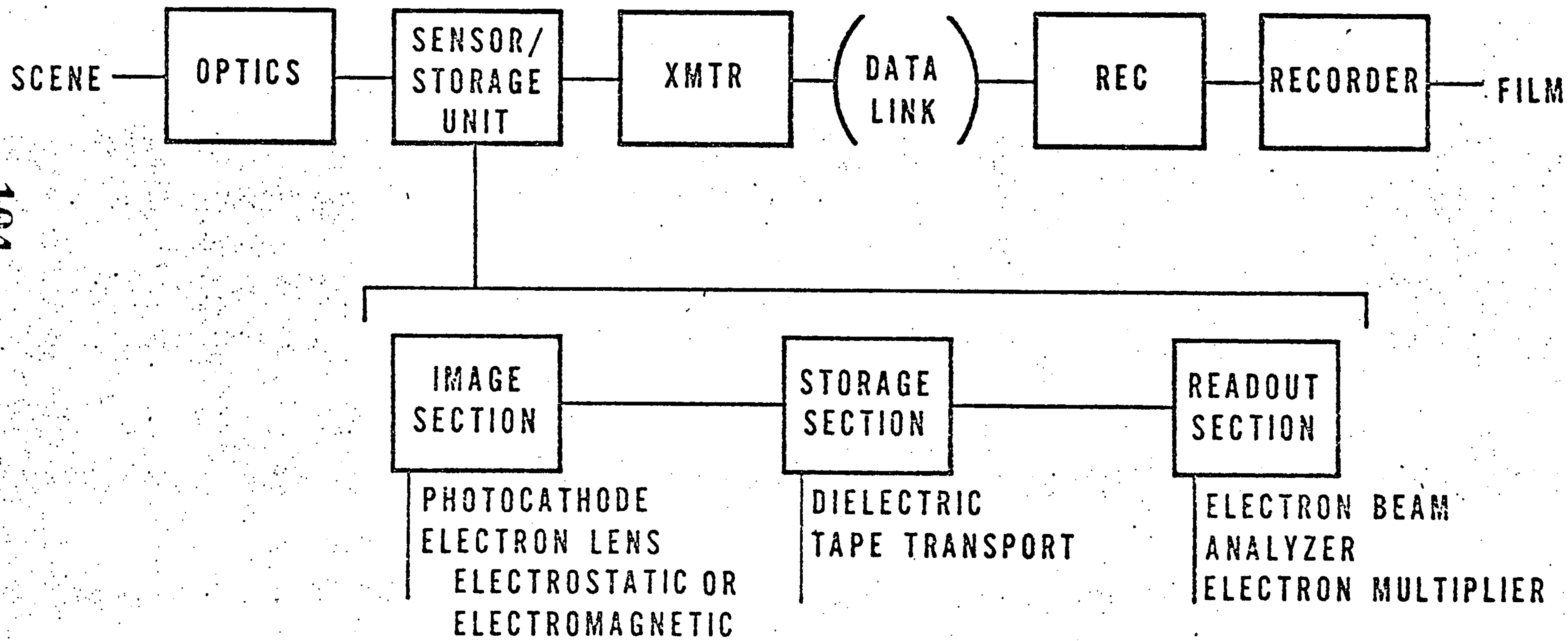
ATTACHMENT 2

"DIELECTRIC TAPE CAMERA PRESENTATION"

(JPL - 22 June 1971)

1. Science Imaging Subsystem
2. Imaging Subsystem Characteristics
3. Image/Storage Operation
4. Readout
5. Image/Data Storage Unit
6. Modulation Transfer Functions
7. Camera Operation
8. Noise Factors
9. Sensor Resolution vs. Exposure
10. Features of Approach
11. Environmental Factors
12. Life/Reliability
13. Photograph of Tape Tester
14. Photograph of Recorditron
15. Photograph of Recorditron Tape Drive
16. Breadboard Image Tube
17. Photograph of Breadboard Readout Section
18. Development Schedule
19. Feasibility Breadboard Program

SCIENCE IMAGING SUBSYSTEM

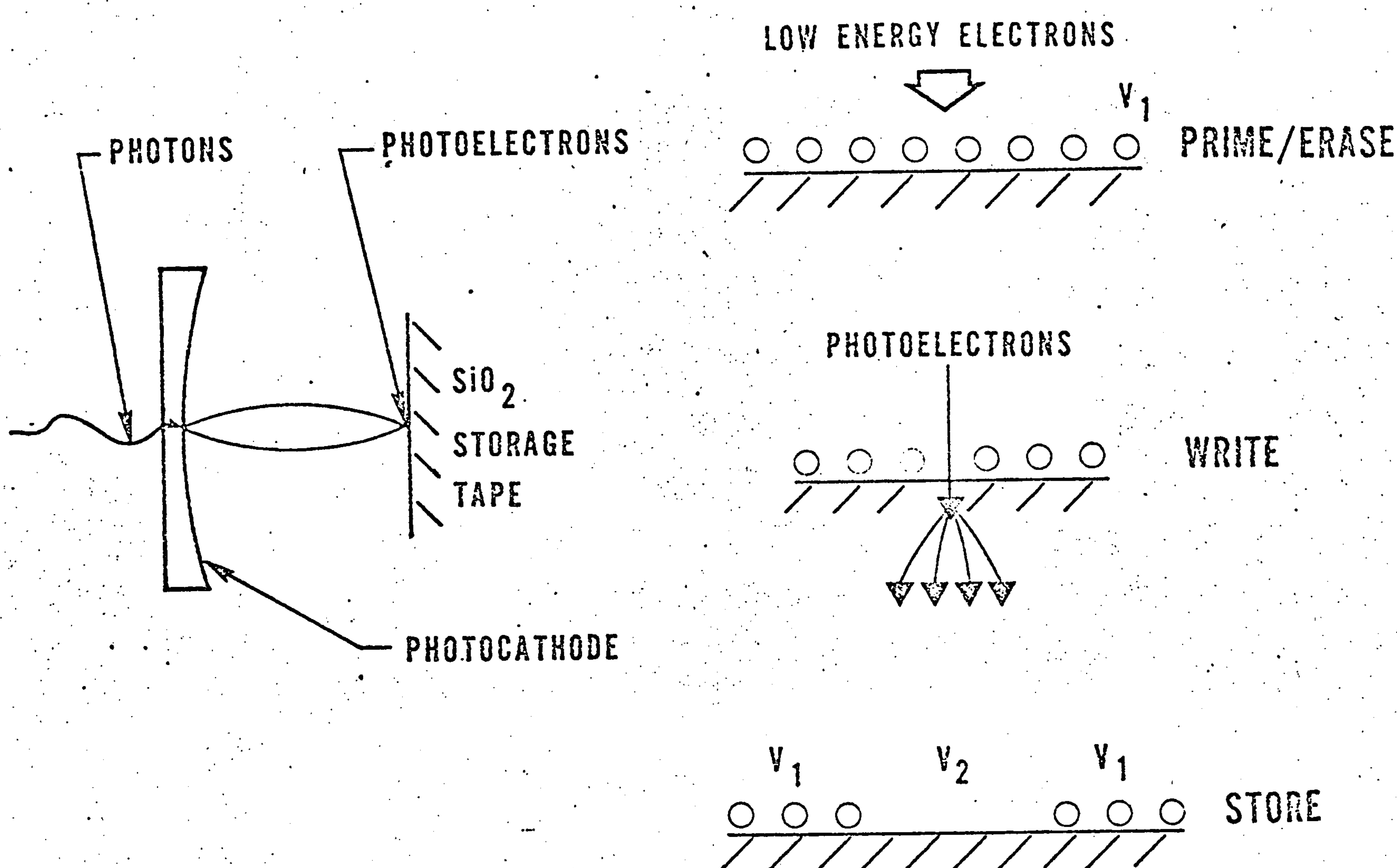


IMAGING SYSTEM CHARACTERISTICS

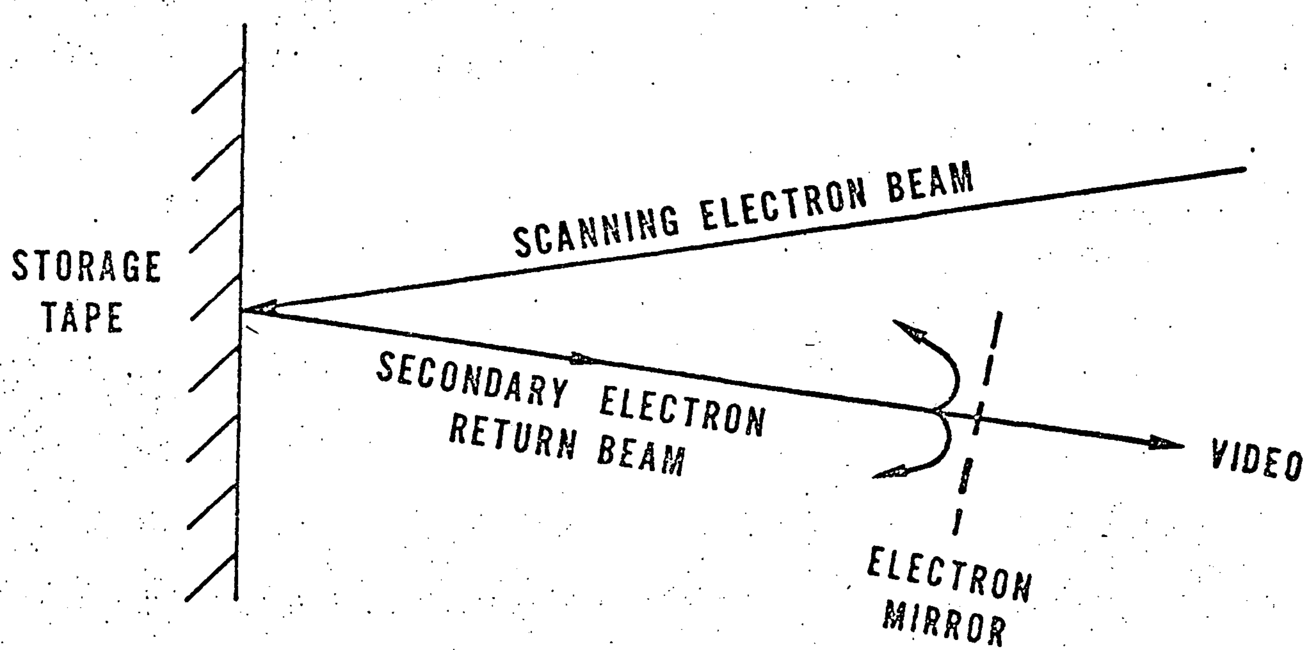
	BASELINE*	IDSU
ACTIVE TARGET DIMENSIONS	16×16MM	24×24 MM
FORMAT	800 LINES × 800 PIXELS (25 CYCLES/MM)	1920 LINES × 1920 PIXELS (40 CYCLES/MM)
SPECTRAL RANGE	.3 TO .8 MICRONS	.3 TO .8 MICRONS
DYNAMIC RANGE	64:1	64:1
NUMBER OF FRAMES	200	144 PER SQ FT OF STORAGE TAPE
FRAME TIME	40 SEC	EXPOSURE TIME

*OUTER PLANETS GRAND TOURS, SCIENCE PRE-PROPOSAL BRIEFING, J.P.L., 17 NOVEMBER 1970. FUNCTIONAL REQUIREMENTS, TOPS FLIGHT EQUIPMENT, SCIENCE IMAGING SUBSYSTEM, J.P.L., 25 MARCH 1970.

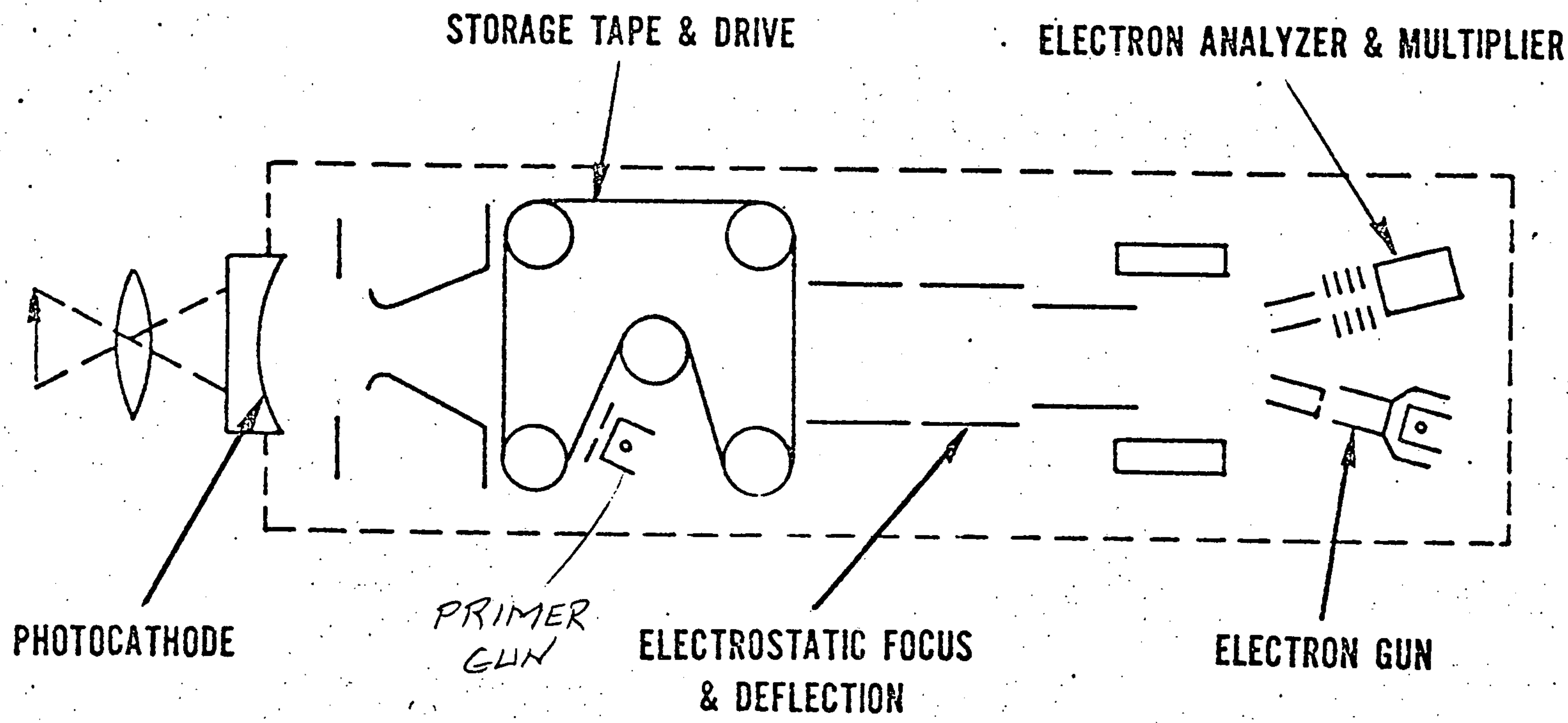
IMAGE/STORAGE OPERATION



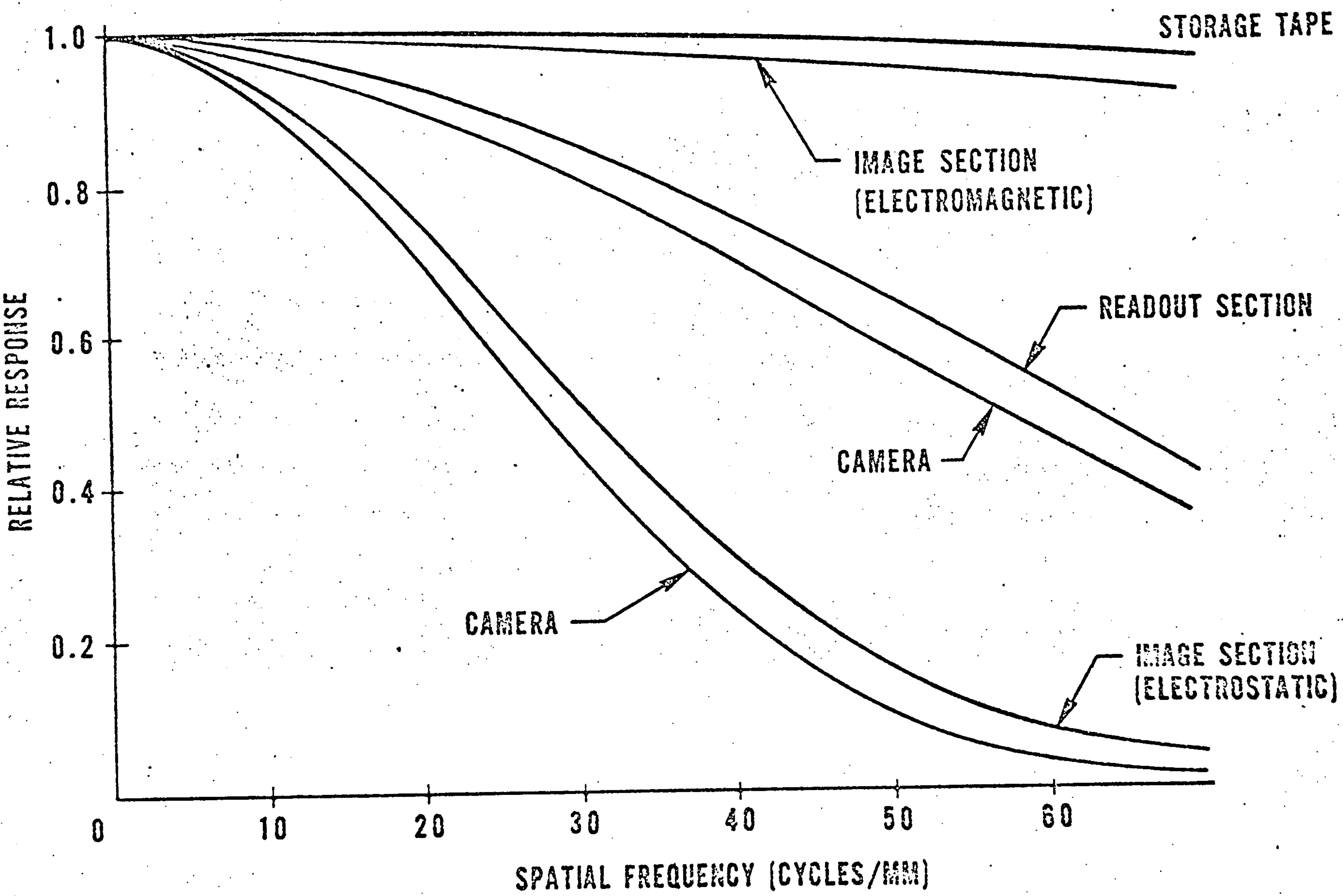
READOUT


STORAGE
TAPE
SCANNING ELECTRON BEAM
SECONDARY ELECTRON
RETURN BEAM
VIDEO
ELECTRON
MIRROR

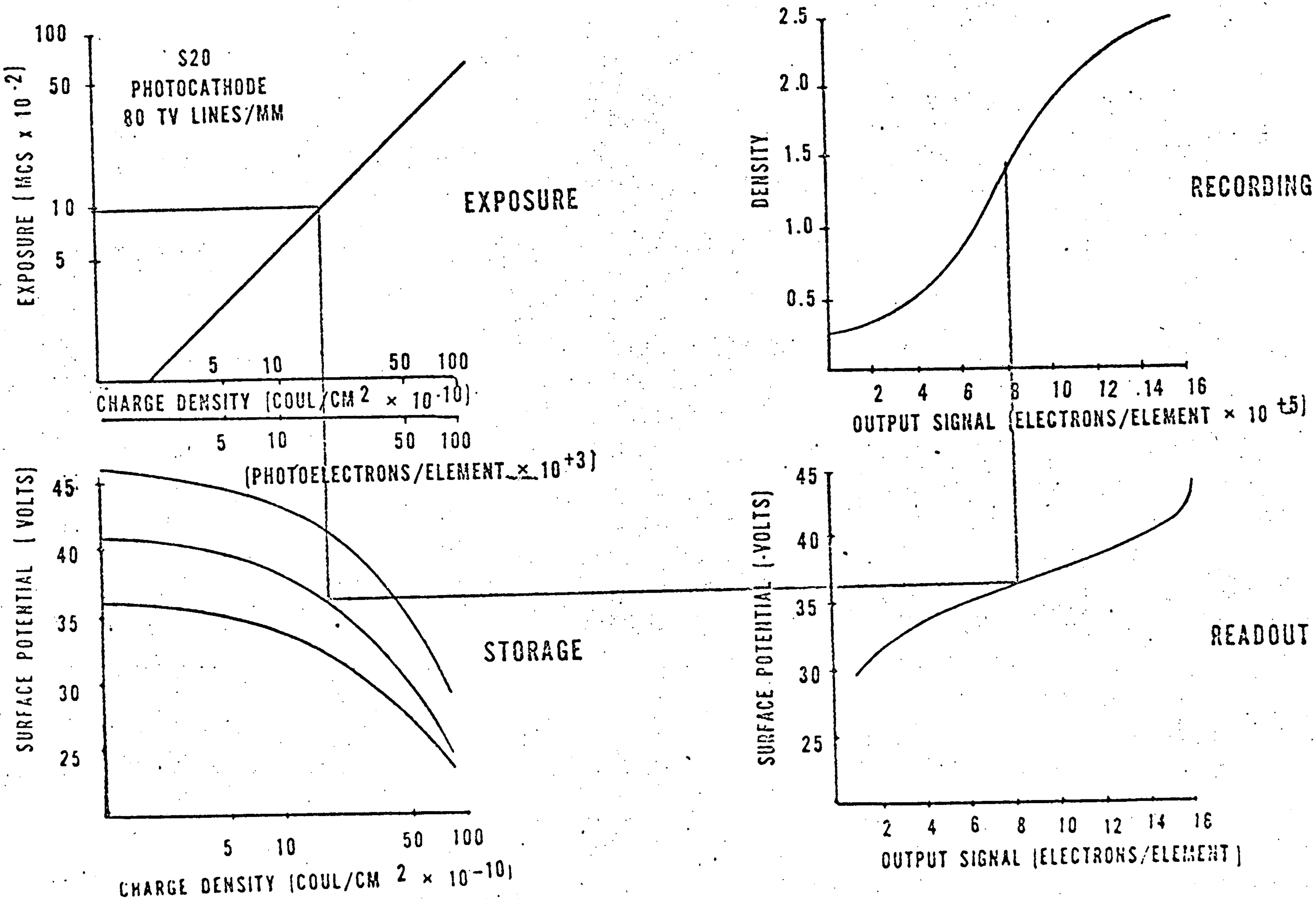
IMAGE/DATA STORAGE UNIT

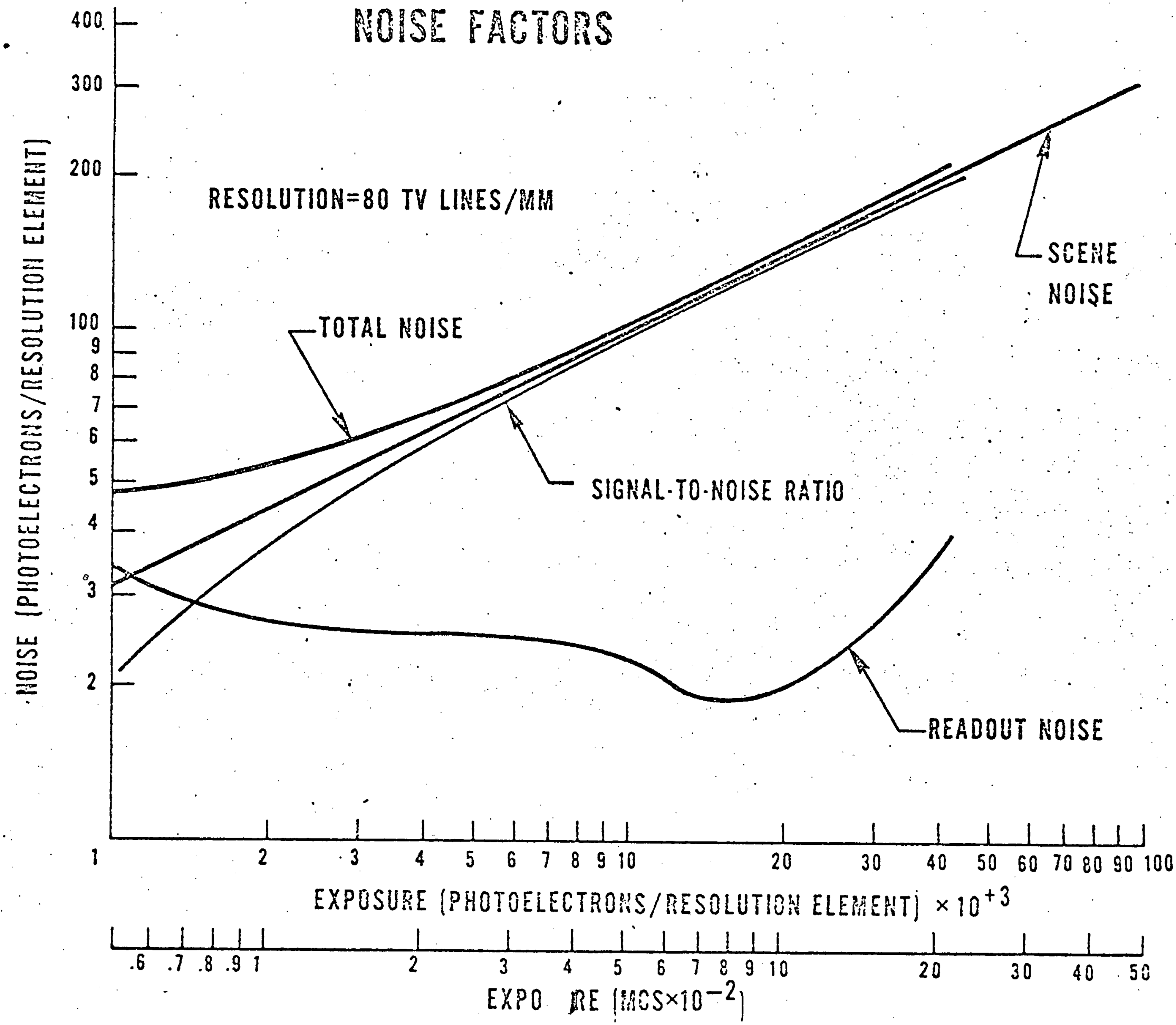


MODULATION TRANSFER FUNCTIONS

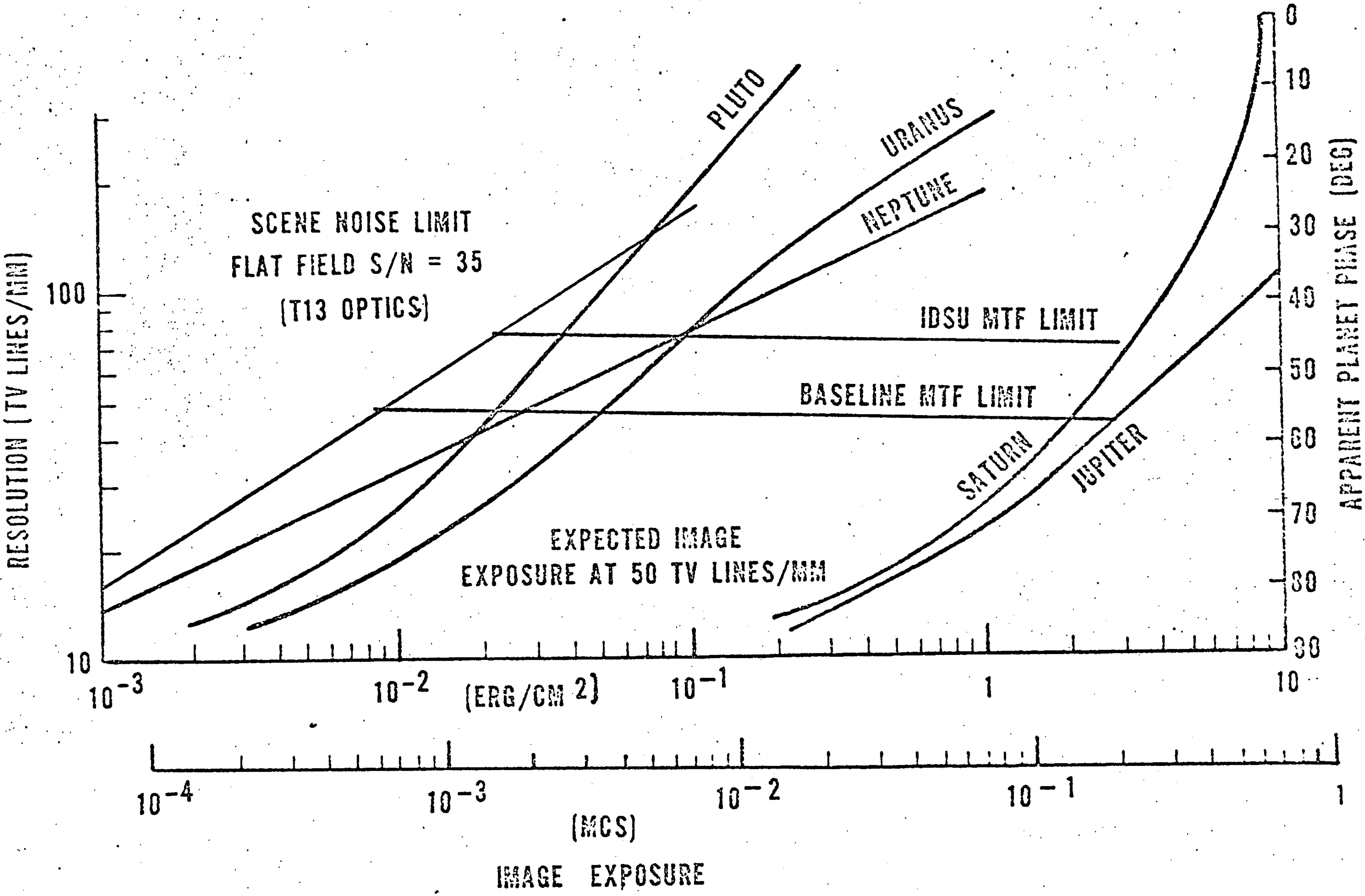


CAMERA OPERATION




NOISE FACTORS
RESOLUTION=80 TV LINES/MM
TOTAL NOISE
SIGNAL-TO-NOISE RATIO
SCENE NOISE
READOUT NOISE
NOISE (PHOTOELECTRONS/RESOLUTION ELEMENT)
400
300
200
100
9
8
7
6
5
4
3
2
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
EXPOSURE (PHOTOELECTRONS/RESOLUTION ELEMENT) × 10+3
.6
.7
.8
.9
1
2
3
4
5
6
7
8
9
10
20
30
40
50
EXPO RE (MCS×10-2)

SENSOR RESOLUTION vs EXPOSURE



FEATURES OF APPROACH

HIGH RESOLUTION

STORAGE CAPACITY

FLEXIBILITY

- FORMAT
- GROWTH POTENTIAL TO MATCH SYSTEM IMPROVEMENTS

REDUNDANCY FOR OTHER EXPERIMENTS

MULTISPECTRAL CAPABILITY

ENVIRONMENTAL FACTORS

113-a

MAGNETIC FIELDS

- DEVICE REQUIREMENTS
- SHIELDING/FIELD CANCELLATION TRADEOFF

RADIATION

LIFE/RELIABILITY

PHOTOCATHODE

STORAGE MATERIAL

BEARINGS

MOTORS

THERMIONIC CATHODE

DEVELOPMENT SCHEDULE

FEASIBILITY BREADBOARD	1972
DEVELOPMENT MODEL	1973
ENGINEERING MODEL	1974
QUALIFICATION MODEL	1975
FLIGHT MODEL	1975

FEASIBILITY BREADBOARD PROGAM

OBJECTIVE

DEMONSTRATION OF DEVICE PERFORMANCE INCLUDING TAPE FLEXURES

SCOPE

- COMPONENT BREADBOARDS
  - IMAGE SECTION—TAPE DRIVE—READOUT
- CAMERA BREADBOARDS
  - SAME SCALE AS END DEVICE

EXPECTED RESULTS

- RESOLUTION
- DYNAMIC RANGE
- THRESHOLD MODULATION

DURATION

ONE YEAR

2. REPORTS OF FUNDED STUDIES

A. Filter Study

1. Contractor: Eppley Laboratory, Incorporated, Newport, Rhode Island

2. Amount: $12,000 (Fixed price)

3. Project Manager: John Hickey

4. Task Description: Determine availability of interference filter material that will endure the launch and space environments contemplated for the Outer Planet Mission.

5. Work Product: Select candidate materials resulting from literature search and design, fabricate and test three filters in the spectral region extending from 350 to 900 nanometers. Environmental tests to include exposure to electron, neutron, proton and gamma radiation.

6. Schedule:
   Start - 24 January 1972
   Complete Literature Search - 1 March 1972 (First Progress Report)
   Complete Manufacturing - 25 April 1972 (Second Progress Report)
   Complete Environmental Tests - 10 May 1972
   Final Report - 1 June 1972

7. Current Status: Preparing final version of contract. Telephone negotiations completed.

B. Optics Study

1. Contractor: Itek Corporation, Lexington, Massachusetts

2. Amount: $45,000 (CPFF)

3. Project Manager: Dick Forkey

4. Task Description: Perform optics study in accordance with imaging requirements and spacecraft constraints for the Outer Planet Mission. Both wide and narrow angle systems will be considered. One and two meter narrow angle telescopes will be investigated. Mechanical considerations are a part of this study and will include a narrow angle optics aperture versus weight trade-off analysis. Optical switching is required in all options.

5. Work Product: A single unit-two camera system design fulfilling candidate requirements for the Outer Planet Mission. Specifically, the wide angle optics will have a 300 mm focal length and operate at a relative aperture of f/4. The narrow angle optics will have a one-meter focal length and operate at f/5.6. An alternate system, also employing optical switching, will have a two-meter focal length narrow angle optics operating at f/11.2 and a 200 mm wide angle optics operating at f/4.

6. Schedule:
   Start - 3 January 1972
   Complete Study Plan - 10 January 1972
   Complete Optics Study - 10 April 1972
   Interim Presentation, JPL - 15 April 1972
   Complete Final Report - 10 May 1972
   Final Presentation, JPL - 15 May 1972

7. Current Status: Negotiations completed - final contract documents have been transmitted to Itek.

C. Data Compression Study

The purpose of the study was to simulate the effect of data editors and compressors on typical planetary photography. The simulation was limited to simple editing and compression schemes. Image degradation due to noise in the telemetry channel was taken into account.

The study was conducted during September-November, 1971, in the Image Processing Laboratory at JPL. The work required three man-months and approximately $5000 in computer costs. Several individuals from JPL Sections 362 and 821 participated informally, as did members of the Imaging Team. The results of this study are described in section 6 of Part 1 of this report.

D. White Reseau Study Description

On September 30, 1971 a study was initiated with RCA, Lancaster, Penna., to determine the feasibility of incorporating a white reseau pattern in a silicon diode array target.

This study is in the form of an addition to an existing contract with RCA to develop an advanced class of silicon target image sensors qualified for space exploration applications.

The study is to be of five months' duration and will define the photo-lithographic masks, processing steps, and electrical performance of a white reseau pattern that can be incorporated in a silicon diode array target. Experimental targets with a white reseau pattern have been fabricated and are presently under electrical evaluation.

E. Dielectric Tape Camera Study

The purpose of this study is to determine the suitability of the dielectric tape camera for use on the OPGT missions. The study includes a functional design and mechanical and electrical analysis for an electrostatic camera system. Weight, power consumption, and system reliability are all being considered to determine if a camera can be constructed that will be compatible with the spacecraft requirements.

Work on the study started in October of 1971 and will run through January of 1972. An interim report has been published by CBS on 7 December 1971, detailing the work that has been done on the study to that date. As of the date that the interim report was published, the work was about 50% complete.

The results expected from this study are: the configuration of the proposed camera, electronic package, housing, and mountings; a functional block analysis, a weight and power analysis; and an indication of any special requirements, such as the need for shielding.

The configuration of the camera tube has been designed and a drawing of the tube was furnished with the interim report. Designs for the camera housing, shielding, mountings and electronics package have not yet been configured. The functional block analysis of the electronic circuits must be completed before configuration drawings of the system's electronic package can be accurately defined.

The basic camera tube configuration is almost the same as has been previously described. One basic change consists of the elimination of the prime/erase gun which helps reduce both the weight and volume of the camera. The prime/erase function will now be performed by the readout electron gun. Another change is the use of a multiple faceted storage drum instead of a film transport with supply and take up reels for the storage section.

The functional block analysis is currently in progress. Values for the various camera operating parameters are being selected on the basis of the SNR, exposure, storage and readout requirements. Such values as have already been determined were included in the interim report. It was pointed out in the interim report that if the tube was to be constructed with an electromagnetic image section, the exposure requirements would be reduced. This would occur because the fiber optics faceplate with its transmission losses would no longer be needed.

Some weight and power estimates related to the basic camera tube have been made. However, as of the date of the interim report, little of the work on the weight and power analysis had been carried out. Once the work on configuring the electronic packages, housing, and mounting is complete, the weight and power analysis will be completed and budgets established.

The effects of space radiation on camera components have been compiled from existing literature and is being compared to maximum expected mission radiation dosages. This information, and calculations based on magnetic field considerations, will be used to determine shielding requirements.

The method of calibration has not yet been selected, although the functional block diagram indicates a calibrated source. Use of an extended source has not been rejected as a reasonable method.