NORTH CAROLINA SCIENCE AND TECHNOLOGY RESEARCH CENTER

A UNIT OF THE DEPARTMENT OF NATURAL AND ECONOMIC RESOURCES

MAPPING INDIVIDUAL LOGICAL PROCESSES IN INFORMATION SEARCHING

by

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NOVEMBER 1974

(NASA-CR-142207) MAPPING INDIVIDUAL LOGICAL PROCESSES IN INFORMATION SEARCHING (North Carolina Science and Technology Research) CSCL 05B G3/82

N75-19074

Unclas 17576

STR-506

RESEARCH TRIANGLE PARK, NORTH CAROLINA 27709

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Introduction

Certain individuals display an unusual ability to find specific information quickly in large collections such as libraries. Perhaps if one understood sufficiently well the complex logical processes by which these individuals operate, he might formalize these processes somewhat and so enhance the effectiveness of other information searchers. Experience in many fields of science teaches, however, that careful measurement of a phenomenon usually precedes its understanding and description. With this precept in mind, the acquisition of a computer terminal with attached printer (the terminal being connected to a computer programmed to search a large file in an interactive fashion) seemed to offer an opportunity to chart in a quantitative fashion the logical processes used by various individuals in isolating specific information from a very large set.

Accordingly, an experiment was designed around this terminal equipment and a number of tests were conducted. This is a report on the experiment and the results which were obtained. The results seem to be sufficiently specific and informative that one may recommend the procedure, or variants thereof, as a tool for acquiring a statistically significant number of logic mappings from which some universal laws perhaps can be deduced. This report, however, is intended to describe only the mapping process itself and to illustrate it by one example rather than to present a detailed analysis of the effectiveness of various search techniques as revealed by maps of their logical processes.

EXPERIMENT DESIGN

The terminal was connected by telephone line to a computer located in College Park, Maryland, on which is mounted the entire NASA scientific information collection.* This collection, dating from 1962, contains approximately 750,000 items.* Each item is indexed under an average of 15 terms.** The number of separate index terms recognized by the computer is somewhat in excess of 18,000. The collection covers a very broad spectrum of scienfific disciplines.

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* An item may be a patent or a computer program instruction manual as well as those documents cited in the next paragraph.

** An index term is a word or phrase describing a concept. For example, a document dealing with psychological testing may be indexed under such terms as "psychometrics," "testing," etc.

Some disciplines, of course, are represented more extensively in the collection than others. Items come from both domestic and foreign sources. Approximately half of the items are report-type literature and the other half are from the journal literature.

The report literature contains documents from government laboratories, government contractors, translations of foreign reports, doctoral dissertations, university reports, etc. Some 1800 scientific and technical journals from all over the world are scanned for relevant items to add to the collection. For many problems in the physical sciences, the NASA collection is the most accessible one available. For suitable problems, it permits the searcher to exercise his knowledge, experience, and ingenuity to a considerable extent in order to improve his recall of relevant documents. The flexibility it offers makes it a good vehicle to use for studying the logical processes a searcher employs in going about the task of identifying the relevant documents in a large collection and the differences in the logical tacks taken by various searchers.

At the terminal is located an instruction manual which the user may consult to refresh his memory on the operations needed to access specific information in the system. The system will accept commands to display:

1. A portion of the list of accepted terms, in an alphabetical order with 5 terms prior to the specified term and up to 37 subsequent terms, if desired. This is termed an expansion about the specific term. Beside each term will be indicated the total number of documents in the system indexed under that term.

2. A hierarchial list of terms related by subject to the specified term. This is called a thesaurus expansion. The number of documents posted to each term is also shown.

3. The accession number or identifying number of every document indexed under a given term.

4. A full bibliographic citation of every document indexed under a given term.

5. An alphabetical list of authors of documents in the system with the number of documents by each listed beside the name. The author's name can be used to obtain the accession numbers or full bibliographic citation of all documents associated with that name.

6. The same can be done for corporate source or contract number, but these are seldom used.

The system can also be commanded to search all of the documents posted under a given term for the presence in the indexing of a second (or third, etc.) term. The occurrence of a second desired term can be made the basis either to select or reject the document. If the document is selected on this basis it may be said to have been selected through a logical "and"

process, i.e., the document must be indexed under both term A and term B. If the document is rejected, the process is termed a logical "nor" or "not" process. The reader may quickly determine that this capability permits literature searches of very elaborate strategy to be constructed. On the other hand, the indexing is assigned manually. This means that in addition to the general rules usually observed by the indexers (which are soon apparent to the veteran searcher) there are also anomalies caused by misunderstanding of the document by the indexer, inconsistency from day to day, the desire to limit the number of index terms to around 15, or by simple human error. As a result, it is usually not productive to write searches of great complexity. Requiring that the indexing of a particular document contain more than two desired terms usually results in unacceptably small output.

This, then, is the system with which the human searcher interacts. He is put before a cathode ray tube display and a typewriter keyboard. He communicates his thoughts to the computer through this keyboard. The CRT screen displays his question, the system's response, questions from the system to him, and his response. A printer alongside is rigged to record the entire "conversation" including clock time for the process. The searcher is handed a statement of the problem and asked to go to work. The room is semi-sealed against disturbance. Only if the searcher has trouble making himself understood to the system (which sometimes happened with inexperienced searchers) or encountered technical difficulty (which occurs at random times) does he emerge and ask assistance of monitoring personnel.

The search problem selected to illustrate the capabilities of such a procedure to map thought processes was one that was received during the normal course of business at the North Carolina Science and Technology Research Center. It had proven to be particularly troublesome because the 400 or so relevant documents in the collection suffered from indexing vagaries that made their retrieval difficult without, at the same time, retrieving a large quantity of extraneous material. In such a problem, it was felt, a searcher could really demonstrate his skill and knowledge. The search problem statement is reproduced in the Appendix. The printed record of the "conversation" with the computer was given to the experiment director along with the "hit" list the searcher felt was his best effort. Abstracts for all of those "hits" were examined by the experiment director who decided which of the hits were relevant. This was done to determine what portion of the searcher's hit list was pertinent and how many of the pertinent documents in the entire collection the search identified.

The printed records of the "conversations" with the system were then prepared in the form of a standardized flow chart to facilitate identifying the approach and results of each searcher. In the process of preparation, mistakes which elicited responses from the system such as "Invalid Command Proceed" were eliminated as were garbled conversations resulting from system failures. Reproduced below as Figure 1 is the flow chart for a search performed by an undergraduate engineering student with a fair knowledge of system operation and indexing problems. The search shown in Figure 1 required the searcher to remain at the terminal approximately three hours.

LOGICAL PROCESSES EMPLOYED BY THE SEARCHER AS DEDUCED FROM HIS SEARCH

In order to follow the logical processes depicted in Figure 1, one should note that the following symbolism is employed:

(1) A rectangle indicates the term which was the basis for a following operation.

(2) In the upper left corner of the rectangle is a symbol denoting the source of the term:

m	from his mind
e	from a previous expansion
t	from a thesaurus expansion
c	from a document's bibliographic citation

(3) A rectangle with curved sides attached indicates what the searcher saw on the CRT screen, e.g., a "display."

(4) The elongated hexagon denotes an operation, e.g., expand "thermal."

(5) The diamond indicates a decision which can be answered yes or no.

(6) The circle indicates premature termination of an operation.

(7) Operations, display, etc., are arranged in chronological order with arrows leading from the proper antecedants and to the point in the search where subsequent operations are performed.

(8) Where it is necessary to break a line at the bottom of a column, an identifying letter is inserted so that when the reader again sees that letter, he knows the line of which it is a continuation.

(9) Lines to the right of terms in a display indicate that the searcher selected those terms to form sets.

The searcher began by requesting an expansion about the term he considered to be basic to the whole search, the term "thermal." On the basis of the first display[+] he selected two terms and felt that these were sufficiently pertinent for him to continue the displays until the display limit[++] was reached. From this expansion he selected a total of 9 terms and formed

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+ Display refers to the material presented at a given time on the face of the cathode ray tube viewing device.

++ Approximately 14 additional terms are displayed on the CRT each time the command "more" is given until the limit of 41 terms has been reached.

8 sets.[+++] Note that he is assured of a large number of documents upon which he could perform further logical operations by the fact that the term "thermal" is posted* to 10,954 documents.

One of the terms displayed in the expansion, "thermal emission," seemed, on the basis of the problem statement and his general knowledge of the subject area, to be worth examining further. The searcher therefore requested a thesaurus expansion from which he selected three terms. He then combined these to form set 9.

To get another start on the problem, the searcher went back to the central idea and selected a broad but related term, "temperature," on which to request an expansion. He knew from previous experience that asking the same question in several ways is often necessary to assure that documents dealing with a particular subject (but indexed by different individuals using similar but not identical terms) are retrieved. Unfortunately, he misspelled it "temperture." The display indicated no postings under this term. The searcher nevertheless did find what he considered to be a useful term in this display. He then decided to overcome his spelling deficiency by using first the root of the term, "tempera." This produced the desired result and he again displayed all the terms up to the limit, selecting 12 to form 10 additional sets.

Next, he chose to perform a thesaurus expansion on one of the terms which appeared during the previous display, "temperature measurement." This term, of course, is specifically what the search is about. Since the measurement was to be carried out by observing the radiation, he chose "radiation pyrometer" as a set.

Because the search statement had contained the term "radiometer," he then decided to see what useful terms might be alphabetically related to this. The expansion was reasonable productive but he decided on viewing the first display that a thesaurus expansion would be more appropriate. From this he selected seven terms.

He then went back to the general concept of "measurement" and performed a thesaurus expansion which yielded a number of useful terms.

+++ A set is a group of documents labeled by one or more specific terms or an ensemble of such groups. It is created by the searcher because of his desire to perform some further operation with this group of documents. Each successive group of documents, or set, is assigned a number in order by the computer.

* This is to say that the index term "thermal" has been assigned to 10,954 documents in the collection. To speak of "postings" means that x number of documents are assigned, or posted to, a specific index term.

In the general sense the concepts of "temperature" and "heat" are closely related. Seeking to formulate the idea of "temperature measurement by detection of radiant heat flux" in other terms, he chose to expand the general term "heat." Only three of the terms displayed, he felt, added significantly to those he had already selected.

He then approached the idea of measuring the temperature distribution over a surface as a form of mapping and sought to determine whether any of the related terms would be useful. From the thesaurus expansion he selected only three.

He then tried a different approach on the idea of measurement by using the term "sensing." This appeared to be quite productive. At this point he decided to winnow down the number of documents to those more pertinent. He combined those sets dealing with temperature measurement to get a single set, number 39. He also combined sets dealing with radiometers to obtain set 40 and sets dealing with mapping and sensing to obtain set 41. The sets dealing with temperature in a general way were intersected** with set 41 to give a new set, 42, which contained 465 documents indexed under both the idea of temperature and that of mapping. The general idea of measurement was then combined with set 41. The new set, number 43, was intersected with sets on heat and radiation measurement to obtain 1443 documents dealing specifically with radiation mapping. Set 43 was also intersected with sets 39 and 40. The result was a set of 1473 documents dealing with mapping by radiometer.

In this process, one term with only two postings caught his eye: "sensor for airborne terrain analysis." He decided therefore to display the two citations to see if they were relevant. They were not.

Up to this point, he had established that the documents in sets 39, 40, 42, 44, and 45 with some 9000 postings seemed to bear on the problem of measuring or mapping radiation fluxes over large areas. Since he was specifically interested in the emission from water, he developed some expansions about the idea of liquids. Except for the general terms themselves, the results did not appear to him to be particularly promising. He then began to explore the idea of surfaces and assembled all the documents (495) dealing with the idea of liquid surfaces.

Backtracking for a moment, he intersected the idea of radiometers (set 40) with the concepts of temperature measurement, temperature mapping, and radiation mapping (sets 39, 42, and 44). This produced set 53 with 347 accessions. Ultimately, he decided that set 53 represented his best effort on the question, but at the time, he decided to try one more tack to see if some useful documents might show up.

** To intersect means to require that the indexing for a particular document contain both a term from list "A" as well as a term from list "B."

He had not yet investigated the possibilities of approaching the question from the point of view of sensing from an aerial platform, which is how this job was to be done in the field. He began to travel this path by asking for an expansion on airborne. Although he selected one term, the expansion did not appear to be too fruitful. He then made a thesaurus expansion on the selected term without gaining what he considered to be additional insight. At this point, he tried an expansion on a general, but related, term, "aerial." Again he got only one term which he felt might be useful, so that he decided not to continue the expansion.

The two terms selected from this effort he combined to create set 56. He was obviously undecided as to what to do with it at the moment because he then intersected set 53 with set 52 (dealing with liquid surfaces) and got only 4 documents (set 57). This, of course, is too few so he then tried searching the 2956 accessions in set 56 for index terms also in set 53 (by performing a logical intersection or "and"). The gave set 58 with 31 documents.

To see if he were in the right area in his selections, he asked for two of the citations from set 57. These looked to be very pertinent, so he intersected set 57 with set 58. Since three of the four documents in set 57 also appeared in set 58, he felt that set 58 probably was also quite pertinent. He therefore asked that complete bibliographic information on the documents in 57 and 58 be printed. Since both were subsets of 53, he felt that 53 would probably also contain a large amount of relevant data. Finally, then, he asked that all the accession numbers in set 53 be printed.

As a matter of interest, it may be noted that ultimately 388 separate relevant documents were found in the system through a total of eight searches by different individuals. The particular search discussed here found 121 or 31.2% of these. Of the 347 hits designated by the searcher as constituting his search results, 34.9% were relevant. This is a very good performance for this type of question (i.e., one without highly specific indexing).

The foregoing is a recitation of the specific steps taken at each point in the search process by the searcher as he developed his list of relevant documents. It was deduced from the printed record of the searcher's conversation with the computer in the form of the flow chart (Figure 1). Perhaps, however, the thought processes involved here can be better understood by viewing the search in somewhat more general terms. The searcher seems to have operated implicitly under these guidelines:

1. Attack the problem in as many different ways as you can reasonably conceive. Note that in this search he employed at least 4 distinct approaches.

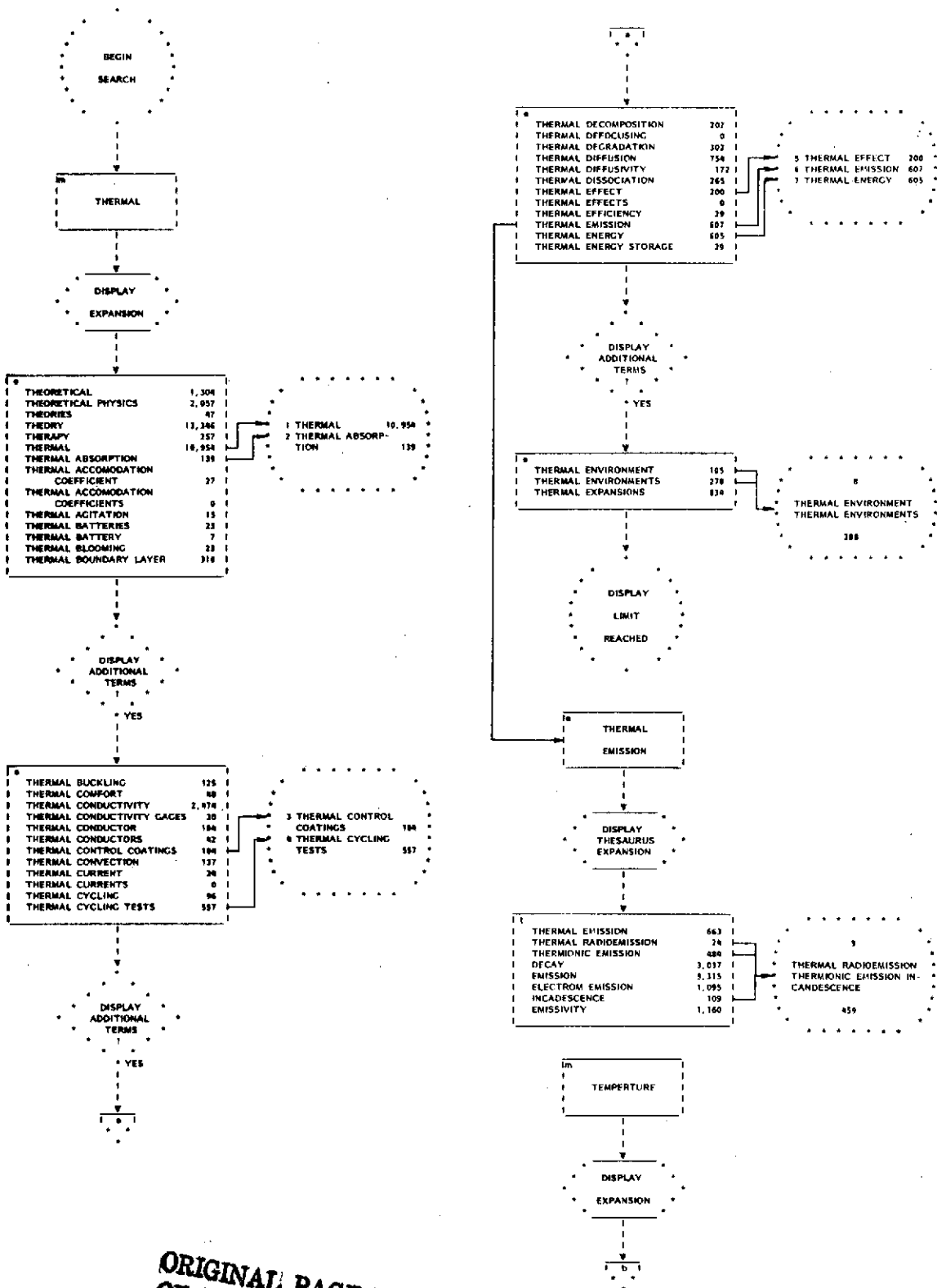
2. Employ intersections between rather general terms or strings of related terms in addition to more specific terms to identify pertinent documents.

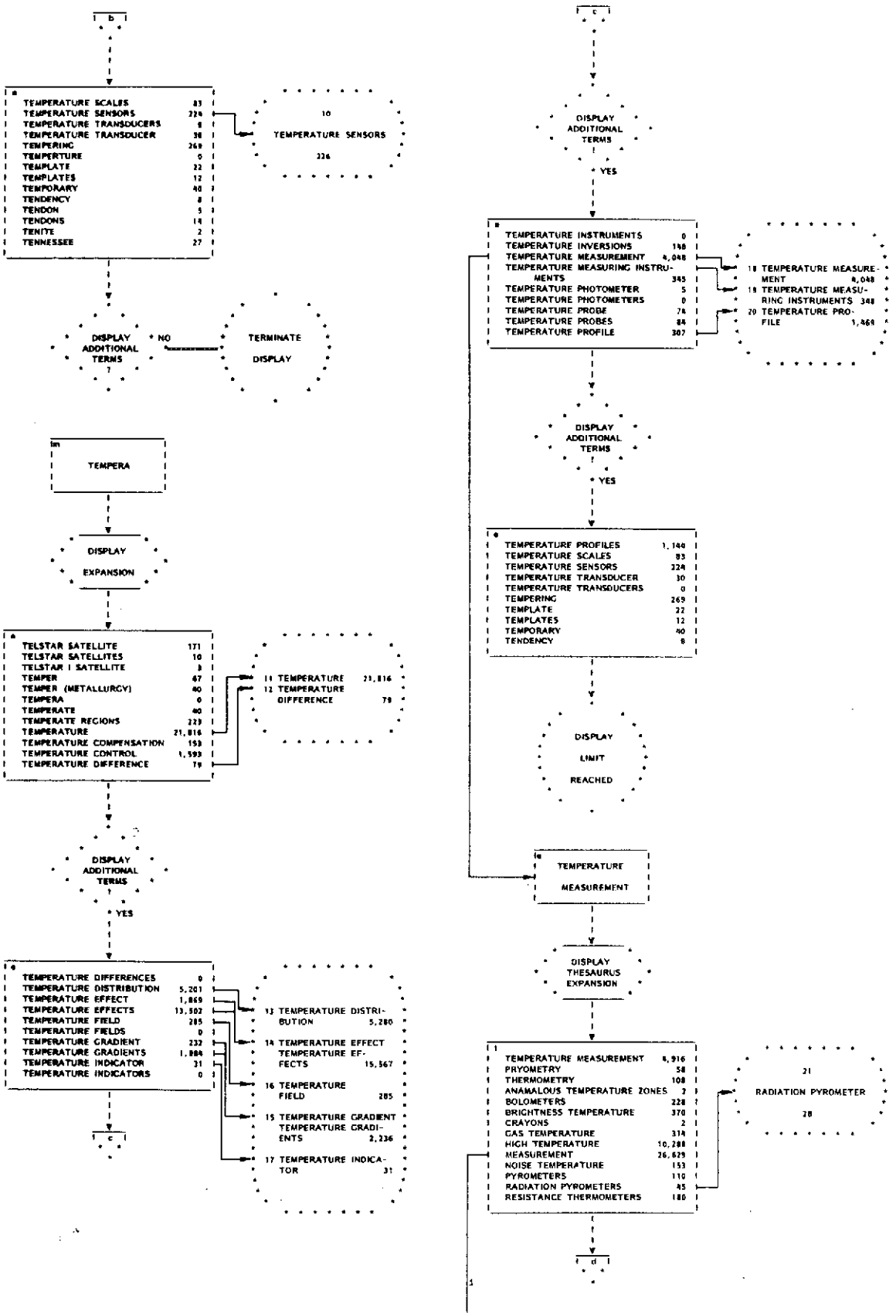
3. Do not be afraid to use a large number of terms. This search used about 75.

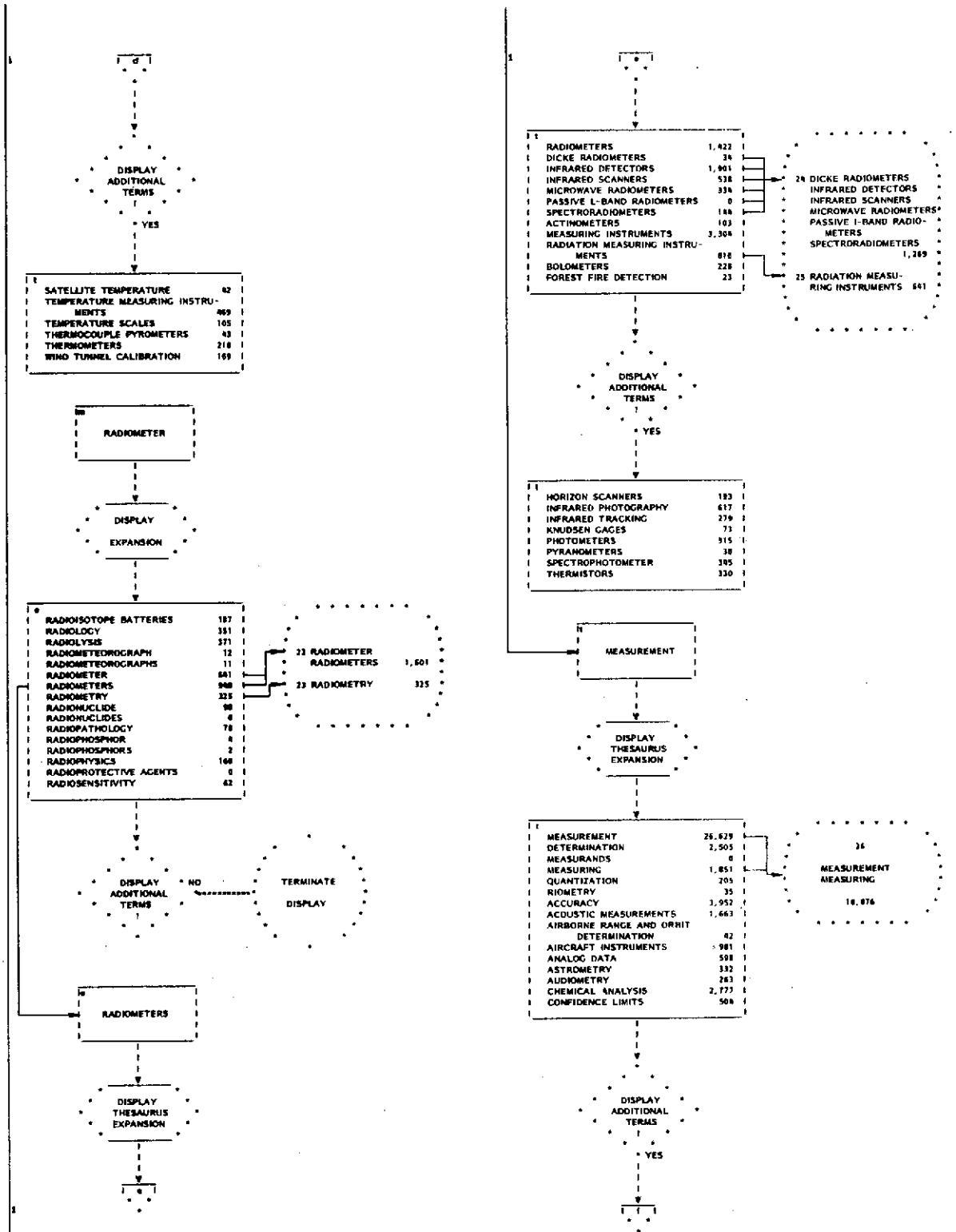
4. Examine some of your intermediate output from time to time to see if you are on the right track.

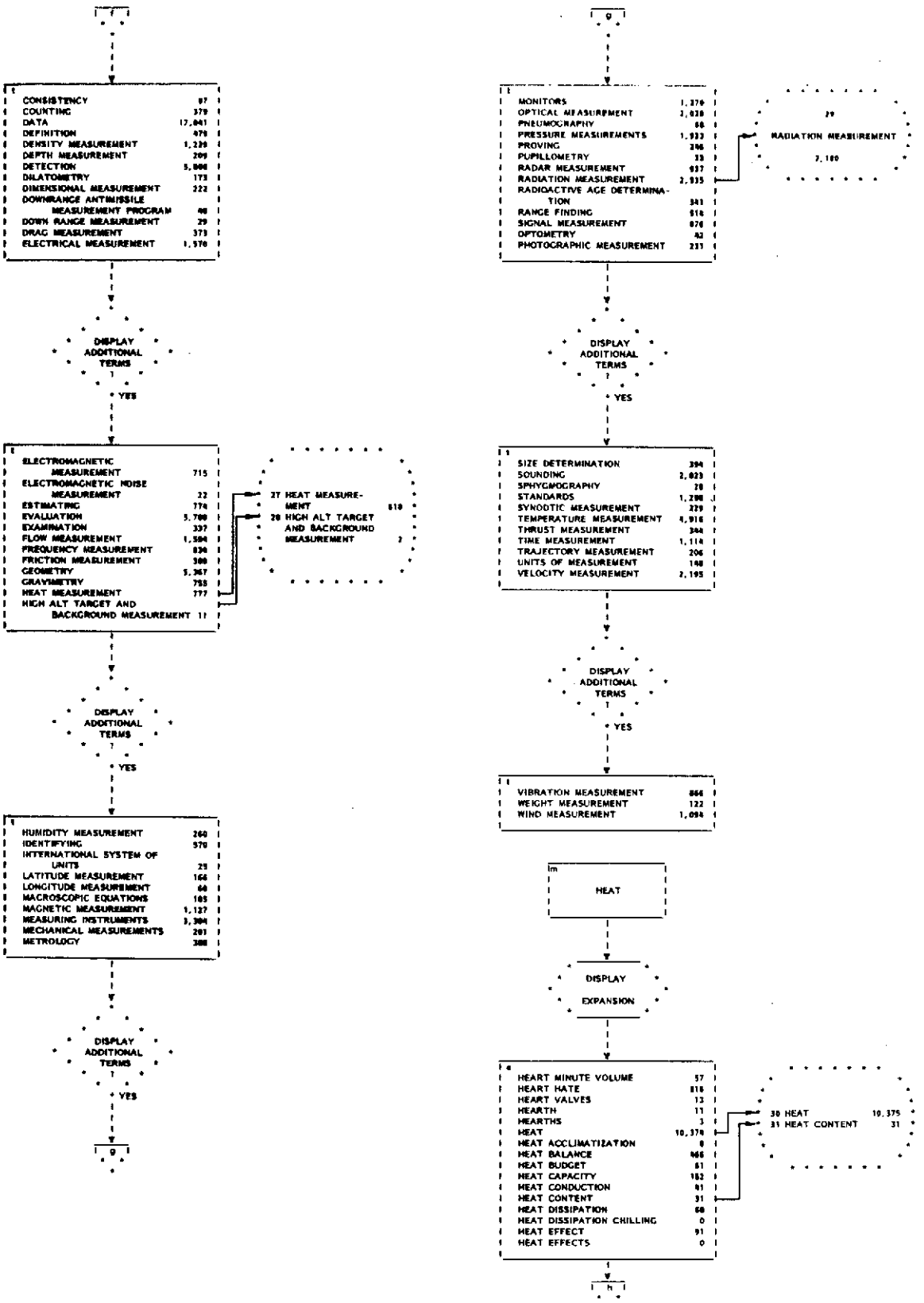
5. The number of pertinent documents retrieved is related in a general way to the time spent in pursuing the search; thus, keep on thinking.

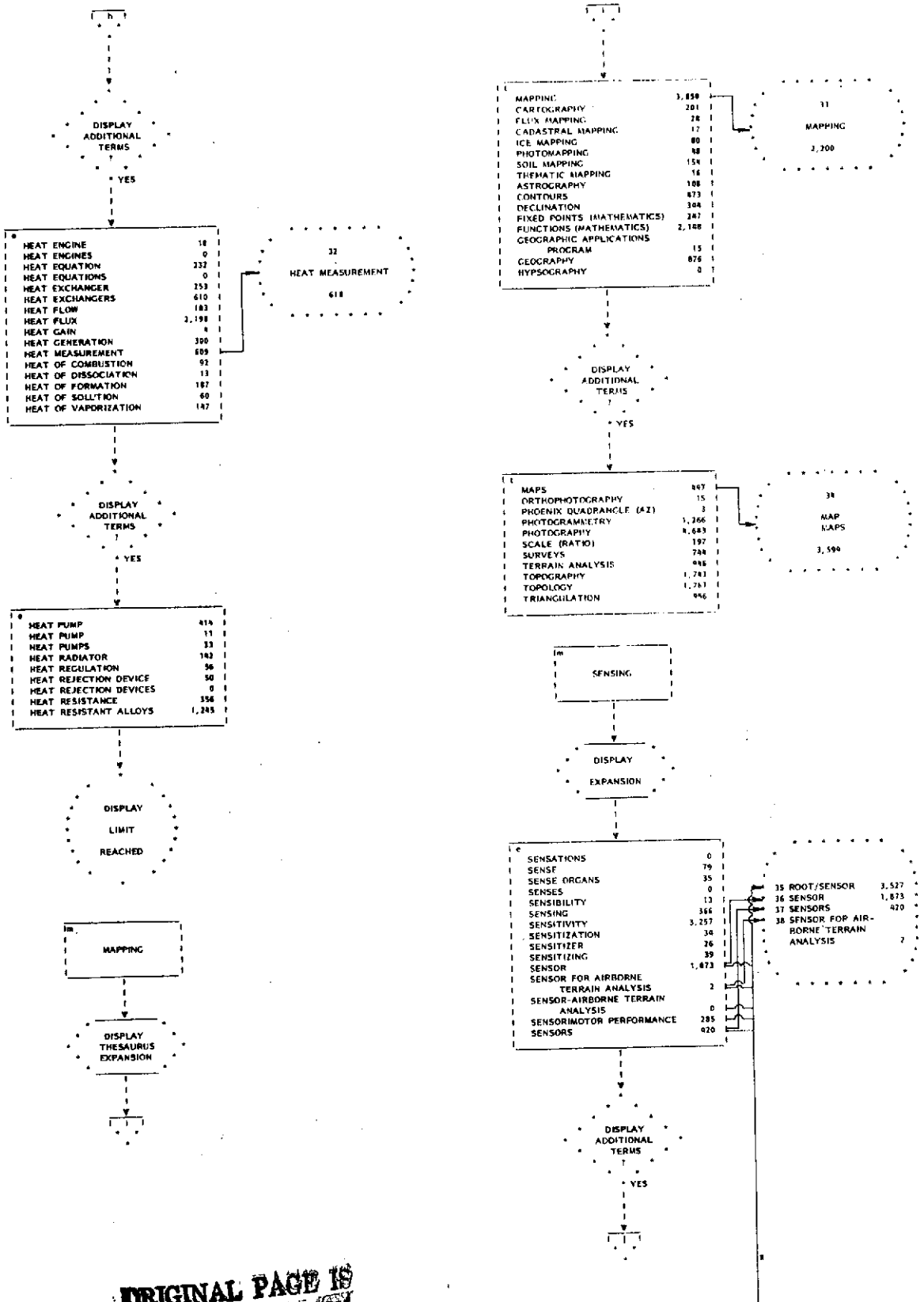
FIGURE 1

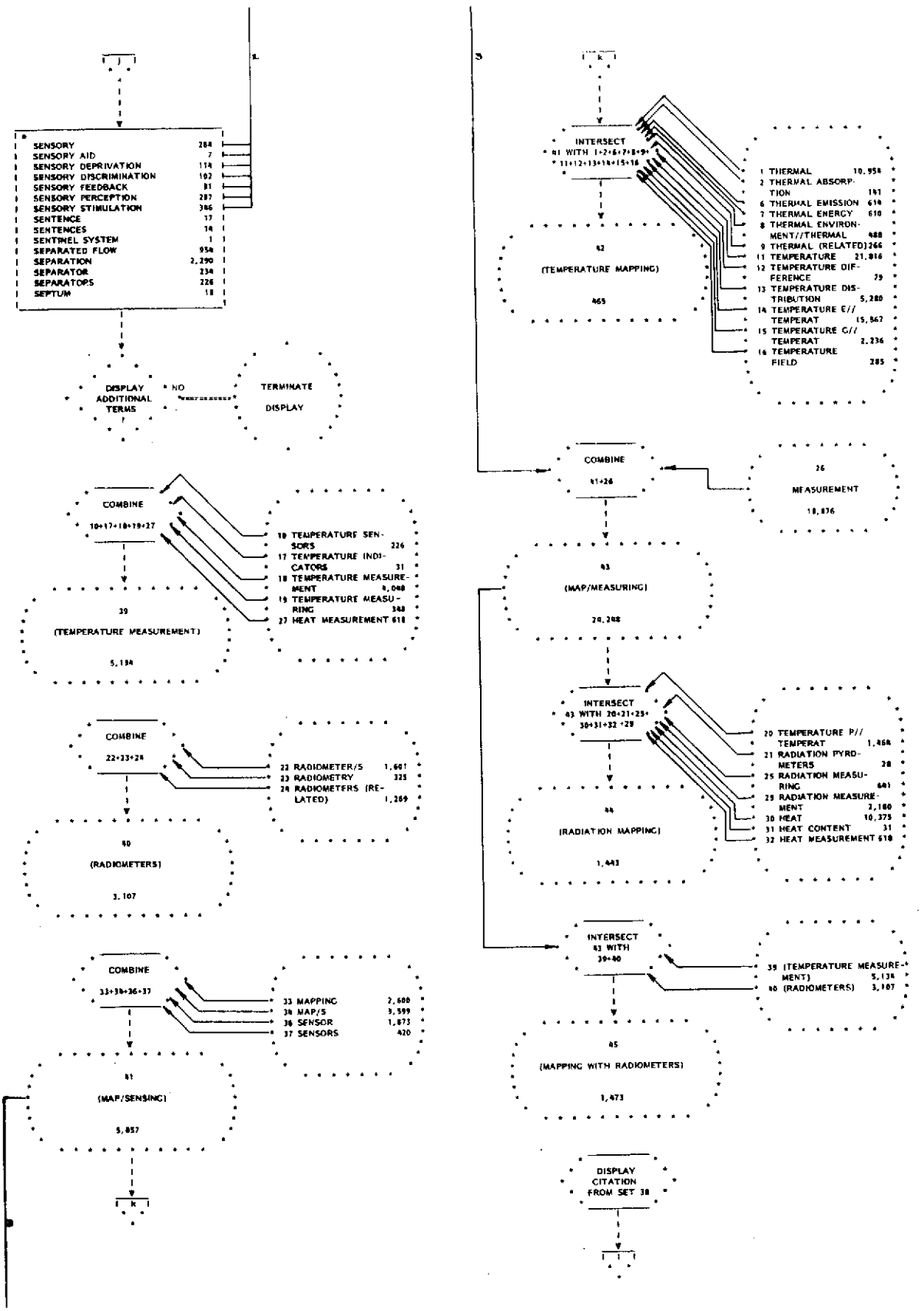


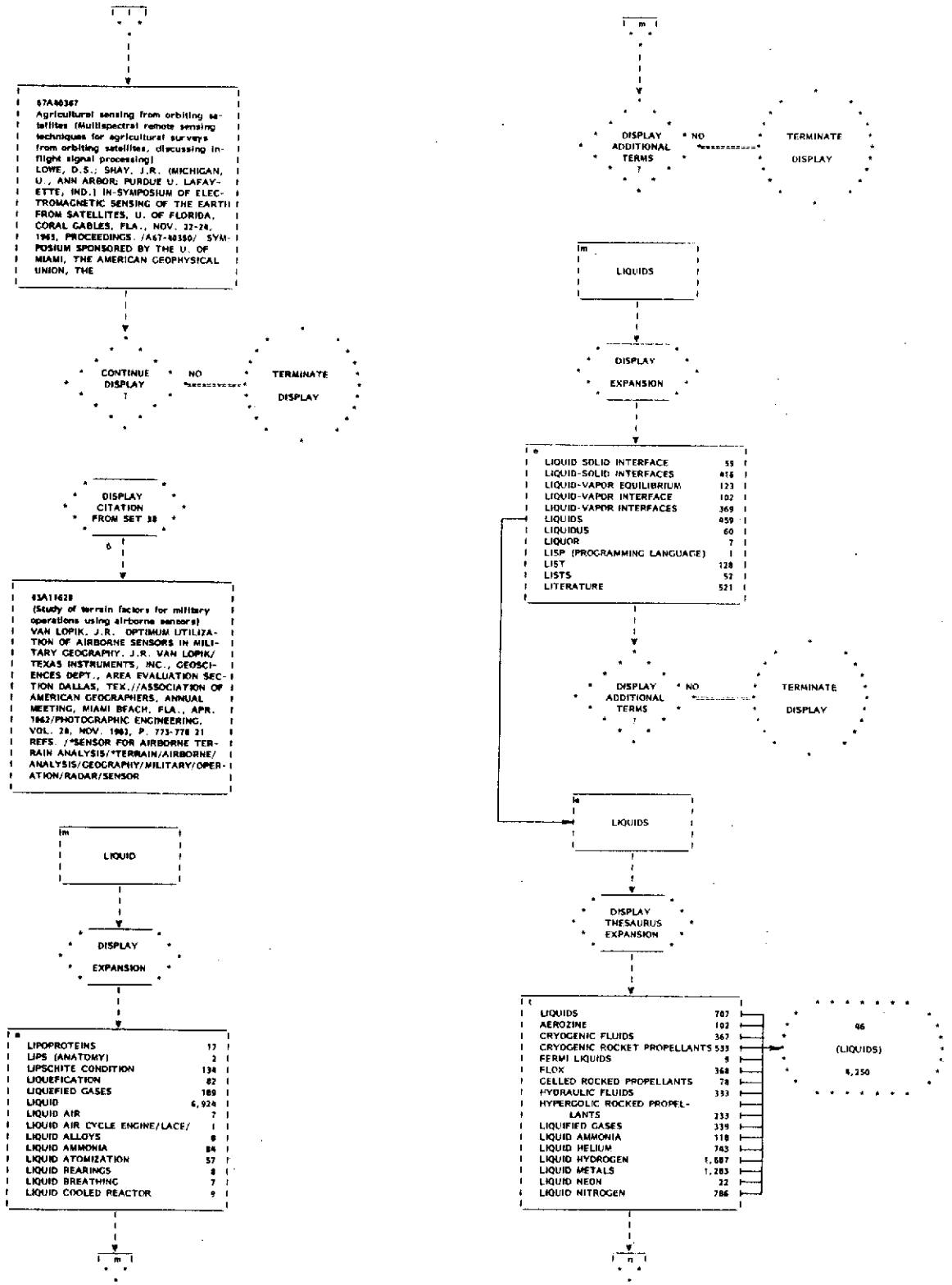

b
TEMPERATURE SCALES 83
TEMPERATURE SENSORS 224
TEMPERATURE TRANSDUCERS 8
TEMPERATURE TRANSDUCER 30
TEMPERING 269
TEMPERTURE 0
TEMPLATE 22
TEMPLATES 12
TEMPORARY 40
TENDENCY 8
TENDON 5
TENDONS 18
TENITE 2
TENNESSEE 27
10 TEMPERATURE SENSORS 224
DISPLAY ADDITIONAL TERMS ?
NO
TERMINATE DISPLAY
TEMPERA
DISPLAY EXPANSION
TELSTAR SATELLITE 171
TELSTAR SATELLITES 10
TELSTAR I SATELLITE 3
TEMPER 67
TEMPER (METALLURGY) 40
TEMPERA 0
TEMPERATE 40
TEMPERATE REGIONS 223
TEMPERATURE 21,816
TEMPERATURE COMPENSATION 153
TEMPERATURE CONTROL 1,593
TEMPERATURE DIFFERENCE 79
11 TEMPERATURE 21,816
12 TEMPERATURE DIFFERENCE 79
DISPLAY ADDITIONAL TERMS ?
YES
TEMPERATURE DIFFERENCES 0
TEMPERATURE DISTRIBUTION 5,201
TEMPERATURE EFFECT 1,869
TEMPERATURE EFFECTS 13,502
TEMPERATURE FIELD 285
TEMPERATURE FIELDS 0
TEMPERATURE GRADIENT 232
TEMPERATURE GRADIENTS 1,884
TEMPERATURE INDICATOR 31
TEMPERATURE INDICATORS 0
13 TEMPERATURE DISTRIBUTION 5,280
14 TEMPERATURE EFFECT TEMPERATURE EFFECTS 15,567
16 TEMPERATURE FIELD 285
15 TEMPERATURE GRADIENT TEMPERATURE GRADIENTS 2,236
17 TEMPERATURE INDICATOR 31
c
DISPLAY ADDITIONAL TERMS ?
YES
TEMPERATURE INSTRUMENTS 0
TEMPERATURE INVERSIONS 148
TEMPERATURE MEASUREMENT 4,048
TEMPERATURE MEASURING INSTRUMENTS 345
TEMPERATURE PHOTOMETER 5
TEMPERATURE PHOTOMETERS 0
TEMPERATURE PROBE 76
TEMPERATURE PROBES 84
TEMPERATURE PROFILE 307
18 TEMPERATURE MEASUREMENT 4,048
19 TEMPERATURE MEASURING INSTRUMENTS 348
20 TEMPERATURE PROFILE 1,469
DISPLAY ADDITIONAL TERMS ?
YES
TEMPERATURE PROFILES 1,140
TEMPERATURE SCALES 83
TEMPERATURE SENSORS 224
TEMPERATURE TRANSDUCER 30
TEMPERATURE TRANSDUCERS 0
TEMPERING 269
TEMPLATE 22
TEMPLATES 12
TEMPORARY 40
TENDENCY 8
DISPLAY LIMIT REACHED
TEMPERATURE MEASUREMENT
DISPLAY THESAURUS EXPANSION
TEMPERATURE MEASUREMENT 4,916
PYROMETRY 58
THERMOMETRY 108
ANAMALOUS TEMPERATURE ZONES 2
BOLOMETERS 228
BRIGHTNESS TEMPERATURE 370
CRAYONS 2
GAS TEMPERATURE 314
HIGH TEMPERATURE 10,288
MEASUREMENT 26,629
NOISE TEMPERATURE 153
PYROMETERS 110
RADIATION PYROMETERS 45
RESISTANCE THERMOMETERS 180
21 RADIATION PYROMETER 28
d

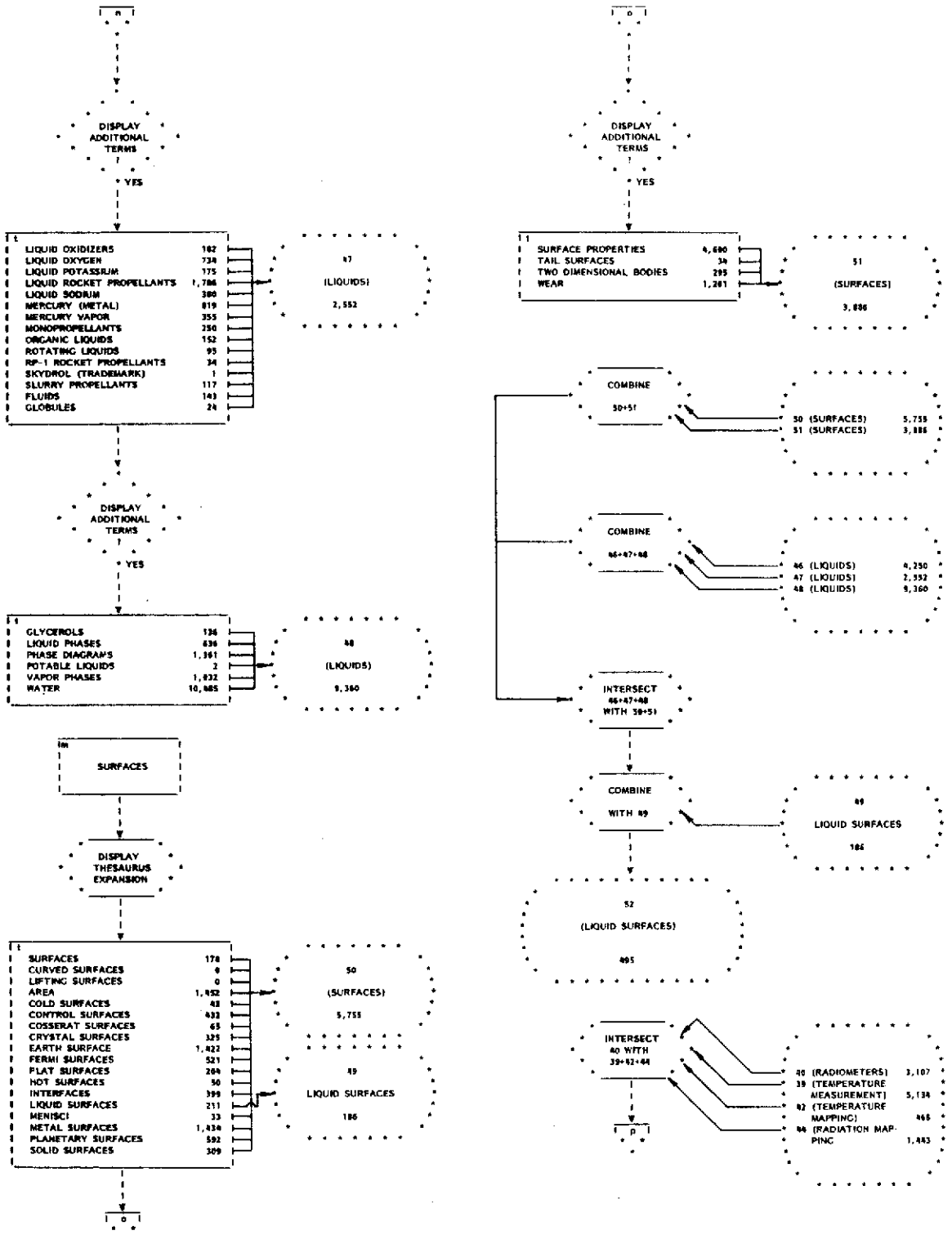


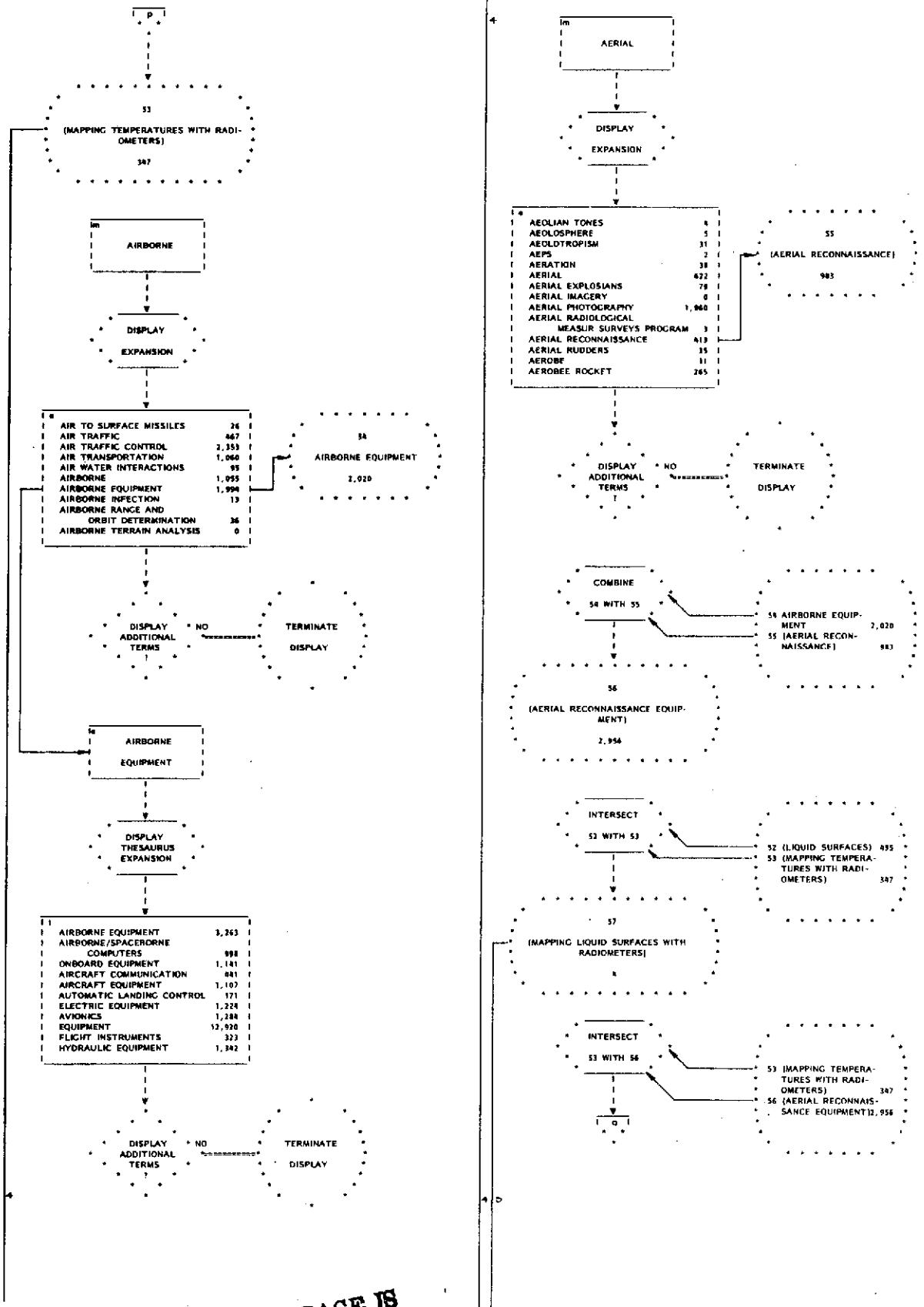

f
CONSISTENCY 97
COUNTING 379
DATA 17,041
DEFINITION 479
DENSITY MEASUREMENT 1,239
DEPTH MEASUREMENT 209
DETECTION 5,898
DILATOMETRY 173
DIMENSIONAL MEASUREMENT 222
DOWNRANGE ANTIMISSILE MEASUREMENT PROGRAM 98
DOWN RANGE MEASUREMENT 29
DRAG MEASUREMENT 373
ELECTRICAL MEASUREMENT 1,570
DISPLAY ADDITIONAL TERMS
YES
ELECTROMAGNETIC MEASUREMENT 715
ELECTROMAGNETIC NOISE MEASUREMENT 22
ESTIMATING 774
EVALUATION 5,700
EXAMINATION 337
FLOW MEASUREMENT 1,504
FREQUENCY MEASUREMENT 836
FRICTION MEASUREMENT 300
GEOMETRY 5,367
GRAVIMETRY 755
HEAT MEASUREMENT 777
HIGH ALT TARGET AND BACKGROUND MEASUREMENT 11
27 HEAT MEASUREMENT 810
28 HIGH ALT TARGET AND BACKGROUND MEASUREMENT 2
DISPLAY ADDITIONAL TERMS
YES
HUMIDITY MEASUREMENT 260
IDENTIFYING 570
INTERNATIONAL SYSTEM OF UNITS 25
LATITUDE MEASUREMENT 166
LONGITUDE MEASUREMENT 66
MACROSCOPIC EQUATIONS 105
MAGNETIC MEASUREMENT 1,127
MEASURING INSTRUMENTS 3,304
MECHANICAL MEASUREMENTS 201
METROLOGY 308
DISPLAY ADDITIONAL TERMS
YES
g
g
MONITORS 1,370
OPTICAL MEASUREMENT 3,020
PNEUMOGRAPHY 66
PRESSURE MEASUREMENTS 1,933
PROVING 296
PUPILLOMETRY 33
RADAR MEASUREMENT 937
RADIATION MEASUREMENT 2,935
RADIOACTIVE AGE DETERMINATION 341
RANGE FINDING 516
SIGNAL MEASUREMENT 870
OPTOMETRY 42
PHOTOGRAPHIC MEASUREMENT 231
29 RADIATION MEASUREMENT 2,100
DISPLAY ADDITIONAL TERMS
YES
SIZE DETERMINATION 394
SOUNDING 2,023
SPHYGMOGRAPHY 20
STANDARDS 1,290
SYNOPTIC MEASUREMENT 229
TEMPERATURE MEASUREMENT 4,916
THRUST MEASUREMENT 344
TIME MEASUREMENT 1,114
TRAJECTORY MEASUREMENT 206
UNITS OF MEASUREMENT 140
VELOCITY MEASUREMENT 2,195
DISPLAY ADDITIONAL TERMS
YES
VIBRATION MEASUREMENT 866
WEIGHT MEASUREMENT 122
WIND MEASUREMENT 1,094
HEAT
DISPLAY EXPANSION
HEART MINUTE VOLUME 57
HEART RATE 815
HEART VALVES 13
HEARTH 11
HEARTHS 3
HEAT 10,375
HEAT ACCLIMATIZATION 0
HEAT BALANCE 466
HEAT BUDGET 61
HEAT CAPACITY 182
HEAT CONDUCTION 91
HEAT CONTENT 31
HEAT DISSIPATION 68
HEAT DISSIPATION CHILLING 0
HEAT EFFECT 91
HEAT EFFECTS 0
30 HEAT 10,375
31 HEAT CONTENT 31
h

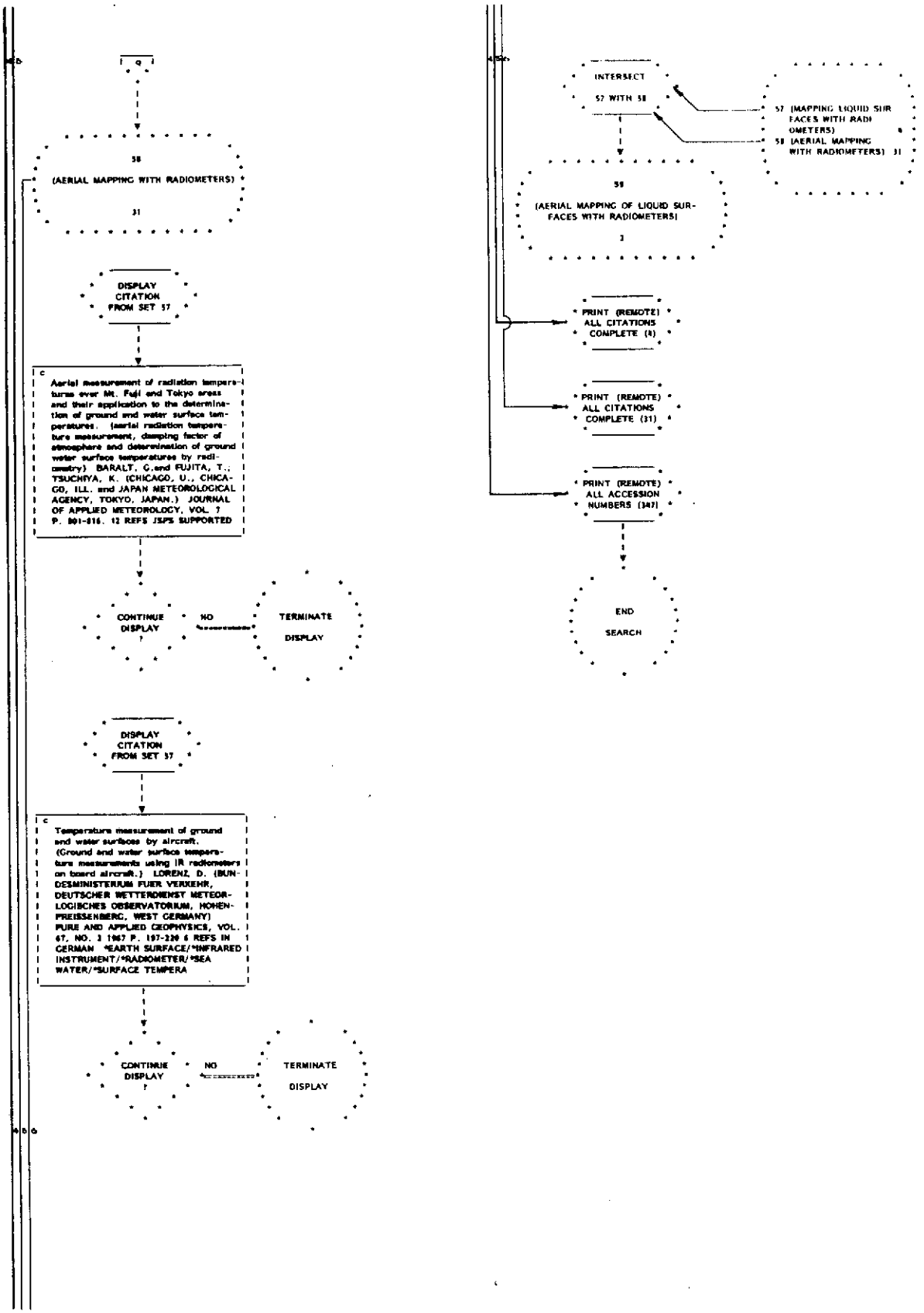



SENSORY 284
SENSORY AID 7
SENSORY DEPRIVATION 114
SENSORY DISCRIMINATION 102
SENSORY FEEDBACK 81
SENSORY PERCEPTION 287
SENSORY STIMULATION 386
SENTENCE 17
SENTENCES 14
SENTINEL SYSTEM 1
SEPARATED FLOW 954
SEPARATION 2,290
SEPARATOR 234
SEPARATORS 226
SEPTUM 18
DISPLAY ADDITIONAL TERMS
NO
TERMINATE DISPLAY
COMBINE 10+17+18+19+27
39 (TEMPERATURE MEASUREMENT) 5,134
10 TEMPERATURE SENSORS 226
17 TEMPERATURE INDICATORS 31
18 TEMPERATURE MEASUREMENT 4,040
19 TEMPERATURE MEASURING 340
27 HEAT MEASUREMENT 618
COMBINE 22+23+24
40 (RADIOMETERS) 3,107
22 RADIOMETER/S 1,601
23 RADIOMETRY 325
24 RADIOMETERS (RELATED) 1,269
COMBINE 33+34+36+37
41 (MAP/SENSING) 5,857
33 MAPPING 2,600
34 MAP/S 3,599
36 SENSOR 1,873
37 SENSORS 420
INTERSECT 41 WITH 1+2+6+7+8+9+11+12+13+14+15+16
42 (TEMPERATURE MAPPING) 465
1 THERMAL 10,958
2 THERMAL ABSORPTION 193
6 THERMAL EMISSION 614
7 THERMAL ENERGY 610
8 THERMAL ENVIRONMENT//THERMAL 488
9 THERMAL (RELATED) 266
11 TEMPERATURE 21,816
12 TEMPERATURE DIFFERENCE 79
13 TEMPERATURE DISTRIBUTION 5,280
14 TEMPERATURE E// TEMPERAT 15,562
15 TEMPERATURE C// TEMPERAT 2,236
16 TEMPERATURE FIELD 285
COMBINE 41+26
26 MEASUREMENT 18,876
43 (MAP/MEASURING) 20,288
INTERSECT 43 WITH 20+21+25+30+31+32+28
44 (RADIATION MAPPING) 1,443
20 TEMPERATURE P// TEMPERAT 1,868
21 RADIATION PYRDMETERS 28
25 RADIATION MEASURING 641
28 RADIATION MEASUREMENT 2,180
30 HEAT 10,375
31 HEAT CONTENT 31
32 HEAT MEASUREMENT 618
INTERSECT 43 WITH 39+40
45 (MAPPING WITH RADIOMETERS) 1,473
39 (TEMPERATURE MEASUREMENT) 5,134
40 (RADIOMETERS) 3,107
DISPLAY CITATION FROM SET 38




n
DISPLAY ADDITIONAL TERMS ?
YES
LIQUID OXIDIZERS 102
LIQUID OXYGEN 734
LIQUID POTASSIUM 175
LIQUID ROCKET PROPELLANTS 1,786
LIQUID SODIUM 380
MERCURY (METAL) 819
MERCURY VAPOR 355
MONOPROPELLANTS 250
ORGANIC LIQUIDS 152
ROTATING LIQUIDS 95
RP-1 ROCKET PROPELLANTS 34
SKYDROL (TRADEMARK) 1
SLURRY PROPELLANTS 117
FLUIDS 143
GLOBULES 24
47 (LIQUIDS) 2,552
DISPLAY ADDITIONAL TERMS ?
YES
GLYCEROLS 136
LIQUID PHASES 636
PHASE DIAGRAMS 1,381
POTABLE LIQUIDS 2
VAPOR PHASES 1,832
WATER 10,885
48 (LIQUIDS) 9,360
m
SURFACES
DISPLAY THESAURUS EXPANSION ?
SURFACES 178
CURVED SURFACES 9
LIFTING SURFACES 0
AREA 1,852
COLD SURFACES 48
CONTROL SURFACES 433
COSSERAT SURFACES 65
CRYSTAL SURFACES 325
EARTH SURFACE 1,822
FERMI SURFACES 521
FLAT SURFACES 284
HOT SURFACES 50
INTERFACES 399
LIQUID SURFACES 211
MENISCI 33
METAL SURFACES 1,434
PLANETARY SURFACES 592
SOLID SURFACES 309
50 (SURFACES) 5,755
49 LIQUID SURFACES 186
o
o
DISPLAY ADDITIONAL TERMS ?
YES
SURFACE PROPERTIES 4,680
TAIL SURFACES 34
TWO DIMENSIONAL BODIES 295
WEAR 1,281
51 (SURFACES) 3,886
COMBINE 50+51
50 (SURFACES) 5,755
51 (SURFACES) 3,886
COMBINE 46+47+48
46 (LIQUIDS) 4,250
47 (LIQUIDS) 2,352
48 (LIQUIDS) 9,360
INTERSECT 46+47+48 WITH 50+51
COMBINE WITH 49
49 LIQUID SURFACES 186
52 (LIQUID SURFACES) 495
INTERSECT 40 WITH 39+42+44
40 (RADIOMETERS) 3,107
39 (TEMPERATURE MEASUREMENT) 5,134
42 (TEMPERATURE MAPPING) 465
44 (RADIATION MAPPING 1,443
p




INTERSECT
57 WITH 58
57 (MAPPING LIQUID SUR FACES WITH RADI OMETERS) 6
58 (AERIAL MAPPING WITH RADIOMETERS) 31
59
(AERIAL MAPPING OF LIQUID SUR-FACES WITH RADIOMETERS)
3
PRINT (REMOTE) ALL CITATIONS COMPLETE (6)
PRINT (REMOTE) ALL CITATIONS COMPLETE (31)
PRINT (REMOTE) ALL ACCESSION NUMBERS (347)
END SEARCH
58
(AERIAL MAPPING WITH RADIOMETERS)
31
DISPLAY CITATION FROM SET 57
Aerial measurement of radiation tempera-tures over Mt. Fuji and Tokyo areas and their application to the determina-tion of ground and water surface tem-peratures. (aerial radiation tempera-ture measurement, damping factor of atmosphere and determination of ground water surface temperatures by radi-ometry) BARALT, G.and FUJITA, T.; TSUCHIYA, K. (CHICAGO, U., CHICA-GO, ILL. and JAPAN METEOROLOGICAL AGENCY, TOKYO, JAPAN.) JOURNAL OF APPLIED METEOROLOGY, VOL. 7 P. 801-816. 12 REFS JSPS SUPPORTED
CONTINUE DISPLAY ?
NO
TERMINATE DISPLAY
DISPLAY CITATION FROM SET 57
Temperature measurement of ground and water surfaces by aircraft. (Ground and water surface tempera-ture measurements using IR radiometers on board aircraft.) LORENZ, D. (BUN-DESMINISTERIUM FUER VERKEHR, DEUTSCHER WETTERDIENST METEOR-OLOGISCHES OBSERVATORIUM, HOHEN-PREISSENBERG, WEST GERMANY) PURE AND APPLIED GEOPHYSICS, VOL. 67, NO. 3 1967 P. 197-220 6 REFS IN GERMAN *EARTH SURFACE/*INFRARED INSTRUMENT/*RADIOMETER/*SEA WATER/*SURFACE TEMPERA
CONTINUE DISPLAY ?
NO
TERMINATE DISPLAY

CONCLUDING REMARKS

The example presented above illustrates how one can use interactive computer, recording, and flow charting techniques in order to map human thought processes rationally and in considerable detail. It seems reasonable to suggest, then, that we might adapt these techniques to measuring thought processes in other areas of human endeavor. In particular, they seem adaptable to those thought processes which involve a cycle of observation, decision or action, and revelation of the consequences of that decision or action. Analysis of a large number of such measurements in a variety of problem areas and on a variety of individuals should be quite beneficial in formulating both specific and general educational policies and methods.

APPENDIX

Airborne Thermal Mapping of Water Surfaces

A consulting firm is bidding on a contract to map the water temperature in lakes which are used to cool thermal power plants. The mapping will be done by flying over in an airplane (3000' - 6000' above lake surface), observing the lake with a radiometer, recording the radiometer output, and then processing the data so as to be able to draw lines of constant temperature on an accurate outline of the lake. The purpose, of course, is to make it possible to check compliance with thermal pollution standards easily and quickly.

Specifications call for measuring accuracies of 0.5°F. The consulting firm thinks that 1°F. is about all that they can do realistically. So, they would like to know (a) does any responsible group claim 0.5°F. accuracy? (b) If so, what

1. *sensor technology*
2. *mathematical modeling techniques*
3. *data reduction methods*
4. *computerized data processing techniques*

do they employ?

NOTE: A radiometer is a device which senses the heat radiated from the surface of a body. It can be focused so that it "looks" at a relatively small area. The atmosphere absorbs some of this radiation, the absorption being dependent upon air temperature, density, and distance the radiation travels. Therefore, the angle at which the radiometer looks at the surface from the airplane determines how much air the heat waves have to go through, what its density is, and how it's "layered."

From this knowledge and a mathematical model of the absorption and dispersion of infrared radiation by a variable density atmosphere, one can arrive at an estimate of the surface temperature in terms of the radiometer indication. Also, a lake is only a semi-opaque body, which means that not all of the radiation that one detects is from the layer immediately below the surface. These effects are also included in the mathematical model.

The radiometer output is an electrical signal proportional to the intensity of the thermal radiation and its spectral distribution (how much energy is radiated at each wavelength). One must therefore have a procedure for converting this signal to temperature. Ideally, the whole process could be one in which the user merely submits a magnetic tape recording of radiometer output looking at a given part of the lake to a computer program. The program reduces the data from this and other passes over the lake and from these maps the lake surface temperatures.