ORBITAL OPERATIONS STUDIES

Natural Resources Research Institute
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ORBITAL OPERATIONS STUDY
Technical Report No. 4

1965 STATUS OF TACOS,
AN EXPERIMENTAL TABULAR COMPUTING SYSTEM

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BRIEF

LIST OF FIGURES

1965 STATUS OF TACOS,
AN EXPERIMENTAL TABULAR COMPUTING SYSTEM

1. INTRODUCTION

This report is one of a series[1,2] on the progress of a general program of Informatic Data Research at the University of Wyoming and, specifically, of an Orbital Operations Study in association with the National Aeronautics and Space Administration under Grant No. NsG 658. In particular, the research reported upon here is concerned with the "Informatic Data Recorders" and "Continuous Data Recording Buffers" designated[3] as Tasks B and C of that Orbital Operations Study.

In brief review of the basic precepts of this research program, orbital operations are an outstanding example of a rapid growth of automatic data acquisition and processing operations. For example, rapidly increasing amounts of observational data are now being acquired automatically in scientific satellites for automatic transmission to the ground for largely automatic processing on the ground. The "-matic" phase of "informatic" data research is concerned largely with finding and proof-testing better automatic ways of acquiring, transmitting and processing even larger amounts of such observational data more efficiently, effectively and economically. Toward this end, "TACOS" is the terse name used to identify the experimental TAbular COmputing System with which this research is being conducted.

On the other hand, the "inform-" phase of "informatic" data research is concerned with the primary purpose of such large data acquisition and processing operations; namely to provide information to men for manual interpretation and decision-making. Clearly, the ever increasing amounts of automatically acquired data must be formulated in much more readily interpretable and informative ways if man is to perform his role of interpreter and controller with intelligent effectiveness and temporal efficiency.

The basic postulate of this research program is that both of these "inform-" and "-matic" problems can be solved by utilizing new numerals to represent numbers now that it is no longer necessary for man to write them. Or, as defined in the Plan of Study,[3]

The Goal of Informatic Data Research is

    To establish the principles and practices of utilizing newly possible
    <u>informatic</u> ways of representing large sequences of numbers as concise
            complete "pictures" or portrayals of
    <u>inform</u>ation which can readily be acquired, processed, recorded and
            reprocessed in numerical detail with appropriate
    auto<u>matic</u> equipments in large scale operations,

where

Informatic Forms of Data are defined to be

    Ordered series of numbers represented by numerals which can readily be
    * recorded (only) automatically,
    * automatically sensed and processed quantitatively, and
    * manually interpreted both quantitatively and, especially,
      qualitatively.

The validity of this basic postulate has been partially established by the formulation of some notable samples of concise "shades and shadows portrayals" of the space-time distributions of atmospheric temperatures[1,2] and precipitation.[4] Briefly, such portrayals have been found to depend upon the data being continuous in the sense[3] that

Continuous Data are

    Ordered series of numbers in which no two
    successive values differ by more than unity.

Such a complete kind of data is required so that it can be represented extremely concisely, simply and pictorially with

Incremental Data, or

    Tallies of the numbers comprising continuous data
    in terms of the +1, 0 or -1 increments between
    successive numbers,

by utilizing appropriate

Tallic Numerals, or

    Small marks of differing lengths and widths
    for tallying, scaling and/or labeling
    incremental representations of continuous data.

Such informatic data research to date has clearly demonstrated the need (1) to adapt particular forms of tallic numerals to particular kinds of data and (2) to test their potentialities with large "real" samples of each of those kinds of data. It has also clearly demonstrated that the full realization of the potential advantages of tallic numerals depends upon developing appropriate (potentially very simple) devices for recording and automatically reading them. Consequently "TACOS" is needed and intended to serve the dual role of:

o Providing an effective means of preparing test-samples of several kinds of informatic forms of large amounts of numerical data; and

o Providing experimental experience with the kinds of equipments with which the resultant informatic forms of data might well be formed and utilized operationally in the future.

2. PURPOSES

This experimental TAbular COmputing System is thus intended to help lead to improved procedures for any or all aspects of orbital operations. Toward this end, the various kinds of orbital data and operations can usefully be classified[3] in terms of

Operational Data Traverses:
    Alternating cyclic sequences of odd-numbered operators and even-numbered data-operands such as, typically,
    1. OBSERVING Occurrences, 0, to get
    2. Observations for
    3. COLLECTING as
    4. Reports for
    5. COMPILING as
    6. Portrayals of past and probable future conditions for
    7. DISTRIBUTING as
    8. Predictions of specific future conditions for
    9. PLANNING to formulate
    10. Plans for
    11. ACTING to intelligently utilize and/or encounter
    0. Occurrences by/for
    1. OBSERVING them to get...and so forth.

Since the inputs and outputs of each of the capitalized operations, 1, 3, 5,$\cdot\cdot$(2i+1), of this sequence are data (or occurrences), each of these operators can be defined by -

Operational Data Traverse Operators:
    Odd-numbered operators, (2i+1), of operational data traverses which consist of the alternating sequences of signal-operators and signal-operands of
    (2i+1).1 SENSING Occurrences, 0, or Input Data, (2i), to get
    (2i+1).2 Input Signals for
    (2i+1).3 TRANSFORMING in form, content, place, etc. into
    (2i+1).4 Output Signals for
    (2i+1).5 RECORDING as Output Data, (2i+1), or
                    as Planned-For Occurrences, 0.

For example, the OBSERVING operation with satellites such as the Orbiting Geophysical Observatory could well be considered to consist of those on-board operations whereby natural and space-craft occurrences are sensed, digitized and recorded as Observations with an on-board magnetic tape recorder. The COLLECTING operation then comprises the on-board playback and radio transmission of the observed data, followed by receiving and recording of the data

as <u>Reports</u> on magnetic tape in telemetry receiving stations on the ground. A second COLLECTING operation is then usually required with which the initial Reports on magnetic tape are either mailed or transmitted by radio or land-line to a control center for the subsequent COMPILING operation. At the present time this COMPILING operation consists primarily of:

o Collating successive values of each variable in association with space and/or time coordinates,

o Rectifying values for each variable in accordance with their sensor-calibration data; and

o Recording the data in a form suitable for manual reading and inter-pretation.

A primary purpose of TACOS is thus to help prepare test-samples of informatic forms of the kinds of Portrayals which might better be produced as the output of the COMPILING operation. For this purpose it is necessary that TACOS provide, first, a means of formulating rigorously continuous data from "real", now usually discontinuous, data from satellites. The initial way of doing so with TACOS is by the "incrementation" process described in Section 4. Second, realistic evaluations of the test-samples of data require that they be made with a recording process which is potentially adaptable to routine operational use. The recorder of this kind which has been selected for initial trial-use in TACOS is described in Section 5.

As indicated by its name, however, the core of this experimental TAbular COmputing System is its "tabular-conversion" unit described in Section 3. Briefly, "tabular conversion" refers to the use of a concise incremental form of numerical tables for transforming input numbers into output numbers in accordance with a wide choice of functional relationships between them. Previous experience[5] has indicated that such incremental conversion tables can be utilized automatically with potentially simple, inexpensive and reliable equipments. Consequently the purposes of the tabular conversion unit in TACOS are to provide:

o Direct experience with the automatic reading characteristics of informatic forms of data;

o A versatile computing capability for the experimental formulation of test-samples of this and other kinds of informatic data; and

o The experience needed to evaluate the potentialities of tabular conversion in any or all of the operations of OBSERVING, COLLECTING or COMPILING orbital data.

3. TABULAR CONVERSION

The mechanical portion of the initial TACOS tabular converter is pictured in Figure 1. It consists of a motor driving a horizontal shaft upon which one or more tabular discs can be mounted, and upon each of which one or more incremental conversion tables can be permanently recorded. The six stationary horizontal rods provide for mounting the light sources and photo-transistors with which the incremental marks of the conversion tables are sensed. This experimental model has purposely been made quite large to provide for ease of adjustment of the optical reading heads and speeds of rotation.

This particular configuration was selected to test the characteristics of transmission optics, as illustrated schematically in Figure 2, in comparison with the reflective optics used in the only known previous tabular converter.[5] (Just before the time of this writing, the Cook Electric Company of Morton Grove, Illinois donated that tabular converter and associated equipments to the University of Wyoming to become, in effect, an additional experimental unit of TACOS). The rotating discs are composed of transparent plastic about ten mils thick upon which any desired pattern of either opaque marks in a transparent field or transparent marks in an opaque field are formed photographically. Lateral stability of such thin plastic discs is provided by mounting the shaft horizontally, by reinforcing them with metal discs to within about two inches from their circumference, and by the centrifugal force associated with their rotation.

An especially convenient form of incremental notation illustrated in Figure 3 has been used for the initial check-out of the characteristics of this form of tabular converter. In this form of incremental table, photosensing and pulse-detecting problems have been minimized by utilizing three separate lines of incremental marks and optical reading heads for each of: an Argument (or input) channel; a Function (or output) channel; and a Command (or "start counting") channel.
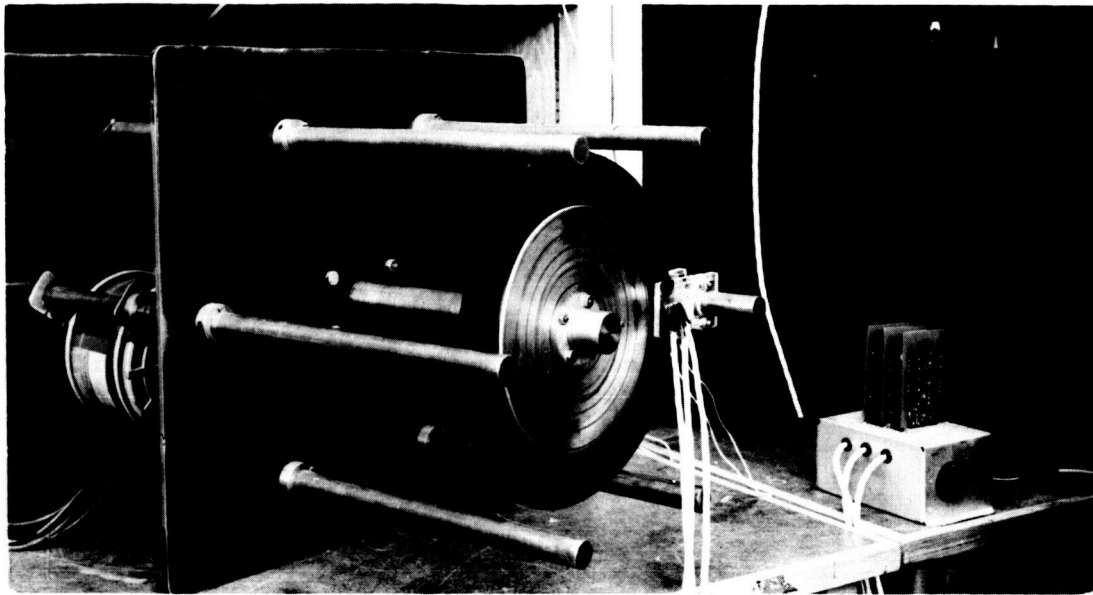
FIGURE 1
EXPERIMENTAL TABULAR CONVERTER MECHANISM
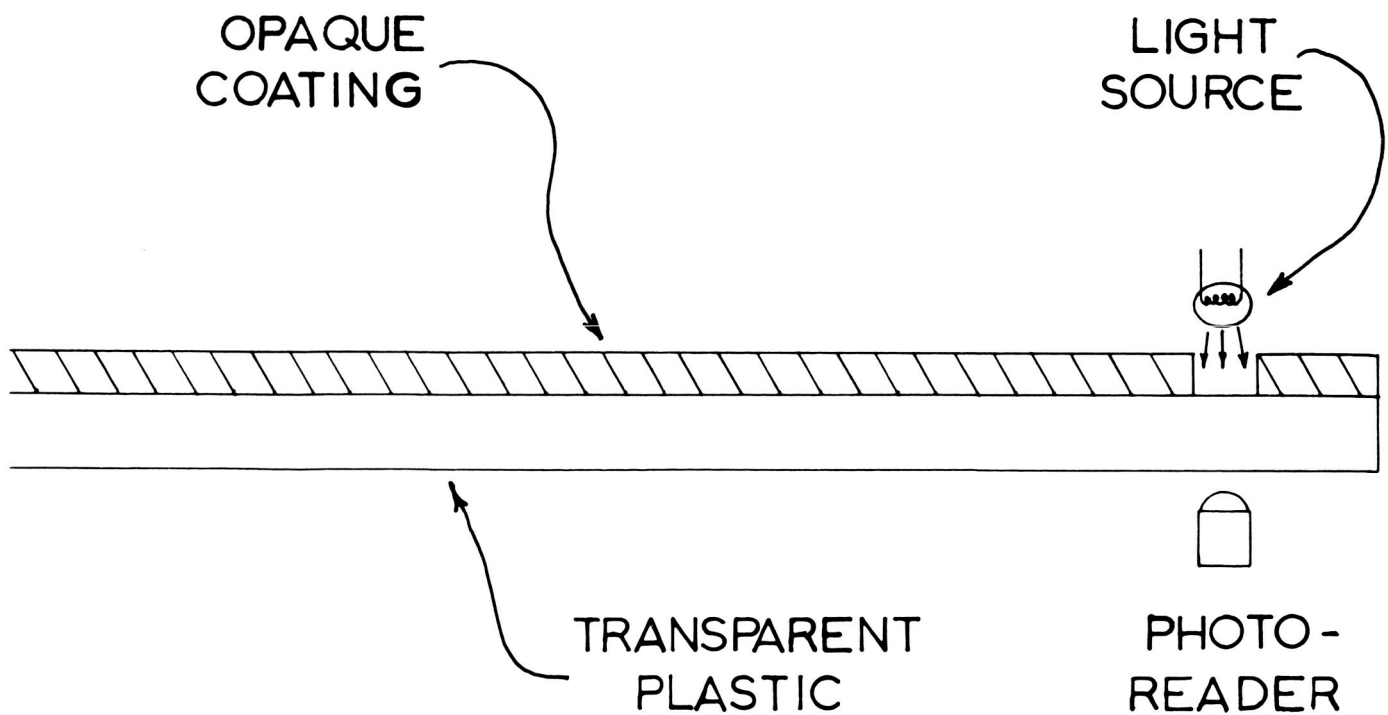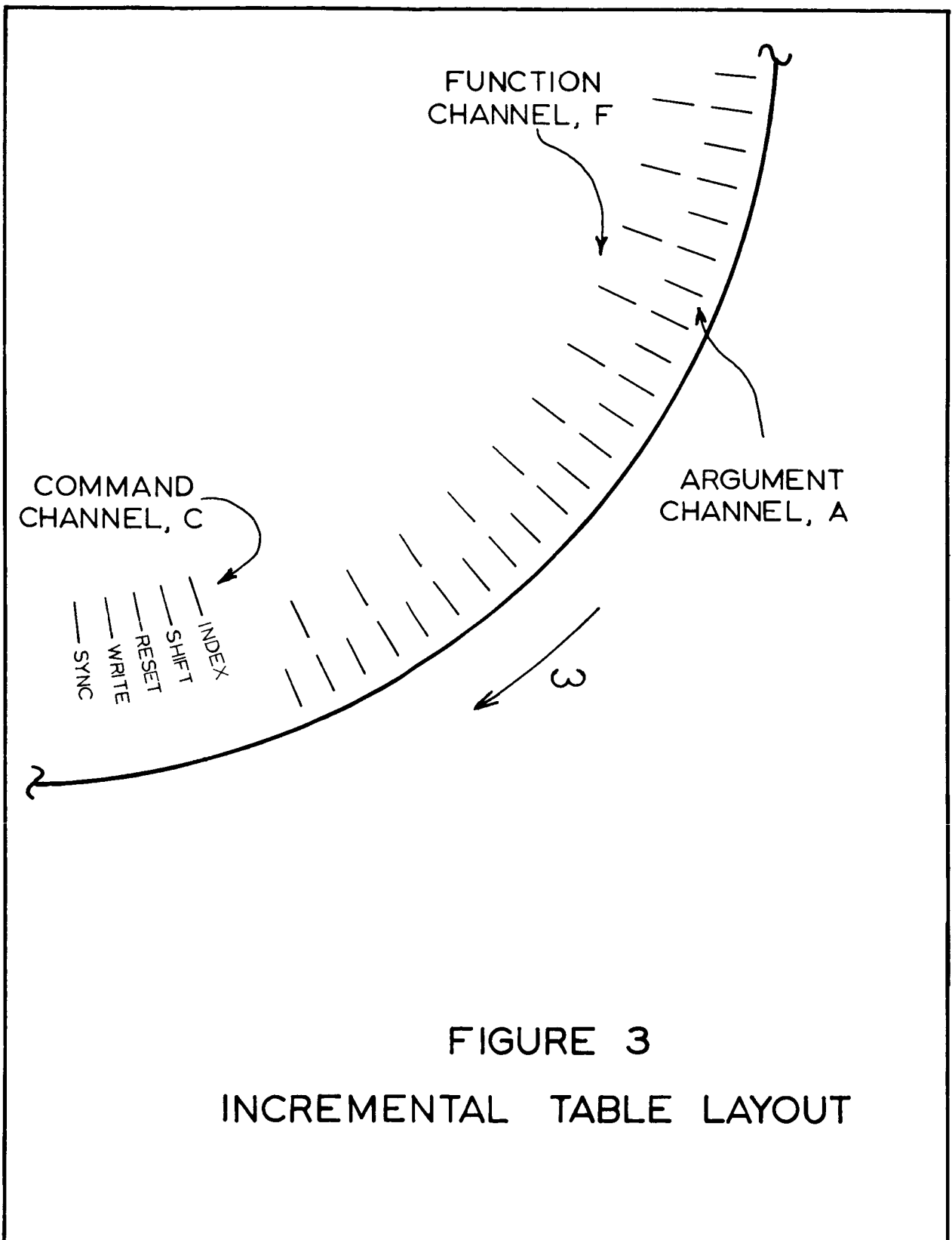

OPAQUE
COATING

LIGHT
SOURCE

TRANSPARENT
PLASTIC

PHOTO-
READER

FIGURE 2
DISC PHOTOREADER CONFIGURATION

FUNCTION
CHANNEL, F

ARGUMENT
CHANNEL, A

COMMAND
CHANNEL, C

INDEX
SHIFT
RESET
WRITE
SYNC

3

FIGURE 3

INCREMENTAL TABLE LAYOUT

Tabular conversion is accomplished in basic principle with such an incremental conversion table as follows. As the tabular disc rotates its marks generate electric pulses in the optical reading heads, and the data-conversion operation can be considered to start at the time the marks are sensed in the Command channel. At that time, all succeeding pulses from the Argument and Function reading heads are gated into corresponding Argument and Function counters. The desired output number will then be that number of Function marks which will have been counted in the Function counter by the time the input number of Argument marks will have been counted in the Argument counter.

In the particular table illustrated in Figure 3, for example, incremental marks occur in the Function channel opposite every other one of the marks in the Argument channel. Consequently only one half the number of marks will have been counted in the Function counter as in the Argument counter at any instant, and the use of this particular table performs the operation of dividing by two. Although this particular functional relationship is rather trivial, it serves well to determine the operational characteristics of the converter. It is only necessary to replace this table with one in which the successive marks in the Argument and Function channels have been appropriately positioned with respect to each other to obtain virtually any desired functional relationship between the input and output numbers.

The conversion table used for the experiments to date is such a divide-by-two table which contains about 1,024 Argument increments spaced at about 28 marks per inch around a nearly 36 inch circumference. Rotational speeds of 600 revolutions per minute thus provide 10 data-point conversions per second with counting rates of about 10,000 pulses per second. Experience to date indicates that rotational speeds up to perhaps 3600 revolutions per minute might be used, if required, to obtain 60 data-point conversions per second with each of however many different tabular discs and tables per disc might be used in parallel. In addition, at least 100 marks per inch or possibly 3,600 marks in each 36 inch circumference should be readily useful with the simple type of reading head optics presently in use. An upper limit of higher speeds and more closely spaced marks is currently imposed, however, by an upper frequency limit of about 124,000 pulses per second of the present electronic circuitry.

4. INCREMENTATION

It was anticipated at the outset of this study[3] that the preparation of test-samples of informatic forms of orbital data would involve, first, tabular conversion to obtain numerical values of appropriate variables with a variety of digital radices and, second, the formulation of the rigorously continuous kind of data which is characteristic of incremental forms of data. Consequently the initial test-configuration of TACOS combines the operations of tabular conversion and "incrementation."

Briefly, "incrementation" designates that computational process whereby "continual data"[6] is formed in accordance with the definition –

CONTINUAL DATA:

Rigorously continuous (output) data, $^oQ(P)$, consisting of integral numbers, ^oQ, at successive ordinal positions, $P = 0, 1, 2, 3 \cdots$, which has been formulated from input signals or data, $^iQ(P)$, in accordance with the rules that

$$^oQ(0) = {}^iQ(0)$$

and
$$^oQ(P) = {}^oQ(P-1) + \delta^oQ(P)$$

where
$$\delta^oQ(P) = +1 \quad \text{if} \quad {}^iQ(P) - {}^oQ(P-1) \geq 1,$$
$$\delta^oQ(P) = 0 \quad \text{if} \quad {}^iQ(P) - {}^oQ(P-1) = 0,$$

and
$$\delta^oQ(P) = -1 \quad \text{if} \quad {}^iQ(P) - {}^oQ(P-1) \leq 1.$$

In other words, continual data consists of those sequences of numbers which would be obtained with running counts of the +1, 0 or -1 increments, $\delta^oQ(P)$, of which incremental forms of data consist. In case differences between successive numbers of the input signals or data, $^iQ(P)$ exceed unity, these rules for determining $\delta^oQ(P)$ produce continuous output data $^oQ(P)$ which corresponds to the input data as closely as possible without changing the units of resolution associated with either Q or P.

In the current configuration of TACCS, the tabular conversion of input numbers, N(P), into functionally related numbers, $^iQ(P)$, is combined with the incrementation operation of forming corresponding continual data $^oQ(P)$ and incremental data $\delta^oQ(P)$. As indicated by the block diagram of Figure 4, this is accomplished by first using the incremental conversion table

FIGURE 4

SYSTEM BLOCK DIAGRAM
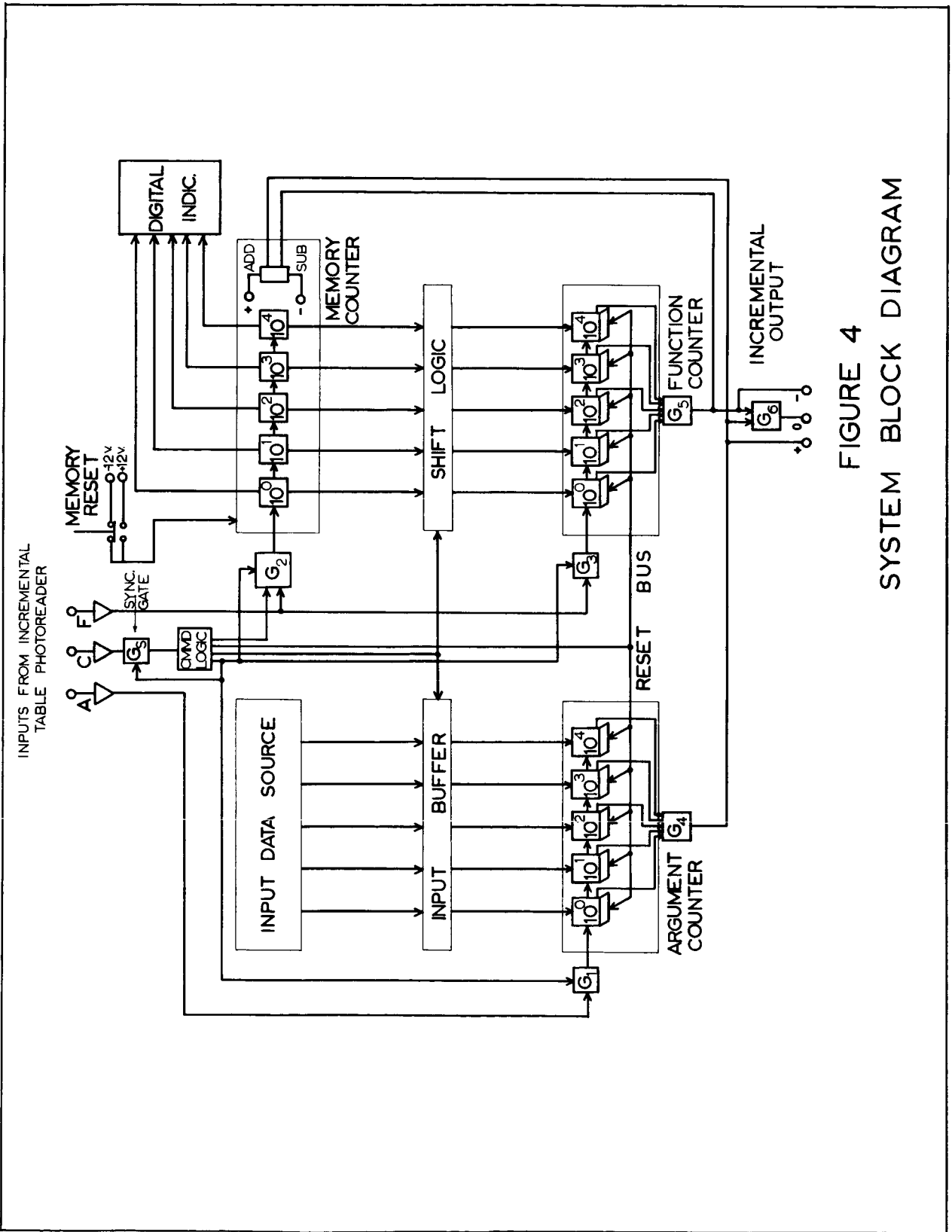
to convert an initial input number $N(0)$ into the initial continual value $^oQ(P)$ and storing it in the Memory counter. This Memory counter is subsequently used, first, as the source of the continual values $^iQ(P-1)$ required to determine the incremental values $\delta^oQ(P)$ and, second, to compute the succeeding values of $^oQ(P)$ by keeping a running count of those plus or minus unity increments.

The Input Buffer shown in Figure 4 serves the function of loading input values, $N(P)$, from the Input Data Source into the Argument counter at the time of initiation of the P-th computational cycle. The Argument counter consists of a five stage, binary-coded-decimal (BCD) counter, and the Input Buffer loads all of its binary stages simultaneously. The initial mechanization of the Input Buffer provides for loading input values from a series of manually operated, binary-coded-decimal, input keys; subsequent buffers are now being designed to accommodate the outputs of other, automatically operating data sources.

Each P-th computational cycle is initiated by, first, receiving a signal from the Input Data Source that the number $N(P)$ is ready for loading and, second, by the detection of the Shift mark illustrated in Figure 3 the next time it passes under the Command reading head. As indicated by the logical circuitry diagram of Figure 5, the Command Logic block of Figure 4 then generates the following sequence of operations.

Shift: Parallel-loading the input number $N(P)$ from the Input Data Source through the Input Buffer into the Agrument Counter; <u>and</u> Parallel-loading the $^oQ(P-1)$ number then existing in the Memory Counter through the Shift Logic into the Function Counter.

<u>Index</u>: Qualifying Gates G_1 and G_3; <u>and</u> Qualifying Gate G_2 <u>if also</u> the Memory Counter is in the zero state to which it is set at the outset of the initial, $P = 0$, cycle.

<u>Convert</u>: Counting-down in the Argument and Function Counters with pulses from the A and F reading heads (and counting-up in the Memory Counter with F-pulses in the $P = 0$ cycle) <u>until</u> an empty-counter signal is passed by Gate G_4 and/or Gate G_5, at which time Gates G_1, G_2 and G_3 are disqualified and all counting ceases.
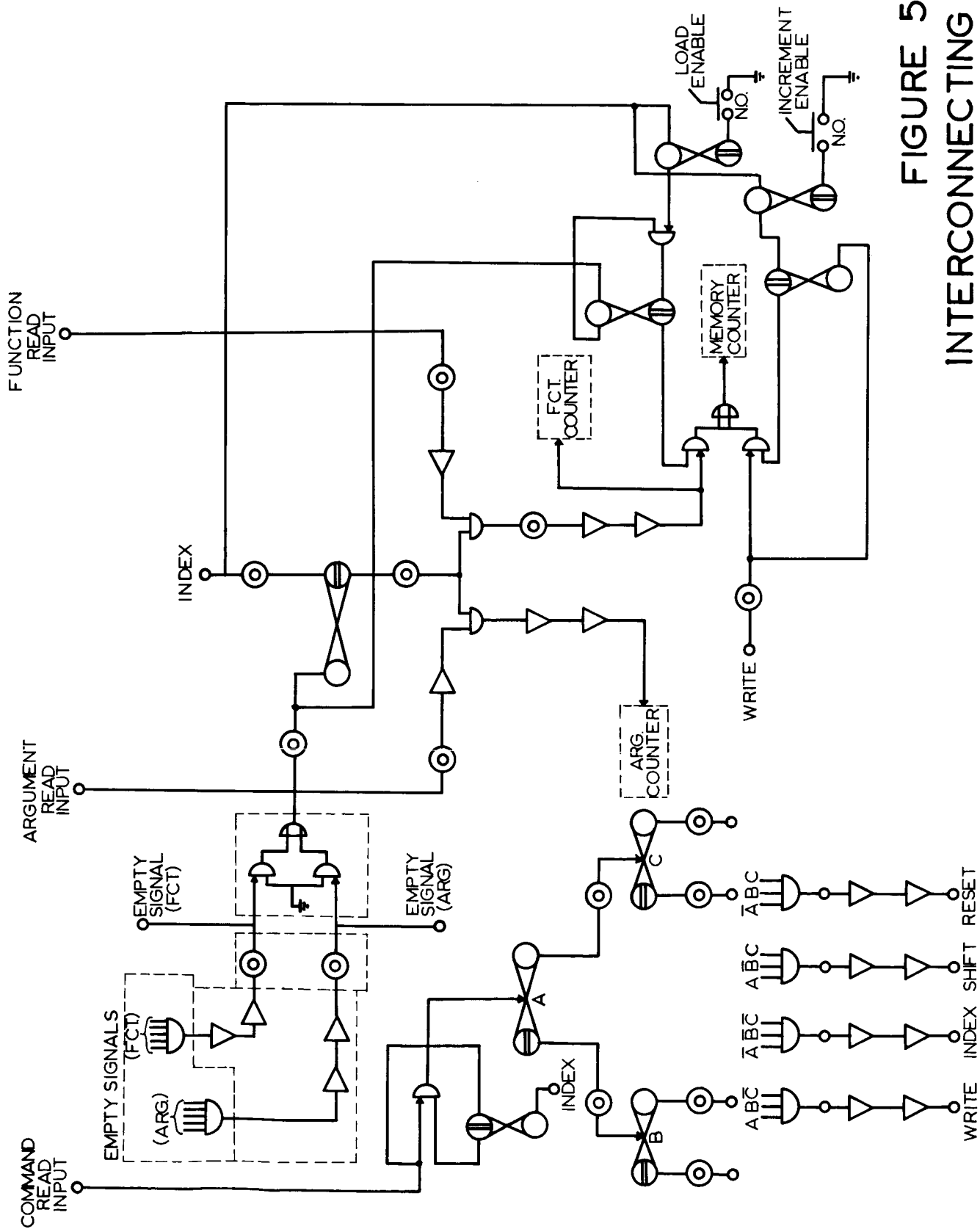
FIGURE 5
INTERCONNECTING LOGIC
BLOCK DIAGRAM

<u>Sync</u>:   Eliminating false noise signals from the Command reading
head by utilizing the timing relationship between the sync
and subsequent command signals.

<u>Write</u>:   Providing incremental signals, $\delta^o(P) = +1$, 0 or -1, to
external recorders or devices <u>and</u> to the Memory Counter
for counting one unit up, down or not in accordance with
the conditions that

$$\delta_o^o(P) = +1 \text{ if } G_4 \text{ is and } G_5 \text{ is not qualified,}$$
$$\delta_o^o(P) = 0 \text{ if } G_4 \text{ and } G_5 \text{ are both qualified,}$$
$$\delta^o(P) = -1 \text{ if } G_4 \text{ is not and } G_5 \text{ is qualified.}$$

<u>Reset</u>:   Precluding the generation of false incremental signals
before or during the next, P+1, Shift by setting all
binary elements of the Argument and Function Counters
into their high or 1 states.

With this sequence of operations in the initial, P=0, cycle,
the Shift operation puts a number N(0) in the Argument Counter and zero
in the Function Counter. The Convert operation then procedes until
N(0) pulses have been counted-down in the Argument counter to put it and
leave it in its zero state, and to stop the count-up in the Memory Counter
at the number $^oQ(0)$ corresponding to N(0) in accordance with the functional
relationship which has been tabulated on the rotating disk. During this
initial cycle, the control with which a zero was preset into the Memory
counter also disenables the possibility of having the initial zero state
of the Function counter stop all counting, and of having a negative
increment added to $^oQ(0)$ in the next succeeding Write operation.

It is noteworthy as an illustration of how this particular way
of mechanizing the divide-by-two and incrementation relationships works,
the Argument and Function counters can reach zero simultaneously and
produce a zero-increment output in any subsequent cycle only if N(P) = N(P-1)
and both N(P) and N(P-1) are a multiple of two. If, for example, N(P) and
N(P-1) were odd or N(P)=N(P-1)=2n+1 and the "nearest" value of $^oQ(P-1)=n$
were stored in the Memory Counter, the Function counter would reach zero
first and the resultant positive incrementation, $\delta^oQ(P)=+1$, of the Memory
counter would generate a value of $^oQ(P)=n+1$. Then, if N(P+1) were also
equal to 2n+1, the Argument counter would reach zero first in the P+1 cycle
and the resultant negative incrementation, $\delta^oQ(P+1)=-1$, of the Memory Counter
would return it to the value of $^oQ(P)=n$.

Although this alternating characteristic of output values might be useful for some purposes, it would clearly not be desirable for others. It has been eliminated in most of the experiments to date with the divide-by-two table by simply providing an appropriate time delay between the generation of a zero-state signal in the Function counter and the disqualification of the Argument input gate, G_1. Another simple kind of logical circuitry is now being fabricated to eliminate such a characteristic when dealing with tables of non-linear as well as linear functions.

As indicated in Figure 4, the count of $^oQ(P)$ stored in the Memory Counter has been brought out to a digital indicator. In addition, the Write operation has been mechanized so that it can be used to synchronize the recording of these values of $^oQ(P)$. At the present time both the Memory and Function Counters are binary-coded-decimal counters and appropriate diode decoding matrices are used to provide the desired form of indication and/or recording. Figure 6 is a picture of the present "packaged-bread-board" input, logical, counting and indicating parts of TACOS.
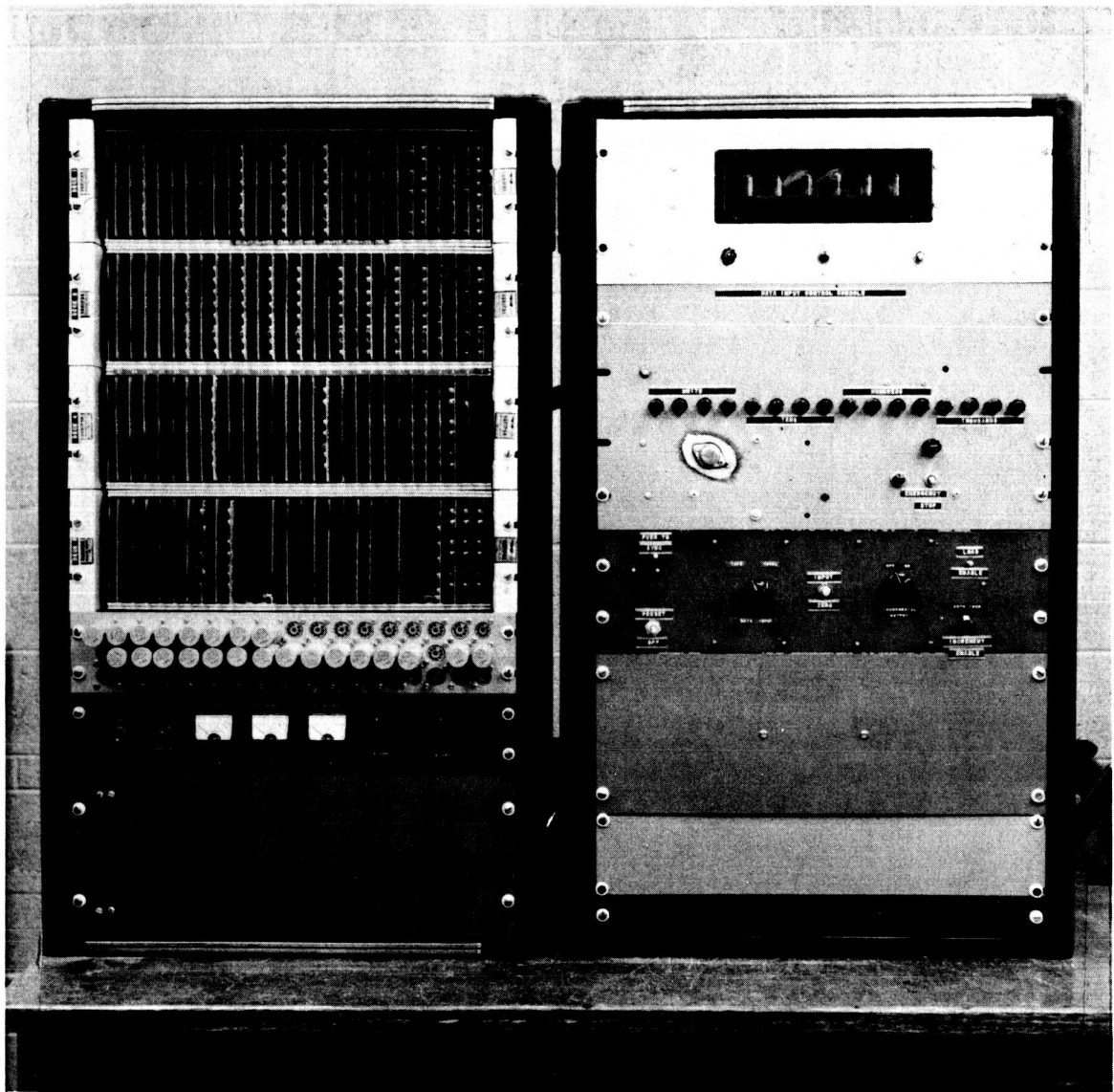
FIGURE 6
ELECTRONIC AND MANUAL INPUT ASSEMBLIES

5. RECORDING

The initial experimental output-recording unit of TACOS is pictured in Figure 7. It consists basically of an Alden Model 305A multistylus electrochemical type of recorder with a special Slo-Syn Model SS-150 stepping motor. Chart-drive circuitry is packed in the bottom of the assembly and makes it possible to advance the chart paper by either about 1/37 or 1/74 of an inch per step upon demand. The plug-in modules shown on the right rear of the unit are marking-current amplifiers for each of the 60 stylii with which the recorder was originally equipped.

In addition, this recorder has been fitted with some more closely spaced recording stylii. The original stylus modules, as pictured on the left in Figure 8, each contain ten, individually spring loaded stylii in about three quarters of a transverse inch. The experimental module shown on the right of Figure 8 contains four groups of five piano-wire stylii spaced about 1/32 inch apart in a transverse width of about two thirds of an inch. The operation was found to be improved, especially when using the new stylii, by adding the paper take-up roll shown on the front of the recorder in Figure 7.

Figure 9 is a full-scale reproduction of the kinds of marks that this recorder produces with its more closely spaced stylii. This particular example was made by manually entering arbitrary, successively quite different or "step-function," numbers into TACOS and recording the incremental outputs generated during the process of proceeding incrementally from one such step-function input to the next. One, three and five transverse dots have been used to denote incremental values of -1, 0 and +1, and the option of 37 paper-drive-steps per inch has been used to provide an open space between successive increments.

This same set of marks has been reduced photographically by factors of 2 to 1 and 5 to 1 in Figure 10 and 11 in order to illustrate how they might appear at more nearly their ultimately desired size. In these illustrations, about 37, 74 and 185 incremental data points per lineal inch are contained in each of 6, 12 or 30 incremental columns of data per transverse inch; or of the order of 222, 888 and 5,550 data points are contained in each square inch of record. This particular
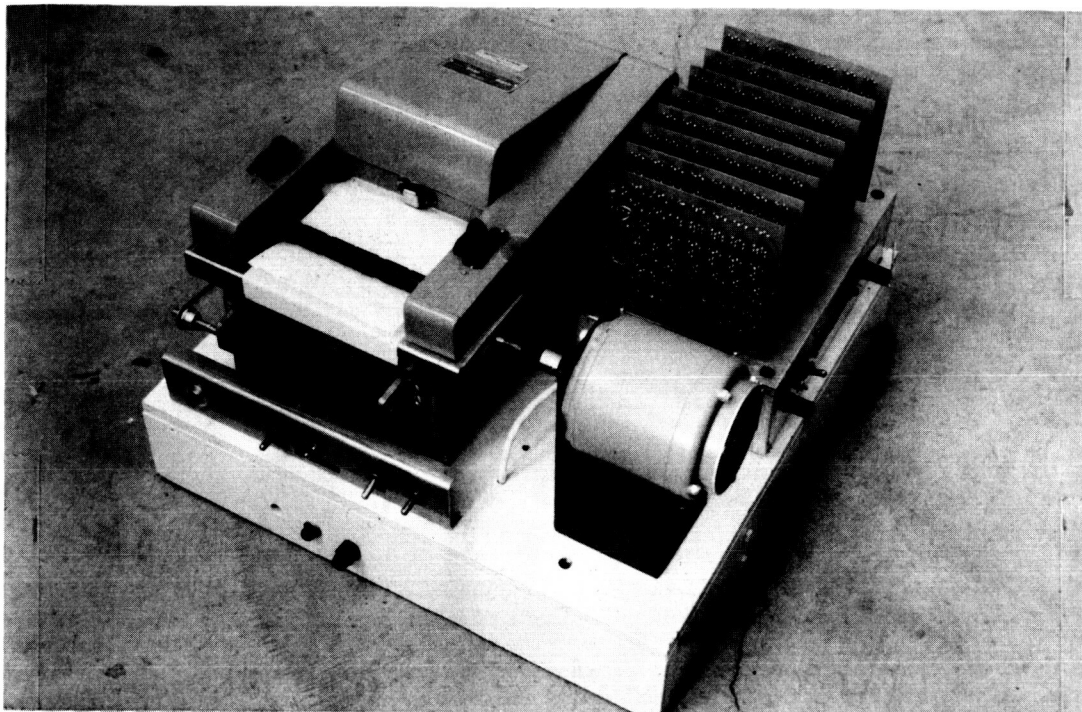
FIGURE 7
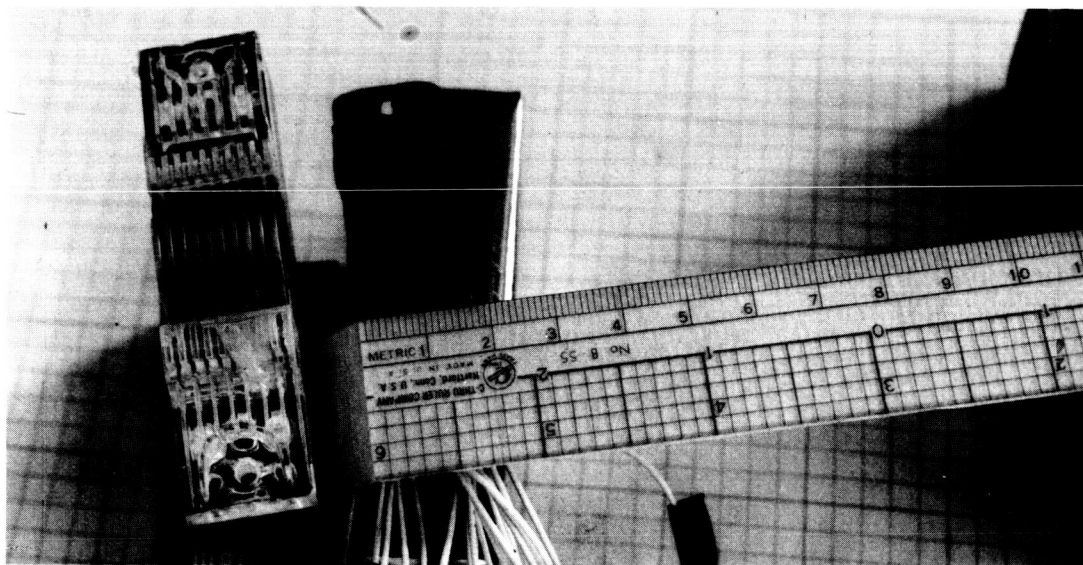EXPERIMENTAL OUTPUT RECORDING ASSEMBLY
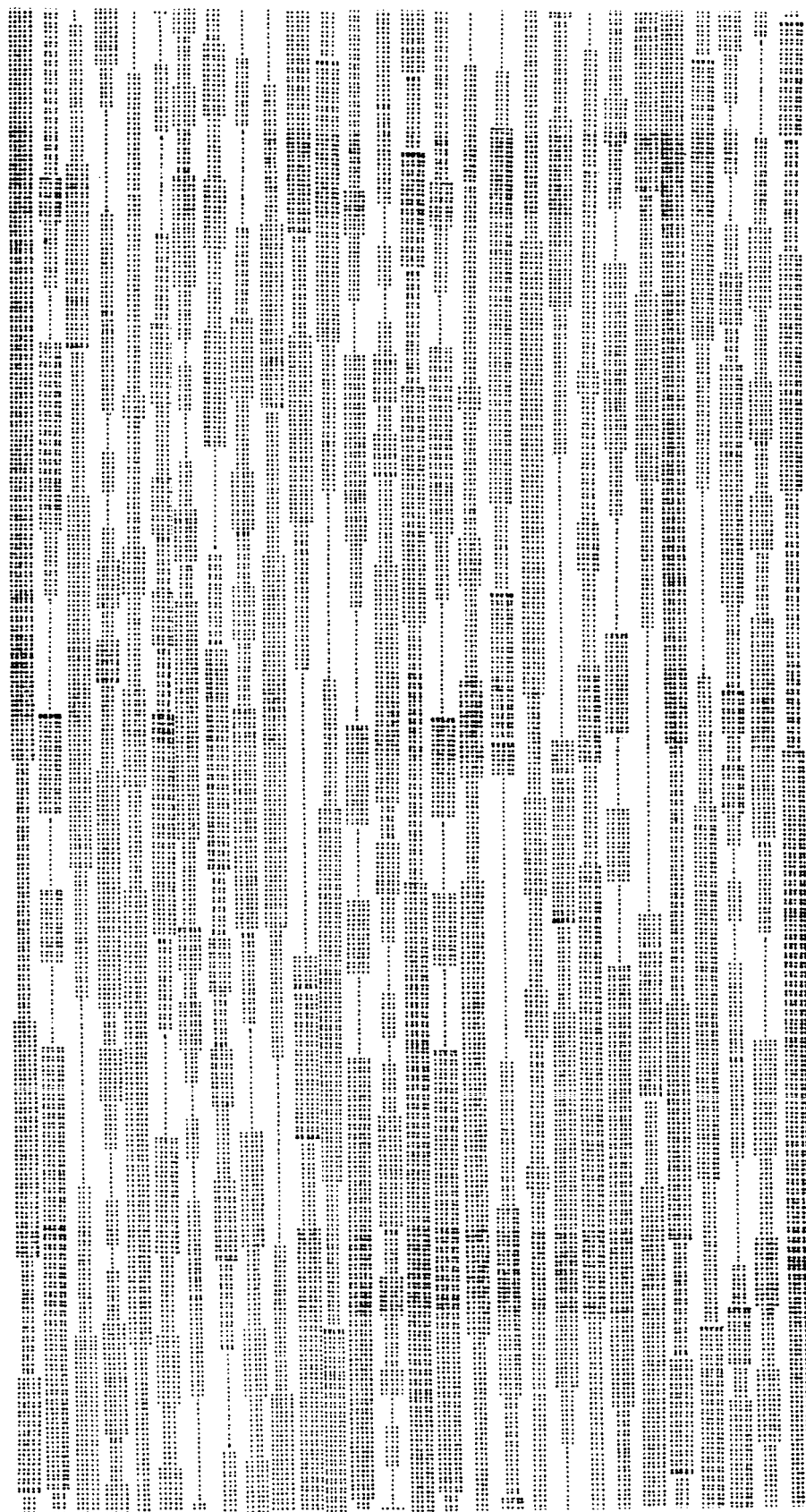

FIGURE 8
EXPERIMENTAL STYLUS MODULES

FIGURE 9
TRIAL INCREMENTAL NUMERALS, ORIGINAL SIZE
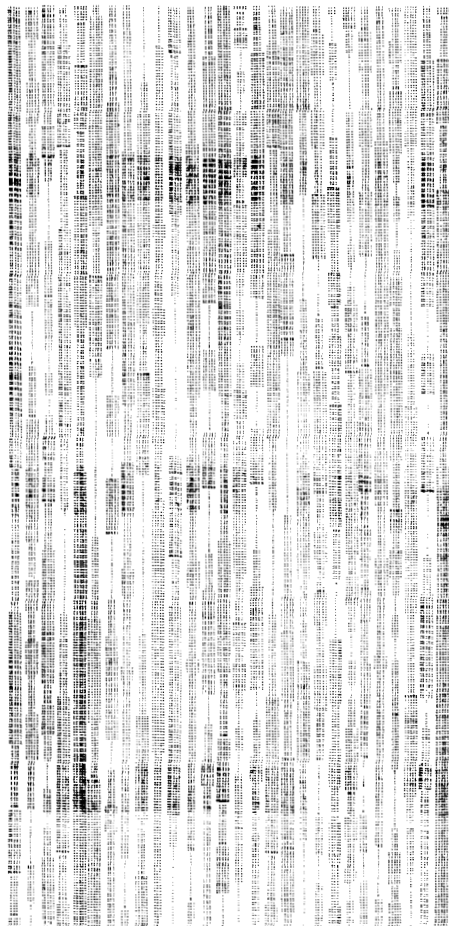
FIGURE 10   FIGURE 11

TRIAL INCREMENTAL NUMERALS

1/2 ORIGINAL SIZE   1/5 ORIGINAL SIZE

sample contains about 10,000 data points and, for convenience of recording, was composed by assemblying several strip recordings side-by-side. The dark transverse bands apparent especially in Figure 10 are caused by the transparent Scotch tape with which those side-by-side strips were held together.

Figure 12 illustrates the appearance of another, "uadic", kind of informatic numeral which has been produced[7] with this recorder and reduced photographically by a factor of about 4 to 1. In this notation, values of digits with digital radices of three, four, five or perhaps six are represented, in basic effect, by replacing the Arabic numerals 0, 1, 2, 3, 4 and perhaps 5 with "uadic" numerals which consist of corresponding number of dots in a transverse row. This particular data was transcribed[7] from some readily available strip-chart records of measured snow depths. This transcription was accomplished with an assemblage of multiple contact, manually set, rotary switches to energize the desired patterns of recording stylii.

FIGURE 12
TRIAL UADIC NUMERALS, 1/4 ORIGINAL SIZE

6. EVALUATION

The experience gained with TACOS to date indicates that the tabular conversion technique is likely to prove to be very useful in future operations. It is especially promising for rectifying observational data in terms of empirical sensor-calibration relationships. Currently this rectificatio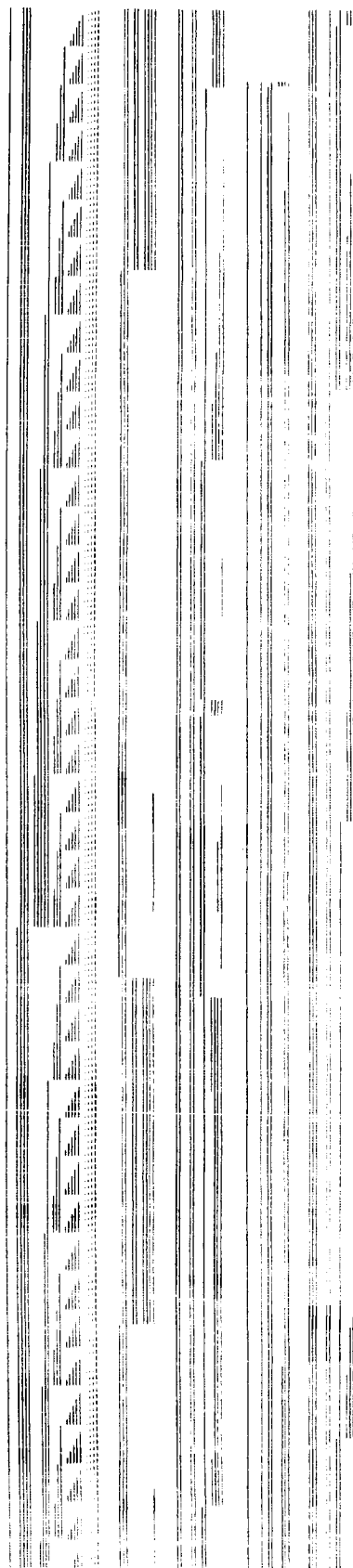n process is usually accomplished by approximating the sensor-calibration data with analytical functions stored in the memory of large, general purpose, digital computers. Consequently it is now necessarily delayed until the data has been collected in large enough centers to warrant the installation of such a computer. In contrast, many quick-look and band-width-utilization advantages are offered by performing this rectification process as soon as possible in the operational data traverse outlined in Section 2. In addition, the use of complete (or hence continuous) tables of sensor-calibration data precludes the introduction of unnecessary approximations inherent in the practical use of analytical interpolation formulae for such empirical relationships.

The potential conservation of required band-widths depends primarily upon formulating continuous data in incremental form so that, for the most part, only a ±1 or 0 signal need be transmitted for each data point. Such incrementation should, however, be preceded by rectification since at least one increment of input data, $^iQ(P)$, must be tabulated between any two successive incremental marks of the output data, $^oQ(P)$, if that output data is to be continuous. In other words, whatever nonlinearities exist between input and output data require that more input than output data points be processed, and hence that rectification should be accomplished as soon in the data processing sequence as possible.

It thus now seems likely that tabular conversion might well first be utilized in the control centers for individual satellites such as TIROS, NIMBUS, OSO or OGO to rectify their "housekeeping" data as part of the COMPILING operation. Such experience is expected to lead to a shift of the rectification process to the COLLECTING operation in the telemetry receiving stations at some later time. This would provide

for a quicker quick-look capability and, especially, offers potentialities of greatly reducing the band-width requirements between data acquisition stations and control centers. The basic simplicity of tabular conversion is such that it might well ultimately be utilized in the OBSERVING process within the satellites themselves in order to reduce the band-widths or transmission times required to telemeter their data to the ground stations.

This experience has also demonstrated that, although tabular conversion is a basically simple process which can potentially be accomplished with advantage in any one of the OBSERVING, COLLECTING or COMPILING operations, the kind of incrementation used in TACOS is not. The difficulty is that an inordinate amount of memory would be required to retain each of the values of $^oQ(P-1)$ until the subsequent values of $^iQ(P)$ became available for each of at least 100 different variables Q.

The consideration of this particular problem was that which led to the conception of utilizing the "uadic" form of numerals illustrated in Figure 12. It is postulated that the numbers now received and recorded on magnetic tape in the COLLECTING and/or COMPILING operations might well be converted from binary to more appropriate digital radices for recording in "uadic" form. In this process the numbers would also be collated so that successive values of each variable, Q, would be aligned vertically. In that case, an informatic form of data would be formed which would provide for convenient manual quick-look interpretability and, especially, very convenient incrementation. This form of record should, in itself, provide the memory required to compare values of $^iQ(P-1)$ and $^oQ(P)$, and the values of $\delta^oQ(P)$ should then be detectable merely by detecting changes of width of the units column of the ^iQ numbers.

This experience with TACOS has, however, brought to light a major developmental problem; namely the need to develop recorders which are potentially suitable for operational use. To date most sample[1,2,4] forms of informatic data have been made by fitting typewriters with special keys and photographically reducing the results by factors of as much as 20:1. This experimental procedure is not very realistic, however, since it provides little if any information concerning the appearance of the kinds of numerals which might readily be produced directly at the

ultimately desired small size. It has also become evident that no recorder now on the market can do so; indeed it is not now clear which of several possible recording techniques are likely to be found to be most suitable for this purpose.

The recorder development work described in Section 5 has served more to demonstrate its difficulty than to obtain a solution. An inordinate amount of work was found to be required to develop this recorder to the point that it could be used to make the samples illustrated in Figures 9, 10, 11 and 12, even though the direct recordings were of the order of four to five times larger than ultimately desired. In addition, these sample forms of numerals are not considered to be entirely satisfactory. The format of the incremental numerals illustrated in Figures 9, 10 and 11 clearly need to be improved if they are to provide as clear a picture as has been obtained in previous[1,2,4] examples of incremental and SIPLIC forms of data. Clearly, also, the first trial sample of the newly conceived uadic form of numeral illustrated in Figure 12 indicates good potentialities, but just as clearly it also demonstrates a need to improve upon their format if those potentialities are to be fully realized.

7. PLANS

Plans for the future use and improvement of TACOS are centered on using it to produce some trial samples of "real" orbital data transcribed into both uadic and incremental forms. For this purpose representative Arabic numeral tabulations of "housekeeping" data have been acquired at the time of this writing from each of the TIROS, NIMBUS and OSO satellites. It is planned to transcribe initial samples manually with typewriters fitted with "uadic" keys with proportions which have been found by experience to be realistically appropriate for multistylus kinds of recording. The characteristics of those initial samples of "real" data are expected to provide the information needed to establish methods of automatically transcribing more extensive samples with TACOS.

For this purpose it is planned to incorporate an incremental interpolation capability within TACOS. Although the kind of incrementation described in Section 4 is appropriate for some kinds of data, the sampling rates (or units of resolution of ordinal variables, P) now in common use are frequently too gross to provide representative continual data. Consequently it is more realistic to formulate continuous data portrayals from currently available input data, $^{i}Q(P)$, by interpolating to formulate continuous output data, $^{o}Q(p)$, in which the output unit of resolution, p, is an appropriately selected fraction of the input unit of resolution, P. A "unitary, complementary counter readout" technique of making such interpolations has been found[5] to be especially appropriate for use in conjunction with tabular conversion and is now being implemented for use in TACOS.

A basic characteristic of the uadic form of numerals is that they can best be used with digital radices of three, four, five or sometimes six. Consequently it is necessary that TACOS provide the capability of selecting and utilizing whatever combination of such digital radices might best serve some particular kind of data. Current plans are to provide such a recording output capability by designing and fabricating electronic counters for each of those digital radices. These counters are being designed so that they can be cascaded in any desired order, and so that they can be utilized directly as the output counters of the forementioned incremental interpolator.

26

Two kinds of automatic data input devices are also to be incorporated in TACOS. The first, a punched tape reader with appropriate input buffers, is currently being constructed and tested to provide a convenient interface between the University of Wyoming Philco 211 computer and TACOS. It is expected to provide an interim capability whereby magnetic tape recordings of various kinds of orbital data can first be processed by the Philco computer. Our experience to date[7] has shown, however, that such general purpose computers are neither easily nor economically adaptable to this kind of data processing. Consequently it is planned to also provide TACOS with a direct magnetic tape input as soon as warranted by the availability of compatible interpolation and recording capabilities. This latter development is expected to provide the experience needed prior to any future operational use-test of informatic techniques.

Finally, research on more suitable ways of recording the informatic forms of data is to continue. Significantly in this regard, considerable effort was expended during the 1965 summer to modify an electric typewriter so that its carriage and paper were advanced with much smaller than normal steps. This effort was largely negated, however, by the extreme difficulty of obtaining and maintaining a compatibly precise registration of the striking positions of the keys. Consequently future investigations of the potentialities of mechanical means of informatic recording are to concentrate on the use of individually actuated tapper bars in fixed lateral positions. Such a recording technique has previously been used[5] with good success and is utilized in the equipment recently donated for use in TACOS by the Cook Electric Company. That recorder is currently being modified for the primary purpose of producing incremental tables for use in both reflective and transmission kinds of tabular converters.

It is also planned to continue to investigate the operational potentialities of the multistylus kind of recorders. It now seems likely that some form of electroscribing offers more promise than the electro-chemical process used in the initial TACOS recorder of Figure 7. By "electroscribing" is meant here the control of electrical currents through stylii to vaporize small regions of very thin aluminum coatings on Mylar. Although this marking technique has received a great deal of research attention in the informatic research program to date without complete success, it now seems to be on the verge of becoming practicable.

27

In addition, a novel way has recently been conceived to utilize cathode-ray-tube flying-spot-scanners and optical recording techniques to produce very small informatic forms of numerals very rapidly and conveniently. It is planned to investigate the potentialities of this technique initially with standard wet-process photographic procedures. In case this basic technique thereby proves to be as useful as expected, it would then be possible to utilize a dry xerographic process in like equipments for real-time use in orbital operations.

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