WORLD DATA CENTER A

Solid Earth Geophysics

REPORT SE-11

Solar-Terrestrial Physics

REPORT UAG-65

THE INFORMATION EXPLOSION AND ITS CONSEQUENCES FOR DATA ACQUISITION, DOCUMENTATION, AND PROCESSING

An Additional Aspect of the Limits to Growth

May 1978

WORLD DATA CENTER A
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C., U.S.A., 20418

World Data Center A consists of the Coordination Office

and seven Subcenters:

World Data Center A
Coordination Office
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C., U.S.A., 20418
[Telephone: (202) 389-6478]

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World Data Center A: Glaciology
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[Telephone: (303) 492-5171]

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by

G.K. Hartmann
Max-Planck-Institut für Aeronomie, P.O. Box 80
D-3411 Katlenburg-Lindau 3, German Federal Republic

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FOREWORD

"The Information Explosion and Its Consequences for Data Acquisition, Documentation, and Processing" is the first data report bearing document numbers of both World Data Centers A for Solid Earth Geophysics and for Solar-Terrestrial Physics, *SE-11* and *UAG-65*, respectively. This cross-listing is our way of acknowledging the broad applicability of the report to any data center, regardless of discipline.

The issuance of this report by WDC-A should not be interpreted as an indication that these ideas and systems have been or will be adopted. The report is more of a working document to stimulate discussion both here and elsewhere in the WDC community. We are impressed or intrigued by Dr. Hartmann's philosophy and generalized approaches and want to give them wider dissemination in the data center communities.

* * * * * * * * * * *

With the advent of digital computers, science entered an inevitable--and now exponential--growth cycle. Other technological improvements, together with the growth of international cooperative scientific endeavors and, particularly, the onset of space observations in situ, have combined to unleash a flood of data from which we have not recovered. Even Center disciplines that still rely heavily on the "classical" archival techniques, such as filing sheets of paper, bound volumes, and film records, have shared in this almost overwhelming growth (due in large measure to easy, inexpensive copying techniques and to computer-produced microfilm).

In the 1976 report "Geophysical Data Centers: Impact of Data-Intensive Programs," the Geophysical Research Board of the U.S. National Academy of Sciences' National Research Council evaluated the impact of large-scale geophysical programs on the U.S. and WDC-A. They found that the National Climatic Center then had about 77,000 reels of digital magnetic tape. The National Space Science Data Center had about 41,000 reels, and the National Geophysical and Solar-Terrestrial Data Center had about 600 tapes from only a few years of data acquisition of this type. These Centers, together with the National Oceanographic Data Center, had millions of feet of film records and cubic feet of paper documents. Further, a sampling of some 14 national and international data-collection programs then in progress indicated that these data loads would increase by some 10^{14} "bits" (equivalent to 2½ million digital magnetic tapes). This is in addition to the continuing important Center roles of archiving data in photographic, graphical, and paper tabular forms--truly a formidable task.

The impact of the data and information explosion is further enhanced by present and probable future budget constraints. Original data collectors, both research and monitoring, are tending more and more to work only with a portion of their data. Often their uses are narrowly restricted to achieving specific goals. The great expense of the data-collection effort makes the Centers' role as data preservers for the secondary users ("third parties") more important. Thus, there is increasing need for the Data Centers to receive and store large data masses efficiently for future accession, and to prepare inventories, data summaries, and data syntheses that most efficiently convey the sense of the massive detailed collection to secondary users. Because of the costs of data storage, retrieval, and reproduction, a role is emerging for the Centers as places to which scientists may go to preview data, perform preliminary analyses, and define precisely the minimal needs of their home institution for data.

The challenges of coping with the data explosion through techniques such as "preediting" raw data, properly documenting data sets (preparing "datographies") for future use, and efficiently blending the skills of engineers, data specialists, and user-scientists are the subjects Dr. Hartmann addresses in this report. His ideas are firmly based on personal experience with analyzing large quantities of satellite-ionosphere digital data. He believes that the systematic application of the latest computer digital and graphic technology by specially trained, broad-based "documentation personnel" offers the only practical way to avoid impending "information chaos." A principal tool may be the "VIdeo-GRaphic-COmmunication and DOcumentation System (VIGRODOS)."

As World Data Centers A for Solid Earth Geophysics, for Solar-Terrestrial Physics, and for Glaciology, we hope that this report will play a role in leading us, other international and national data centers, university data archivers, and industrial data collectors toward the time when the data explosion can be contained and harnessed.

* * * * * * * * * * *

This report has been edited at WDC-A/Boulder (which is collocated with the National Geophysical and Solar-Terrestrial Data Center) to make it more readable for English-speaking readers. Mr. Jerry Coffman, chief editor of the NGSDC staff, has tried to achieve a compromise between idiomatic construction and the flavor of the author's style. There was not opportunity for Dr. Hartmann to review the edited manuscript. Ms. J.V. Lincoln and Mr. J.H. Allen also have helped in the process.

A.H. Shapley
World Data Centers A at Boulder

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THE INFORMATION EXPLOSION AND ITS CONSEQUENCES FOR DATA ACQUISITION, DOCUMENTATION, AND PROCESSING

An Additional Aspect of the Limits to Growth

by

G.K. Hartmann
Max-Planck-Institut für Aeronomie, P.O. Box 80
D-3411 Katlenburg-Lindau 3, German Federal Republic

Abstract

Most of the highly industrialized nations are approaching a so-called post-industrial society, which has two major structural elements: information and knowledge. In this context the question arises: "Will the tremendous information growth rates soon lead to information chaos?" Several complex problems are discussed, relating personal experiences to general information problems and characterizing the present information situation. Two principal information problems are noted: (1) Information can be accumulated; time (e.g., the human lifetime) cannot be accumulated. (2) Further growth in information increases the tension between structural differentiation (i.e., branching) and integration (i.e., striving for better overall views, a consequence of new scientific results and technical tools). Branching often results in an organizational and institutional separation between data acquisition, data documentation, and data processing activities as well as between research and service activities. Documentation activities will play the key role in avoiding and (or) reducing the negative separation effects. The following economical, political, and technical possibilities might abate the approach of information chaos: Make use of new technological tools in the information documentation and information processing arena. Combinations of the recent graphic communication techniques with the new video (laser, holography, and semiconductor) techniques may lead to a new communication system: Video-Graphic-Communication and Documentation System (VIGRODOS). Any reasonable test and later operation of VIGRODOS techniques, at various levels, require additional versatile scientists and documentation personnel thinking in interdisciplinary terms. Support from an electronics laboratory with qualified engineers is required, at least during the test phases. Planning and (or) performance of such a feasibility study, applying the VIGRODOS technique to two different types of solar data, is suggested as a possible cooperative program.

INTRODUCTION

In *The Coming of Post-Industrial Society,* Bell (1976a) employed the term "post-industrial" in the following context: If industrial society is based on machine technology, post-industrial society is shaped by an intellectual technology; if capital and labor are the major structural features of industrial society, information and knowledge are those of the post-industrial society (see also Kahn and Wiener, 1967). Whether industrial nations in Western Europe, Japan, the U.S.S.R., and others become post-industrial societies like the United States, they all have increasingly severe information problems. Some specific problem areas are described here in more detail.

The author has worked for more than 10 years in space research (Davies and Hartmann, 1975), a domain that probably has had a larger growth rate in information production (acquisition of raw data) than any other field. After tremendous increases in funding in the early 60s, the late 60s brought drastic recession effects to space research, even though a recession was not yet prominent elsewhere. Nevertheless, there was a further increase in information because of advances in technology. Thus, the author was faced with many of the information problems that are now starting to affect other disciplines from their inception. Only the continuous, simultaneous consideration of specific information problems related to experimental research work and of general problems related to information, technology, and societies could lead to the following critical analysis of the present information situation and to some practical suggestions for solutions that are economically and politically feasible.

The results of this study can very likely be used for alleviating information problems in many other fields of science, including the humanities, and our daily life. They might also provide a stimulus for new "psycho-logic" training of man against information chaos.

PRESENT INFORMATION SITUATION

In this section, 16 statements (thoughts) are presented that describe the current information situation. Some numbers, 2, 10, 11, 14, and 16, will be considered in detail in this report.

1. Owing to recent technical developments, there is a need for the planning and building of a completely new information environment. Its "quality," however, will be influenced more by the limitation of human capabilities and the willingness for self-limitation than by the concept: "It can be done; therefore, it must be done."

2. Data and picture documentation will become more important owing to the latest advances in computer and video technology and to new needs of society resulting from scientific advances. At first, the new generation of the minicomputer with graphic display will play a more important role (see Gesellschaft fur Mathematik and Datenverarbeitung mbH (GMD), 1974). This will lead to new "Video-Graphic-Communication and Documentation Systems" (VIGRODOS: a term introduced by the author).

3. Increases in the software-hardware gap (because of economic growth and recession) and in the acquisition of raw data result in a tremendous information growth.

4. An increase in information leads to the first principal information explosion problem: knowledge can be accumulated and time cannot be accumulated.

5. Beyond a certain point, an increase in information production and storage capacity implies a rise, rather than a reduction, in the price for the final information product because of the increasing costs for transmission, translation, and selection of the relevant information.

6. Economic and scientific growth impact not only on information growth rates, but also lead simultaneously to structural differentiation ("branching" and "subdividing"). At some point there is an anti-growth trend, a trend for synthesis instead of analysis. Further growth only increases the tension between differentiation and integration. This is the second principal information explosion problem.

7. There is an interdependence between information and control as well as between information and energy (Hammond, et al., 1973; Tribus and McIrvine, 1971).

8. If no greater efforts are made to meet these expanding information problems in the future, we will know increasingly less in a relative sense despite the information growth.

9. Eventually, our attitudes may have to change significantly. Presently, most of the plausible suggestions that might alleviate the information burden cannot be accomplished because of psychological and economic barriers. For example, one suggestion is the voluntary slowing down of the growth rate. Assuming the simultaneous, efficient use of recent information technologies, this would imply that new information is no longer needed so quickly. Hence, there would be more time for information filtering and evaluation. In addition, our environment slowly reduces the growth rate, even if it is due only to continuously increasing social burdens that decrease capital accumulation. (See Final Remarks on p. 33.)

10. A fairly efficient, realistic, and reasonable method to slow down the trend toward information chaos seems to be based upon an intensive, integrated use of recent technologies for literature, data, and picture documentation and processing (VIGRODOS techniques). This requires, among others, additional "documentation personnel" with a diversified educational background.

11. Information technology, in contrast to energy and resource technologies, has few intrinsic limitations. However, there exist other intangible limitations, namely those that arise from the human biological nature.

12. The phenomenon of "time shortening" owing to exponential growth makes the extrapolation of human experience for the determination and judgment of future probabilities increasingly questionable.

13. When the rate of change of our environment exceeds society's maximum "speed of learning" and "speed of reaction," a limit is reached beyond which no reasonable and useful data evaluation is possible.

14. The rapid progress in digital techniques for data acquisition and processing makes it necessary to differentiate between raw and (pre)edited data (basic data, preprocessed data), which are the actual basis for all that is called data processing or analysis. Furthermore, it leads to the need for detailed "datographies" (term introduced by the author; see Table 2, p. 12) and to data format problems.

15. An improved relationship between natural science and the humanities now is observed for the first time since the rise of modern natural science in the 18th century and the rise of modern historical science (based on objective knowledge). The credit for closing the gap between these "opposite poles" is due to two scientific disciplines: (1) mathematical logic and (2) analytical science theory (Heisenberg, 1962; Seiffert, 1971).

16. In general, numerical data are the most objective information sources; therefore, they are the most important basis for rational decision-making processes. However, many decisions and actions are based on emotions; i.e., they depend on subjective information (Heisenberg, 1973). The growing information problem, especially that of the software-hardware gap, leads to the increasing use of subjective information such as informal information channels (see Fig. 13, p. 29). This ultimately implies that decisions reached on a golf course, for example, might dominate by far those based upon more objective data that flow from specific information systems. In the long run this will strongly affect all kinds of official information channels, especially the large Information Analysis Centers (IACs), the World Data Centers (WDCs) (World Data Center ICSU Panel, 1973; World Data Center A for Solar-Terrestrial Physics, 1976, 1973), and all larger data acquisition systems, e.g., Space Environmental Laboratory Data Acquisition and Display System (SELDADS) (Williams, 1976).

Remarks

These specific information problems are essential aspects of the present information situation. There is a very strong interdependence with many other societal problems that are not mentioned here. Only some selected references are given (Bell, 1976a, 1976b; de Solla Price, 1961, 1963, 1965; Friedman, 1977; Gabor, 1972; Gabor, et al., 1976; Hartmann, 1975; Heisenberg, 1962, 1973; Illich, 1973; Kahn and Wiener, 1967; Meadows, 1972; Mesarovich and Pestel, 1972, 1976; Pestel, 1973; Rogge, 1975; Scholder, 1973; and Senghaas, 1977).

GENERAL ASPECTS OF INFORMATION, COMMUNICATION, AND DOCUMENTATION

Definitions

The term information, which is used at present in a very broad sense, is increasing in importance (Seiffert, 1971). There is a strong interdependence between information, communication, and documentation (see Figs. 1a-1d). Communication includes all methods for information transmission. Documentation includes the systematic collection of information and methods for storage and retrieval of information, which is here called literature in the broader sense (see Fig. 2, p. 6).

Since most information cannot be evaluated immediately, it has to be documented for later use. Thus documentation is a consequence of and generates a need for most of the modern communication processes. In this context, information (data) processing is just part of a larger communication process (see also Data Acquisition, Preediting, and Processing section, 3d paragraph, p. 10).

The advances of natural science and technology during the past 2 centuries have created many new and very efficient methods of communication and documentation that have led to the tremendous information growth rates (often denoted as exponential information growth).

Some Information Characteristics

1. Information removes uncertainty.

2. Information can be received and disseminated.

3. For practical purposes, it is more useful to talk about information stock and information growth rate.

4. Three parameters determine information quantitatively:

a)	Signal mass	H [bit]
b)	Information mass	$M = M(S)$
c)	Redundance	$R = R(S)$
		$H = M + R$.

(Text continues on p. 6)

Figure 1a.--Scheme of a general information processing system with its three main elements

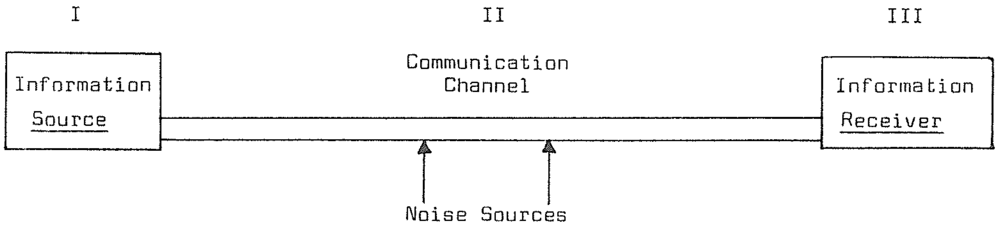


Figure 1b.--The human being as an information processing system with input and output channels

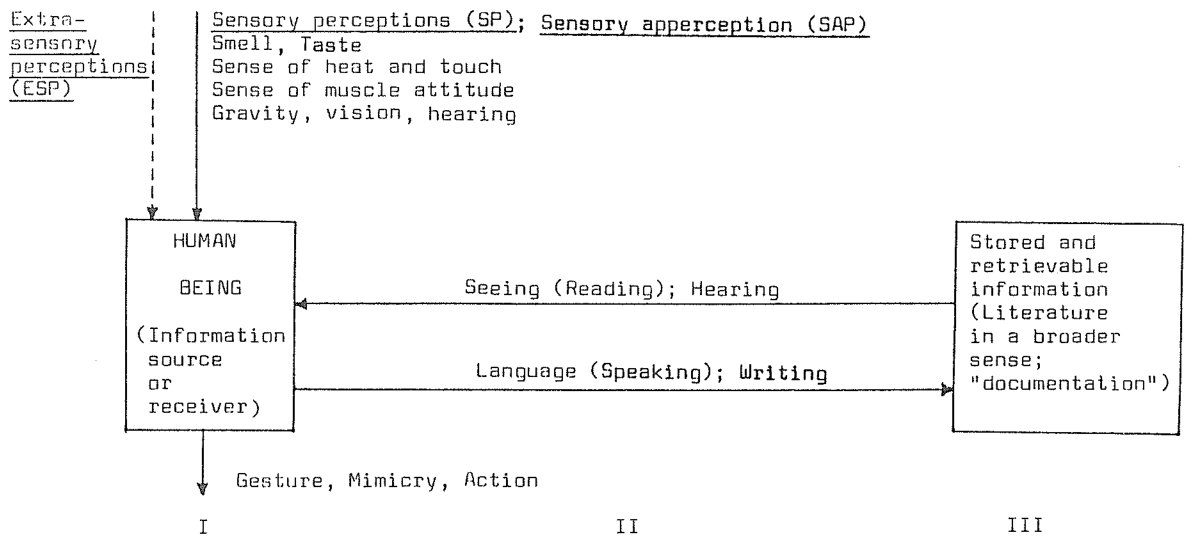
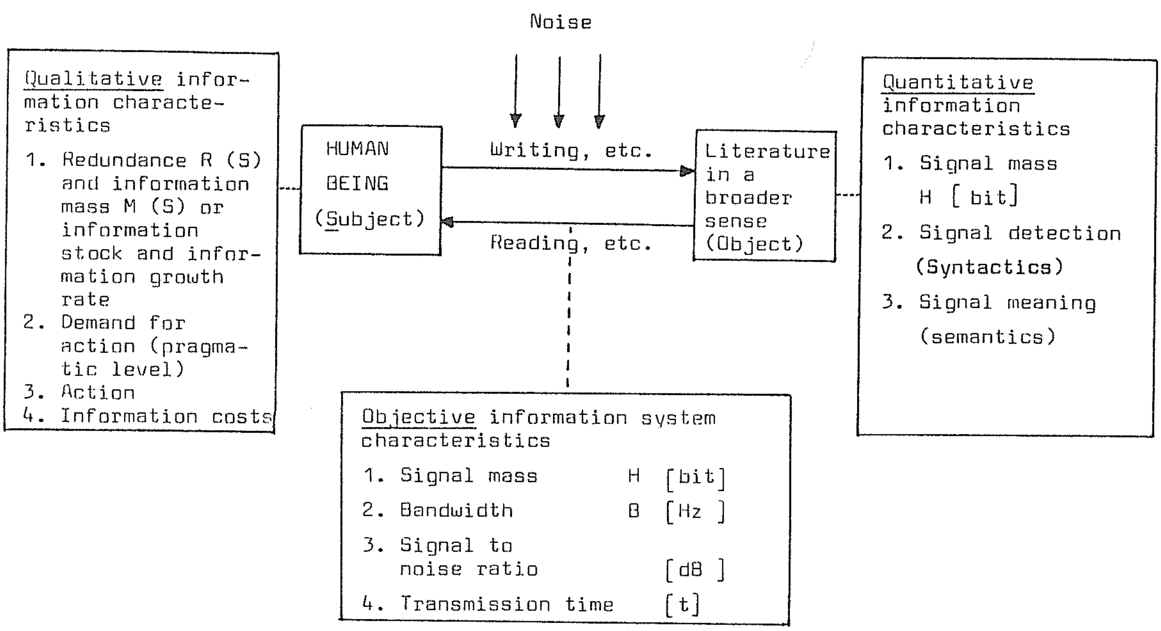


Figure 1c.--Characteristics of the three main elements of an information processing system exemplified by human being and literature in a broader sense

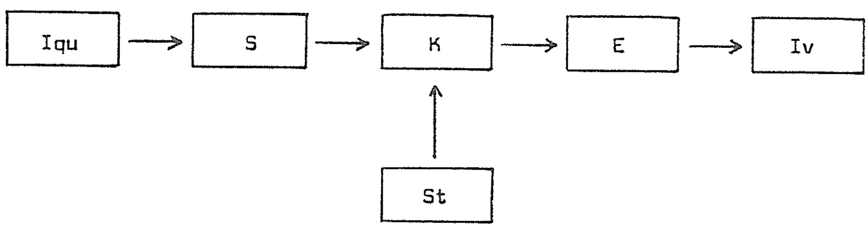


$H = 2 * B * t * \log (V_S/V_R)^2 = R (S) + M (S)$ [bit]

V_S: Signal voltage, V_R: Noise voltage, S: Subject

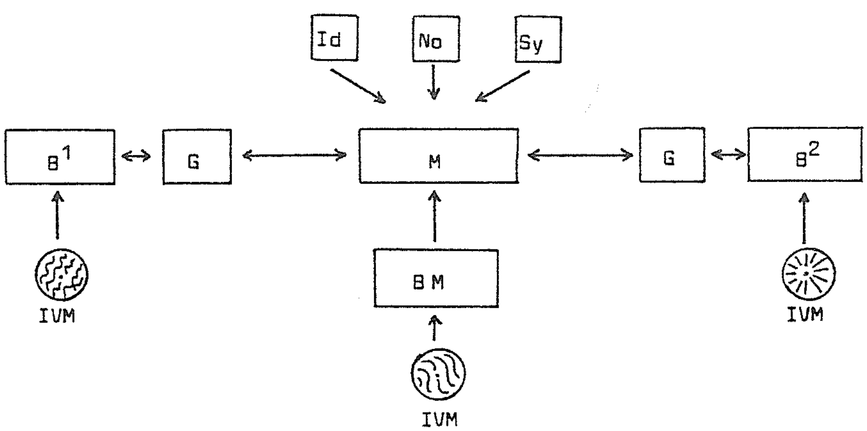
Redundance, as defined by information theory, determines to what extent a message can be edited without losing information. The lower the redundance of coded signals the shorter the message; the higher the redundance, the longer the message and the better the disturbance and noise problems can be overcome. Redundance is necessary for data protection. M = M(S) and R = R(S) (where M = information mass, R = redundance, and S = subject) mean that both quantities are dependent on the relevant human being (subject). bit: binary digit, i.e., smallest information unit $\approx 10^{-23}$ joule per degree-kelvin (Tribus and McIrvine, 1971).

Figure 1d.--Communication schemes



Scheme of a communication chain:

Iqu: Information source
S : Information Transmitter
K : Communication Channel
E : Information Receiver
Iv : Information processing (Storage, coding, action)
St : Distortions, noise



Communication scheme between conscious systems: $B^1 - B^2 - BM$
B^1, B^2, BM: Consciousness; BM: Information moderator;
G: Human brain acting as transmitter and/or receiver
M: Communication medium.

Sources of distortions are:
a) BM - conscious manipulation of news
b) In all cases: IVM: inner "soul" imaginations (conceptions, structures)
c) Distortions by collective influences: Id: Idols of the mass, - No: Standards of the behaviour of the collective-consciousness, -Sy: Symbols of the collective unconsciousness

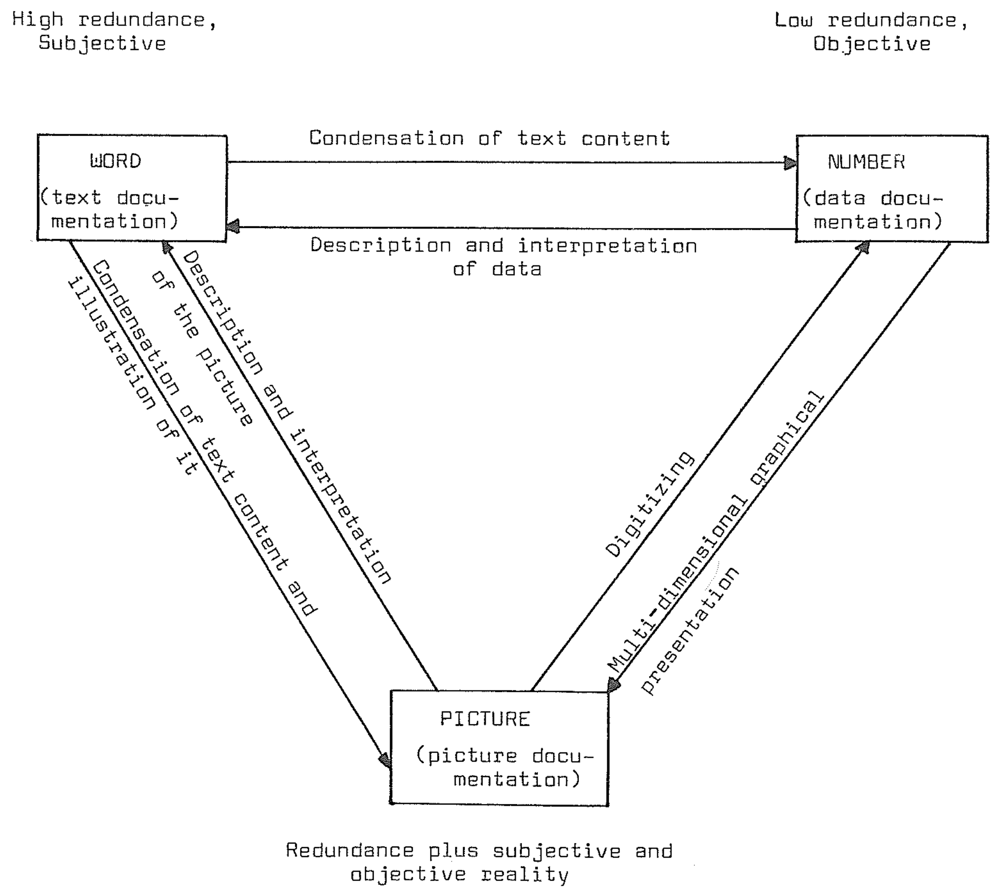
5. The description of information is possible on several different levels (see Fig. 1c, p. 4). Three basic ones will be mentioned here (Seiffert, 1971).

a) Syntactic level: The relation of the signals among each other, problems of signal detection, and aspects of accuracy of signal transmission.

b) Semantic level: The meaning of signals (message) and aspects of the accuracy with which the meaning can be transmitted.

c) Pragmatic level: The effect of the message, i.e., the demand for action and the resulting action.

Figure 2.--Three basic elements of literature in a broader sense and their relevant documentation methods



WORD: Printed texts; tape-recorded sound
Text means literature in the classic documentation sense.

NUMBER: Numerical data (tables); mathematical functions.

PICTURE: Graphical presentation, e.g. curves, planes, etc; chart recordings, drawings, photos, slides, films, cartoons, movies, video (tape-recorded moving picture + sound)

6. There is a close relation between information, control, and entropy (equivalence relation) not only in computer sciences but also in cybernetics and biology. Information always seems to be at the transition level between a static system and a dynamic process.

7. Information is only valuable as long as it is directly linked to a dynamic process (defined by its entropy), or as long as there is a close interaction between the two. Generally speaking, information is valuable only when it is known who uses the information, for what purpose, and when. Owing to the vast possibilities of science (Hartmann, 1975; Heisenberg, 1962), it is often impossible to decide what information might be required tomorrow.

8. There also is a close relation between information and energy. This is denoted by the newly defined quantity "essergy" (Tribus and McIrvine, 1971).

9. Information transmission also is determined by some purely technical characteristics of the communication system, such as channel bandwidth, signal-to-noise ratio, transmission time, and signal mass (see Fig. 1c, p. 4).

10. People react to subjective and objective realities (information). It is characteristic that they convey to others their thoughts, ideas, and experiences. This information exchange is based not only on transitory sounds and gestures, as is common among animals, but also on longer lasting types of communication, such as handwritten and printed papers, graphics, tables, photographs, sound recordings, chart and digital recordings of measured data, and movies (cinema). This type of information, denoted as literature in the broader sense, is the subject of the documentation methods and activities.

SPECIFIC DOCUMENTATION PROBLEMS

General Aspects

Documentation means the systematic collection of literature in the broader sense, analysis of the facts, and storage of its principal elements with the intention of providing a fast and complete retrieval of the information upon request.

Despite the fact that the main emphasis here is on data documentation, some general aspects of the other two basic documentation elements, i.e., text and picture documentation, are mentioned. The latest advances in information technology now allow new and intensive documentation methods to emerge from the former classic scene, where the three elements were fairly separated and independent of one another. These new methods are essentially combinations of the three basic ones and are of increasing importance because of the new societal needs resulting from the large information growth rates. Figure 2 (p. 6) shows the three basic elements of literature in the broader sense and their relevant documentation methods. The arrows indicate the various interdependences.

Figure 3 (p. 8) shows an example for the three basic literature elements. This presentation, which can also be regarded as a new form of "combined abstract," contains much more information than the classic abstract (only text). If copyright problems can be solved satisfactorily, this might be the abstract of the future.

Figure 4a (p. 9) shows the three basic elements of literature and their major documentation techniques with combinations.

Figure 4b (p. 10) shows the three basic elements of literature and their main related sciences.

Data Documentation

Talking about data documentation implies that the term data has already been defined (Hartmann, 1977). Generally speaking, any information that can be processed by a computer can be regarded as "data." However, this general meaning produces many misunderstandings in connection with the planning of new and relevant information systems. Thus for practical purposes, the various data types that are included in this term have to be specified.

According to Figure 2 (p. 6), the term data is used in a much more specific sense (Hartmann, 1977). Data documentation, the basic features of which are numbers, is subdivided into Groups I and II: Alphanumerical and Numerical data documentation. Table 1a (p. 11) shows the main areas of data documentation, and Table 1b shows some data filing aspects. Group II is further subdivided into three subgroups: (1) properties of matter, (2) engineering data, and (3) environmental data. At this stage a new concept of so-called reproducible and nonreproducible data is introduced: *Most data obtained in geophysics are dependent upon the time t and the location x where the measurement was carried out. In contrast to the majority of data obtained in laboratory physics, which may also be dependent upon space and time, most of the geophysical data are nonreproducible. This means that the conditions at the time t and the location x of the first measurement cannot be reproduced at any subsequent measurement. This implies that in geophysics, long time series very often have to be measured, which leads to different and sometimes complex problems.*

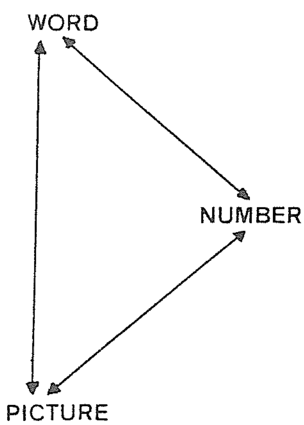
Figure 3.--Example of the three basic literature elements

EHF Properties of Air

By Hans Joachim Liebe NTZ 1/77, pp. 76-84

EHF Properties of Air

Abstract — EHF spectra of the clear atmosphere are expressed by transfer and emission functions using a complex refractivity as the measure for the interaction between radiation and gas. The refractivity is expressed as a function of frequency, dry air and water vapor pressure, and temperature. No reference is made to complicated quantum-mechanical descriptions is avoided. The engineering presentation of the main transfer characteristics requires five parameters each for 46 O_2 and 15 H_2O lines plus a nonresonant H_2O absorption spectrum. Several examples of calculated atmospheric spectra are given, and recent advances in the application of such basic information to radio wave propagation and remote sensing are discussed.



i	Center Frequ. ν_0	Strength S^0	a	Width γ^0	Interference y^0	z		
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	50 473.6	.00060	9.694	1.33	1		1.0	
	50 987.3	.00156	8.688	1.36	.9		1.4	
	51 503.02	.00386	7.736	1.38	.9		2.0	
5	52 021.17	.00899	6.840	1.41	.927		1.7	
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	53 066.80	.04072	4.840	1.46	.806		1.9	
	53 595.72	.07919	4.482	1.49	.790		1.9	
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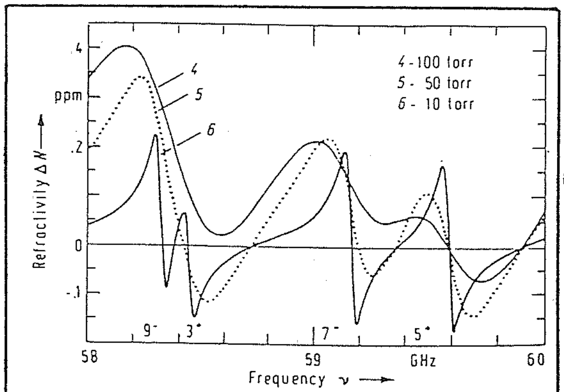
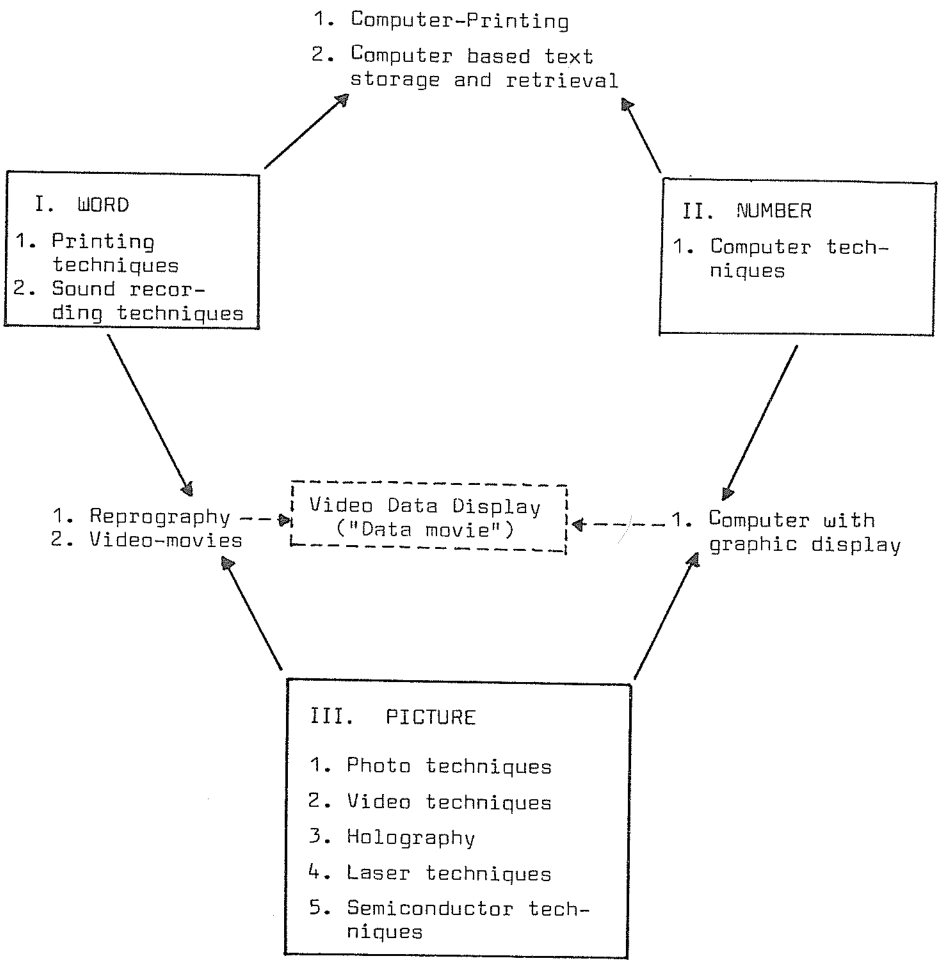
	55 783.80	.6056	2.110	1.601	.497		2.1	
	56 264.78	.3487	0.0138	2.212	.962		.9	
	56 363.39	.8539	1.655	1.635	.383		2.3	
15	56 968.18	1.1204	1.255	1.672	.263		2.7	
	57 612.49	1.3595	0.9101	1.714	.103	4.8	4.2	3.7
	58 323.89	1.5150	0.6206	1.762	− .090	−2.9	−5.8	0.3
	58 446.60	.9251	0.0827	1.964	.754		.8	
	59 164.22	1.5263	0.3861	1.819	− .329		.1	
20	59 590.98	1.3410	0.2069	1.859	.448		.5	
	60 306.04	1.3487	0.2069	1.890	− .562		.7	
	60 434.78	1.5626	0.3861	1.789	.185	− .6	−1.0	−2.3
	61 150.57	1.5899	0.6206	1.736	− .029	11.1	7.6	5.7
	61 800.17	1.4588	0.9101	1.694	− .189		3.0	
25	62 411.22	1.2272	1.255	1.658	− .335		2.3	
	62 486.26	.9634	0.0827	1.990	− .636		.9	
	62 998.00	.9540	1.655	1.627	− .433		2.2	
	63 568.52	.6898	2.110	1.598	− .554		2.0	
	64 127.78	.4656	2.620	1.568	− .611		2.0	
30	64 678.92	.2942	3.186	1.54	− .716		1.9	
	65 224.08	.1744	3.806	1.51	− .726		2.0	
	65 764.74	.0971	4.482	1.49	− .822		1.9	
	66 302.06	.0508	4.840	1.46	− .835		1.8	
	66 836.77	.0250	5.999	1.44	− .878		1.9	
35	67 369.51	.0116	6.840	1.41	− .947		1.7	
	67 900.73	.00508	7.736	1.38	− .9		2.0	
	68 430.8	.00210	8.688	1.36	− .9		1.4	
	68 960.1	.00082	9.694	1.33	−1		1.0	
	69 488.7	.00030	10.756	1.31	−1		1.0	
40	118 750.34	.5973	0.0138	2.140	− .056		.9	
	368 499.0	.0434	0.2020	2.10	0	—	—	—
	424 763.8	.411	0.0112	1.98	0	—	—	—
	487 250.0	.153	0.0112	1.98	0	—	—	—
	715 394.4	.0626	0.0891	1.93	0	—	—	—
	773 841.0	.365	0.0798	1.88	0	—	—	—
46	834 147.0	.117	0.0798	1.88	0	—	—	—



If the term data is used in the above-mentioned specific sense, Figure 2 (p. 6) shows clearly that data documentation has generally low redundance and thus is very sensitive toward any kind of distortion (noise). If data also are to be of maximum usefulness for "third users," a fairly detailed written description is necessary in addition to the recorded data. For the sake of brevity let us denote this complex description "Datography" (see Table 2 (p. 12), which gives an example of a datography, and Dieminger and Hartmann (1977) and Williams (1976)).

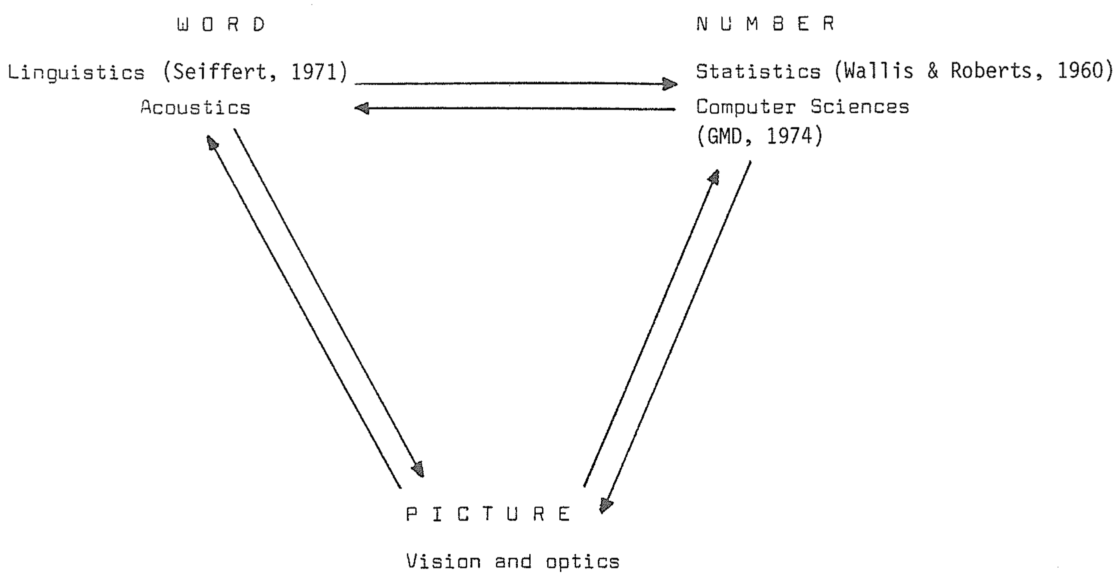
Requirements for any reasonable sort of life in a society of human beings include production, transport, exchange of goods (merchandise), the growth of opinions and their interchange, as well as the coordination of activities. Man has lived in a planned world since he moved from nomadism to an agrarian state and further to highly industrialized societies. For any of the above-mentioned planning activities, people need facts and data. The vast majority of the data belong in the "nonreproducible" category. The data ordering given in Table 1a (p. 11) has proved to be useful and reasonable. But to discuss the problems of time series data management in more detail additional considerations, which will be presented now, are needed.

Figure 4a.--Three basic elements of literature in a broader sense and their major documentation techniques with combinations



The broken arrows and the relevant rectangle indicate a possible future step for an effective data presentation and/or compression. Just now the new generation of minicomputer with graphic display opens a new era of intensive and effective graphic communication between man and computer, which is a first step in the direction toward "data movies".

Figure 4b.--Three basic elements of literature in a broader sense and their main related sciences



(Schober and Rentschler, 1972; van Appledorn, 1972)

Figure 5a (p. 13) shows the elements of empirical sciences, Figure 6a (p. 17) a display of science, Figure 6b (p. 18) fundamental aspects of physics as a science, and Figure 6c (p. 20) some aspects of learning, cognition, thinking, and consciousness. Figures 5b (p. 15) and 5c (p. 16) will be referred to in more detail in the section "Time Series Data Management."

Figure 5a (p. 13) presents an alternative to explain the terms "reproducible" and "nonreproducible." When the effects of the controlled conditions greatly exceed the uncontrolled conditions, reproducible data result, and the reverse gives nonreproducible data. Figure 5a further shows that there are three different types of ignorance about uncontrolled conditions: a) fundamental, b) preliminary, and c) aware (known). Many of the nonreproducible data, e.g., in geophysics, biology, medicine, and economics, are due to the third type--the known one. For any reasonable interpretation of an observed phenomenon, it is necessary to define the effect of uncontrolled conditions to the extent possible in a mathematical form. For this purpose, mathematics has developed various statistical models (see Figs. 5b and 5c). Thus, a discussion of nonreproducible data simultaneously implies a dialogue about statistical methods and quantities. Figure 4b (p.10) shows the relation of statistics to literature in a broader sense.

DATA ACQUISITION, PREEDITING, AND PROCESSING

The tremendous information growth rate of the last two decades has caused structural differentiation ("branching" and "subdivisioning") of the entire information scene. Compared to analog data, digital data have become more important, principally owing to advances in relevant digital computer technologies.

Figure 7 (p. 21) shows "data reading" to be a necessary transitional step from analog data acquisition to data processing. This necessarily implies intensive interactions with man in using analog data whose acquisition and processing is an "old and classical" domain, but this is not true for digital data. Figure 7 also shows a new transitional step called "data preediting" between digital data acquisition and data processing. Until now this has been taken into consideration only partially; therefore, the following statements should emphasize this important step in more detail.

1. Digital data acquisition can lead to efficient data processing (step 3) only if the data have been thoroughly preedited (step 2).

(Text continues on p. 13)

Table 1a Main areas of data documentation

I. Alpha-numerical data documentation

Systematic filing of facts
Examples: Bibliographic files, address files, merchandise lists, geographical distribution of insects, etc.

Remark: Hartmann, 1977, used the term non-numerical instead of alpha-numerical, which produced misunderstandings in context with text- and picture documentation.

II. Numerical data documentation

1) Physical-chemical data, i.e. properties of matter and substances;
Physical constants
Data are independent of time and space
Data are reproducible since the conditions of the first measurement can be reproduced for any subsequent measurement.

2) Raw material- or Engineering data
Data are dependent on the production technology of the material, its preliminary treatments and its "geometry".

3) Environmental data
a) Data from natural matter and from nature, i.e. from the three Geospheres (1. Lithosphere, 2. Hydrosphere, 3. Atmosphere), the Biosphere, and the Interplanetary Space, e.g.: Geosciences, Biosciences, Medicine, Astro-sciences. Data are practically all non reproducible - conditions of the first measurement cannot be reproduced for any subsequent measurement - and are time and/or space dependent.

b) Data from Economics, Social and Political Sciences, and from Arts and Humanities. Example: The statistical almanac issued by the Federal Republic of Germany gives data which are mostly time and space dependent and which are non-reproducible.

Table 1b Some data filing aspects

I.	Properties; characteristics e.g. time and/or space dependent	(1. Step)
II.	Origin; domain	(2. Step)
III.	Measuring methods	(3. Step)
IV.	Utilization, application	(4. Step)

Table 2 Example of a "Datography" See also Williams (1976) for other examples.

Necessary information for optimal comparisons of location- and time-dependent, non-reproducible data (Dieminger & Hartmann, 1977).

I. Classification of the observation

II. Measured effects
- a) Description of the effects
- b) Point observations: data from a point source
- c) Line observations: data measured along a line, e.g. along a satellite orbit
- d) Area observations: data measured upon a surface in space
- e) Volume measurement: data measured within a volume
- f) Integral quantity: data measured by integration over a volume or surface or along a line
- g) In situ: measuring equipment is located at the place of the measured quantity
- h) Remote sensing: measurement equipment is located some distance from the point of the measured quantity

III. Parameters derived from II.
- a) Direct
- b) Indirect
- c) By correlation with other data
- d) Precision of evaluation
- e) Total error: error of measurement + error of processing

IV. Periods for which measured and/or processed data are available

V. Type of data recording
- a) Analogue with corresponding characteristical resolution
- b) Digital with corresponding characteristical resolution
- c) Teletransmission of data
- d) Number of observatories

VI. Data access
- a) At the observatories (yes, no)
- b) At national data centers (yes, no)
- c) At international data centers (WDCs, etc.) (yes, no)
- d) If b) no, question: "Is it planned for the future?"
- e) If c) no, question: "Is it planned for the future?"
- f) Means of accessibility

VII. Noise characteristics (equipment characteristics)
- a) Range of measurements
- b) Resolution of the instrument and sensitivity
- c) Precision
- d) Spatial resolution

VIII. Economic questions
- a) In large quantities, industrially produced equipment (serial production)
- b) In large quantities, industrially produced equipment (single production)
- c) Research model
- d) Laboratory prototype
- e) Combination of a) through d)
- f) Cost of development, time of development
- g) Operational cost of a single observatory
- h) Operational cost of a network of observatories

IX. What kind of documentation exists about the equipment, data acquisition, data (pre-)editing (pre-processing), and final processing?

X. Do scientific publications exist?

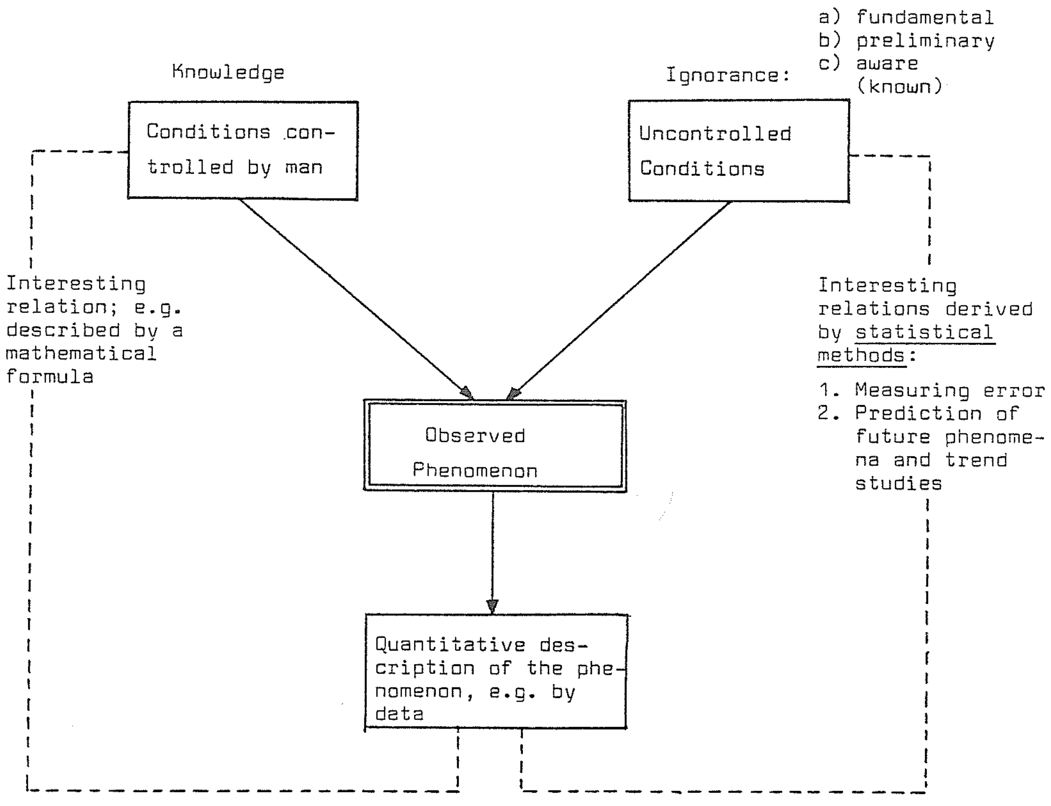
2. Only data that have passed detailed preediting are reasonably efficient for further processing for "third users".

3. After completion of step 2 the raw data can be erased in almost all cases, thus reducing storage problems.

4. Data preediting requires various intensive interactions between man and computer (machines).

These statements are of extreme importance when, because of branching effects, data acquisition, documentation, and processing are institutionally separated. Then the normally smooth transitions between the three steps often are interrupted drastically, and usually no one feels responsible for reducing the resultant negative effects. Although data documentation is not mentioned specifically in Figure 7 (p. 21), some of the data preediting and processing activities belong in the documentation domain. As a consequence of this structural differentiation that now occurs in many fields, documentation has to be an actual, active link between data acquisition and data processing, not only a mere storage and handling tool, which, in the worst case, might increase the time delay between data acquisition and data processing (e.g., by third users).

Figure 5a. Elements of empirical science



Remarks:

A. The ignorance about the uncontrolled conditions can be of three different types a) fundamental type - if for instance the influence of a parameter cannot be determined in principle (time of nuclear splitting); b) preliminary type - if we can hope that by the use of new information we can expand the range of controllable conditions; c) aware (known) type - if we know of the existence of some uncontrolled conditions and disregard them, since regulating them is either of no interest or technically not feasible or too expensive.

B. There are two principal statistical methods to treat large amounts of data 1. Frequency distributions 2. Descriptive statistical parameters.

This is a great task and challenge for the new and larger information systems (e.g., the World Data Centers (1973); and the Information Analysis Centers like the Fachinformationssysteme (FIS) presently planned and partially established in Germany (Hartmann, 1977)). (See also Fig. 12, p. 28) It seems absolutely necessary to incorporate some "space for research" within these systems and to arrange cooperative projects with scientific groups actively working in data acquisition and data processing in various research institutes. Otherwise the necessary link might be out of phase, in which case the present gaps and barriers between scientific and documentation activities would be increased instead of decreased. See also "Consequences for Information Systems" for further details.

The new generation of minicomputers with graphic display allows an intensive, effective, and fairly inexpensive graphic communication between man and computer and thus is an excellent device for data preediting at many levels and in many fields. Figure 8 (p. 22) shows an example of an effective data preediting system. In 1976 it was used in the context of a joint NOAA Space Environment Laboratory (SEL) and Max-Planck-Institut (MPI) für Aeronomie program for the evaluation of data from the radio beacon experiment of the geostationary satellite ATS-6 (Davies and Hartmann, 1975). Figures 9a (p. 24) and 9b (p. 25) show examples of data preediting procedures using large computing systems. The one shown in Figure 9a is less flexible, more time-consuming, and more costly than that in Figure 8. Some recent problems that developed in one of the world's largest computing systems (ILLIAC IV) are mentioned by Falk (1976).

The general term data processing (in a broader sense) comprises three steps: (1) data collection; (2) data filing, storage, and retrieval (data documentation), and (3) data compression. This last step again can be subdivided into: (a) graphic presentation, (b) statistical analysis, and (c) modelling. (The steps are ordered with increasing degree of abstractness).

Remarks: Very often only step (3) is specified as actual data processing. This much narrower definition often means that step (2) is almost completely disregarded. However, a thorough data documentation is a consequence of and a need for any reasonable data processing (in a narrower sense). This leads, among other things (as mentioned in the Data Documentation section), to the need for so-called "datographies." Even if data processing is understood in its broader sense, step (2) is not given enough attention. This is due partly to an often unconsidered and (or) too euphoric use of computers during the last decade. Now, this sometimes seems to switch to "computer pessimism," rather than to a realistic view, which lies somewhere between the two extremes. Falk (1976) shows this clearly using the technical failure of ILLIAC IV as an example. It is further shown by a branching effect, a consequence of growth rates, which now introduces in addition to software and hardware the new term and domain orgware.

The greatest progress in data processing in its broader sense was achieved for step (1), owing to recent technological advances. Less progress was achieved for step (2), since filing, indexing, etc., are not only organizational problems, but also simultaneously require (besides human intelligence and practical experience) something that seems to be almost forgotten--human imagination (Kahn and Wiener, 1967). This is of growing importance with the increasing complexity of the documentation problem.

Much less progress was achieved for step (3), mainly owing to human beings finally having to interpret and use the processed data for various decision-making processes and actions. The biological limitations of human information-processing capabilities and the far from optimal communication between man and computer lead to a continuously decreasing ratio between finally processed (used) data and raw data, especially in the highly industrialized nations.

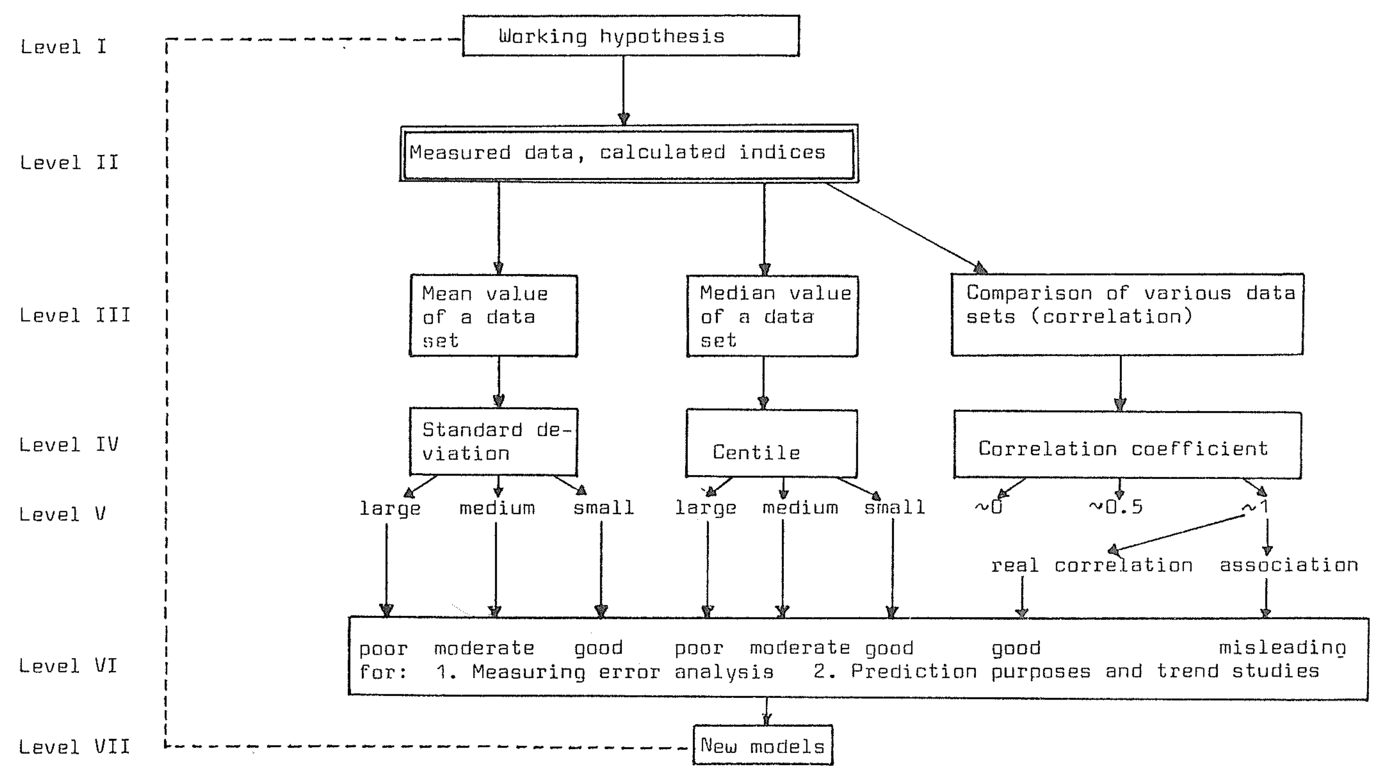
To slow down the trend toward information chaos the software-hardware gap, especially for steps (2) and (3) above, must be decreased by developing more useful data documentation and compression methods (see also Fig. 7, p. 21) and by establishing better cooperation and communication between personnel active in science, information documentation, and information planning (see Fig. 11, p. 27). Initially, all possible combinations of the graphic communication techniques (GMD, 1974) with the recent video (Goldmark, 1976) communication techniques, including laser and holography (Kahn and Wiener, 1967), should be investigated extensively. This will lead to a new type of communication system, "Video-Graphic-Communication and Documentation System" (VIGRODOS) (see also Fig. 10, p. 26).

GRAPHIC PRESENTATION

General Aspects

Mankind exists in a four-dimensional world that consists of three space coordinates and one time coordinate. Human perception (intuitive knowledge, vision) restricts us in general to three dimensions, i.e., our understanding of graphic presentations refers at maximum to three coordinates. However, in most cases this is insufficient when, for example, environmental parameters are to be described. If λ is the geographic longitude, θ the geographic latitude, h the altitude above or under the surface of the Earth, and t the time, then all observed environmental effects (measured data) are more or less dependent on all four parameters. Therefore, $F = F(\lambda, \theta, h, t)$.

Figure 5b.--Some important descriptive statistical parameters and their applications



Remarks: A. The measuring errors can generally be reduced by better and more sophisticated measurements.

B. Three steps - at best parallel - can lead to an improvement of models for the prediction of geophysical phenomena. 1. Expanding the time series measurements and increasing the number of observatories (more "classical" data). 2. Measuring additional new parameters for better correlation analysis, especially for a better distinction between correlation and association. 3. Updating of the model calculations with real time data.

C. In context with the urgent needs of fast and efficient processing of these data the new graphic communication and documentation systems - later very likely also VIGRODOS - will be of extreme importance.

In the previous section three steps for data compression were mentioned: a) graphic presentation, b) statistical analysis, and c) modelling. Here only graphic presentation is considered. It has become increasingly important because of the new graphic communication system (e.g., minicomputer with graphic display), which might develop into VIGRODOS. To display the above-mentioned F, a five-dimensional presentation (four independent variables and the value of the function F) is needed. If a cathode ray tube (CRT), which itself is two-dimensional, is utilized for displaying F, the following three possibilities are obtained:

1. Graphic display (still picture) of F as a function of one variable, i.e., an actual two-dimensional presentation. This is the well-known, widely used classical display method.

2. Graphic display (still picture) of F as a function of two variables, i.e., a three-dimensional presentation on a two-dimensional screen. This is the main subject of computer graphics (GMD, 1974; see also: Kestner, et al., 1974). Using holography techniques an actual three-dimensional presentation is possible (Kahn and Wiener, 1967).

Figure 5c.--A subdivision of time series data into three generations (time)

As an example we use atmosphere data

1. First generation of atmospheric data

↓

Mean behaviour with large standard deviations

↓

Very coarse scale reference atmosphere

\+

2. Second generation of atmospheric data

(further,additional data + processing)

↓

Mean behaviour with moderate standard deviations

↓

Coarse scale reference atmosphere

\+

3. Third generation of atmospheric data

(further, additional data + processing)

↓

Mean behaviour with small standard deviations

↓

Fine scale reference atmosphere

Remarks:

Due to the growth rates we observe "branching"effects also in the data acquisition and processing areas. In this context it seems reasonable and useful for time series data to introduce also a subdivision in time. See also level V of Fig. 5b. These subdivisions are here denoted as first, second and third generation and lead to very coarse, coarse and fine scale reference atmospheres (models). It should be noted that these terms are meant in a relative sense. The first generation is mainly controlled by step 1 - see remark 8 to Fig. 5b - the second by step 2 and the third by step 3.

Figure 6a.--Display of science (Hartmann, 1975, 1977; Heisenberg, 1962, 1973)

Science = System of :			
	terms	basic conceptions (explications) derived terms (definitions)	Prior conditions of science (Object)
	statements	basic statements (axioms) derived statements (theorems)	Actual Science
	rules	for definition purposes for derivation purposes	Meta Science (Method)

such that the system is as far as possible

1. contradiction free
2. complete
3. independent
4. formally simple

3. Graphic display (moving picture) of F as a function of three variables, i.e., three-dimensional presentation plus "time scale" on a two-dimensional screen. Using holography techniques, "moving" three-dimensional presentation is possible. Applying additional video and (or) regular film techniques will expand the presentation by adding color, sound, and fast-motion effects, and others.

Remark: It is possible that color will bring another "new dimension."

Applying the future possibilities of laser and semiconductor techniques, the new type of communication and documentation system called VIGRODOS is finally approached. Its optimum use will be determined principally by human intelligence, organization talents, practical experience, imagination, and communication talents. During the early stages it requires a genuine, close cooperation between versatile, interdisciplinary-type scientists and relevant documentation personnel (see also Fig. 11, p. 27) with a feeling for a synergetic (combinatorial) (Kahn and Wiener, 1967) use of the new technologies and with auto-didactic (self-training) capabilities. Furthermore, it requires the support of a good electronics laboratory with appropriate engineers, at least during the test phases.

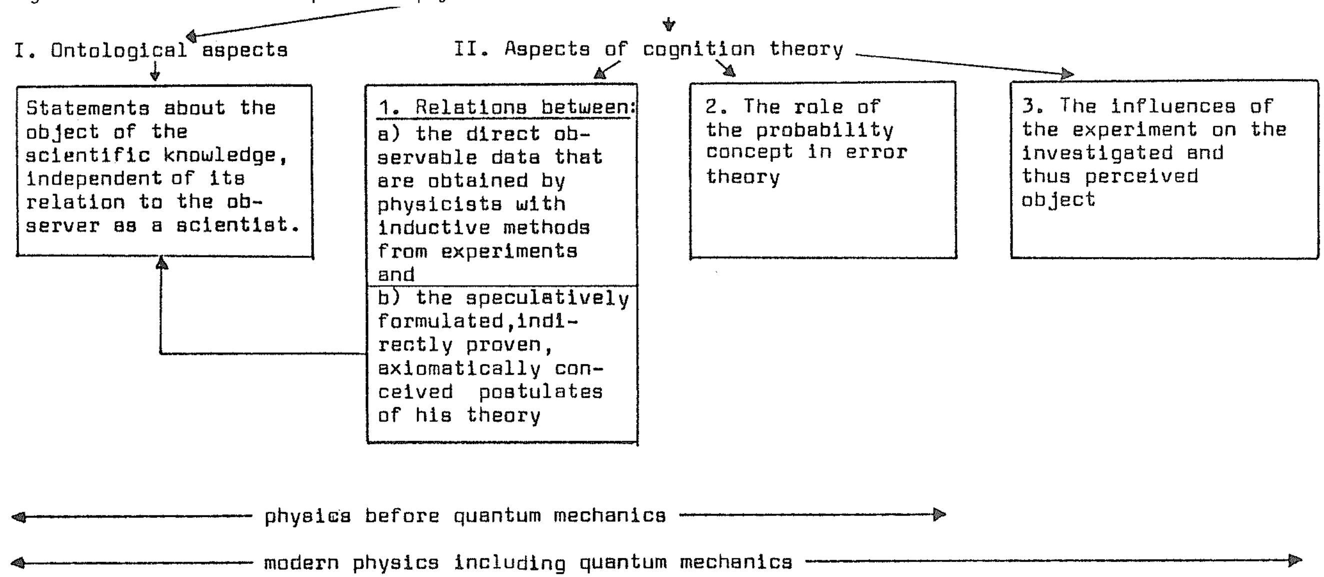
Consequences

Considering the most sophisticated communication and documentation system (VIGRODOS), we can display at maximum an effect F as a function of three variables. In general, the effects are dependent on more than three parameters, while the above-mentioned environmental effects are dependent on four. This implies that we cannot display the complete behavior; i.e., we have to neglect one variable (perhaps its influence is slight or uninteresting), or to produce a second, third, and fourth display, where the fourth variable is displayed instead of one of the three previously chosen.

Thus, in order to display from all aspects, phenomena that are strongly dependent on more than three parameters, we need an increasing number of presentations that grows with the number of variables. Systems like VIGRODOS very likely will accelerate man's ability to create broad and new experiences, not only in the domain of natural science, but also in the humanities (Gabor, 1972).

However, several limitations and dangers also should be mentioned. There is, first of all, the problem of optical illusion (Schober and Rentschler, 1972; van Appledorn, 1972). There also are unconscious or conscious problems of misleading or incorrect presentations, caused either by a poor understanding or incorrect conception of a subject or by ideological biases.

Figure 6b.--Fundamental aspects of physics as a science



Remarks:

II.1: The last portion b) determines the object of the scientific knowledge and thus leads to the ontology. The relation between a) and b) defines a parameter in cognition theory.

II.2: The role of the probability factor in error theory is the following: With its help the physicists decide how far the results of their experiments can deviate - due to human faults - from the results deduced from the model (theoretical) calculations before they regard this deviation as a disproof of the theory.

general: Any theory of physics makes more physical and philosophical assumptions than the facts alone give or imply. For this reason, any theory is subject to further modification and reconstruction with the advent of new evidence that is incompatible with its basic assumptions.

CONSEQUENCES FOR INFORMATION SYSTEMS

General Aspects

A discussion of modern information systems, including information acquisition, documentation, and processing, simultaneously implies the consideration of the mostly unspoken, but extremely important, research and service ambivalence. Neglecting it can lead to serious performance problems in any system. Information growth rates lead to various structural differentiations in the entire field. Figure 12 (p.28) shows some characteristics of large, medium, and small information system-units that are a consequence of branching.

Another major important branching effect is the organizational and institutional separation of research and service activities, that now can be observed in many areas. One of the negative consequences is that each part usually will begin to exist alone, often disregarding the inherent, essential interdependence between research and service. This then produces an artificial gap between research and service that increases in proportion to the growth rates.

Falk (1976) discusses some negative effects of the research and service (operational) ambivalence in the ILLIAC IV project. In space physics, many of these negative effects can be demonstrated. For example, the satellite technique in many cases still shows big gaps in data processing between test (pure research) and operational (service) systems (e.g., weather and ERTS satellites). The transition region from research to service, due to the organizational separation, is insufficiently considered and treated. At the present, this leads to an undesirable decrease in the ratio of used to unused data, which new information systems will have to correct.

If research and service activities are not separated organizationally, the necessary dynamic balance usually is achieved automatically owing to the fairly smooth transition between the two extremes. After a separation, this usually is no longer the case, and it becomes further complicated because of the following facts: 1) The speed of growth makes it in principle more difficult to achieve a dynamic balance; 2) The reaction-rate time constant that is inherent in any system increases as the information system increases (see Fig. 12, p. 28), i.e., as its flexibility and feed-back capability decrease; and 3) Large information systems are used principally for multilateral, international contracts. This leads to a second reaction-rate time constant, somewhat independent of the first, that might by far exceed the one mentioned earlier owing to international politics and negotiations.

Thus, the larger the information system, the more likely that many of its actions will be out of phase with actual needs, and that it cannot make optimum use of recent scientific and technical tools. To reduce these dangers there must be an ample amount of "practical research space," with sufficient funding and manpower, within each new and larger information system. This is obviously in contrast to our wishes for efficiency, especially to plan information systems effectively, and shows another ambivalence--between basic research and economic aspects. However, this voluntarily created "unplanned space" seems to be the only guarantee that the systems really can serve, and progress, with actual needs, and that they will not be dominated by problems like overcentralization and other Parkinson's effects--growing with the increasing size of the information systems (Bell, 1976a, 1976b; Friedman, 1977; Kahn and Wiener, 1967; Mesarovich and Pestel, 1976; and Senghaas, 1977). Furthermore, it seems necessary that the IACs arrange cooperative projects with scientific groups actively working in data acquisition and data processing in various research institutions.

Each of the three information system-units mentioned in Figure 12 is necessary. Their usefulness depends on the question and problem to be addressed. Thus not only one, but all three, must be supported. Though there are smooth transitions between them, it seems both useful and reasonable to have these system-units, especially since they also are specific organizational units. The terms large, medium, and small information system-units might have been named more appropriately large, medium, and minicomputers. In this context Falk (1976) shows what it means for an information system to approach critical size using the ILLIAC IV project as an example. See also Friedman (1977).

Table 3a (p. 23) lists some major tasks of larger national and international information (data) services, excluding data acquisition and data preediting and reading activities (see Figs. 7, p. 21, and 8, p. 22). Table 3b (p. 23) shows that the main tasks of information systems change with time. Seven different tasks, in order of increasing complexity, are presented in Table 3a. The second step, which includes data collection, normally should start with the preedited data. The newly defined step, data preediting (see Fig. 7), is the "interdisciplinary," but now fairly crucial, link or transition between the acquisition systems and any subsequent information service. It is crucial because primary data users or data suppliers (e.g., the data producers) to information systems normally conceive and design their data acquisition and processing systems according to their tasks, their financial and technical means, their manpower, and their know-how. This often does not meet the needs of others who may try to get the data via an official information channel (see Fig. 13, p. 29). To make the data useful for such third users, a major task of the data-handling information systems is "reformatting." This is especially important when looking at the research aspect of data handling by large information systems. Because modern and larger information systems normally deal with research aspects and with service aspects, they have a real chance, and are challenged, to close the gap between research and service. A first step could be achieved by treating data preediting problems in more detail.

Figure 6c.--Learning, cognition, thinking, consciousness

A. LEARNING

I. By direct experience "Experiential knowledge" 1. Sensory apperception 2. Conditional reflexes 3. Trial and error	II. By indirect experience "Faith" 1. Imitation 2. Instruction	III. By understanding 1. Logical thinking 2. Intuition
← man and animals →		← man only →

B. COGNITION

I. Observation	II. Model cognition	III. Intuition

C. THINKING

I. Magic	II. Logic	III. Identity

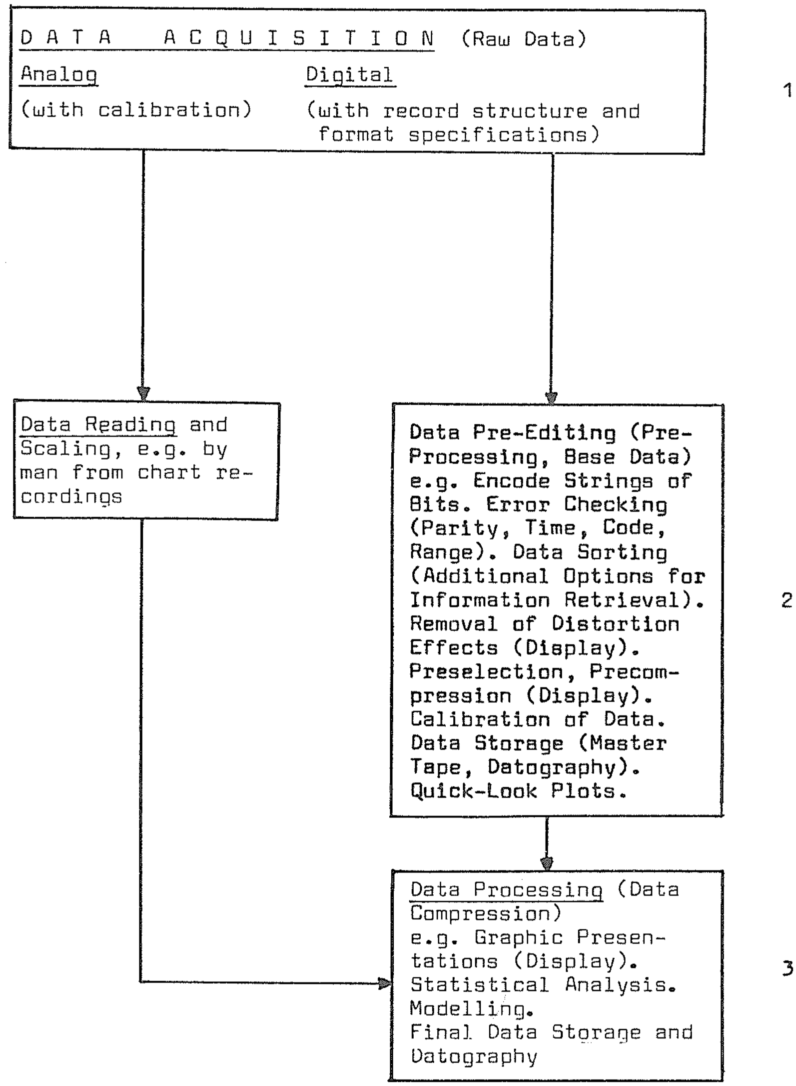
D. CONSCIOUSNESS

I. Level: Storage of information and logic, rational processing by human brain considering aims and utilities

II. Level: Ability to check the meaning of the information in its context. Cognition of the plan that controls the events

III. Level: Extended consciousness (evidence: Doucet, F.W., 1973). Consciousness of plan and structure of the "program" including the information that controls the "program run".

Figure 7.--From data acquisition to processing

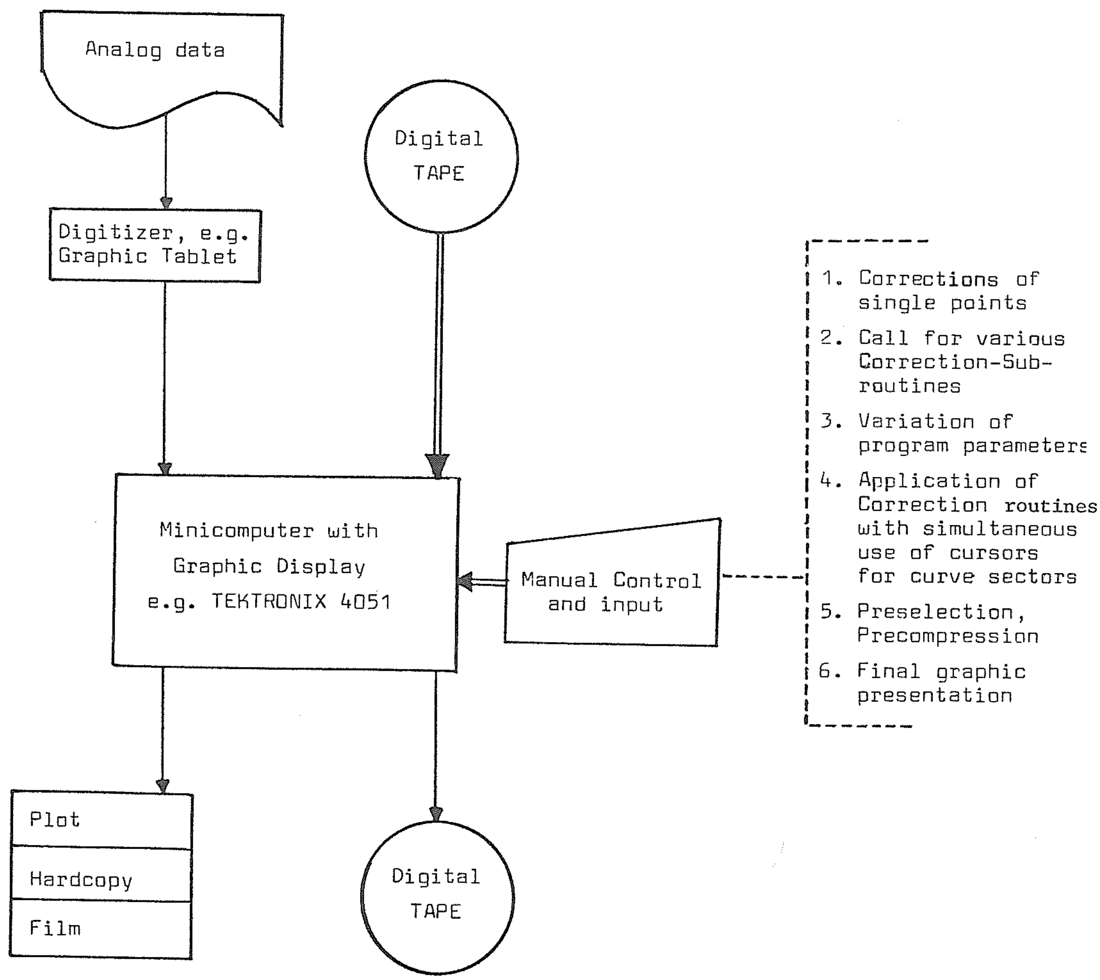


Because the transition area between research and service is poorly covered in many fields, especially when they are organizationally separated, the ratio of the used to unused information (raw data) continuously decreases as long as the information rates continue to grow. It, furthermore, gets increasingly more difficult to select desired information from the total file. The development of new compression methods, in conjunction with the VIGRODOS techniques and in close cooperation between the information systems, the information suppliers, and third users, seems promising and may help to alleviate the problems. The huge problems of the efficient, future use of formal information channels (see Fig. 13, p. 29), especially data bases, have reinforced the use of informal channels in most fields. This ultimately implies that decisions reached at a golf course might dominate those based upon more objective data from a specific information system.

The reported "data explosion phenomenon" is not only a severe one in natural science, but also in many other fields, e.g., economics (marketing). The explosion of data in marketing is exemplified

Figure 8.--Example of effective data preediting with intensive feed-back using the Tektronix 4051 Graphic Computing System

(W. Degenhardt, G.K. Hartmann, H. Oberländer (MPAE); T. Gray (NOAA/SEL)-- also see Davies and Hartmann, 1975.



by an extract from a news release (from R.J. Bregenzer, A.C. Nielsen Co. Northbrook, Ill., dated May 19, 1977):

"A.C. NIELSEN COMPANY ACQUIRES COORDINATED MANAGEMENT SYSTEMS, INC.

Commenting on the development, McCurry said: "The explosion in data processing capabilities in recent years has led to a corresponding explosion in the amount of data available to marketing executives. As a result, one of the most pressing problems today is translating that data into a readily accessible, meaningful form which can be used as a basis for executive marketing decisions. By combining CMS's expertise in user-oriented time sharing systems with Nielsen's marketing research resources, clients will now have a wealth of data instantly retrievable with the press of a button."

(Text continues on p. 26)

Table 3a Some tasks of national and international information (data) services

I. Data references

Supply of information about the location of the various data sources and their data use conditions.

II. Data coordination and data collection with datographies (see Table 2, p.12) including also:

Guarantee of the "grip-width, grip-depth, and grip-speed" to the most important data sources.

Remarks: 1) Grip-width: Fraction of the total available data of one parameter;
Grip-depth: Fraction of the available information about a data set (datography), e.g., reliability.

2) In general only preedited data should be considered (see also Fig. 7, p. 21, and 8, p. 22).

III. Data handling (research and service aspects)

Supply of data upon request. The most important service in this context is a reformatting of the data, that stem from different sources and have different formats, to a specific uniform format that can be used easily and quickly by third users. It is unlikely that the data collected from various sources will have the same formats because of different technical and financial means, different knowledge, and different objectives for which the acquisition of the raw data was planned.

Remarks: If all data, together with relevant software programs, could be recorded on a tape (like that used with the graphic minicomputer system shown in Fig. 8) that is then supplied to the user, much higher efficiency could be achieved.

IV. Data compilations

Supply of uncritically compiled data.

V. Data advice - including a reduction of data misuse caused by:

a) unauthorized data use;
b) inappropriate data use.

VI. Data refinement (processing, information analysis)

Supply of critical, evaluated data compilations or compressed data sets, e.g., by graphic presentation, etc. This seems possible only for groups that simultaneously carry out actual research in this or a related field.

VII. Trend studies

Table 3b The change of main tasks of information systems with time

I. Information (data) collection and handling (first generation).

II. Information (data) documentation (second generation).

III. Information (data) compression (third generation).

Figure 9a.--Example of a preediting procedure for phase data using a large computing system, Siemens 305, at MPAE Lindau

(W. Degenhardt MPAE - see also Davies & Hartmann, 1975)

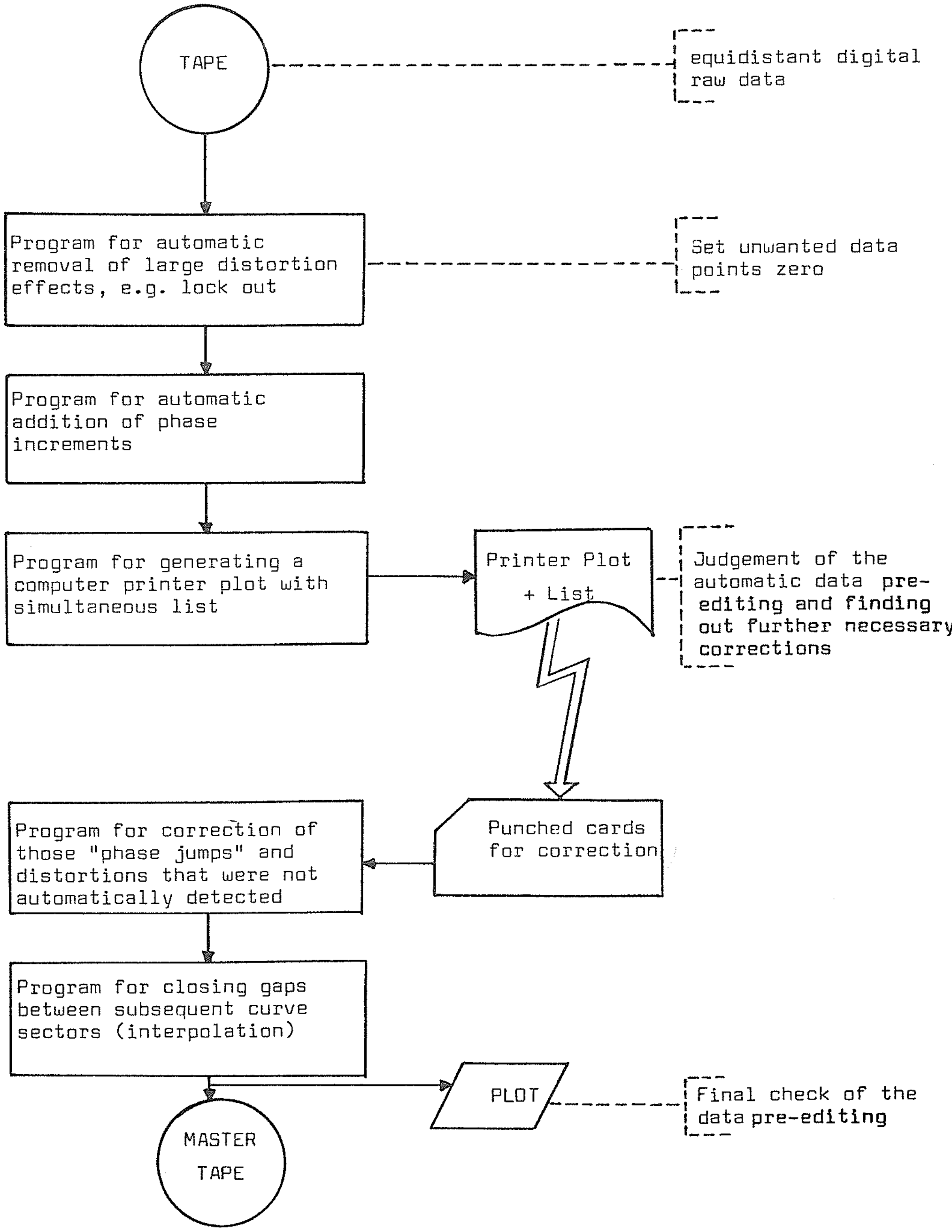
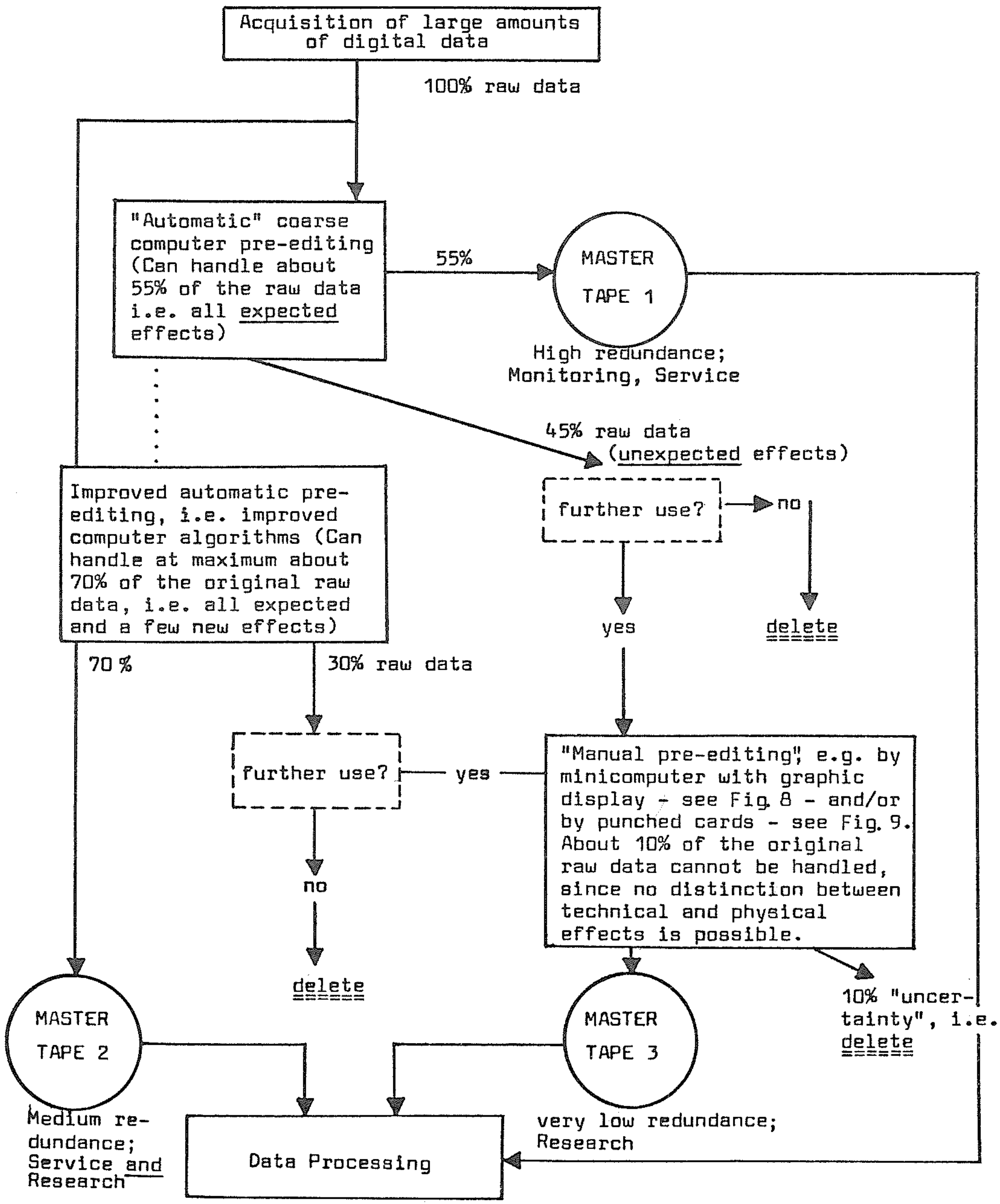


Figure 9b.--From digital data acquisition to data processing by automatic and manual data preediting

Example: Radio Beacon Phase Data from ATS-6 (Davies & Hartmann, 1975)

Remark: The given percentage numbers will very likely also apply to many other fields



Time Series Data Management

It is a prevalent belief that larger amounts of time series data can be dealt with only in large computing centers. Because of the serious data growth rates in space physics, some new software and orgware concepts were proposed and successfully tested by McPherron (1976).

However, the new generation of minicomputers, especially those with graphic display, now show clearly that many of these problems also can be solved in medium or small computing centers. This will get a further boost if additional and recent videotechniques also are applied (the trend toward VIGRODOS techniques). These new techniques will be used at all three levels; some common aspects will now be mentioned. Figure 5a (p. 13) shows the elements of empirical sciences. Most of the observed phenomena of our environment are time series data and, furthermore, are caused mainly by so-called uncontrolled conditions (time- and space-dependent, nonreproducible data (Hartmann, 1977)). Thus, we have to treat these data with statistical methods. There are two principal methods: 1) frequency distribution; 2) descriptive statistical parameters. The first one often requires a graphic presentation of the results. However, the large data growth rates and the advent of the new graphic communication systems lead to an increased interest in graphic presentation in the second case as well.

Figure 5b (p. 15) shows some important descriptive statistical parameters and some of their applications. The terms large, medium, and small at level V are used only in a relative sense. The subdivision of level V also can be considered as a subdivision in time, since at the onset of measurements, the standard deviations are large and then decrease as time and technical progress proceed. Figure 5c (p. 16) demonstrates this other possible point of view, namely, the possible time subdivision into three generations.

A stepwise improvement of the models (in our specific case the reference atmosphere) can be achieved by application of remark B in Figure 5b. It is quite clear that we can improve (refine) our models most by studying in detail the unexpected and unexplained effects. This implies that the main emphasis lies in the research aspects; it further implies human interaction in the data preediting, documentation, and processing. The computer may help to search (retrieve) these effects from the "bulk data," but the computer cannot reasonably process these data before its programing is updated. In this context, the computer often cannot distinguish between unexpected technical disturbances and new physical phenomena.

(Text continues on p. 30)

Figure 10.--Steps toward Video-Graphic-Communication and Documentation System (VIGRODOS)

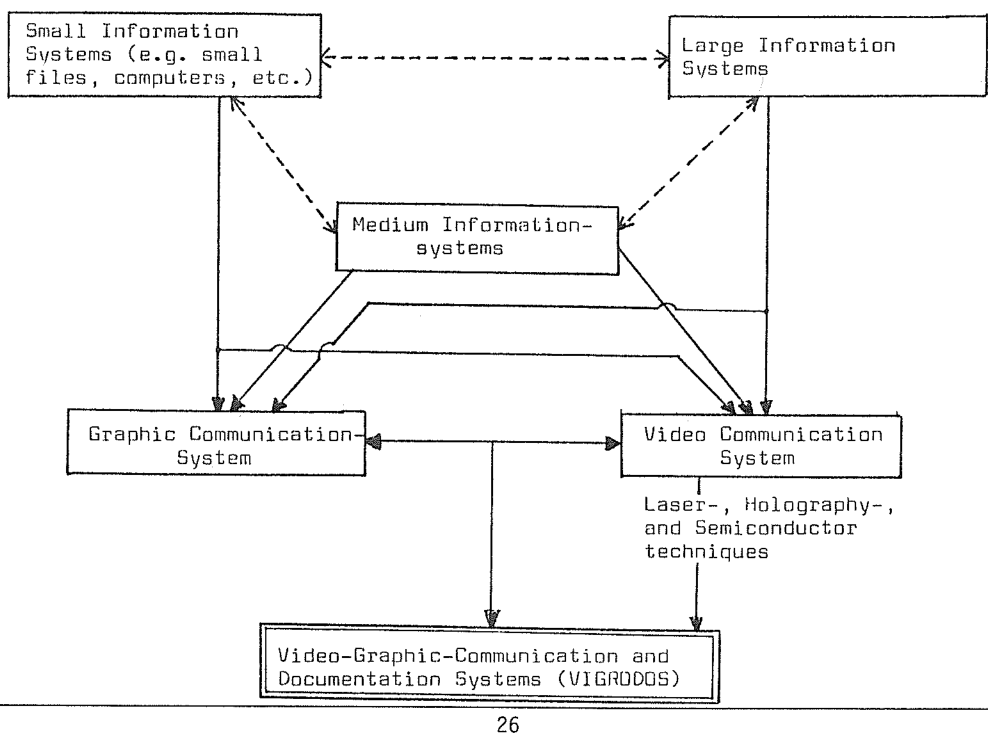


Figure 11.--Sketch of the characteristic features of science, information, science planning, and their interdependences (Hartmann, 1977)

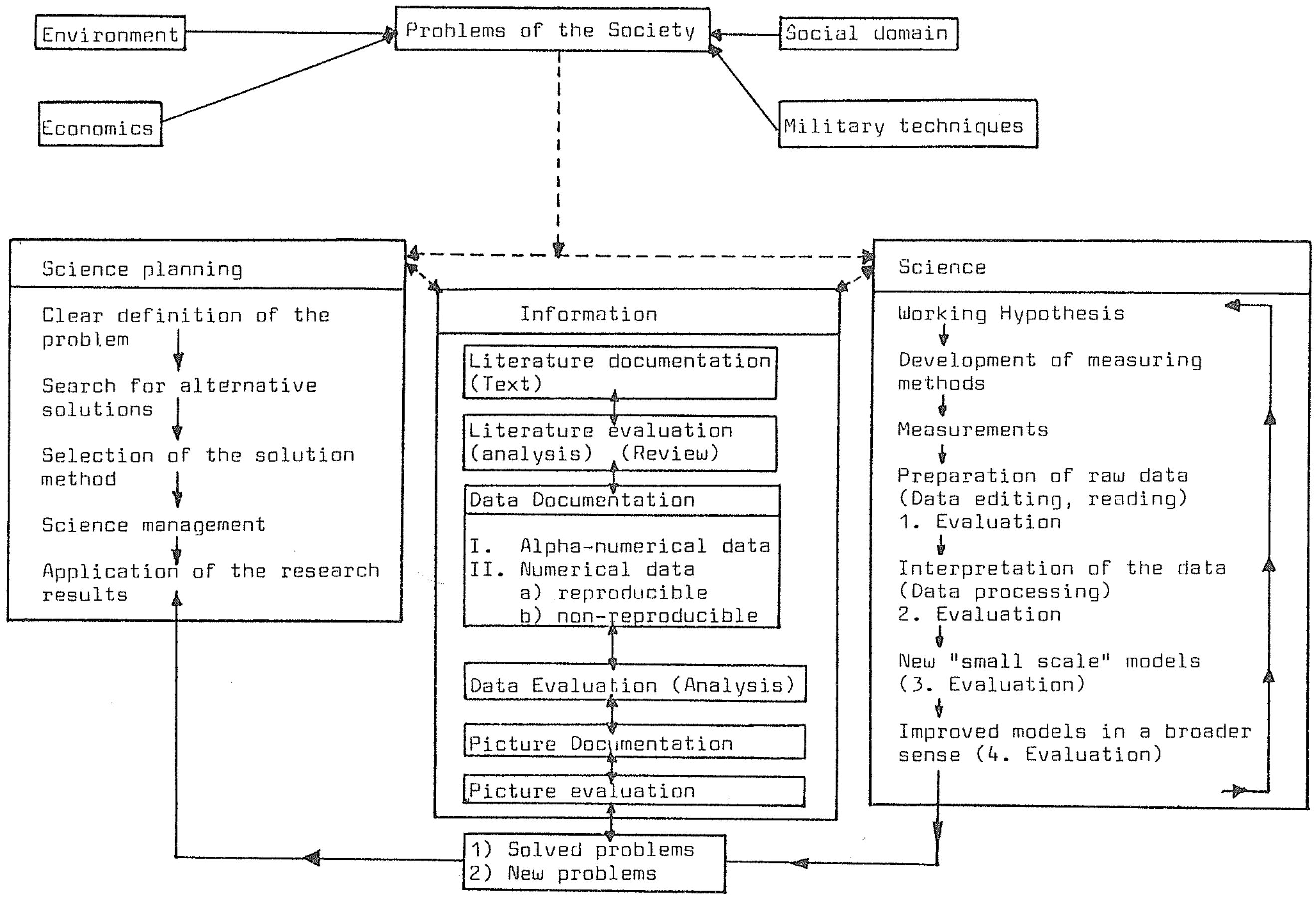


Figure 12.--Some characteristics of three different information system units

Characteristics	I Large information system unit	II Medium information system unit	III Small information system unit
1. Amount of information	large	medium	small
2. Costs	large	medium	small
3. Dynamics, flexibility	small	medium	large
4. Access	good; by international contracts	depends on mutual contracts	depends on mutual contracts
5. Type of information storage	general (user oriented)	mixture between I and III	specific (producer oriented) individual
6. Possibilities of data misuse today	great	medium	small
7. Accumulation problems	large	large	large
8. Today's ratio between text and data documentation	large (except for some specific data bases)	varies between large and small depending on size of institution	large (except for some specific data bases)
9. Today's ratio between text and picture documentation	very large	very large	very large
10. Availability of the literature (text)	predominantly abstracts, microfiches, original reports, books	predominantly abstracts, and original papers in Journals and Reprints, some microfiches	predominantly original papers as reprints, xerox copies, microfiches, some Journals, some reports
11. Location	Generally at the location of IAC; far from the user	Generally decentralized from the large IAC	Almost always decentralized from IAC; close to the user
12. Storage period for data	long term	medium term	short term
13. Ratio of informal to formal information	small	medium	large

Remark: IAC: Information Analysis Center

I might be represented by: WDCs, SELDADS, Large computing systems, large IACs
II might be represented by: Medium computing systems, medium IACs, etc.
III might be represented by: Minicomputers, small IACs, etc.

Figure 13.--Circulation of literature in a broader sense

Literature in a broader sense comprises any combination of Words (printed or tape recorded), Numbers (printed or tape recorded), and pictures, figures, graphics (printed or tape recorded) as well as movies and cartoons.

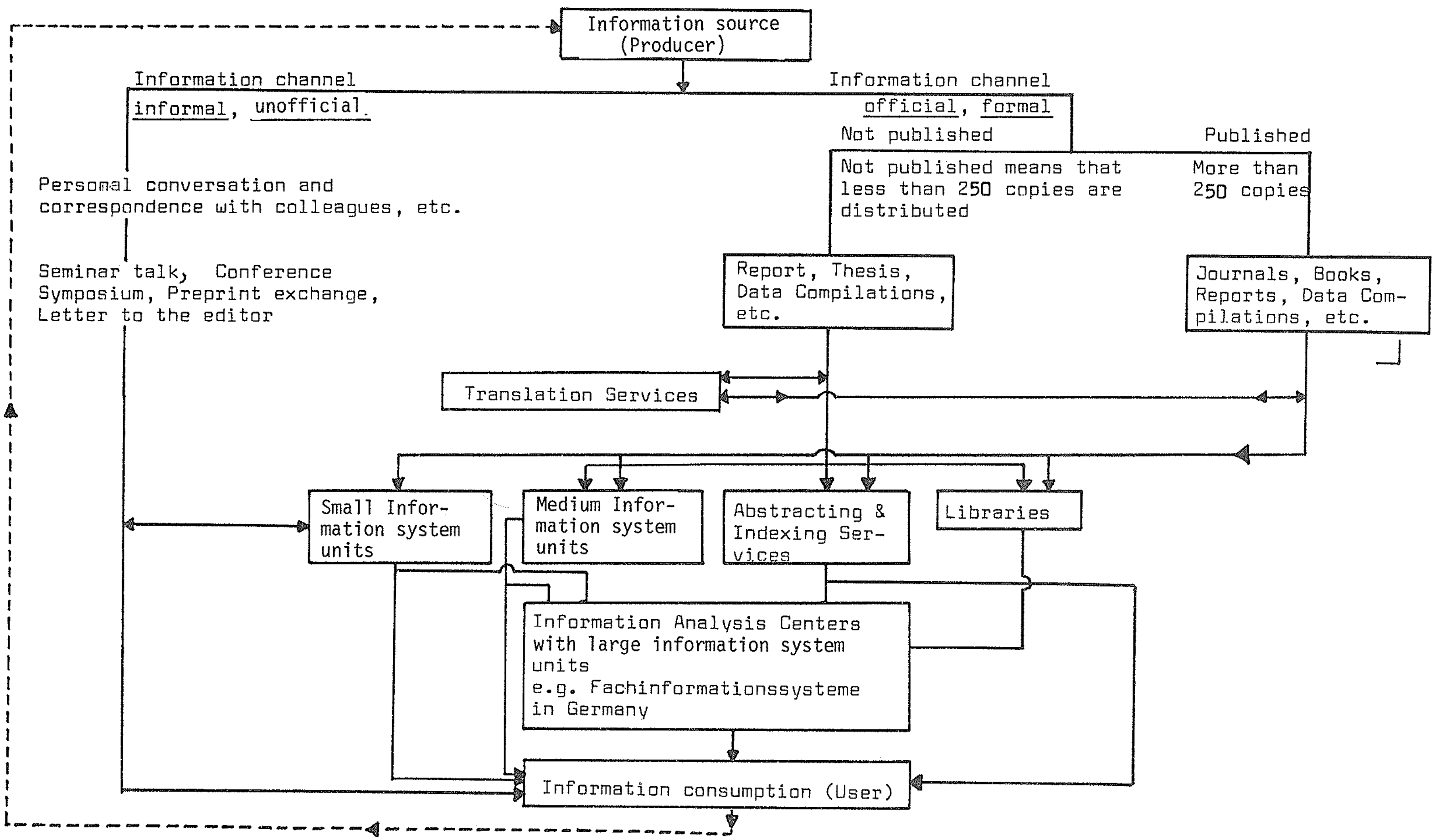
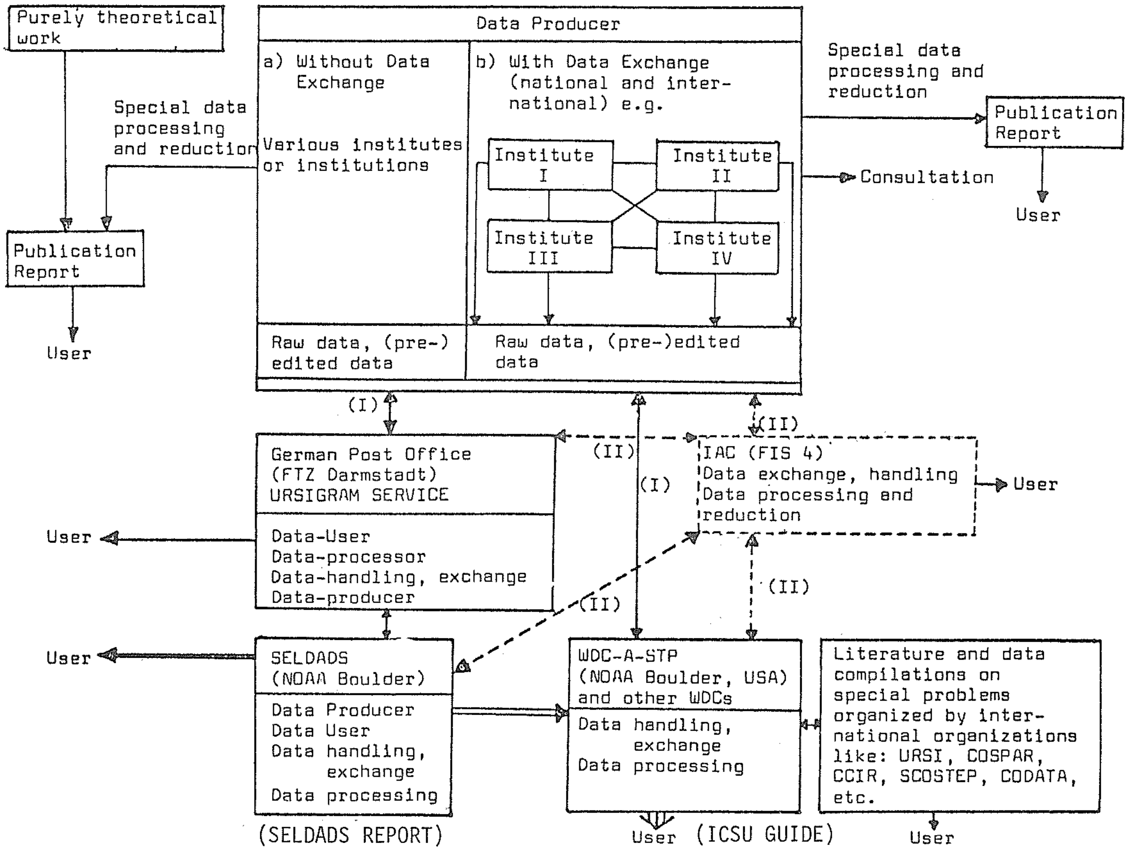


Figure 14.--The most important present STP information flux channels



Remarks: 1. FIS 4: Possible future role of the Fachinformationssystem 4 (information analysis center 4) for Solar-Terrestrial Physics in Germany, (I) might be stepwise replaced by (II)
2. Aeronomy Data are part of the STP Data
3. Data acquisition means: Measuring of the raw data, i.e. data production and to some extent also data (pre-)editing (See also Figs. 7 and 8).
4. Data documentation means: Collection, filing, storage, and retrieval of the data and to some extent also data (pre-)editing.
5. Data processing includes: Graphic presentation, statistical analysis, and modeling.

Striving for reliable environmental prediction services, based upon our present knowledge, principally means using only the "bulk data" and supplying these somewhat classical data to the relevant service agencies (e.g., Weather Service) after their routine acquisition by the monitoring systems. In conjunction with an updating of model calculations with real time data, the alerting and real time data transmission activities of modern information systems such as SELDADS (Williams, 1976) also are important.

In the context of striving for better models to describe and predict the environmental phenomena that are generally dependent upon many parameters, any refinement implies a simultaneous increase in complexity of the model. The number of unexpected and unexplained effects and also the standard deviations thus decrease; conversely, the computational efforts and costs increase as much as that for scientific and technical purposes and personnel. This means that three limits finally are approached where it is scientifically, technically, and economically unreasonable to strive for further model refinements. The procedure of a model-updating with real time data (see remark B.3. of Fig. 5b, p. 15) might indicate that such a limit now is close. Ultimately, a certain amount of unpredictability is always present, whatever the circumstances (see Heisenberg, 1962).

The Space Environmental Laboratory Data Acquisition and Display System (SELDADS) (Williams, 1976), the World Data Center-A for Solar-Terrestrial Physics (ICSU Panel, World Data Centres, 1973; World Data Center A for for Solar-Terrestrial Physics, 1973, 1976)and the Information Analysis Centers (IACs) like Fachinformationssystem (FIS) 4 at Karlsruh (Hartmann, 1977) are chosen only as examples for large information system units of different ages. WDC-A for STP is fairly old, SELDADS is fairly young, and FIS 4 is in "statu nascendi" (birth process). All three have in common that they must deal with solar terrestrial data. All three suffer (SELDADS and WDC-A for STP in their operational phases, FIS 4 in its planning phase) from the information growth problems and from the ambivalence between research and service. They all reveal the major characteristics of large information systems mentioned in Figure 12 (p. 28). They furthermore have in common the serious challenge of the need for better, faster, and more economical information selection and compression methods. Many institutes handling large amounts of data, e.g., from space physics, are faced with similar problems; some, however, are different and more direct. The forthcoming VIGRODOS techniques will alleviate many of these problems and will meet the needs much better than our present information techniques.

Two examples will demonstrate some major needs that might be met with VIGRODOS techniques.

1. The data compilation of the August 1972 Solar-Terrestrial Events (WDC-A for Solar-Terrestrial Physics, 1973), which is well done in the old classical sense, is so extensive (three volumes) that the use of VIGRODOS techniques would allow versatile combinations, comparisons, rearrangments, and presentations of the data and would facilitate a better overall interpretation of the phenomena. The foreword to these collected data reports follows below.

2. The positive reactions to a literature review (prepared by G.K. Hartmann and H. Oberländer) on the topic "Physical Water Research Methods" included a request for a supplementary volume with a compilation of the most important data extracted from the referenced literature. However, this can be done economically and efficiently only by applying the new graphic communication techniques (see Figs. 7, p. 21, and 8, p. 22). There was neither financial support for purchasing or renting the necessary technical equipment nor for employing and training the relevant documentation personnel (Hartmann, 1976).

* *

Foreword to Collected Data Reports on Solar-Terrestrial Events (August 1972)

The assembling of a volume of detailed data reports on the August 1972 solar-terrestrial events has come about because of recommendations by the ICSU Special Committee on Solar-Terrestrial Physics (SCOSTP), the International Union of Radio Science and numerous leaders in the international complex of scientific organizations. A circular letter from World Data Center A to the largest available list of observers resulted in the about 150 contributions collected in this special WDC-A data report.

The August 1972 events were a self-declared retrospective interval (confirmed by the SCOSTP) for intensive research and study, and the subject of a number of national and international symposia in the succeeding year. While a number of prompt data reports (see below) have appeared, the present volume is a channel for detailed data reports and brief discussion by individual observers. These data reports should facilitate multi-station or interdisciplinary interpretation of the complex phenomena and make more efficient the future scientific symposia on their physical explanation, notably the 1973 IAGA symposium at Kyoto.

The data reports in this volume have been given a minimum of editing, and where there has been editing there has not been time to check back with the authors and still have the volume distributed in a timely fashion. It is hoped that not too many substantive errors have thus crept in, but the compilers had no alternative.

The data reports are grouped under seven major headings, but many reports cover several of the major disciplines of solar-terrestrial physics. The index may help identify where data in one discipline are reported in a data report primarily concerned with another discipline.

Brief summaries of each major discipline appear at the front of the volume. These were written on short notice by members of the MONSEE Steering Committee of the ICSU Special Committee on Solar-Terrestrial Physics, each for his specialty. The time schedule was such that not all reports were available at the time the summaries were written, although most titles were available. The writers were asked to provide summaries or "overviews" and specifically not to attempt critical review articles. The summary articles may, however, serve as a guide to the detailed data reports; they attempt to meet a justified criticism of earlier detailed data reports on cosmic events compiled by WDC-A.

At the very beginning is a summary of the discipline summaries. While Dr. J. Roederer agreed to prepare this section, not enough material was available before he had to be absent on pressing matters and the overall summary was completed by the undersigned who should therefore take all responsibility.

Attention should be called to other data compilations on the August 1972 events. Many basic data and indices appear in UAG-21 issued by WDC-A in November 1972. That report includes the systematic data tables and solar maps which appear in "Solar-Geophysical Data" and other data periodicals; these data are not repeated in this volume, but in appendix I are reprinted the table of contents and the introduction for UAG-21. Appendix I also includes selected additional data (primary and analyzed) which have been received at WDC-A, as well as lists of detailed and special data held at WDC-A and elsewhere. Much data obtained in Japan in all solar-terrestrial disciplines appear in "Report of Ionospheric and Space Research in Japan", 26, 1972. In addition, much data and discussions have already appeared in standard journals or have been presented at scientific meetings and symposia. Appendix II lists many of these and should identify the many additional scientists who are actively interested in understanding the August 1972 phenomena and events.

The huge job of preparing these data reports for publication has been mainly borne by Helen E. Coffey, but with editing and checking assistance from most of the staff of the U.S. National Geophysical and Solar-Terrestrial Data Center, notably J.V. Lincoln, N. Smith, J.H. Allen, J.N. Barfield, K. Kawasaki, S.M. Ostrow, and D.B. Bucknam. The contribution of many typists and draftsmen can easily be appreciated and that of the printing operation of the U.S. National Climatic Center. The whole undertaking has been done in less than three months.

A.H. Shapley
Chairman, MONSEE Steering Committee
ICSU Special Committee on Solar-Terrestrial Physics

Director, National Geophysical and Solar-Terrestrial Data Center
Environmental Data Service
U.S. National Oceanic and Atmospheric Administration

* *

Because VIGRODOS techniques (see Fig. 10, p. 26) will be used for data preediting and data compression purposes in large, medium, and small information systems (see Figs. 7, p. 21, and 8, p. 22), it is suggested that joint feasibility studies be initiated soon. In this context it does not matter that these techniques finally will be used with different degrees of complexity. Now, it is important to obtain integrated viewpoints, not only in natural science but also in various fields of the humanities. We might then get "more user-oriented" data sets. Possibly, this then will allow the information centers to reach faster and more objective decisions on problems about which, and how, data sets should be stored, which should be newly collected, and which should be deleted.

The suggested VIGRODOS feasibility study could use some available and important solar-terrestrial physics data from the first or second generation (see Fig. 5c, p. 16). As an example, the contents of the SELDADS report is reproduced below. The data mentioned in 3.1 (solar X-ray data) and (or) 3.7 (solar microwave data) could be used, considering simultaneously the possible needs of the future Middle Atmosphere Program (MAP). It is suggested that SELDADS, WDC-A for STP, FIS 4, and the MPI für Aeronomie cooperatively plan for such a feasibility study. The general and new experiences in the data preediting and data compression fields, even by the application of only the early stages of VIGRODOS techniques, can be applied in many other fields of science and will likely yield various synergetic (Kahn and Wiener, 1967) aspects. The main requirements are: 1) Use of some technical SELDADS and WDC-A for STP facilities; 2) use of Tektronix 4051 plus peripherals; 3) use of video camera plus video recording, mixing, and playback units; and 4) manpower.

Contents of the S E L D A D S Report

FINAL REMARKS

General Growth Problems

(Mesarovich and Pestel, 1976): "The intensity of the crisis in global world development and the elusiveness of effective measures to bring about a solution challenge premises that have long been most fundamental in guiding the evolution of human society. Although these premises have paved the way for human progress in the past, they have also, finally, led to the present conditions. Mankind, therefore, appears to be at a turning point: to continue on the old road--that is, to follow the traditional route, unchallenged, into the future--or to start on a new path. In the search for such a new direction the old premises must be reevaluated.

"One such premise concerns the phenomenon of growth. Many of the global crises have been attributed to continuous and rapid growth. It has been argued, therefore, that growth must be stopped, or at the very least, deliberately retarded. Conversely, it has also been maintained that solutions of the world crises could be found only through continued growth. The fact is that both of these points of view require a great deal of qualification and more explicit definition before either one can be accepted as correct on a rational, rather than an ideological or emotional, basis. In other words, we need to know what is meant by 'growth,' and in what sense growth is considered as desirable or undesirable. Growth, after all, is a process, not an object; it cannot be pointed at physically, like a chair or table, for the sake of explication; rather it must be conceptually defined.

"But defining growth (especially in support of positions "for" or "against" growth) is not necessarily straightforward--as the confusion characteristic of current debate on growth or no-growth indicates. On certain growth issues there would seem to exist universal agreement. Consider, for example, the issue of population growth. Few would quarrel with the position that the global population cannot and should not be permitted to grow unchecked forever. That the population must level off some time, i.e., that population growth should stop, is the view gaining universal acceptance. On the other hand, none would argue against the growth in medical services leading to increased life expectancy and declining mortality rates; but this leads to increase, rather than decline, in population. The area of material consumption provides yet another example of the complexity of the growth issue and highlights the peril in taking a stand for or against growth as an abstract concept. It is a well-established fact that in the world's developed, industrialized regions materials consumption has reached proportions of preposterous waste. In those regions there must now be a relative decline in the use of various materials. On the other hand, in some less fully developed world regions, there must be substantial growth in the use of some essential commodities, either for food production or for industrial production. The very existence of the population in those regions depends on such growth. Hence, unqualified arguments for or against growth are naive; to grow or not to grow is neither a well-defined nor a relevant question until the location, sense, and subject of growing and the growth process itself are defined."

In this context, the information growth process might be defined as the accumulation of scientific knowledge. (See Figs. 1a-1d, p. 4-5, and Information, Communication, and Documentation, p. 3.)

W. Heisenberg (1962, 1973) (a statement made in context with nuclear and quantum physics): "The further we proceed in analyzing the surrounding nature, the more refined models we use and the more sophisticated models we use, the less we experience about the real objective nature of the world and the more we learn about ourselves." (Free translation into English by the author.)

C.F. v. Weizsäcker: "Finally I have to repeat that we have to make ugly prognostications. Indeed this seems to be the most important thing I have to say, and I'll finish with a well known fable which I changed slightly.

"Three frogs fell in a milk can. The first was a pessimist and said, "I'll never get out," and was drowned. The milk glued up his lungs and thus he died. The second was an optimist and said, "It does not matter; I'll get out," and showed no activity and thus he was drowned, too. The third was what one calls a realist - his own opinion is fairly often denoted as realistic - and he paddled. He said, "One never knows." After having paddled for several hours he felt something hard underneath his feet. He had churned the milk into butter and then he jumped out of the can." (Free translation into English by the author.)

ACKNOWLEDGMENTS

I wish to thank the Directors of the Max-Planck-Institut für Aeronomie--Prof. Dr. W.I. Axford and Prof. Dr. G. Pfotzer--for their support, and Dr. R. Abbel (IDW, Frankfurt) and Dr. H. Behrens (ZAED, Karlsruhe) for their valuable discussions, and my colleague, Dr. W. Degenhardt, for valuable discussions and contributions of Figures 8 and 9a. Prof. Dr. H.A. Whale provided valuable comments and proofread the first English draft; Prof. Dr. V.M. Vasyliunas assisted in proofreading.

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