BELLCOMM, INC.

COVER SHEET FOR TECHNICAL MEMORANDUM

TITLE- Tape Recording of Lunar Orbiter Pictures

TM- 65-1012-6

FILING CASE NO(S)- 211

Cat 14

DATE- July 6, 1965

AUTHOR(S)- C. J. Byrne

FILING SUBJECT(S)- (ASSIGNED BY AUTHOR(S)) Site Survey
Lunar Orbiter Pictures -
Tape Recording

(NASA-CR-156208) TAPE RECORDING OF LUNAR ORBITER PICTURES (Bellcomm, Inc.) 9 p
N79-72860
Unclas
00/35 12610

ABSTRACT

The primary means of recording Lunar Orbiter telemetry is on photographic film. This memorandum discusses the potential value of tape recording for analysis of the data in support of Apollo.

There are four major advantages of pre-detection tape recorded data:

(1) No new hardware need be developed to rapidly convert the data to digital form for computer analysis.

(2) Predetection tape recorded data is free from degradation by the ground detection and ground photographic recording equipment.

(3) The tape may be replayed through the ground recording equipment with parameters optimized for particular condition of the data.

(4) Tape recorded data is useful in end-to-end calibration of the system.

Provision of tape recorders may also guard against loss of signal in certain non-nominal conditions; this topic is not discussed in this paper, however.

It is concluded that the ability to fully optimize the later site survey missions on the basis of early Lunar Orbiter data depends on an immediate decision to provide tape recorders.

FEB 1979 RECEIVED NASA STI FACILITY

FACILITY FORM 602

[redacted]

(ACCESSION NUMBER) (THRU)

14 RA

CR-75451

(NASA CR OR TMX OR AD NUMBER) (CATEGORY)

DISTRIBUTION

COMPLETE MEMORANDUM TO

CORRESPONDENCE FILES:

OFFICIAL FILE COPY
plus one white copy for each additional case referenced

TECHNICAL LIBRARY (4)

NASA HQ.
M. W. Krueger - MT-1
T. A. Keegan - MA-2
L. J. Kosofsky - SL
L. R. Scherer - SL
J. H. Turnock - MA-4

Langley Research Center
C. D. Engle
C. H. Nelson
I. Taback

JPL
F. Billingsley
R. Huyser
R. Nathan

USGS
J. McCauley
K. Watson

NASA - MSC
J. Dornbach
J. Sasser

J. A. Hornbeck
B. T. Howard
M. W. Hunter II
J. Z. Menard
C. R. Moster
I. D. Nehama
I. M. Ross
T. H. Thompson
R. L. Wagner
Department 1023
All Members, Division 101

COVER SHEET ONLY TO

BELLCOMM, INC.

SUBJECT: Tape Recording of Lunar Orbiter Pictures - Case 211

DATE: July 6, 1965

FROM: C. J. Byrne

TM-65-1012-6

TECHNICAL MEMORANDUM

Introduction

Lunar Orbiter data should be analyzed in time to optimize the operation of succeeding missions in support of Apollo site survey. The first data may be available within one year. Succeeding Lunar Orbiter and Surveyor missions will follow at the rate of one launch each every three months.

Research at USGS/Branch of Astrogeology[1] and at JPL[2] has established the value of quantitative analysis of lunar photography. The information from one Lunar Orbiter is so great (about 10^{11} elements) that practical data processing rates will limit the amount of information which can be analyzed in time to influence succeeding site survey missions.

A general purpose digital computer is clearly needed because there is not sufficient time to develop a special purpose high rate data processor. The data rates in existing computer facilities are limited by tape recording movements. A typical rate is 62.5×10^3 samples per second (6 bits per sample).[3] At this rate, 5% of the information from one Lunar Orbiter can be transferred in 24 hours.

The Lunar Orbiter data must be converted to digital form before it can be processed in a computer. The conversion rate should be comparable to the computer rate, or the conversion process will limit the value of the data. The feasibility of matching the conversion rate to that of the computer facility without degrading the data and within the available time depends on the data format.

This paper discusses the relative advantages and disadvantages of photographic and tape recorded formats for the high rate, high quality data analysis needed for Apollo site survey.

BA-147A (8-64)

Available to NASA Offices and Research Centers Only.

FACILITY FORM 602

X66 36756

(ACCESSION NUMBER) (THRU)

14 2A

(PAGES) (CODE)

CR # 75651

(NASA CR OR TMX OR AD NUMBER) (CATEGORY)

It is concluded that tape recordings are needed in addition to photographs.

At present Lunar Orbiter photographic data is recorded on photographic film alone. Although the Ranger and Surveyor programs chose to complement photographic recording of picture data with tape recorders, Lunar Orbiter has not provided such equipment. The existing Deep Space Network tape recording equipment is committed to Surveyor when Lunar Orbiter will be flying.

A decision on tape recorders must be made soon. In order to record data from the first Lunar Orbiter, only one year is available for procurement, shipping, and installation at Goldstone, Madrid, and Woomera.

Photographic Format

Lunar Orbiter photographic data is recorded on photographic film by the Ground Recording System (GRS). The signal received on the ground is demodulated by passing through a frequency-modulation-with-feedback (FMFB) dectector and a vestigial sideband detector. The signal is filtered for noise reduction and converted to an image by a cathode-ray tube.

The image is recorded on 35 mm film in framelets. The scan lines run across the film and are spaced 50 μ apart; the length of each framelet is 42.8 cm. There are 56 framelets for each high resolution frame and 14 framelets for each low resolution frame. The total length of film for one Lunar Orbitar is about 20,000 feet.

Other forms of photographic data will also be available. One type, for example, will be re-assembled subframes which consist of 9 framelets side by side. Although such forms may be considerably more convenient for data processing, they must be derived from the 35 mm framelets and must be slightly degraded. The trade-off between quality and convenience is not considered here; it is assumed that the framelets are to be converted to digital form.

Conversion of the data from photographs introduces four difficult problems:

(a) accurate measurement of light

[redacted]

(b) rapid scan motion

(c) accurate mechanical indexing

(d) re-scanning a previously scanned and reconstructed image

The measurement of light should be accurate to better than 1% (rms error) to avoid degrading the overall quality of the data.[4] The scan rate, for 62.5×10^3 elements per second and 50 μ element size, would have to be 3.125 meters per second. The mechanical indexing error should be a fraction of a resolution element, or about 25 μ.

The re-scan problem is a critical one. When the image is read out of the spacecraft film, the two-dimensional image is converted to a one-dimensional signal by rectilinear scanning. When the image is recorded on ground film, a two dimensional image is re-formed, but the scan structure remains. It is not feasible to remove the scan structure without degrading the data.

The two dimensional film image must be re-scanned into a one dimensional signal for transfer to the computer. If the new scan structure is not precisely aligned with the old scan structure, beats (or Moire patterns) will be generated between the two structures. In working with the re-scan of Ranger photographs, scan synchronization was not attempted; instead, the resolution of the data was degraded by a factor of four.[1]

No hardware presently available can handle all of these problems. The scan rate is two orders of magnitude faster than typical rates for mechanical microdensitometers. Cathode-ray scanners can meet the scan rate problem, but a special mechanical indexing and scan synchronization system would have to be developed.

Optical scanning of the photographs does have advantages, such as ease in visual indexing, flexibility of scanning direction, and easily variable magnification. In terms of growth optical scanning will be necessary when photographs are recovered directly without read-out and telemetry. There is no question that this would be the better method, if it could be developed in time.

Unfortunately, development of hardware for rapid, high quality analog-to-digital conversion from photographic film will take approximately one year. Organization, software development, equipment installation, and personnel training will take an additional year. Therefore, there is not enough time to influence site survey missions on the basis of high rate data analysis if the only available format is photographic film.

Tape Recording Format

The relative attributes of pre-detection, post-detection, and digital recording are discussed in the Appendix. It is assumed that the signal is tape recorded before detection. One reel of pre-detection magnetic tape can hold one low resolution frame and one high resolution frame. The information from one Lunar Orbiter can be held on 200 reels of tape.

The major advantage of tape recording is that it preserves the initial scanning structure in one dimensional form, making re-scan unnecessary. A second advantage is that the output signal is in convenient form for conventional high rate analog-to-digital converters. The rate of 62,500 elements per second, at 6 bits per sample, can be easily met by tape movements (the recording speed is roughly twice as fast) and by analog-to-digital converters.[5]

Use of the magnetic tapes must be coordinated with the photographs. Visual inspection of the photographs is needed to select areas for analysis. Furthermore, quantitative work at low rates will be necessary, for example, to interpret calibration data. Therefore, the magnetic tape must be cross-indexed to the photographs. A suitable means of indexing would be recording of a time signal on an auxiliary track on the tape.

If tape recorders are provided, the technical problem of high rate data analysis is restricted to definition of the task, software development, and processing. Under these circumstances, high rate, high quality data analysis can influence later missions if work is initiated immediately.

Conclusion

Pre-detection tape recording of Lunar Orbiter data is needed to permit high rate, high quality data processing

in time to optimize the Lunar Orbiter/Surveyor survey for Apollo landing sites. The decision to provide tapes must be made immediately in order to install them overseas in time for use with the first Lunar Orbiter.

C. J. Byrne

1012-CJB-crr C. J. Byrne

Attachments
References, Appendix

REFERENCES

1. Personal communication, J. McCauley and H. Pohn, USGS/Branch of Astrogeology.

2. Personal communication, Dr. R. Nathan, Jet Propulsion Laboratories.

3. Personal communication, T. C. Wood, Bellcomm, Inc.

4. Work in progress, C. J. Byrne.

5. Personal communication, H. S. MacDonald, Bell Telephone Laboratory.

APPENDIX

TYPES OF TAPE RECORDING

There are three basic ways of tape recording Lunar Orbiter data; pre-detection, post-detection, and digital. Pre-detection tape recordings are made from a carrier frequency modulated by the signal. Post detection recordings are made from the detected baseband signal. Digital recordings are made from the baseband signal after quantizing and encoding into digital form.

Pre-detection:

The main advantage of pre-detection tape recording is that the least number of operations are performed on the signal before recording. Further, non-linearities in the recording and playback equipment do not degrade the signal because it is in frequency modulated form.

Because of the high frequency of the pre-detection data, the recording head must be moved as well as the tape, to attain the needed surface velocity. This dual motion results in high compaction of the data. One reel of tape can hold one low and one high resolution picture; a total of about 200 reels would be needed for each Lunar Orbiter. Tapes need be changed only once an hour.

A disadvantage of pre-detection tapes is that the signal must be demodulated during playback. This requires special purpose Lunar Orbiter equipment.

Post-detection:

Post-detection recording can be done on a linear recorder, but the wide bandwith (230 kilocycles) requires very high tape speeds. As a result about 5 reels of tape would be needed for each Lunar Orbiter frame, and about 1000 reels would be needed for each mission. Tapes would have to be changed every 10 minutes, so two recorders would be needed to avoid interruption of the data.*

The major advantage of post-detection recording is that playback would not require demodulation. However, failure of the demodulator during recording results in loss of data.

---

*Linear recorders are inefficient in tape usage because only a narrow track can be used on one pass. Moving head machines run the track across a wide tape, achieving higher packing density. A moving head machine could be used with post detection recording, but the data would be degraded by the detection system.

Digital:

The major advantage of digital tape recording would be compatibility with computing facilities. However, the data would have to be recorded at 2.5 megabits per second (6 bits, 230 kc bandwith). The feasibility of this is doubtful. Further, about 30,000 reels would be needed for all the data of one Lunar Orbiter.