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A Review and Evaluation of the Langley Research Center's Scientific and Technical Information Program

Results of Phase VI - The Technical Report: A Survey and Analysis

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INTRODUCTION

The technical report is used by the National Aeronautics and Space Administration (NASA) and many research and development (R&D) organizations as an information product, a primary means for communicating the results of their research to the user. For calendar year 1980, NASA published 3,399 technical reports of which 612 were published by the Langley Research Center (LaRC).

As part of the review and evaluation of the Langley Research Center's scientific and technical information (STI) program, the technical report was examined to determine the organization of the report (sequential components), the language used to convey the information (language components), and the methods used to present the information (presentation components). The examination included a survey of the literature pertinent to the subject and an analysis of current usage and practices of publishers of technical reports. The results of the examination are presented in this report.

STATEMENT OF THE PROBLEM

NASA technical reports serve as a primary means of communicating the results of NASA's research. Consequently, NASA technical reports must be organized and written to accomplish effective communication. NASA employs uniform publications standards which are designed to ensure the clarity, quality, and the utility of its technical reports. These standards include a basic report format which defines the report's components and establishes their sequence. The standards address, in a limited sense, language (verbal and visual) and presentation (typography, graphic design, and physical media) components. To date, these standards have not been examined to determine the extent to which they contribute to the effectiveness of the NASA technical report as a product for information dissemination. However, there were no generally accepted standards against which NASA publications standards for technical reports could be compared.

Purpose of the Study

The purpose of the study is three-fold: (1) to survey and analyze current practice and usage using selected technical reports; (2) to survey and examine available literature relative to the sequential, language, and presentation components of technical reports; and (3) to compare the NASA technical report publications standards with the findings of the examination. The reported findings would permit NASA management to assess its publications standards and to initiate changes, as needed, to increase the effectiveness of the technical report as a product for information dissemination.

Objectives of the Study

Four objectives were established for the study. These objectives were to

1. Survey and analyze selected technical reports to determine the current usage and practices for technical report preparation as they pertain to sequential, language, and presentation components;

2. Conduct a survey of experimental/theoretical literature to gather information pertinent to the sequential, language, and presentation components of technical reports;

3. Using textbooks, style manuals, and publications guides, gather prescriptive information pertinent to the sequential, language, and presentation components of technical reports; and

4. Compare/contrast the results of the study with the NASA technical report publications standards.

Importance of the Study

A comprehensive examination of the NASA publications standards for technical reports had never been conducted. No previous formal attempts had been made to determine the extent to which the NASA publications standards contribute to the effectiveness of the NASA technical report as a product for information dissemination. A survey of the literature did not reveal the existence of a published compilation or reference source of information pertinent to the subject. Thus, the study represents the first or the most recent attempt to survey and analyze technical reports and technical report literature with respect to the organization of the technical report (sequential components), the language used to convey the information (language components), and the methods used to present the information (presentation components).

Scope of the Study

The study was limited to (1) searches of manual and machine-readable data bases; (2) style manuals, publications guides, and textbooks; (3) books, periodicals, reports, conference proceedings, and research specifically concerned with sequential, language, and presentation components of technical reports; and (4) the analysis of the technical reports obtained from a survey of technical report producers. The study was limited to those technical reports which recorded significant scientific or technical accomplishments and which were specifically prepared for distribution outside of the originating organization. Thus, in-house memo/letter reports, corporate proposals, institutional reports such as periodic reports and annual reports, and contract progress reports were eliminated.

The study focused on the sequential, language, and presentation components of the technical report. The contents of the reports, the pertinence of the research areas represented, and the adequacy/effectiveness of the process used to disseminate the reports were not addressed in this study.

The study was not concerned with the adherence of the reports obtained to the standards or criteria for report preparation set forth by the producers. Adherence of NASA technical reports to NASA publications standards was addressed. However, it should be noted that a single NASA technical report was used in the review. Therefore, while the findings are valid in terms of that particular report, they should not be extended or generalized for the entire Agency without confirmation through a statistically designed Agency-wide audit. Such an audit was beyond the scope of this study.

NASA publications standards for technical reports were obtained from the NASA Publications Manual 1974 and the NASA Technical Publications Program: A Working Guide (1979). The study was not concerned with the basic series of technical reports as described in NASA Management Instruction (NMI) 2220.1B in terms of the adequacy of the various categories of reports to convey the results of NASA research.

The results of the study were reported without regard to economic consideration. For this reason, before implementing changes based on the results, cost/benefit analyses should be performed to ensure that reader benefits will outweigh the cost to the producer.

The study spanned the period from December 1980 to November 1981.

DEFINITION OF TERMS

Academic organizations. Academic organizations were interpreted as institutions of higher education or consortia of these institutions.

Back matter. Back matter of a technical report was defined as the section immediately following the body or text of a technical report. Supplemental materials such as appendixes, index, references, and bibliography appear in this section.

Body or text. The body or text of a technical report was defined as the section immediately following the front matter. The development of the central theme of the report including the introduction; the investigative, analytical, or theoretical material; the description of the research; the results and discussion; and the conclusions, appears in this section.

Congeniality. Congeniality was used to describe the subjective impression that typographic arrangements convey or as commonly stated, "judging a book by its cover." Factors such as reader preference and appropriateness of a type face determine the congeniality of printed material (Zachrisson, 1965).

Current practice and usage. Current practice and usage were defined as the methods or modes for report format, organization, and presentation employed by the selected technical reports surveyed and analyzed as part of this study.

Diagrams. Diagrams were defined as the group of visual representations which are primarily concerned with displaying relationships of contingency (computer flow charts and verbal algorithms), mechanism (schematic and circuit diagrams), and subordination (management organization charts and charts of biological orderings).

Experimental/theoretical literature. Experimental/theoretical literature was defined as periodicals, literature, reports, and research containing empirical results specifically concerned with or related to the organization, the language, and the presentation components of the technical report.

Figures. The term figures in this report was used to mean the entire family of visual representations other than tables. Major classifications are charts, graphs, diagrams, and illustrations.

Front matter. Front matter of a technical report was defined as the section immediately preceding the body or text. Included in this section are the foreword, preface, and contents. This section is related only to the writing of the technical report itself and is not essential to the subject matter.

Government organizations. Government organizations were defined as state and federal agencies engaged in research, regulatory, or service functions.

Illustrations. Illustrations were defined as figures which are representations of the actual appearance of things. Categories of illustrations are orthographic illustrations, isometric illustrations, photographs, and freehand drawings.

Industrial organizations. Industrial organizations were interpreted as private, for-profit firms whose principal activities were design and fabrication of tangible products.

Isometric illustrations. Isometric illustrations were defined as projections by lines perpendicular to the drawing surface in which a rectangular solid appears as inclined and shows three faces.

Language components. The language components were interpreted to be the collection of symbols and forms which can be arranged to represent ideas, data, or operations within a technical report. Language components can be verbal representations or visual representations such as tables and figures.

Leading. As used in this report, leading referred to the spacing between lines of type, as measured in points. One point equals .0138 inches. Seventy-two points equal one inch.

Legibility. Legibility encompassed the typographical aspects of readability and referred to the ease or difficulty of reading continuous passages of prose set in type.

Offsetting. Offsetting referred to the unwanted image transferred to the back of a printed page by the page beneath it as the sheets are stacked after printing.

Orthographic illustrations. Orthographic illustrations were defined as projections of a single view of an object in which the view is projected along lines perpendicular to both the view and the drawing surface.

Perceptibility. As used in this report, perceptibility was defined as the state of seeing and understanding what is seen. (Generally, most people call this condition "legible," i.e., "His handwriting is illegible.")

Perfect bound. Perfect binding referred to a method of binding which uses no sewing or stitching. Instead the pages are held together by glue. The backs of the gathered report pages are ground off, leaving a rough surface to which the adhesive is applied. The telephone book is an example of perfect binding.

Pica. As used in this report, pica referred to the unit of measurement principally used in printing to measure lines. A pica is equal to 12 points; for practical purposes, 6 picas are equal to 1 inch.

Plastic bound. Plastic or comb binding referred to a method of mechanical binding which utilizes a plastic center strip from which curling prongs extend. The prongs are inserted in holes punched into the pages. This form of binding is also referred to as GBC binding, after General Binding Corporation which introduced the process.

Prescriptive standards. Prescriptive standards were defined as criteria for technical report preparation recommended or suggested by style manuals, publications guides, and textbooks on writing and editing, typography, and design and layout.

Presentation components. The presentation components of a technical report were interpreted to include typography, graphic design, and the physical media such as paper, ink, and binding.

Readability. Readability was defined as the extent that meaning can be easily and quickly comprehended by persons reading for an intended purpose under normal conditions of motivation, alertness, time, and pressure. Test results are often expressed in terms of grade levels.

Research, trade, and professional organizations. Research, trade, and professional organizations were interpreted to be entities whose principal activity was to provide research or support activities and whose principal final product was the report medium.

Ring bound. In this report, ring binding was used to include any technical report which was bound, loose-leaf in a 3- or 5-ring binder. Ring binding is often used to permit the interchange or replacement of sheets or pages.

Saddle stitched. Saddle stitched referred to a method of mechanical binding that permits a technical report to be opened to its full extent. The report is opened to the center spread and wire-stapled through the saddle in two or three places. People Magazine, for example, is saddle stitched.

Sequential components. The sequential components were interpreted to be the elements or parts of a technical report such as the introduction, the summary, and the bibliography. The sequential components would be found in certain parts of the report either as front matter, body or text, or back matter; and each component would have a particular function.

Sidestitched. Sidestitched referred to a method of mechanical binding in which a technical report is stitched at the sides. "At the sides" means that the technical report is stitched in the closed position; therefore, the pages cannot be opened to their full width nor will the report be flat when opened. NASA Quick Release Technical Memorandums are usually sidestitched.

Technical report. The technical report was defined as an information product designed to convey the comprehensive results of basic and applied research to an external audience. Included in the technical report was the ancillary information necessary for the interpretation, replication, and application of the results or techniques.

Visibility. As used in this report, visibility referred to how well type can be seen. Visibility was judged to be poor if type was too small, too light, or too thin.

GLOSSARY

ABDEN	Aerospace, Basic Research, Defense, Energy, and Engineering
AERO	Aerospace
ANSI	American National Standards Institute
APA	American Psychological Association
BRS	Bibliographic Retrieval Services
Chicago	Chicago Manual of Style
COSATI	Committee on Scientific and Technical Information, U.S. Federal Council on Science and Technology
DoD	Department of Defense
DTIC	Defense Technical Information Center
ERIC	Educational Resources Information Center
GBC	General Binding Corporation
GPO	Government Printing Office (U.S.)
LaRC	Langley Research Center
LISA	Library and Information Science Abstracts
NACA	National Advisory Committee for Aeronautics
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NMI	NASA Management Instruction
NTIS	National Technical Information Service
ORBIT	Online Retrieval of Bibliographic Information Tymshared
R&D	Research and Development
RECON	Remote Console Interactive Computer System
SATCOM	Committee on Scientific and Technical Communication, National Academy of Sciences - National Academy of Engineering
SDC	System Development Corporation
SR	Scientific Report

STAR	Scientific and Technical Aerospace Reports
STC	Society for Technical Communication
STI	Scientific and Technical Information
TM	Technical Manual
TR	Technical Report
USGS	United States Geological Survey

RELATED RESEARCH AND LITERATURE

The research and development expansion, which began during the second world war, resulted in significant changes in scientific and technical information activities in the United States. These changes, which were necessary to handle the increased production of STI, included new methods of publishing, disseminating, storing, and retrieving scientific and technical information. A significant change occurred in the way in which the results of research were published. During this period, the distribution of R&D activities changed from almost complete reliance on traditional journals and monographs to the widespread use of the technical report (Adkinson, 1978)

History and Growth of Technical Report Literature

According to Brearley (1973), scientists were exchanging reports with one another long before scientific communication was institutionalized. He further suggested that technical reports may predate scientific journals. Auger (1975) stated that the history of technical report literature coincides entirely with the development of aeronautics and the aircraft industry. He further stated that in the United States the aircraft industry has been represented continuously by the National Advisory Committee for Aeronautics (NACA), now known as the National Aeronautics and Space Administration (NASA), which issued its first technical report on The Behaviour of Aeroplanes in Gusts in 1915. However, as Auger points out, some authorities consider that these dates are anticipated by publications which were reports in all but name, notably the Professional Papers of the United States Geological Survey, which appeared in 1902, and the Technologic Papers of the National Bureau of Standards, which were first published in 1910. The development of the technical report as a major means of communication, according to several authorities such as Auger (1975), dates back to about 1941, with the establishment on June 28, of the United States Office of Scientific Research and Development.

Grogan (1976) agreed with Brearley that scientists have been writing reports since the earliest days; what has changed over the years has been their method of communicating these reports. In describing the development of scientific communication, Grogan (1976) stated that dissemination of research was made first through personal correspondence and then through papers given at society meetings. As science grew and became more specialized, the journal became the accepted method of reporting new work. However, as the growth of science and technology began to rapidly escalate, the scientific journal was no longer capable of meeting the total information needs of the researcher. The technical report, according to Grogan (1976), emerged as an alternative method of disseminating the results of research.

The volume of technical report literature has increased proportionally to the increase in government spending for research and development (R&D) (Subramanyam, 1981). For many R&D agencies of the federal government, including the National Aeronautics and Space Administration, the technical report constitutes an information product, a primary means of communicating the results of research to the user (Stohrer and Pinelli, 1981).

During the past 40 years, the technical report has developed into an important medium of communication in science and technology to the extent that it has sometimes been viewed as a threat to the scientific journal. Prior to World War II, the technical report was used primarily by industry and by agencies of the federal government. Due primarily to the federal government's support of R&D activities and the associated need to record the progress and document the results of government-performed and -sponsored research, the volume of technical report literature has grown steadily. In 1973, approximately 80-85 percent of the world's technical report literature was of U.S. origin (Chillag, 1973).

Numerous technical reports are issued annually; the exact numbers are unknown because production figures are usually obtained from a variety of sources. Production figures usually do not include those reports which are classified or limited in distribution. In fiscal year 1963, of the 38,880 technical reports produced by or for the U.S. Department of Defense (DoD), 62 percent were subject to limited or restricted distribution (Hall, 1967). A similar case can be made for technical reports which document the results of industrial research. Quite often this research is considered proprietary and is subject to restricted distribution.

By 1950, the annual output of technical reports in the U.S. was placed at between 75,000 and 100,000 (Tallman, 1961). According to the 1963 Weinberg report, some 100,000 technical reports were being issued each year in the U.S. alone (Grogan, 1970). By 1965, the number of technical reports had decreased to 15,000. A decade later, in 1975, the yearly total of technical reports being produced in the U.S. exceeded 60,000. The projected production for 1980 was estimated at 80,000 technical reports (King, 1977). The number of U.S. produced technical reports as compared with other STI media is shown in Figure 1.

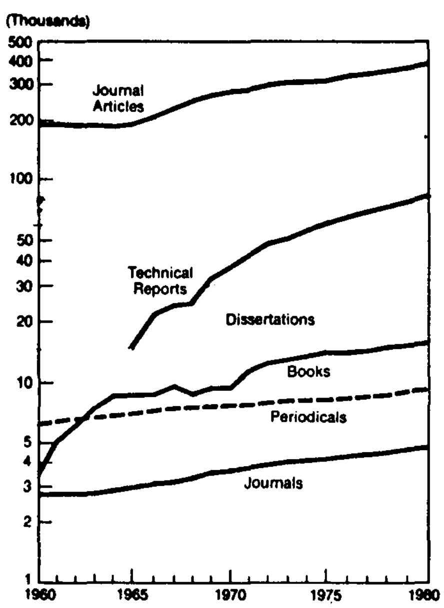

Figure 1. Number of U.S. STI literature items by medium (1960-1980)

Technical Report Production by NASA

All significant scientific and technical findings derived from NASA activities, including those generated by NASA-sponsored R&D and related efforts, are disseminated either in NASA technical publications and/or in suitable non-NASA scientific and technical media such as journals, conference proceedings, symposia, and workshops. Accordingly, NASA operates a scientific and technical information program to acquire, process, announce, publish, and disseminate STI required for or resulting from its research activities (NMI 2220.5A). Central to the operation of the NASA STI program is the NASA STI Facility, which acts as the clearinghouse for NASA STI; the NASA STI Branch at NASA Headquarters, which has functional management responsibility for the program; and the NASA STI operations at each of the NASA field centers, which are responsible for managing their center's STI output. The total research output for the Agency from 1971-1981 appears in Figure 2.

NASA technical reports constitute a primary means of communicating the results of research to the user. Its history of technical report production dates back to and is built upon the heritage established by its predecessor, the National Advisory Committee for Aeronautics (NACA). The NASA technical publications series included several categories of technical reports, each designed to accomplish a specific purpose or function. Uniform publications standards designed to ensure the clarity, quality, and the utility of its technical reports are employed by NASA (NASA, 1974).

	Accession Year											
STI Media	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	Totals
Formal Reports	1131	898	704	736	590	530	506	440	420	420	301	6676
Contractor Reports	3732	3440	3891	3023	2735	2570	2627	2078	2121	1572	2355	30,144
Informal Reports	2088	2189	1811	2525	1926	1613	1511	1430	1318	1407	2386	20,204
Other Published Literature	5125	4502	4775	4687	4587	4527	4614	4547	5038	4563	4527	51,492
Totals	12,076	11,029	11,181	10,971	9,838	9,240	9,258	8,458	8,895	7,962	9,569	108,516

Figure 2. Total agency STI output for 1971-1981 by medium

Characteristics of Technical Reports

The definition of the technical report varies because it serves different roles in communicating within and between organizations. The technical report has been defined etymologically according to the report content and method (DoD, 1964), behaviorally according to the influence on the reader (Ronco, 1965), and rhetorically according to the function of the report within a system for communicating STI (Mathes and Stevenson, 1976). The boundaries of technical report literature are difficult to establish because of wide variations in the content, purpose, and audience being addressed. The nature of the report--whether it is informative, analytical, or assertive--contributes to the difficulty.

Technical reports may exhibit some or all of the following characteristics (Gibb and Phillips, 1979 and Subramanyam, 1981):

- o publication is not through the publishing trade;
- o readership/audience is usually limited;
- o distribution may be limited or restricted;
- o material may be classified or proprietary;
- o content may include statistical data, catalogs, directions, design criteria, conference papers and proceedings, literature reviews, or bibliographies; and
- o publication may involve a variety of printing and binding methods.

The National Academy of Sciences - National Academy of Engineering Committee on Scientific and Technical Communication (SATCOM, 1969) listed the following characteristics of the technical report:

- o it is written for an individual or organization that has the right to require such reports;
- o it is basically a stewardship report to some agency that has funded the research being reported;
- o it permits prompt dissemination of data and results on a typically flexible distribution basis; and
- o it can recount the total research story, including exhaustive exposition, detailed tables, ample illustrations, and full discussion of unsuccessful approaches.

The Role of the Technical Report in Scientific Communication

Technical reports and scientific journals are two of the principal information products used by engineers and scientists to communicate the results of their research. According to Brearley (1973), the journal has served the scientific community by providing a system for open, formal, and orderly communication among scientists. In this sense, "open" means that the journal is freely available to anyone who pays the subscription or has access to a library; "formal" means that the journals are part of the scientific archive and that an accepted convention (the bibliographic description) permits unambiguous reference to be made to any given paper, thus permitting its retrieval by any interested person; and "orderly" means that the system is operated by scientists for scientists, and that papers are subjected to some form of screening or review prior to publication (Pasternack, 1966). The status of technical reports in terms of their ability to meet these criteria has been questioned repeatedly (Subramanyam, 1981).

The technical report has been accused of not meeting the same criteria or standards of authority, scientific rigor, and retrievability as conventional journal articles (Brearley, 1973). Much of the debate concerning technical reports centers around four themes: 1) availability, 2) quality, 3) diversity of content, and 4) status as primary publications, especially in relationship to scientific journals.

Availability. A significant proportion of the R&D conducted in the U.S. is sponsored or supported by the federal government. The results of this research, financed by the taxpayer, should be made accessible to the American public unless security is likely to be jeopardized. The agencies such as the DoD and NASA, which are major producers of technical reports, have established the necessary bibliographic controls, systems, and clearinghouses to announce and otherwise disseminate these reports.

The Defense Technical Information Center (DTIC) was established by the DoD to act as a clearinghouse for all reports produced by or as a result of defense R&D activities. These reports may be classified, unclassified, or restricted. Those reports that are unclassified and publicly available are released for announcement and distribution by the National Technical Information Service (NTIS).

NASA's enabling legislation states that the Agency "shall provide for the widest and appropriate dissemination of information concerning its activities and the results thereof" (NMI 2220.5A). The NASA scientific and technical information system was designed to acquire, process, publish, announce, and distribute the results of NASA-conducted and -sponsored research. NASA technical reports are processed into RECON, NASA's computerized bibliographic data base; and indexed and abstracted in STAR, NASA's announcement publication for technical report literature. NASA technical reports, which are publicly available, can be obtained from the National Technical Information Service (NTIS) and are accessioned into the NTIS data base.

The National Technical Information Service was established as part of the Department of Commerce to simplify and improve access to technical reports produced by federal agencies and their contractors. NTIS accessions approximately 70,000 technical reports annually. These reports are indexed, abstracted, and announced in Government Reports Announcements and Index, NTIS's announcement journal for technical report literature, and are accessioned into the NTIS data base. The NTIS data base may be searched through such commercial data bases as SDC's Orbit II®, Lockheed/DIALOG™, and BRS.

Many technical reports produced by or for U.S. government agencies appear in The Monthly Catalog of the U.S. Government Printing Office (GPO), which is now searchable on-line through Lockheed/DIALOG™. These publications are distributed in hard and microfiche copy through the GPO library depository program. Many of these appear in long-established and well-known series such as the U.S. Geological Survey's Professional Papers.

(For detailed accounts of the various federal information programs established to further access to technical reports, see Adkinson, 1978. The following bibliographic guides provide additional information about U.S. government publications including technical reports: Schmeckebier and Eastin, 1969 and Morehead, 1978).

Quality. Most technical reports are the products of government-sponsored R&D. As a contractual requirement, the performing organization is required to submit a report which documents the effort. Authorship is generally the responsibility of the principal investigator or project director. Many government agencies include and/or provide publication standards as part of the contract language. This is not always the case nor are these standards always followed. According to Subramanyam (1981), the uneven quality of technical reports may be attributed to the following factors:

- Most technical reports are written by engineers or technologists.
- The reports are addressed to the technical experts of the sponsoring agency and not to the entire scientific and technical community.
- The time available for the preparation of reports is usually very limited.
- Because technical reports are intended to be working documents and not a part of the archival literature of science and, in many cases, because of the confidential nature of their contents, reports are not refereed by outside experts.
- Technical editing expertise and facilities available for report editing are usually very limited.

Most federal agencies which produce technical reports utilize a publication control system designed to ensure the proper (unique) numbering of each technical report. These systems also include bibliographic standards which state the information to appear on the cover and title pages and its location. These same agencies utilize editorial standards and style manuals to be used in preparing technical reports. Technical reports prepared by these agencies are generally subjected to an editorial process in which technical editors and writers prepare the text for publication and ensure that editorial quality and uniform appearance are maintained.

With respect to quality, not all technical reports are refereed. Those reports produced by federal agencies are generally subjected to internal technical and editorial review. Some agencies utilize outside referees or reviewers. The authors of some technical reports are from outside the agency (joint authorship), which serves to provide a type of outside review.

As for technical reports produced under contract, the technical monitor of the contract performs a type of review. However, while the report may not be refereed or subjected to peer review, the work itself has undergone scrutiny or review of some kind. Research proposals are frequently evaluated by advisory panels, the potential ability of the investigators to perform the work considered, and their performance or previous proposals assessed. As Brearley (1973) stated, the report resulting from the work has, in a sense, been pre-screened and therefore cannot exactly be likened to a manuscript received by a journal editor which deals with work outside his own specialty and which is written by an author whose name is unfamiliar. This is not to say that all reports have scientific merit (any more than all journal articles have), but to point out that comments regarding review procedures for reports may not deserve all the weight they sometimes receive.

<u>Diversity of content</u>. Technical reports vary greatly in the nature of their content. As previously cited, a diversity of material appears as technical reports. The subjects covered encompass all branches of engineering, science, and technology. Additionally, there exist categories of technical reports including quarterly progress reports, annual reports, and corporate proposals. The argument is that it is difficult to differentiate between reports of substance and all others. The result is a frustrated user or information seeker. Given the volume of technical

reports produced annually, it would be impossible for an individual to scan the report literature for current awareness in the same manner that one might scan the contents page of a scientific journal (Brearley, 1973).

Status as primary publications. Editors of some scientific journals have criticized both the quality and seemingly uncontrolled growth of technical reports. Subramanyam (1981) reported the observance of a certain ambivalence on the part of journal editors toward technical reports. On one hand, many editors refused to consider manuscripts which had previously been distributed on the grounds that distribution constituted prior publication. On the other hand, many editors have discouraged their authors from citing technical reports as references on the grounds that reports are not "published" literature and are not easily accessible. This same ambivalence on the part of journal editors was reflected in a survey conducted by COSATI, the Committee on Scientific and Technical Information (U.S. Federal Council for Science and Technology, 1968). Most of the editors generally agreed that limited dissemination of information in the form of technical reports did not constitute prior publication. However, many editors qualified their opinion by saying that they would deem a report as a regular publication and would not consider it for publication in their journal if the report had been announced (accessioned) and was available from a clearinghouse or from the sponsoring organization.

Technical reports are so diverse and so heterogeneous that examples can be found to support any argument for or against them. Perhaps the true nature of the issue is best expressed in the following quote from the 1969 SATCOM report (National Academy of Sciences, National Academy of Engineering, 1969):

> "One can find ready examples to support almost any generalization that happens to strike his fancy: that they are too long or too short; badly refereed or well refereed--or not refereed at all; reliable or unreliable; inadequately distributed or too widely distributed; too detailed and technical or not technical enough; too expensively printed or shoddily assembled; a valuable complement to journals or a serious handicap to conventional publication."

Notwithstanding the controversy over their status, technical reports constitute an important vehicle for disseminating the results of research. The COSATI Task Group (1968), which appraised the role of the technical report in the scientific and technical information process, found the technical report to be the primary recording medium for applied research and thus favored by the technologists. The technologists saw great merit in a number of features of the technical report including timeliness, comprehensive treatment, inclusion of ancillary information, and the frequent inclusion of negative results. On the other hand, the COSATI study found that scientists were concerned with the reliability of the technical report because of its allegedly unreviewed nature and its availability (accessibility) because of difficulty in obtaining reports through a retrieval, archival, or information system.

Both technical reports and scientific journals play a distinct role in the communication of scientific and technical information. A proper understanding of their unique features should lead to better understanding and effective utilization. The chief strength of the technical report seems to be the currency of the information it contains. As a vehicle for the dissemination of technical information, the technical report is much faster than a journal article since the production of a report is not subject to the delays that are inherent in journal publishing. Perhaps the role of the technical report relative to other forms of scientific and technical communication was best summarized by a journal editor responding to the COSATI Task Group mentioned earlier (COSATI, 1968):

> "The technical report and the published paper each has its (their) function, and to me the reasons seem obvious why neither can or should be expected to play the role of the other . . . . In the final analysis, I still believe the technical report incorporates a group of characteristics not found in any other single medium. It is a report of stewardship to the organization that funded the R&D on which it reports; it permits prompt dissemination of data on a highly flexible distribution basis; and, not being subject to externally imposed space restrictions, it can tell the total R&D project study, including exhaustive exposition and comprehensive tables and illustrations. In my opinion, this makes it neither better nor worse than the published paper as a medium of scientific communication. It means simply that the technical report can fulfill certain functions the published paper cannot, just as the published paper has valuable attributes not found in the technical report."

Technical Report Studies

Various dimensions of the technical report have been studied. Many, if not most of these studies, were limited in scope and were devoted to the use of the technical report within the broader context of scientific and technical communication.

The historical developments of technical report literature have been presented by Tallman (1962), Boylan (1970), and Auger (1975). The complexity of technical report literature has been described by several authors (Wright, 1963 and Hartas, 1966). Studies by Earle and Vickery (1969) and by Coile (1969) determined the use of technical reports as citations in scientific and technical publications such as books, periodicals, and monographs. Wilson (1958), Fuccillo (1967), and Randall (1959) conducted separate studies to determine the half-life of technical reports. The SATCOM Committee (National Academy of Sciences, National Academy of Engineering, 1969) and the report of the Weinberg Panel (Executive Office of the President, 1963) were concerned with the structure, organization, and transfer of scientific and technical information and the role of the technical report within an STI system. Perhaps the largest and most comprehensive studies devoted to the technical report were conducted by the American Psychological Association (Garvey and Griffith, 1965) and a COSATI Task Group (1968) under the direction of Sidney Passman. Very little definitive research on the technical report has been conducted since the early 1970's.

Review of NASA Technical Reports

Three studies which utilized feedback from users of NASA STI were conducted to help evaluate the NASA STI program. All three studies obtained information on various dimensions of NASA technical reports. These studies were reviewed and summarized.

Monge study. In 1978, the NASA Ames Research Center contracted with Communimetrics, Inc., to undertake an evaluation of NASA STI from the viewpoint of non-NASA users in the aeronautical industry. Monge (1979) based The Assessment of NASA

Technical Information on data obtained from 450 employees in 40 of the 49 major aeronautical companies. Three methods of obtaining information were used: a questionnaire containing open- and closed-ended questions, structured interviews, and a multidimensional scaling technique. Data were obtained in these major areas: the efficiency and timeliness of the dissemination process; the method through which the respondent became aware of NASA STI; utilization of NASA STI; usage of a specific announcement medium, STAR; a comparison of documents published by NACA and NASA; suggested improvements in NASA STI; and the image of NASA STI.

Overall, the respondents registered a highly positive perception of NASA STI and, in particular, NASA technical publications. The respondents did, however, express several concerns relative to the content and presentation of NASA technical reports. These concerns were expressed in terms of recommendations for change.

The respondents expressed the desire for NASA to produce more state-of-the-art publications. It was reported that one of the major inadequacies of NASA technical reports was the failure to effectively relate the findings of a new research project to existing knowledge and similar research being conducted. It was recommended that each NASA technical report should have a section which synthesizes other relevant research from within and outside of NASA.

The study further concluded that existing standards and actual practice for technical reports resulting from contractual arrangements should be reviewed to assure greater consistency of these reports with those produced within NASA. Summaries and abstracts should be clear and concise. It was recommended that abstracts should provide an overall description of the research while the summary should contain the essence of the findings or results and that the practice of not developing conclusions in NASA technical reports should be examined.

It was recommended that the style and quality of graphics used in NASA technical reports should be reviewed for consistency and appearance. In particular, graphs, charts, and illustrative material should be examined for compliance to standards. Where standards for graphics, for example, do not exist they should be created. Particular emphasis should be placed on grids and type size.

The study further concluded that the typography used in NASA technical reports should be examined for uniformity. The type size in some cases was too small, the type style too light, and the line length inappropriate. The type of binding used for NASA technical reports should also be examined, particularly for those technical reports which are considered to be informal. A type of binding which would permit the report to lie flat and remain open was recommended. Finally, it was recommended that NASA technical reports should contain information which would permit the reader to contact the author. This could include both a mailing address and business phone number.

Langley STI study. In 1980, the NASA Langley Research Center undertook a comprehensive review and evaluation of its STI program. A series of studies were conducted to determine the extent to which the program was meeting the needs of Langley research personnel and non-NASA users (academic and industrial researchers) of NASA- and Langley-generated STI, the areas of the program which needed improvement, and the ways in which the program could be modified to improve its overall efficiency and effectiveness.

Phase I (Pinelli, 1980) of the review and evaluation study involved a survey of Langley engineers and scientists in the four research directorates. The questionnaire contained 50 closed-ended and 3 open-ended questions. From the internal user population of 1,036 engineers and scientists, 710 valid surveys were returned. From the valid surveys, a random sample of 300 was selected and subjected to analysis. The survey collected information on six topics including the perceived image of NASA and Langley STI.

Phase IV (Pinelli, 1981) of the review and evaluation study involved a survey of academic and industrial research personnel. The questionnaire contained 35 closed-ended and 3 open-ended questions. From a contact list of nearly 1,200 active academic and industrial researchers, approximately 600 addresses were verified. The 497 persons who agreed to participate were mailed questionnaires from which 381 completed questionnaires were received by the cutoff date. The survey collected information on seven topics including the perceived image of NASA- and Langley-authored STI.

The questionnaires administered to both populations covered such dimensions as the prestige of Langley-authored journal articles and technical reports (as compared to other technical literature within the respondent's discipline) and the adequacy of data and the effectiveness of report organization (format) of Langley-authored technical reports. The results of this portion of the questionnaires were compared to determine if similar perceptions and use were shared by the internal and external populations.

An analysis of the findings revealed that, overall, the prestige of Langley-authored (published) STI was perceived as being high by both populations. The perceived prestige of Langley-authored technical reports was higher by the internal population than by the external population. However, a perception of lower prestige for Langley-authored technical reports was indicated more frequently by the internal population than by the external population.

Two questions were included in both surveys to establish two dimensions of technical quality: the effectiveness of report organization (format) and the adequacy of data for Langley-authored technical reports. Both populations indicated that the organization (format) of Langley-authored reports made readability easy. Both populations indicated that Langley-authored technical reports contained sufficient data.

An analysis of the findings revealed that, overall, the effectiveness of the report organization (format) and the adequacy of data were perceived as being higher by the internal population than by the external population. Neither the internal nor the external populations indicated that the organization (format) of Langley-authored technical reports made them less readable. Likewise, neither population indicated that the adequacy of data in Langley authored technical reports was low. However, the external population expressed the following concerns about NASA technical reports: (1) the separation of text from visual material, (2) the absence of grids from graphs, (3) insufficient tabular data, and (4) the exclusion of negative results (Pinelli, 1981).

Summary

The technical report has grown in number and in use to become a primary information product for the dissemination of scientific and technical information. The number of technical reports produced each year is directionally proportional to government support of research and development.

The technical report was shown to possess characteristics which make it unique as a medium for information transfer. As an information product the report has been criticized and praised. Critics charge that the technical report does not meet the rigors or criteria established for scientific journal publication. Lack of screening or peer review was the characteristic listed most frequently as a major weakness. Proponents saw merit in such features of the technical report as timeliness, comprehensive treatment, and inclusion of ancillary information. Notwithstanding the controversy over its status, the technical report was shown to constitute an important vehicle for disseminating the results of research. Both the technical report and the scientific journal played distinct roles in the communication of scientific and technical information.

Since a significant portion of the technical reports produced each year result from government sponsored research and development, agencies of the federal government which produce and/or sponsor these reports have established the necessary systems and clearinghouses to make them accessible to the public. NASA, as a major producer of technical reports, operates the NASA STI program to accomplish this task. Standards have been developed to ensure the clarity, quality, and utility of NASA technical publications.

Very little definitive research on the technical report has been conducted since the early 1970's. The evaluation of NASA technical reports has been confined to feedback obtained from users. This feedback indicated that NASA technical reports were being used and that the perceived prestige of NASA technical reports was high. Specific concerns of the users included consistency in terms of adherence to NASA publications standards, detailed summaries and abstracts, development of conclusions, relating the results to previous and/or existing work, type size, type of binding, absence of grids on graphs, insufficient tabular data, and the exclusion of negative data. Users cited the need for more state-of-the-art publications.

RESEARCH METHODOLOGY AND PROCEDURES

The study was conducted in conjunction with Robert A. McCullough and Douglas D. Pilley of Graffic Traffic Studios and Dr. Freda F. Stohrer of Old Dominion University. Professional research assistance was employed to obtain research capabilities not readily available to the project.

Research Methodology

Current usage and practices for technical report preparation were determined by systematically analyzing selected technical reports and related materials obtained from a survey of technical report producers. Experimental/theoretical literature pertaining to technical report preparation was obtained from a survey of the literature. Manual and machine-readable data bases including DTIC, ERIC, LISA, NTIS, and RECON were searched. Prescriptive standards and criteria were obtained from a review of style manuals, publications guides, and textbooks concerning technical writing and editing, verbal and visual presentation, typography, and graphic design and layout.

Research Procedure - Analysis of Technical Reports

Stage 1 of the procedure used to survey and analyze selected technical reports involved the development of the sample frame. The membership of the Society for Technical Communication (STC) and institutions/organizations on NASA's automatic distribution list for technical publications were used for this purpose. These lists were combined. Names of individuals having no clear organizational/ institutional affiliation were deleted. The final compilation consisted of 1,183 names representing 611 organizations/institutions. Multiple recipients at single organizations/institutions were retained for two reasons: first, to help ensure that the individual(s) having responsibility for and/or authority to respond to the request for information would be contacted, and second, to obtain separate samples of technical reports from organizations/institutions with more than one office or activity which produced technical reports.

Each member of the sample frame was sent correspondence consisting of a cover letter stating the purpose and objectives of the study and a document control form to be completed by the respondent. Appendix A contains copies of the cover letter and the document control form. Respondents were requested to provide (1) copies of technical reports produced by their organization/institution, (2) copies of in-house style manuals and publications/production guides, and (3) information concerning the use of commercially available style manuals.

One hundred twenty-four responses were received from 93 organizations/ institutions. Appendix B contains the names of all organizations/institutions which responded to the request for information. Of the 124 responses, 99 sent material suitable for analysis and data extraction. The remaining 25 responses produced unusable materials, indicated that they did not produce technical reports, stated that their publications were classified or proprietary, or replied too late to be included in the analysis and data extraction.

Stage 2 of the procedure used to survey and analyze selected technical reports involved classifying each document by (1) organizational/institutional type, (2) type of publication, and (3) principal activity or research area of the publication. Organizational/institutional types used were government; industry; academic; and research, trade, and professional organizations. Types of publications included technical reports (TR's), technical manuals (TM's), and scientific reports (SR's). Principal activity or research areas included aeronautics, basic research, defense, energy, engineering, and others.

Stage 3 of the procedure used to survey and analyze selected technical reports involved data extraction through an exhaustive listing of structural components and their position in the report as front, body, or back matter, and through the use of eight data cards. Appendix C shows the data cards used for this operation and the specific information obtained from each document. Data were extracted and calculations were made for sequential components such as the information appearing and its position on the cover and title pages, language components including person and voice, and presentation components including type style and size. The sample size was reduced to 50 documents for all analyses recorded on the data cards. Appendix D contains detailed information on the composition of the two survey samples (n=99 and n=50).

Stage 4 involved the collation of the data cards by organizational type, activity type, and document type. Grouping of some categories was used to increase sample size and to isolate the effects of technical manuals on the data. For analysis and presentation of data, the following categories were usually employed.

Organizational Types

Industry

Research

Government

Document Types

Overall sample

Technical reports and scientific reports (TR's and SR's)

Technical manuals (TM's)

Overall sample excluding technical manuals (all but TM's)

Activity Types

Aerospace (Aero)

Aerospace, basic research, defense, energy, and engineering (ABDEN; NASA-related activities)

The final stage consisted of tabulating the collated data, performing necessary calculations, and recording the results in a log book.

Research Procedure - Sequential Components

From an analysis of the 99 reports, an exhaustive list of structural components for report organization was prepared. In addition, the position of each component as front, body, or back matter was also compiled. The components in the exhaustive listing were refined so that they could be compared more easily with the components covered by the NASA Publications Manual. A reduced sample of 50 reports was analyzed for the content and position of elements of the cover and title page.

Six generally accepted and recently published writing and editing textbooks were consulted to determine their recommendations for report organization. From these books a list of structural components was prepared. Totals were compiled to present relative frequency for suggested inclusion. The position of each component as front, body, or back matter was not compiled.

Four style manuals and two publications manuals used by the respondents to the technical report survey were analyzed to produce a listing of structural components for report organization. The most frequently used style manual, the U.S. Government Printing Office (GPO) Style Manual, was not included in the analysis because it does not deal specifically with report organization. Each style manual was checked for the presence or absence of each report component and for the suggested arrangement or sequence of recommended components.

The standards for report preparation contained in the NASA Publications Manual-1974 were compared and contrasted with the data from the survey, with the recommendations of the style guides, and with the data compiled from the textbooks.

The final step was the preparation of a suggested outline for report components, indicating both placement as front, body, or back matter, and ordering within these divisions.

Research Procedure - Language Components

A review of the literature was carried out to determine what information existed on standard readability tests and levels for technical reports. Three methods were chosen to measure the readability of the survey reports. The methods were the "Reading Ease Formula" (Flesch, 1948), the "Fog Index" (Gunning, 1952), and Kincaid's updated version of Flesch's formula (Hull, 1979). These methods employ formulas with measures of word length and sentence length as the only variables, although authorities recognize that other factors may affect readability. (For a discussion of these factors see Klare, 1975.)

The three readability tests (Flesch, Fog, and Kincaid) were run on each of the 50 survey reports and on the NASA sample report. One-hundred-word samples were used to measure readability. Whenever possible, samples were taken from four sources in each report: (1) summary, (2) text, (3) headings, and (4) captions. All 50 survey reports contained 100-word text samples; however, 100-word samples could be obtained from only 42 reports for the summary, 26 reports for the headings, and 10 reports for captions. Thus, the sample sizes varied accordingly from 50 to 10 in the readability texts for various sections of the survey reports. The summary and text of the NASA sample report were tested for readability; however, there were insufficient heading and caption materials to provide adequate samples for readability tests.

The voice (active or passive) and person (first, second, or third) were also determined and recorded for all summary and text samples from the survey reports and the sample NASA report on which readability tests were run. The results were compared with the six textbooks, the style/publications manuals, and the experimental/theoretical findings.

Three mathematical style books -- Mathematics in Type (William Byrd Press, 1954), The Printing of Mathematics (Chaundy, 1954), and Mathematics into Type (Swanson, 1971) -- were consulted to determine general standards against which the guidelines in the NASA Publications Manual and actual usage in a sample NASA report were compared. Survey reports were analyzed for the presence or absence of mathematical material in text and/or in display; but no observations were made concerning punctuation or breaking of equations.

For the visual language components, tables and figures, the research procedure consisted of extracting and tabulating data from the 50 survey reports and discussing these results in comparison with prescriptive and experimental literature findings, with guidelines set forth in the NASA Publications Manual, and with NASA practice in a sample report.

The total number of tables (excluding tables of contents and indexes) in each survey report was counted. This count was divided by the total number of body and back matter pages in the report to produce a table-to-page ratio, expressed as a percentage. In the same manner, a figure-to-page ratio was calculated for each of the 50 survey reports.

The types of artwork contained in the survey reports were analyzed. Figures in the survey reports were classified into one of the following categories:

Charts (Graphs)

1. Two-dimensional Cartesian graphs
2. Three-dimensional Cartesian graphs
3. Polar coordinate graphs
4. Scattergrams
5. Pie and bar charts

Diagrams

6. Organizational or hierarchical diagrams
7. Functional or schematic diagrams (including flow charts)

Illustrations

8. Orthographic illustrations
9. Isometric illustrations
10. Perspective or freehand drawings and renderings
11. Photographs

Each survey report was checked for the presence or absence of at least one example of each of these 11 types of artwork. Total occurrences of figure types were not tabulated. Illustrations such as cutaways, which were part of a diagram, were counted as diagrams, not illustrations.

More specific data were collected for two-dimensional Cartesian graphs. The Cartesian plot containing the highest number of data paths was identified for each survey report, and the number of paths was recorded. The percentage of two-dimensional Cartesian graphs employing gridlines was also determined for the survey reports. Preprinted gridlines on strip/recorder charts were not counted. Additionally, data on production methods employed by report publishers for graphs were obtained. Each survey report was examined to determine if it contained one or more graphs produced by each of the following methods: hand, strip/recorder, and computer. Presence or absence, not total number, was recorded for each production method in each survey report. Preferred data points and data paths for single Cartesian charts containing multiple plots were tabulated from several literature sources and compared with NASA's recommendations and practice.

Research Procedure - Presentation Components

Presentation components give physical form to the language and structural components of technical reports and serve as the media for their transmission and storage. For this study, presentation components were divided into three major classifications--typography, graphic design, and physical media.

Typography. The typographical aspects of three report elements were considered. These elements were: (1) text, including plain text and mathematics, (2) tables, and (3) displayed material, including covers, title pages, legends and captions, and headings. (For purposes of this report, typeset material was defined as proportionally spaced composition, and typewritten material was defined as uniformly spaced composition.)

For the text portion of each of the 50 survey publications, the following data were recorded:

1. Composition method (typeset or typewritten),
2. Type style (Gothic or Roman),
3. Type size (points),
4. Right-justified margins (presence or absence),
5. Paragraph indentation (presence or absence),
6. Leading (points),
7. Line length (picas), measured for the longest line on a page, and
8. Character count (number of characters per line, calculated as the average for three consecutive lines)

For reports containing mathematics in the text and/or in display, the additional data listed below were recorded for each type of mathematical presentation.

1. Type style (Gothic or Roman)
2. Type size (points)

3. Leading (points)

4. Use of solidus to eliminate stacked fractions (presence or absence)

5. Use of fractional exponents to eliminate radicals (presence or absence)

For reports containing mathematics in the text, the amount of additional leading was calculated and expressed as a percentage of the type size used. For example, 10-point type with 5 points of additional leading was expressed as 50 percent additional leading. Means were computed and compared for the overall survey, for reports containing mathematics in the text, for typeset reports containing mathematics in the text, and for typewritten reports containing mathematics in the text.

The experimental/theoretical literature was used to develop minimum and maximum acceptable limits for type size, line length, number of characters per line, and line length for a given type size. These parameters, as they appeared in the survey results, the NASA sample report, and the guidelines set forth in the NASA Publications Manual, were compared with the limits of acceptability developed from the literature.

For other areas in which survey data were recorded, the experimental/theoretical literature and the prescriptive standards and criteria were included to permit comparison with the NASA publications guidelines, were applicable, and to permit comparison with the practice in the survey reports and sample NASA report.

The following elements were recorded for survey reports containing tables:

1. Data in rows, if grouped in sets (e.g., white space between groups of 5, 8, or 10 entries)

2. The maximum number of columns in any one table

Means from these analyses were presented and compared with experimental/theoretical findings from the literature and the NASA Publications Manual. The NASA sample report did not contain tables; therefore, no observations could be made from that source on these two parameters.

Displayed elements analyzed in the survey reports were cover, title page, headings, legends, and captions. For the cover, the following data were collected from each survey report:

1. Type style (Roman or Gothic)

2. Use of all capitals or upper and lower case

3. Type size used for the title

4. Number of different type sizes appearing on the cover

5. Relative sizes and positions of seven items commonly appearing on the cover (these items were the title, subtitle, author, date, publisher, sponsor, and reference number).

In the relative size analysis, the type sizes of these items were ranked numerically from 1 to a maximum of 7, with 1 assigned to the item with the largest type size and 7 assigned to the item with the smallest type size, if all seven items were present and were different sizes. Typewritten items were excluded from the relative size analysis. Items the same size were given the same ranking. For example, if title and author were the largest elements on the page, and they were the same size, both were ranked as "1". The same type ranking was used for the position analysis, with "1" assigned to the top most item on the page, and sequential numbers assigned to the other elements as they appeared from top to bottom.

For the title page, the following data were tabulated and analyzed:

1. Type style (Roman or Gothic)

2. Number of different type sizes used and

3. Relative sizes and positions of seven items commonly appearing on the title page (The same procedure was used for the relative size and position analysis of the title page elements as was used for the analysis of the cover elements.)

On the subject of legends and captions, the following data were recorded and tabulated from the survey reports:

1. Presence or absence of legends (titles) and/or captions (any additional explanatory material) in reports containing tables and/or figures

2. Composition method (typeset or typewritten) and

3. Use of all capitals or upper and lower case type

For headings, survey documents were analyzed for the following information:

1. Number of heading levels

2. Type style of each heading level

3. Mean type size of each level

4. Percent of publications using the same type size, style, and weight for headings and text

5. Use of all capitals or upper and lower case in each heading level

6. Presence or absence of boldface, italics, and underscoring in each heading level and

7. Location of heading levels (centered or shoulder/side)

Guidelines in the NASA Publications Manual and practice in the NASA sample report were compared with results from the survey analysis and with experimental/theoretical findings from the literature.

Graphic design. Graphic design encompasses the layout and imposition of textual material on the page. The following aspects of graphic design were tabulated or calculated and analyzed in the survey reports:

1. Number of lines per page

2. Character density (number of characters per page, calculated by multiplying the number of lines per page by the average character count per line)

3. Image area as a percentage of page area, (also called size-to-page ratio) and calculated as (text area/page area) x 100

4. Gutter margin width, expressed as a percent of the total page width (The gutter margin was measured up to the innermost page position on which a lengthwise pencil line could be drawn in the bound document.)

5. Folio placement on a right-hand page (center top, center bottom right top, or right bottom)

6. Running heads (presence or absence)

7. Number of columns in the page layout

8. Table and figure orientation (presence or absence of any figures placed sidewise on the page, at 90° angle with the text) and

9. Color in figures (presence or absence)

Guidelines in the NASA Publications Manual and practice in the NASA sample report were compared with results from the survey analysis and with experimental/theoretical findings from the literature.

Physical media. The type of paper used in each survey document was identified as either matte finished (uncoated or dull coated) or glossy finished (calendered or coated). Statistics on paper type were tabulated for the overall survey and various document categories. Paper color and ink color of survey publications were also noted.

The binding method of each survey publication was identified as one of the following: (1) saddle stitched, (2) sidewire stitched, (3) perfect bound, (4) plastic comb (GBC), (5) ring bound, or (6) fan-fold computer output. The types of binding were analyzed by report type, and the average length of documents bound by each method was calculated. Eight NASA reports were examined to determine which binding techniques were employed.

NASA guidelines for the preparation of copy for microfiche were examined relative to other literature recommendations for documents which will be re-imaged. The NASA sample report was analyzed to determine whether internal guidelines were followed. Each of the 50 survey documents and the NASA sample report were examined for the presence of one or more examples of the most frequently occurring printing problems which can lead to poor typographic conditions in re-imaged copies. This analysis of printing quality was a technical assessment performed by Mr. McCullough, who has 10 years of printing and printing quality control work experience. Presence or absence of each of the following problems was noted for each document: slurring, offsetting, overinking, underinking, overdeveloping, and underdeveloping.

One page of text from each of the 50 survey documents was subjected to two forms of degradation through re-imaging. One process consisted of 10 generations of xerographic reproduction. The other consisted of microfilming the original pages and producing an extremely underexposed microfiche printout of each. Ten words were selected at random from each of the 100 resulting pages and mounted on test cards.

Five subjects, each with 20/20 or 20/20 corrected vision, were used for this study. Lighting and reading conditions were uniform for all subjects except that each subject was allowed to hold the test cards at whatever distance was comfortable for him. The subjects were asked to read each card as quickly as possible, to read all numbers digit-by-digit, to spell any words unfamiliar to them, and to indicate the presence of any punctuation. The number of errors per 10 words was recorded for each card read by each subject. Only one error per word was counted. Averages were calculated for each card. This was considered to be a measure of the perceptibility of the re-imaged document.

The five subjects were also asked to subjectively rate the legibility of the words on each card. A scale of 0 to 4 was specified, with 0 = poor, and 4 = very good. The individual subjective ratings were recorded, and means were calculated for the five ratings on each card.

After these data were recorded, the six best scoring and the six worst scoring specimens (by errors per 10 words and by subjective rating) were determined for the xerographic and microfiche studies. The originals of these specimens were obtained, and the following data were recorded: (1) type size (top of ascender to bottom of descender), (2) capital letter height, (3) height of the lower case "x", (4) width of the thick stroke, and (5) width of the thin stroke. All measurements were made in inches to the nearest 0.001 inch, but were converted to millimeters for presentation in this report. The following ratios were also calculated: height of the lower case "x" to height of the capital letter, and width of the thin stroke to width of the thick stroke (brightness ratio).

For all physical media considerations, related observations from the literature were presented along with the experimental data from the survey analysis. NASA guidelines and practice in the sample report were compared with the survey and literature findings.

PRESENTATION AND DISCUSSION OF THE DATA

The results of the study were compiled and presented according to the sequential, language, and presentation components of a technical report. The data are discussed in terms of their relationship to the NASA publications standards for technical reports as contained in the NASA Publications Manual - 1974.

Sequential Components

Data regarding sequential components are presented and discussed in terms of structural components derived from the analysis of the survey reports, style manuals and publications guides, and writing and editing textbooks. Data are next presented and discussed in terms of front, body, and back matter. A suggested outline for sequential components is presented.

Analysis of survey reports. The exhaustive list of structural components and their location in terms of front, body, and back matter was prepared from an analysis of the technical report survey and is shown as Appendix E. The components in the exhaustive list were refined so that they could be compared more easily with components covered by the NASA publications standards. Components which appeared to have the same functions were combined. For example, "List of Drawings" was combined with "List of Figures." Any component mentioned by NASA was included. The number of components was reduced by eliminating any component used by fewer than four report producers. The refined list, shown in Table A, was divided into front, body, and back matter for discussion purposes and for comparison with the NASA publications standards.

Overall, the components and their placement as specified by the NASA Publications Manual - 1974 compared favorably with those contained in the refined list. The analysis revealed some variations in the number and placement of front and back matter components. Where body matter components were concerned, NASA included all but two of the same elements as those in the refined list and placed all of them in the body matter.

Five components (cover, title page, table of contents, introduction, and appendixes) were included in 50 percent or more of the reports surveyed. While strong agreement existed with respect to the location of these components, only the cover and table of contents were represented by unanimous agreement in terms of their placement. The five components, the percentage of use by the survey reports, their placement within the reports, and NASA's treatment are presented in Table B. NASA agreed with the majority of survey reports in terms of both inclusion and placement of the five components.

TABLE A

Refined List of Sequential Components in Reports Surveyed

Component	Listed in NASA Publications Manual	Percent of survey reports using component	Component placement within survey reports, percent		
			Front	Body	Back
FRONT-					
Cover	Yes	67.6	100.0*		
Disclaimers		11.1	90.0		10.0
Notices		24.2	83.3	4.2	12.5
Title page	Yes	72.7	98.6*	1.4	
COSATI standard title page	Yes	8.0	75.0	12.5	12.5*
Copyright		19.1	100.0		
Distribution list		13.1	15.4		84.6
Previous documents		5.0	60.0		40.0
Abstract	Yes	39.3	84.6	10.3	5.1*
Preface	Yes	24.2	100.0*		
Acknowledgement		24.2	91.6	4.2	4.2
Contents	Yes	70.7	100.0*		
List of figures		39.3	97.4		2.6
List of tables		30.3	96.7		3.3
List of symbols	Yes	18.1	61.1	5.6*	33.3
Foreword		19.0	100.0		
BODY-					
Text	Yes	35.3		100.0*	
Summary	Yes	30.3	36.7	53.3*	10.0
Introduction	Yes	57.6	17.6	82.4*	
Purpose	Yes	12.1	16.7	83.3*	
Background	Yes	3.0		100.0*	
Limitations		9.0		100.0	
Equipment	Yes	5.0		100.0*	
Procedures/Methods	Yes	22.2		100.0*	
Results	Yes	27.2		100.0*	
Description	Yes	6.0		100.0*	
Discussion	Yes	11.1		90.9*	9.1
Conclusions	Yes	31.3	3.2	77.4*	19.3
Recommendations		7.0	14.3	85.7	
BACK-					
Appendixes	Yes	59.5		1.7	98.3*
Tables		5.0		20.0	80.0
References	Yes	39.3		5.1	94.9*
Bibliography	Yes	15.1		6.7	93.3*
Glossary		23.2	8.7	4.3	87.0
Index		23.2	4.3		95.7
Reader comment form		8.0	12.5		87.5

*Indicates where the NASA Publications Manual places a component

TABLE B

Components Included in a Majority of Reports Surveyed

Component	Listed in NASA Publications Manual	Percent of survey reports using component	Component placement within survey reports, percent		
			Front	Body	Back
Cover	Yes	67.6	100.0*		
Title page	Yes	72.7	98.6*	1.4	
Contents	Yes	70.7	100.0*		
Introduction	Yes	57.6	17.6	82.4*	
Appendixes	Yes	59.5		1.7	98.3*

*Indicates where the NASA Publications Manual places a component

Style manuals, publications guides, and books. Respondents to the survey indicated the use of thirty-five commercially available style manuals, publications guides, and books covering report preparation and production. The collective list of these materials appears in Appendix F.

Four style manuals, the COSATI Guidelines to Format Standards, and the ANSI Guidelines for Format and Production of Scientific and Technical Reports were used to determine component inclusion and sequence. These materials were all used by several institutions and organizations which responded to the request for information. The GPO Style Manual, although used by 47 percent of the survey respondents, was not included in the comparison because it did not specifically address report component inclusion and sequence.

The structure and sequence of components suggested for inclusion were examined. Those components obviously not concerned with technical reports were deleted. The recommendations of these materials were recorded and appear in Table C. Summations are presented for each component to provide an overview, and NASA's recommended sequence for components is shown for comparison purposes. The numbers in the column for each source indicate the sequence recommended by that publication, while the numbers in the summation column represent the total number of sources which recommended inclusion of that particular component.

The style manuals and publications guides were divided in terms of which components should be included and sharply disagreed in terms of the sequence in which the components should be arranged. Sixteen of the twenty-four components were recommended for inclusion by half or more of the manuals and guides. Unanimous agreement for inclusion existed for three components: the title page, introduction, and appendixes. NASA guidelines included all three of these components.

Of the 16 components recommended by 50 percent or more of the style manuals and publications guides, 11 were recommended by the NASA publications standards. The five not included by NASA were the foreword, list of illustrations and/or figures, list of tables, glossary, and index.

TABLE C

Style Manual and Publications Guide Recommendations for Sequential Components*

Component	Style manual				Publications manual		Summation	NASA Publ. Manual
	APA	Chicago	NAS	USGS	ANSI	COSATI		
Cover			1		1	1	3	1
Title page**	1	1	2	1	2	2	6	2
Foreword		5	3	2			3	
Preface		6	4	3	4	3	5	3
Acknowledgement		7	5				2	
Letter of transmittal			6				1	
Contents		2	7	4	5	4	5	4
List of figures/ illustrations		3	9	5	6	5	5	
List of tables		4	8	6		6	4	
List of symbols and/ or abbreviations		9			7	7	3	7
Glossary		12	15		14	13	4	
Abstract	2			7	3		3	16
Introduction	3	8	10	9	9	8	6	6
Body (text)		10	11	8	10	9	5	8
Method	4						1	9
Results (data)	5			10			2	10
Discussion	6						1	11
Conclusions					11	10	2	12
Recommendations					12	11	2	
References	7		12	11	15	14	5	14
Appendixes	8	11	14	12	13	12	6	13
Index		14	16	13	17	15	5	
Bibliography		13	13		16		3	15
Summary					8		1	5

*The numbers in the column for each source indicate the sequence recommended by that publication, while the numbers in the summation column represent the total number of sources which recommended inclusion of that particular component.

**Includes a conventional title page and/or a report documentation page

Writing and editing textbooks. Six widely accepted and recently published technical writing and editing textbooks were consulted to determine their recommendations for report organization. Table D presents the structural components suggested by each textbook. Summations are presented for each component to provide an overview, and NASA's recommended structure is shown for purposes of comparison.

As can be seen in Table D, all six textbooks recommended the memo/letter of transmittal, title page, abstract, contents, introduction, and appendix as components for inclusion. Additionally, the cover, list of symbols, summary, conclusions, glossary, recommendations, body or text, discussion, bibliography, list of figures/illustrations, and references were included by half or more of the textbooks.

TABLE D

Textbook Recommendations for Sequential Components

Component	Textbook						Summation	Listed in NASA PUBLICATIONS MANUAL
	Houp & Pearsall	Mills & Walter	Mathes & Stevenson	Lannon	Pauley	Oliu, Brusaw & Alred		
Cover	X	X	X	X			4	Yes
Preface	X					X	2	Yes
Foreword			X				1	
Memo/Letter of transmittal	X	X	X	X	X	X	6	
Title page	X	X	X	X	X	X	6	Yes
Abstract	X	X	X	X	X	X	6	Yes
Contents	X	X	X	X	X	X	6	Yes
List of figures/ illustrations	X	X		X	X	X	5	
List of tables						X	1	
List of symbols	X				X	X	3	Yes
Glossary	X			X		X	3	
Introduction	X	X	X	X	X	X	6	Yes
Summary	X	X	X				3	Yes
Conclusions	X	X	X	X	X		5	Yes
Recommendations	X	X	X		X		4	
Body (text)		X		X	X	X	4	Yes
Discussion	X	x	X				3	Yes
Bibliography	X	X		X	X	x	5	Yes
References	X	X				X	3	Yes
Appendixes	X	X	X	X	X	X	6	Yes

Of the six components unanimously recommended by the texts, the NASA Publications Manual included five: the title page, abstract, contents, appendix, and introduction. The memo/letter of transmittal was omitted by NASA. NASA included all of the components mentioned by three or more of the texts except the recommendations, list of figures/illustrations, glossary, and memo/letter of transmittal.

The three sources used in the sequential components portion of the study (survey reports, style manuals and publications guides, and textbooks) were compared to produce a list of components recommended for inclusion by 50 percent or more of any of the three sources. This comparison, shown in Table E, is presented to indicate whether each source, as a consensus, advocated that a particular component should be included as a structural component of a technical report. Components recommended by NASA are included for comparison. The survey reports represented the limiting factor in that, as shown previously, only five components were common to more than half of the reports. Considering only the textbooks and style manuals, agreement existed on 12 components: the cover, title page, abstract, contents, list of figures/illustrations, list of symbols, introduction, body (text), bibliography, references, appendix, and glossary. The NASA Publications Manual discussed 10 of these 12, omitting only the list of figures, illustrations, and the glossary.

TABLE E

Components Included by Half or More of Each Source

Component	Source			
	Included by a majority of survey reports	Included by half or more of style manuals and guides	Included by half or more of textbooks	Listed by NASA Publications Manual
Cover	Yes	Yes	Yes	Yes
Memo/Letter of transmittal	No	No	Yes	No
Title page	Yes	Yes	Yes	Yes
Abstract	No	Yes	Yes	Yes
Contents	Yes	Yes	Yes	Yes
List of figures/ illustrations	No	Yes	Yes	No
List of symbols	No	Yes	Yes	Yes
Introduction	Yes	Yes	Yes	Yes
Summary	No	No	Yes	Yes
Conclusions	No	No	Yes	Yes
Recommendations	No	No	Yes	No
Body (Text)	No	Yes	Yes	Yes
Discussion	No	No	Yes	Yes
Bibliography	No	Yes	Yes	Yes
References	No	Yes	Yes	Yes
Appendix	Yes	Yes	Yes	Yes
Foreword	No	Yes	No	No
Preface	No	Yes	No	Yes
List of tables	No	Yes	No	No
Glossary	No	Yes	Yes	No
Index	No	Yes	No	No

Front matter. The front matter components which appeared in the refined list were compared with and discussed in terms of the NASA publications standards. This comparison appears in Table F. Comments regarding prescriptive sources and experimental/theoretical literature were added where appropriate.

TABLE F

Refined List of Sequential Front Matter Components

Component	Listed in NASA Publications Manual	Percent of survey reports using component	Component placement within survey reports, percent		
			Front	Body	Back
FRONT-					
Cover	Yes	67.6	100.0*		
Disclaimers		11.1	90.0		10.0
Notices		24.2	83.3	4.2	12.5
Title page	Yes	72.7	98.6*	1.4	
COSATI standard title page	Yes	8.0	75.0	12.5	12.5*
Copyright		19.1	100.0		
Distribution list		13.1	15.4		84.6
Previous documents		5.0	60.0		40.0
Abstract	Yes	39.3	84.6	10.3	5.1*
Preface	Yes	24.2	100.0*		
Acknowledgement		24.2	91.6	4.2	4.2
Contents	Yes	70.7	100.0*		
List of figures		39.3	97.4		2.6
List of tables		30.3	96.7		3.3
List of symbols	Yes	18.1	61.1	5.6*	33.3
Foreword		19.0	100.0		

*Indicates where the NASA Publications Manual places a component

Unanimous agreement concerning placement existed only for the cover, copyright, preface, contents, and foreword. These components were located as front matter in all of the reports in which they appeared. Variation in placement occurred for the remainder of the survey components. However, with the exception of the distribution list which appeared as back matter in 85 percent of its occurrences, all other components were placed as front matter in 60 percent or more of the reports in which they were included.

Of the sixteen components listed as front matter, the NASA Publications Manual - 1974 mentioned seven. NASA agreed with the majority of the survey reports in locating the cover, title page, preface, and contents as front matter; however, the list of symbols was included as body matter, and the COSATI standard title page and the abstract were indicated as back matter.

A reduced sample of 50 reports was analyzed to determine which items appeared most frequently on the cover. The data appearing most frequently are shown in Table G.

TABLE G

Items Listed Most Frequently on Covers of Survey Publications

Item	Use	
	Number of reports	Percentage of sample*
Title	49	98
Publisher	47	94
Reference number	36	72
Author	36	72
Sponsor	34	68
Date	29	58
Subtitle	10	20

*n = 50

Of the 50 reports analyzed, 49 contained a cover. All reports containing a cover displayed a title. The publisher was listed by 94 percent of the reports. Subtitles were used by 20 percent of the reports. Security notices did not appear on the covers since only unclassified, unlimited distribution reports were solicited from report producers.

The NASA Publications Manual - 1974 indicated that standard cover designs have been established for NASA formal series technical reports. High number NASA technical reports, according to the NASA Publications Manual, did not carry formal covers. The NASA Publications Manual did not address the content of the cover page for either formal series or high number technical reports. The manual did state, however, that final cover pages are prepared at the Langley Research Center after a formal series technical report has been approved and the print order issued.

An examination of the sample NASA technical report revealed the inclusion of all items found in Table F except for a subtitle and the sponsor. Subtitles are not typically used in NASA formal series technical reports. The sponsor is considered by NASA to be the same as the publisher.

The reduced sample of 50 reports was analyzed to determine the order of occurrence or placement of items appearing on the cover. The two most common orderings of items appearing on the covers of the 50 reports and the ordering used by NASA are shown in Table H. The NASA order was more similar to the most common order of cover items in that both placed the reference number in first position and the title in second position.

TABLE H

Most Common Orderings of Cover Items in the Survey and NASA Ordering

Most common	Second most common	NASA
Reference number	Title	Reference number
Title	Reference number	Title
Publisher	Publisher	Author
Sponsor	Author	Date
Author	Sponsor	Publisher/Sponsor
Date	Date	
	Subtitle	

The reduced sample of 50 reports was analyzed to determine which items appeared most frequently on the title page. The data appearing most frequently are shown in Table I.

TABLE I

Items Listed Most Frequently on Title Pages in the Survey Reports

Item	Use	
	Number of reports	Percentage of sample*
Title	43	86
Author	43	86
Publisher	41	82
Date	40	80
Sponsoring organization	38	76
Reference number	37	74
Subtitle	11	22

*n = 50

A substantial majority (86 percent) of the title pages in the survey listed both a title and an author, and 82 percent cited the publisher. Only 22 percent of the reports contained a subtitle.

The NASA Publications Manual - 1974 referred to the COSATI (Committee on Scientific and Technical Information) title page which is different in terms of makeup and purpose from the title pages used by the reports in the sample. In 1977, NASA publications standards were amended, and the COSATI title page became the last page of a NASA formal series technical report (except for NASA Special Publications which do not contain COSATI pages). The first right-hand page inside the cover of a NASA formal series technical report (former location of the COSATI page) became a standard or conventional title page.

An examination of the sample NASA technical report revealed agreement with all items found in Table I with the following exceptions: no subtitle appeared, the publisher and sponsoring organization were the same, and NASA included the author's center of affiliation.

For the reduced sample of 50 reports, the most frequent orderings of items on the title pages were determined and were compared with NASA's title page. The NASA order of title page components was more similar to the most common order in that both presented reference numbers in the first position and the title in the second position on the title page. The orderings are shown in Table J.

TABLE J

Most Common Orderings of Title Page Items in the Survey and NASA Ordering

Most common	Second most common	NASA
Reference number	Title	Reference number
Title	Author	Title
Publisher	Date	Author & center affiliation
Date	Reference number	Publisher/sponsor
Author	Subtitle	
Sponsoring organization	Publisher/sponsor	

The refined list of sequential front matter components was analyzed in terms of bibliographic and handling information. Bibliographic and handling information serves the accession needs of librarians and information specialists and includes such components as the cover, disclaimers, notices, title page (includes COSATI title page), copyright, distribution lists, and previous documents. The results of the analysis are presented in Table K.

TABLE K

Use and Location of Bibliographic and Handling Components
by Survey Respondents and NASA

Component	Listed in NASA Publications Manual	Percent of survey reports using component	Component placement within survey reports, percent		
			Front	Body	Back
FRONT-					
Cover	Yes	67.6	100.0*		
Disclaimers		11.1	90.0		10.0
Notices		24.2	83.3	4.2	12.5
Title page	Yes	72.7	98.6*	1.4	
COSATI standard title page	Yes	8.0	75.0	12.5	12.5*
Copyright		19.1	100.0		
Distribution list		13.1	15.4		84.6
Previous documents		5.0	60.0		40.0

*Indicates where the NASA Publications Manual places a component

Of the bibliographic and handling components in Table K, only the cover and the title page were used by more than 50 percent of the survey reports. With the exception of the distribution list, which was located as back matter by 85 percent of the survey reports, all bibliographic and handling components were placed as front matter by 60 percent or more of the reports which employed these components.

The refined list of sequential front matter components was analyzed in terms of locators and preliminaries. Locators serve to help the user by providing quick and easy access to the report's contents and include such components as the table of contents and list of tables. Preliminaries help to place the report into a larger context by providing such information as the relationship of the report to previously conducted research and include such components as the foreword and preface. The results of the analysis are provided in Table L.

TABLE L

Use and Location of Locators and Preliminary Components by Survey Respondents and NASA

Component	Listed in NASA Publications Manual	Percent of survey reports using component	Component placement within survey reports, percent		
			Front	Body	Back
FRONT-					
Abstract	Yes	39.3	84.6	10.3	5.1*
Preface	Yes	24.2	100.0*		
Acknowledgement		24.2	91.6	4.2	4.2
Contents	Yes	70.7	100.0*		
List of figures		39.3	97.4		2.6
List of tables		30.3	96.7		3.3
List of symbols	Yes	18.1	61.1	5.6*	33.3
Foreword		19.0	100.0		

*Indicates where the NASA Publications Manual places a component

Of the locator and preliminary components, only the table of contents appeared in a majority of the survey reports (71 percent). However, in at least 60 percent of all the reports containing any specific locator or preliminary component, that component appeared as front matter.

Eight components are listed in Table L. The NASA Publications Manual - 1974 lists four of these eight. Two, the preface and contents, are treated by NASA as front matter. However, NASA included the list of symbols in the body and the abstract as back matter.

Body matter. The body matter components which appeared in the refined list were compared with and discussed in terms of the NASA publications standards. These data appear in Table M. Comments regarding prescriptive sources and experimental/theoretical literature were added where appropriate.

TABLE M

Use and Location of Body Matter Components by Survey Respondents and NASA

Component	Listed in NASA Publications Manual	Percent of survey reports using component	Component placement within survey reports, percent		
			Front	Body	Back
BODY-					
Text	Yes	35.3		100.0*	
Summary	Yes	30.3	36.7	53.3*	10.0
Introduction	Yes	57.6	17.6	82.4*	
Purpose	Yes	12.1	16.7	83.3*	
Background	Yes	3.0		100.0*	
Limitations		9.0		100.0	
Equipment	Yes	5.0		100.0*	
Procedures/Methods	Yes	22.2		100.0*	
Results	Yes	27.2		100.0*	
Description	Yes	6.0		100.0*	
Discussion	Yes	11.1		90.9*	9.1
Conclusions	Yes	31.3	3.2	77.4*	19.3
Recommendations		7.0	14.3	85.7	

*Indicates where the NASA Publications Manual places a component

The body matter was the most difficult section of the technical report to describe. There was no general agreement in either the prescriptive sources or the experimental/theoretical literature regarding the names, use, and organization of the body components.

The prescriptive sources agreed that the text should give full details of the investigation discussed. There should be sufficient information to repeat the experiment, verify the conclusions, or test the assertions. Three possible designs for the text were recommended by the prescriptive sources: (1) abstract, introduction, method, results, discussion, literature cited, and acknowledgements; (2) opening component (summary for executive audience), discussion component (analysis for staff personnel), and appendixes (details for technicians); and (3) introduction, discussion, and conclusions. Thirty-five percent of the survey reports, as did NASA, included a text component and all recommended placement of the text in the body of the report.

The summary appeared in 30 percent of the survey reports. As did NASA, 53 percent of reports placed the summary in the body. The textbooks recommended the use of a summary; however, there was little agreement as to what the summary should contain. The NASA publications standards recommended that the summary be written to stand alone, a "concise recapitulation of the paper."

The six writing and editing textbooks recommended the inclusion of an introductory component as did all six style manuals and publications guides. A typical breakdown of the introduction contained six major considerations: (1) statement of purpose, (2) conditions under which the work was done, (3) plan for treatment of the subject matter, (4) acknowledgement of cooperation and/or help, (5) summary of previous work in the field, and (6) notes on the most important prior publications pertinent to the research. The introduction was used by more than half (57.6 percent) of the survey reports. As did NASA, 82 percent of the reports placed the introduction in the body.

There was no general agreement either in the prescriptive sources or in the experimental/theoretical literature regarding the following components: purpose, background, limitations, equipment, procedures/methods, and description. With the exception of procedures/methods, the remaining components were included infrequently in the reports surveyed.

As a component, discussion was used both by the survey reports and by the prescriptive sources as a single component and as a term which applied to a group of components such as purpose, background, procedures, and results. Neither the style manuals nor the writing and editing textbooks indicated a clear preference.

Results and conclusions were included in more than 25 percent of the survey reports and were also included in the NASA publications standards. There was unanimous agreement by the survey reports as to the location of the results in the body of the report. A strong majority of the survey reports (77 percent) placed the conclusions in the body of the report.

Recommendations were included by only seven percent of the reports surveyed. Of the three sources compared to determine report component consensus, only the textbooks included recommendations in a majority of cases. The NASA Publications Manual - 1974 did not list a recommendations component and warned against statements promising research to be published or performed. The manual suggested that if further research was needed, a simple statement to that effect should be made.

Back matter. The back matter components which appeared in the refined list were compared with and discussed in terms of the NASA publications standards. These data appear in Table N. Comments regarding prescriptive sources and experimental/theoretical literature were added where appropriate.

TABLE N

Use and Location of Back Matter Components by Survey Respondents and NASA

Component	Listed in NASA Publications Manual	Percent of survey reports using component	Component placement within survey reports, percent		
			Front	Body	Back
BACK-					
Appendixes	Yes	59.5		1.7	98.3*
Tables		5.0		20.0	80.0
References	Yes	39.3		5.1	94.9*
Bibliography	Yes	15.1		6.7	93.3*
Glossary		23.2	8.7	4.3	87.0
Index		23.2	4.3		95.7
Reader comment form		8.0	12.5		87.5

*Indicates where the NASA Publications Manual places a component

A majority of the survey reports, as did the NASA publications standards, included appendixes. Both the survey reports (98 percent) and NASA placed the appendixes in the back matter. The style manuals, publications guides, and writing and editing textbooks recommended the inclusion of appendixes as back matter.

References and a bibliography were recommended by the NASA publications standards and were included by 39 percent and 15 percent of the survey reports, respectively. The prescriptive sources recommended three forms of reference citation: (1) author and year, (2) number in order of citation, and (3) number from alphabetical list. NASA publications standards suggested that referenced publications be listed by number in order of citation in the references component which is located immediately after the conclusions component or, if the report has appendixes, after the last appendix.

The glossary and list of symbols were used interchangeably by the survey reports. Collectively, 41 percent of the survey reports included a glossary or list of symbols. Prescriptive sources recommended that symbols, abbreviations, and acronyms be defined where they are used in the report. However, recognizing that readers may not be familiar with the terminology, prescriptive sources recommended the inclusion of a glossary or list of symbols either as front matter following the locators or as back matter. The NASA publications standards did not recommend a glossary but did recommend a symbols list and placed it in the body of the report.

Tables and figures. The majority of the prescriptive sources and the experimental/theoretical literature recommended that figures and tables be integrated into the text. Eighty-two percent of the survey reports integrated both figures and tables with the text as illustrated in Figure 3. The NASA Publications Manual (p. 17-18, 37-38) stated that where practical, tables and figures were preferably placed in the body of the report as soon as possible after mention in the text; however, when visuals were of such volume that insertion in the text would impair readability, they should be placed in the back matter, following the appendixes and references. The sample NASA report did not contain any tables. Figures were grouped in the back matter of the report.

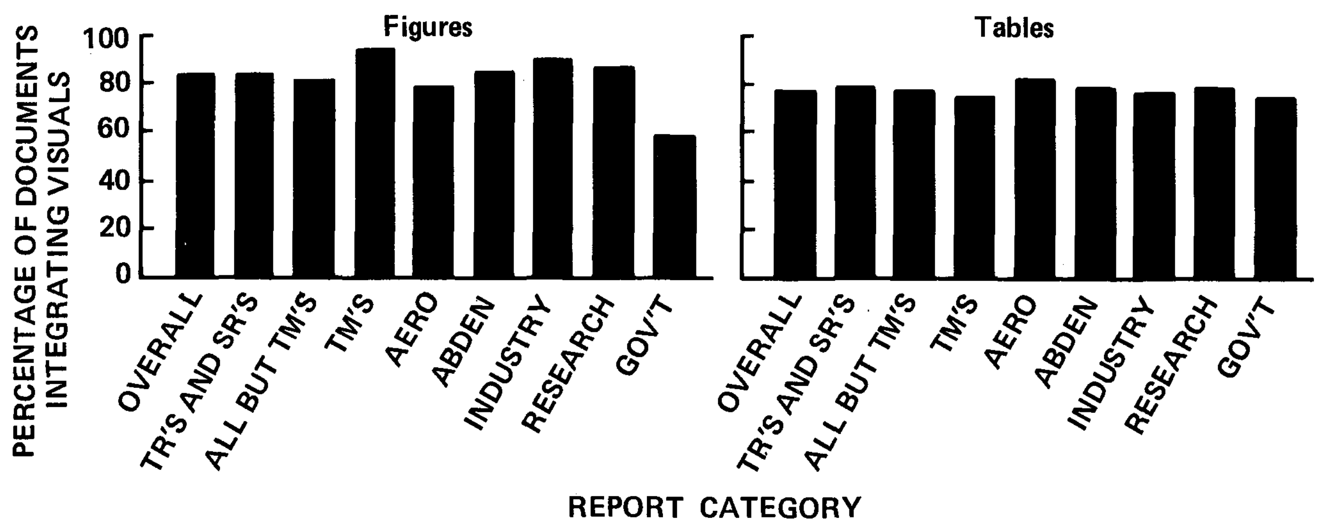

Figure 3.- Percent of survey documents with visuals integrated in text

Suggested outline for sequential components. The following outline of front, body, and back matter components was developed after consideration of the recommendations of style manuals, publications guides, and textbooks; practices of the surveyed reports; and the general literature review. Not all of the headings listed would be necessary or even appropriate to each technical report; however, this list includes most headings which might occur so that it could be consulted for component name and placement in preparing more involved reports requiring many components. The outline includes more components than those on which a consensus existed among the sources consulted because majority agreement existed on too few components to yield a useful guide for reference use in report preparation. The assumption was made in preparing the outline that tables and figures were integrated with the text.

- Front Matter
  - Cover
  - Title page
  - Disclaimers
  - Notices (including copyright)
  - COSATI standard title page (NTIS Bibliographic Data Sheet)
  - Distribution lists
  - Table of contents
  - List of figures/illustrations
  - List of tables/charts
  - Abstract
  - Foreword
  - Acknowledgement
  - Preface
- Body Matter
  - Summary
  - Introduction
  - Text*
    - Methods
    - Assumptions
    - Procedures
    - Results
    - Discussion
    - Conclusions
    - Recommendations
    - Applications
- Back Matter
  - References
  - Bibliography
  - Appendixes (including lengthy mathematical derivations; descriptions of novel techniques; and procedures and equipment not essential to the main purpose of the report)
  - Glossary (including list of abbreviations, acronyms, or symbols)**

*Related research should be included in the text portion of the report, either where appropriate or in a separate section.

**Alternate recommended placement is in the front matter following the locator components. In either case, the assumption was made that each item was defined at first use in the report.

Language Components

Data regarding language components were derived from the following sources: 1) an analysis of the survey reports, 2) information obtained from a review of the prescriptive sources and the experimental/theoretical literature, 3) the NASA Publications Manual, and 4) the sample NASA report. The data are presented in terms of readability, voice and person, mathematical presentation, and visual language components (tables and figures, with particular attention to two-dimensional graphs).

Readability. Results of the Flesch (1948), Fog (Gunning, 1952), and Kincaid (Hull, 1979) readability tests on the survey reports and the sample NASA report are shown in Table O. Numbers in parentheses indicate the sample size for each readability level reported. These sample sizes were determined by the availability of 100-word passages in the survey reports.

TABLE O

Readability Results

Report sample	Report section			
	Text	Summary*	Headings	Captions
Fog index (grade level)				
Overall survey	17.7 (50)	19.5 (42)	14.7 (36)	13.5 (10)
ABDEN reports	18.3 (28)	20.1 (27)	15.1 (19)	13.9 (6)
NASA report	17.6 (1)	17.0 (1)	--- (0)	--- (0)
Kincaid index (grade level)				
Overall survey	14.2 (50)	16.7 (42)	12.0 (36)	12.3 (10)
ABDEN reports	15.0 (28)	16.9 (27)	12.4 (19)	12.2 (6)
NASA report	15.3 (1)	16.0 (1)	--- (0)	--- (0)
Flesch formula (grade level)				
Overall survey	19.3 (50)	21.3 (42)	22.4 (36)	22.5 (10)
ABDEN reports	19.9 (28)	21.8 (27)	22.5 (19)	22.6 (6)
NASA report	18.7 (1)	18.7 (1)	--- (0)	--- (0)

*Summary samples were drawn from the introduction, summary, or conclusions sections. This "definition" was used only for readability tests.

All three readability tests showed the text section to have a lower difficulty level (lower grade level on Fog, Kincaid, and Flesch, indexes) than the summary section. This was true for both the overall survey report sample and the ABDEN reports. For the overall survey, the text scored grade level 17.7 on the Fog index, while the summary averaged 19.5. The Kincaid results followed the same pattern, 14.2 for text and 16.7 for summary material.

The Fog index and Kincaid formula scored headings and captions easier to read than other sections tested for both the overall survey and the ABDEN reports. The Fog index showed average grade levels of 14.7 (headings) and 13.5 (captions) for the overall sample. The Kincaid measured 12.0 (headings) and 12.3 (captions). Only the Flesch scale measured headings and captions to be more difficult than text and summary material. (Because the Flesch scale in the other cases followed the trends of the other two readability measures, these heading and caption measurements were atypical because of methodological differences used to compute reading levels and no conclusions have been drawn based upon them.)

For all report sections and by all three readability tests, the ABDEN reports on NASA-related subject areas tested as more difficult on readability scales than reports of the overall survey. The only exception was the headings section in which the grade levels were almost equal as tested by the Kincaid method.

At 17.6 grade level of the Fog index, the NASA text was approximately equal to the survey reports (17.7) and less difficult than the ABDEN reports (18.3) on related subject matters. Results on the Flesch scale were parallel to those on the Fog index. The text of the NASA report tested at a lower difficulty level (18.7) than the survey overall (19.3) or the reports on NASA-related areas (19.9). By the Kincaid procedure, the NASA report's text tested higher (15.3) than the overall survey (14.2) and the ABDEN reports (15.0).

The summary of the NASA report tested lower in difficulty than the summaries of the general survey or the ABDEN reports by all three procedures. The NASA report did not contain headings or captions; therefore, no comparisons could be made with the survey results in these areas.

Review of the literature showed that although numerous readability tests had been devised and tested, no one test had been accepted as standard for technical reports. Gilliland (1972) found that correlations between tests were generally in the region of 0.7. The survey of the literature also revealed that only general readability standards had been set for technical literature. Scientific journals were tested and scored generally at or about the college graduate level, grade 16 (Klare, 1977).

Person and voice. The data extracted from survey reports concerning use of person and voice are given in Table P. As can be noted, there was a strong tendency toward use of the third person in the text material (88 percent of reports) and in the summary material (95 percent of reports). The passive voice was used more often than the active voice in both text and summary sections. In the texts, 56 percent of the reports used the passive voice exclusively, 38 percent used the active voice exclusively, and 6 percent used both voices. No data were obtained on the use of person or voice in headings and captions.

In the past, a strong tradition existed for use of the passive voice in scientific and technical literature. This is no longer true as was evident from a review of the technical writing/editing textbooks, style manuals, and publications manuals cited in Tables C and D, and other literature sources (e.g., Strunk and White, 1978; Stanley, 1975; and Holloway, 1974). A very strong consensus of current thinking indicated that active voice should be used whenever possible because it is usually more direct, natural, and concise. The active voice was favored over the passive voice whenever verbs concern the interaction of inanimate objects and/or the writer wanted to emphasize who or what performed the action. The passive voice was recommended when the writer wanted to emphasize the receiver of the action rather than the doer.

The textbooks, style manuals, and publications guides were more divided on the question of person. Most did not treat the subject of person. The Publication Manual of the American Psychological Association (1974) indicated that experienced writers can use first person without sacrificing objectivity or dominating the communication. (These are the usual arguments against use of the personal pronouns "I" and "we.") On the other hand, Pauley (1979) stated that the use of first and second persons should be avoided, and Mills and Walter (1978) advocated avoiding first person or using it only sparingly.

The sample NASA report used third person, passive voice in both text and summary sections. The NASA Publications Manual 1974 did not discuss person or voice. However, the current practice in editing branches of the Agency is to encourage use of the active voice whenever possible, while recognizing that the nature of scientific and technical material makes the use of the passive voice necessary or preferable in certain situations. Current NASA practice in regard to person is that third person is preferred, but first person is permitted if the author prefers this form.

TABLE P

Use of Person and Voice by Survey Reports

Report section	Person (No. reports using)				Voice (No. reports using)		
	1st.	2nd.	3rd.	Varied	Active	Passive	Both
Text (n = 50)	2	2	44	2	19	28	3
Summary (n = 42)	1	0	40	1	18	23	1

Mathematical presentations. The mathematical style books of the American Mathematical Society (Swanson, 1971, p. 28-29) and of Oxford University (Chaundy, 1954, p. 54) and Mathematics in Type (William Byrd Press, 1954, p. 17) all recommended that the accepted rules of style, grammar, and punctuation used in constructing the prose of a text also be used for the mathematics in the publication. Swanson (1971, p. 28) and William Byrd Press (1954, p. 25) further stated that the standards of grammar and punctuation are the same for mathematics whether in text or set off in display. Swanson (1971, p. 29) noted that punctuation of display is not universally applied. However, she argued that all mathematics with the exception of diagrams, matrices, and determinants should be punctuated, and she noted that all publications of the American Mathematical Society do follow this standard. Chaundy (1954, p. 22-64) presented a very clear argument for standard English grammar and punctuation of mathematical material, with specific exceptions.

The NASA Publications Manual 1974 (p. 23) stated that, "Punctuation is omitted after displayed equations, but introductory sentences leading into these equations should conform to correct grammatical usage." The sample NASA report did not, on the whole, follow rules of English grammar and punctuation advocated by the commercial mathematical style books in treatment of displayed equations.

The American Mathematical Society style book stated that most authors tend to overdisplay mathematics, frequently with a consequent loss of clarity and emphasis (Swanson, 1971, p. 25, 41). The Oxford (Chaundy, 1954, p. 47-48) and William Byrd (1954, p. 32) style manuals both stated that displayed equations should be numbered only if they are either referenced by number in the accompanying text or are of such a nature that they may be quoted by other authors.

The NASA Publications Manual 1974 (p. 23) stated that, "Short mathematical expressions or equations can be treated as part of the text when it is convenient to do so. All numbered equations, however, regardless of length should be set off and indented or centered on a separate line. . . . Equations needed for reference are numbered as (1), (2), (3), etc., throughout the text." Ninety-three percent of the equations in the sample NASA report were displayed; seven percent were in the text. All of the displayed equations were numbered, but only 57 percent were referred to in the accompanying text.

All three style books recommended essentially the same methods for breaking displayed equations which were too long to appear on one line (Chaundy, 1954, p. 37; William Byrd Press, 1954, p. 20; and Swanson, 1971, p. 42-45). Swanson was the only source which advocated breaking equations in the text. This recommendation was made to reduce the number of displayed equations.

The equations that were broken in the NASA sample report followed the recommendations set forth in the commercial style manuals. The NASA Publications Manual made no recommendations for breaking equations, but did refer the reader to the GPO Style Manual. The GPO Style Manual stated that equations in the text should not be broken, and that displayed mathematical expressions needing to be divided should be broken before an operations sign. To avoid breaking equations in the text, the GPO Style Manual recommended spacing the text so that the equation begins on a new line or, preferably, centering the equation on a line by itself.

Twenty-one of the 50 survey reports contained mathematical material. Four reports contained mathematics in the text, but not in display; four reports contained mathematics in display but not in the text. In the remaining 13 reports (62 percent) mathematical material was divided between text and display. No data were compiled from the survey reports regarding punctuation or breaking of mathematical material.

The textbooks cited in Table D did not cover the presentation of mathematical material. The majority opinion of the style manuals and publications guides (cited in Table C) which discussed mathematics advocated punctuating all equations; displaying complex and numbered equations while retaining simple, short equations in the text; and breaking displayed equations before an operations sign.

Tables. An analysis of the 50 reports from the survey produced a mean table-to-page ratio of 16 percent. Thus, for every 100 pages of body and back matter of these reports, there were 16 tables. The median value was 9 percent. Table-to-page ratios in the 50 reports ranged from 0 to 66 percent. Medians and means did not vary appreciably when the publications were grouped by report type, activity, and organization. The sample NASA report did not contain any tables.

Figures. For the survey reports, the figure-to-page ratios ranged from 0 to 203 percent. The mean ratio was 39 percent or about 0.4 figures per page of body and back matter. The median was 28 percent. Medians and means did not change substantially when the reports were collated and analyzed by publication type, area of principal activity, and organizational type. The sample NASA report had a 69 percent figure-to-page ratio.

Figure 4 shows frequency distributions for the table-to-page and figure-to-page ratios in the survey reports. The frequency distribution for the figure-to-page ratio appears bimodal or multimodal, suggesting the existence of subgroups of survey publications in regard to frequency of figure utilization.

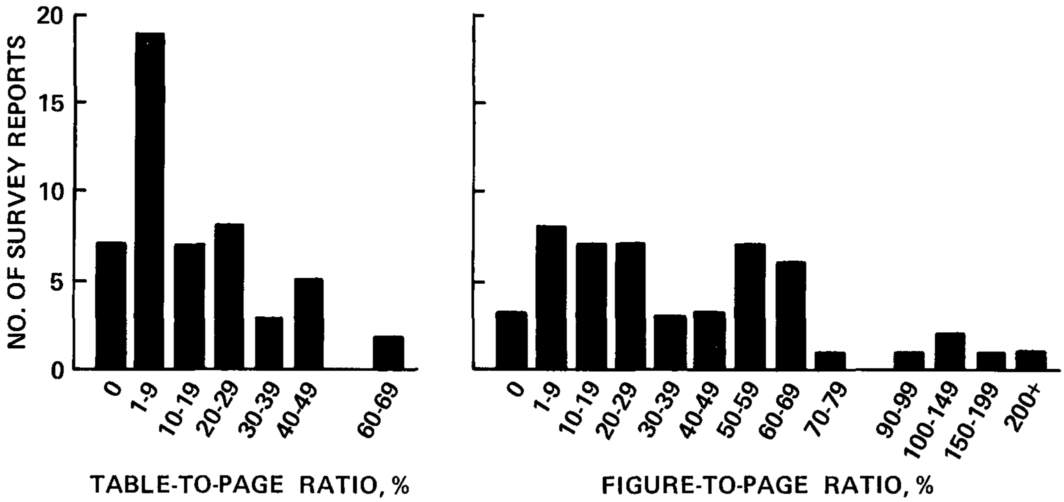

Figure 4. Frequency distributions of the number of tables and figures expressed as a percentage of the number of body and back matter pages in the survey reports (n=50)

Figures can be grouped into three major classifications:

1. charts or graphs, including two- and three-dimensional Cartesian graphs, polar coordinate graphs, scattergrams, and bar and pie charts;

2. diagrams, including organizational/hierarchical diagrams and functional/schematic diagrams such as flowcharts; and

3. illustrations, including orthographic illustrations, isometric illustrations, perspective or freehand drawings and renderings, and photographs.

Spencer (1971, p. 170) concluded that, for the most part, readers preferred representations which most nearly depicted the actual appearance of objects; that is, they preferred isometric illustrations over orthographic illustrations. Ryan (1956, p. 61-69) investigated the effectiveness of four types of illustrations: photographs, shaded drawings, line drawings, and cartoons. Ryan's conclusions, that photographs or shaded drawings of three-dimensional objects were more easily comprehended than images constructed only with lines, generally corresponded with those of Spencer. That is, the more nearly an illustration "looked like" the object it represented, the better it was understood. Ryan found that the cartoon, which simplified, exaggerated, and abstracted, however, outperformed all forms of representation.

Figure 5 shows frequency diagrams for the occurrence of at least one example of these types of figures in survey reports. Types of artwork occurring in 50 percent or more of the overall sample were two-dimensional graphs, functional/ schematic diagrams, and orthographic illustrations. Functional/schematic diagrams appeared in more reports than any other type of figure when the survey is considered as a whole.

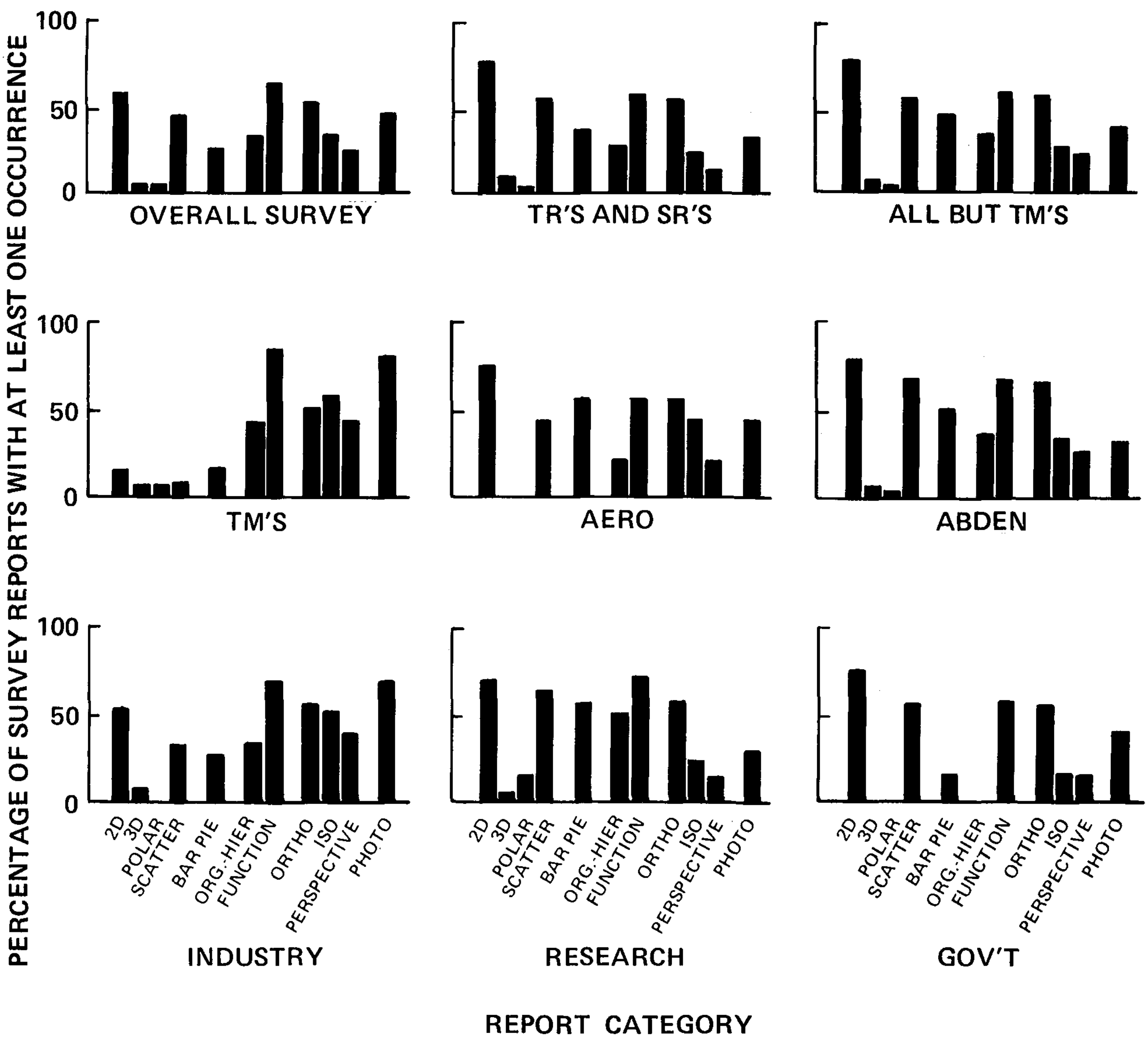

Figure 5. Occurrence of figure types in survey reports

The two-dimensional Cartesian graph was one of the most extensively used visual devices. Approximately 60 percent of the 50-report survey contained at least one two-dimensional graph. When technical manuals were excluded, the usage rate rose to 75 percent, and the two-dimensional graph became the most commonly used type of artwork in the remaining 38 reports. Technical manuals exhibited strong use (80 percent) of functional/schematic diagrams and photographs.

ABDEN reports dealing with NASA-related activities showed a trend toward use of two-dimensional Cartesian graphs, scattergrams, functional/schematic diagrams, and orthographic illustrations. Fifty percent or more of the reports in these categories contained one or more examples of these types of figures.

Three-dimensional Cartesian charts and polar coordinate graphs were used very infrequently in the survey reports overall and in the various subsets. Bar and pie charts appeared most often in reports on aerospace and ABDEN topics and in reports published by research-type organizations.

For illustration-type figures, the only notable trend was the use of more realistic forms of representation (i.e., photographs, perspective drawings, and isometric drawings) in technical manuals and in reports published by industrial organizations as compared with more common use of orthographic-type illustrations by the overall survey and other report categories.

The sample NASA report contained two-dimensional Cartesian plots, orthographic illustrations, and isometric illustrations. No other types of figures were present.

Several of the style manuals and publications guides cited in Table C and a majority of the textbooks cited in Table D offered information on the various types of visual presentations and what type of information each is best suited to convey. For example, photographs were noted for their ability to show details clearly and were generally deemed more realistic than other visual forms. Drawings were noted for the ability to portray mechanisms, enabling readers to understand operational principles. Graphs were stated to be superior to other visuals for comparing quantities and showing trends.

The NASA Publications Manual (p. 38-43) contained some guidelines on figures (photographs, drawings, and graphs), mainly concerning numbering, labeling, legends, and keys. In the case of graphs, specific details were included on scales and scale labels, curves and curve labels, and recommended data paths and data points. No guidance was included on the effectiveness of types of visuals in communicating the results of research.

Two-dimensional graphs. Because two-dimensional line graphs were used so extensively--more than any other type of figure in survey reports when technical manuals were excluded, additional data were extracted concerning the use of gridlines, methods of production, and highest number of different data paths plotted on one graph. Literature sources were consulted and compared concerning these parameters and suggested symbols for data paths and data points.

Figure 6 shows the use of gridlines in graphs for the overall report survey and the various categories analyzed. For the total survey, gridlines were used only in 25 percent of the reports containing two-dimensional graphs. Technical manuals showed the highest use (50 percent) of gridlines. Thus, the survey consensus, overall and for all categories except technical manuals, was to omit gridlines.

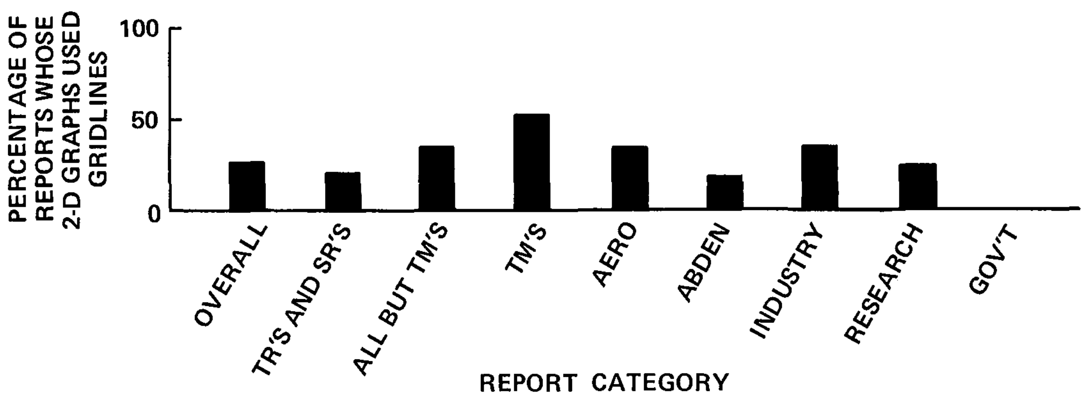

Figure 6. Percentage of reports whose two-dimensional graphs used gridlines

Lockwood (1969, p. 7) and Meyers (1970, p. 40) shared the opinion that gridlines should not be used for most charts. Harvill (1977) extended this by indicating that the ease of the interpretation of data is a function of the absolute size of a chart, not the number of its subdivisions. On the other hand, the Monge study (1979) of NASA technical literature users concluded that, wherever possible, gridlines should be used on graphs.

The NASA Publications Manual 1974 contained a section dealing with the preparation of graphs on grid paper as reproducible copy. Specific instructions were given on types of paper to be employed so that fine grid, coarse grid, or no grid will appear in the finished publication. Thus, authors and editors were given the choice of whether or not to include gridlines, and if they are used, whether the lines should be coarse or fine. Gridlines were not used in the graphs of the sample NASA report.

The incidence of hand, strip/recorder, and computer production methods for graphs in the survey reports is displayed in Figure 7. (Most publishers of technical literature in the survey reports used hand production methods for graphs.) Computer-generated graphs were used substantially by only one report category, technical manuals. Graph production was evenly divided in the technical manuals

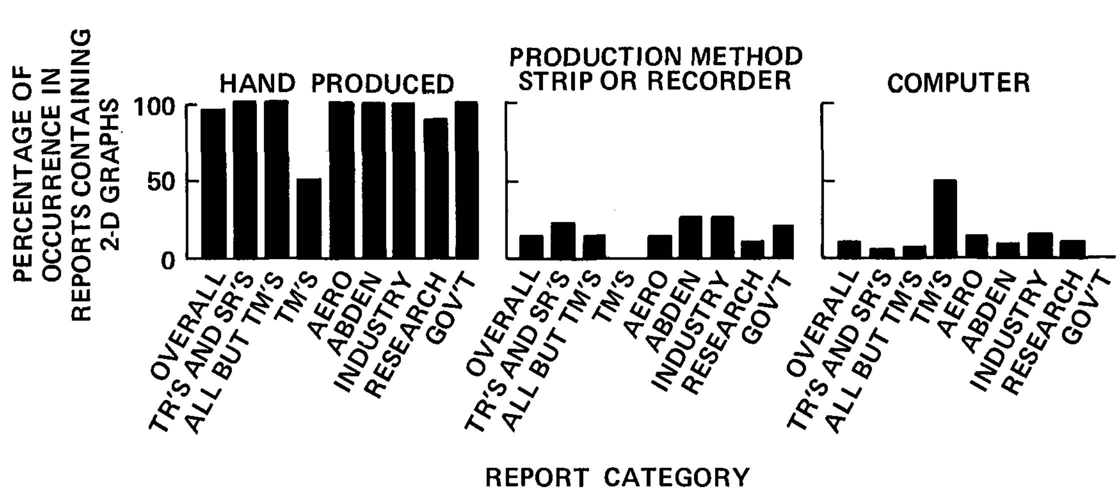

Figure 7. Frequency of use for various production methods employed for two-dimensional graphs

between computer and hand methods. Graphs reproduced from strip/recorder charts were seen most often in ABDEN reports and in reports produced by industrial organizations. Frequency of use in these categories was 30 percent of reports containing Cartesian plots.

Of the survey reports containing two-dimensional charts, 95 percent used hand production methods for one or more graphs, 15 percent used strip/recorder generation for at least one graph, and 10 percent employed computer generation for at least one graph. Some reports obviously used multiple production methods.

The NASA Publications Manual did not address the topic of graph production methods; however, all examples were hand-produced. Two-dimensional graphs in the sample NASA report were also all produced by hand methods.

All survey reports containing two-dimensional graphs were examined to find the maximum number of data paths plotted on one figure. The results ranged from one to ten different plots on the same chart. The mean number of data paths per figure was five, and the median value was four.

The Publication Manual of the APA (1974) recommended a maximum of four curves per figure. Meyers (1970, p. 40) established a limit of three simultaneous curve comparisons. Schutz (1961, III, p. 118-119) concluded that one multiple-path chart was better than several single-path charts for comparing trends; however, the experiments were limited to a maximum of four data paths.

The NASA Publications Manual did not contain specific guidelines on the maximum number of plots to be shown on one chart; however, a list of eight types of lines (data paths) was included and an order recommended for their use in introducing different curves in a single figure. The highest number of data paths on a single chart in the NASA sample report was eight.

Table Q contains the recommendations of Harvill (1977, p. 31), Schutz (1961, II), and the NASA Publications Manual (p. 42) concerning types of data points and data paths to be employed when multiple plots appear on one graph and the order in which the points and paths should be introduced.

Harvill suggested the use of open symbols and stated that a key should be employed within the chart whenever more than one data path exists. Schutz's recommendations were based on experiments which determined not only how well data path/point systems performed, but also which combinations were most likely to be confused with one another. The two sources were not in agreement on their recommendations.

The NASA guidelines agreed with Harvill's recommendations on data points; however, NASA recommended varying data paths while Harvill used the same path. No data were obtained on the data points and data paths used in multi-curve charts of the survey reports or the sample NASA report.

TABLE Q

Preferred Data Points and Data Paths

SOURCE	DATA POINTS	DATA PATHS
HARVILL (1977)	○	————————
	□	————————
	△	————————
SCHUTZ (1961, II)	+	———+———
	○	———○———
	▲	———▲———
	●	○ ○ ○ ● ○ ○ ○
NASA (1974)	○	————————
	□	– – – – – – – –
	▷	— — —— — —
	◇	—-·—— -·—
	◻	—-·-·—-·-·-
	◻	— — - — —
	◇	—— -·- ——
	⬡	— —-·-·— —
	⌂	
	◁	
	◊	

Presentation Components

Data regarding presentation components were derived from the following sources: (1) an analysis of the survey reports, (2) information obtained from a review of the experimental/theoretical literature, (3) the NASA Publications Manual, and (4) the NASA sample report. The data are presented in terms of typography of the text, tables, and displayed elements; graphic design; and physical media.

Typography of the text. Data were recorded and analyzed for various aspects of the typography of the text. The analysis is presented for composition method, type style, type size, margins, paragraph indentation, line length, character count, leading, and mathematics.

Composition method. - The survey documents were evenly divided in terms of composition method. As is evident in Figure 8, approximately half were typeset. The other half were typewritten. Technical manuals used typesetting more than any other subgroup of the survey documents.

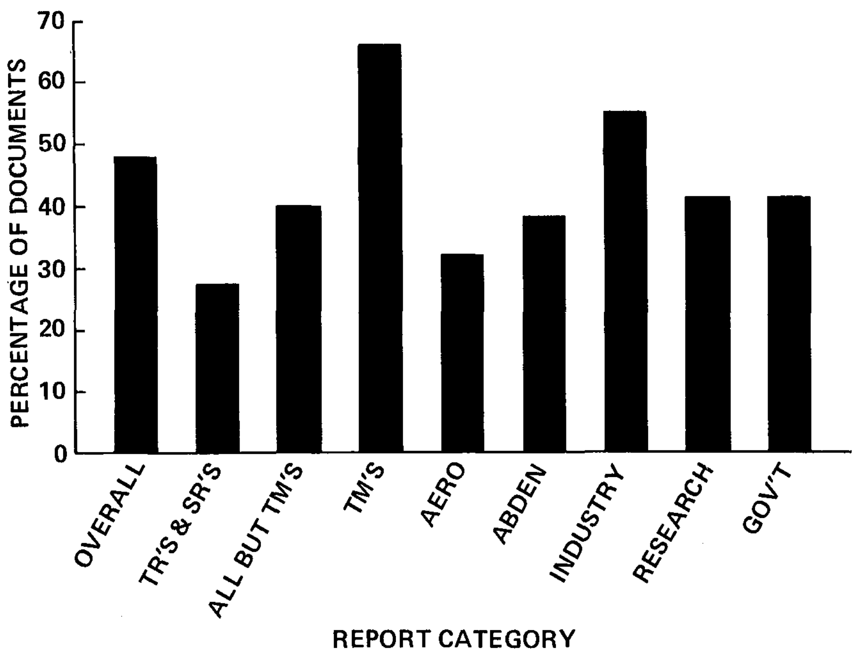

Figure 8. Percent of survey documents which were typeset

Greene (1934, p. 704) found that typeset and typewritten composition could be read with nearly equal speed. Typewritten composition does present a space penalty. For example, Cooper (1979, p. 67) reported that the same text required 44 percent more space if typewritten rather than typeset.

The sample NASA report was typeset using either a word processing system or proportionally-spaced typewriter. The NASA Publications Manual stated that formal series reports other than Special Publications were prepared at originating centers as camera-ready copy and that typewriters with proportional spacing were available.

Type style. - Figure 9 shows the relative use of Roman and Gothic type styles in the texts of survey documents. Seventy percent of the overall survey used Roman type; thirty percent used Gothic type. Roman type styles were used by a

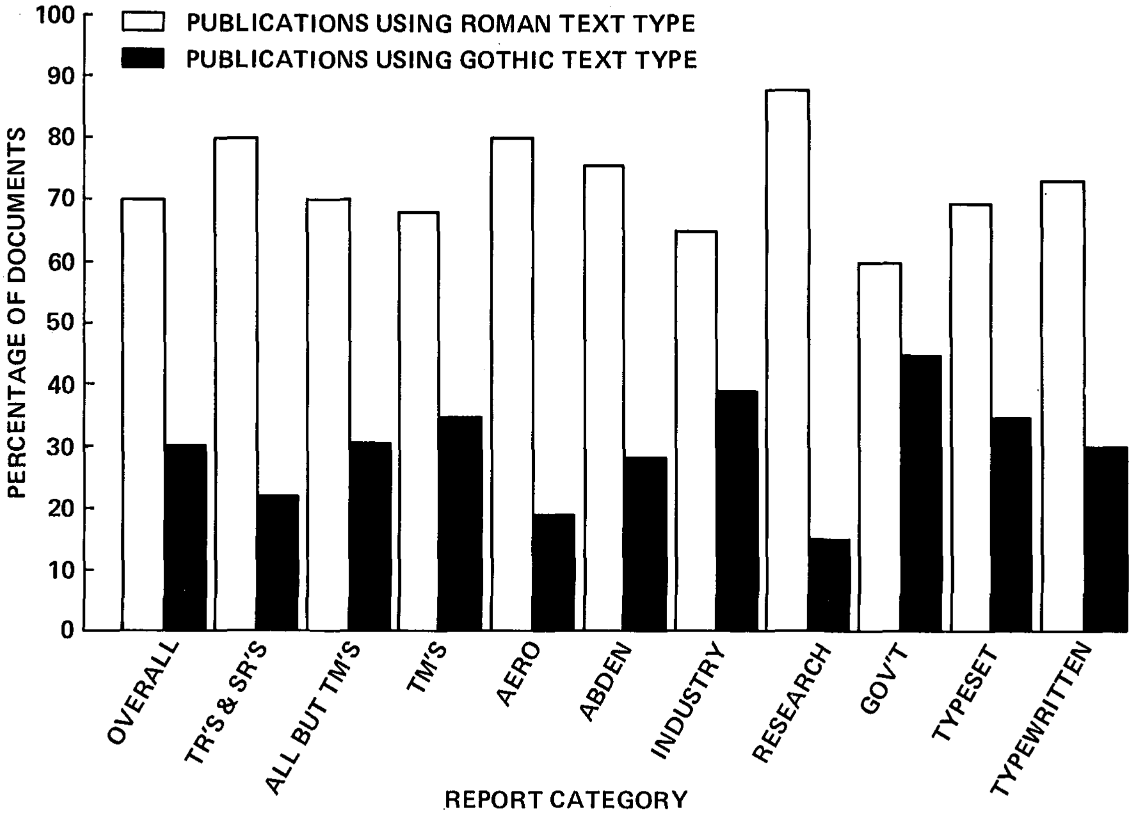

Figure 9. Use of Roman and Gothic type styles in the texts of survey documents

majority of documents in every category analyzed. The NASA sample report employed Roman type. The NASA guidelines did not address the question of type style.

Although a considerable amount of research has been done by psychologists and an equally large number of opinions have been set forth by typographers, the question of which type face is most legible has yet to be answered. Burt (1959) and Monge (1979) stated that Roman faces are superior to Gothic. Tinker (1963), Poulton (in H. Spencer, 1969, p. 27), and Zachrisson (1965, p. 115) discovered little or no difference in legibility between serif (Roman) and sans serif (Gothic) type styles. Generally, the older the finding or opinion, the greater the likelihood that it favors serif type styles. More recent findings either tend to show no difference or to prefer sans serif types. This supports the conclusion of Lee (1965), Ward and Gill (H. Spencer, 1969, p. 29) that acculturation and conditioning strongly influence the performance of the two major type style groupings. Tinker (1963, p. 64) concluded that all type faces in common use are nearly equal or suitable.

In regard to the use of all capitals as opposed to capitals and lower case type, none of the survey documents set text in all capitals. Arnold (1972, p. 83) stated that text type should not be set in all capitals, and Tinker (1963, p. 64) proscribed use of all-capital printing for reasons of legibility. The NASA guidelines did not specifically address this issue; however, the current practice in editing branches of the agency is to use capitals and lower case type. The sample NASA report used capitals and lower case type.

Type size. - Figure 10 presents the findings for type size in the texts of survey documents. Type sizes ranged from 9 points to 13 points. Ten-point type was used most frequently (21 of 50 documents), with 11-point type used almost as often (19 of 50 documents). Only publications on aerospace topics deviated from this distribution. This report category used 9-point type most commonly.

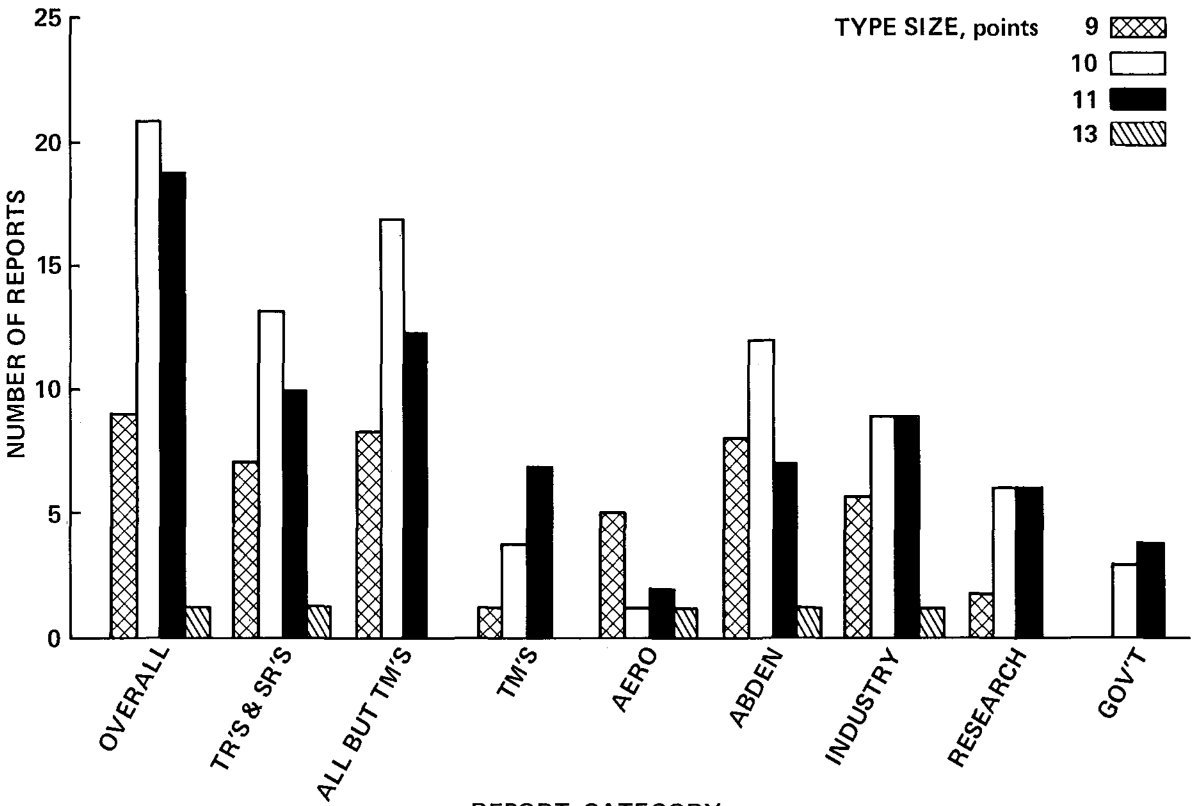

Figure 10. Type sizes used for the texts in survey documents

Figure 11 shows various ranges of type size which researchers have presented as being equally legible. The range that Hovde listed may be misleading because 6- and 8-point type were the only sizes tested. He found that 6- and 8-point type were equally legible, but he did not address the question as to whether these sizes were as legible as 10- or 14-point type, for example.

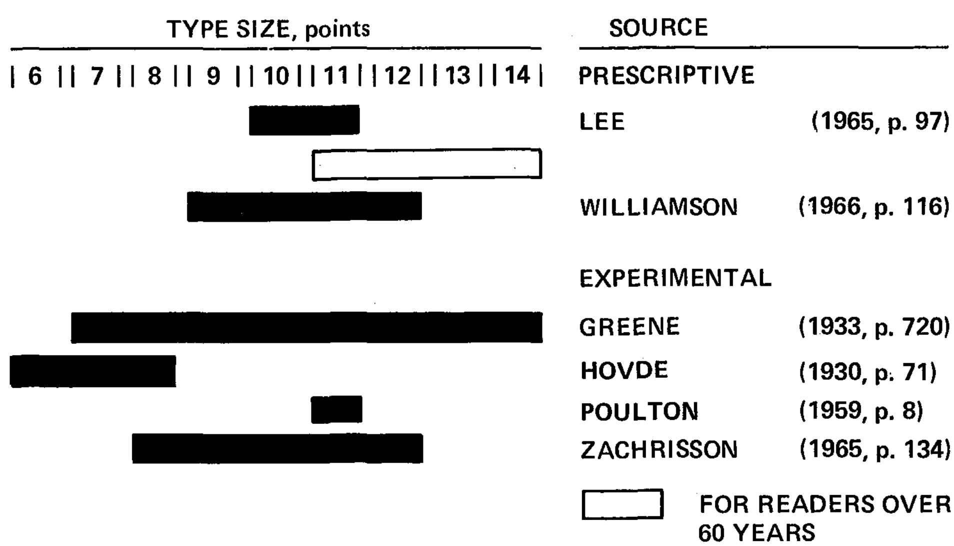

Figure 11. Type size ranges reported as acceptable by various sources

The majority opinion among researchers cited in Figure 11 is that type sizes from 9 through 12 points can be used for text without adversely affecting legibility.

The NASA Publications Manual 1974 did not discuss type size. The NASA sample report was printed in 11-point type. This size was well within the range specified as acceptable by the majority of literature sources and was the second most common type size for text material in survey publications.

Margins. - Sixty percent of the survey documents used ragged right-hand margins. Only in the categories of technical manuals and reports published by research organizations did a majority of the documents use justified right-hand margins. Figure 12 illustrates the proportions of the overall survey and various document categories which employed each margin treatment.

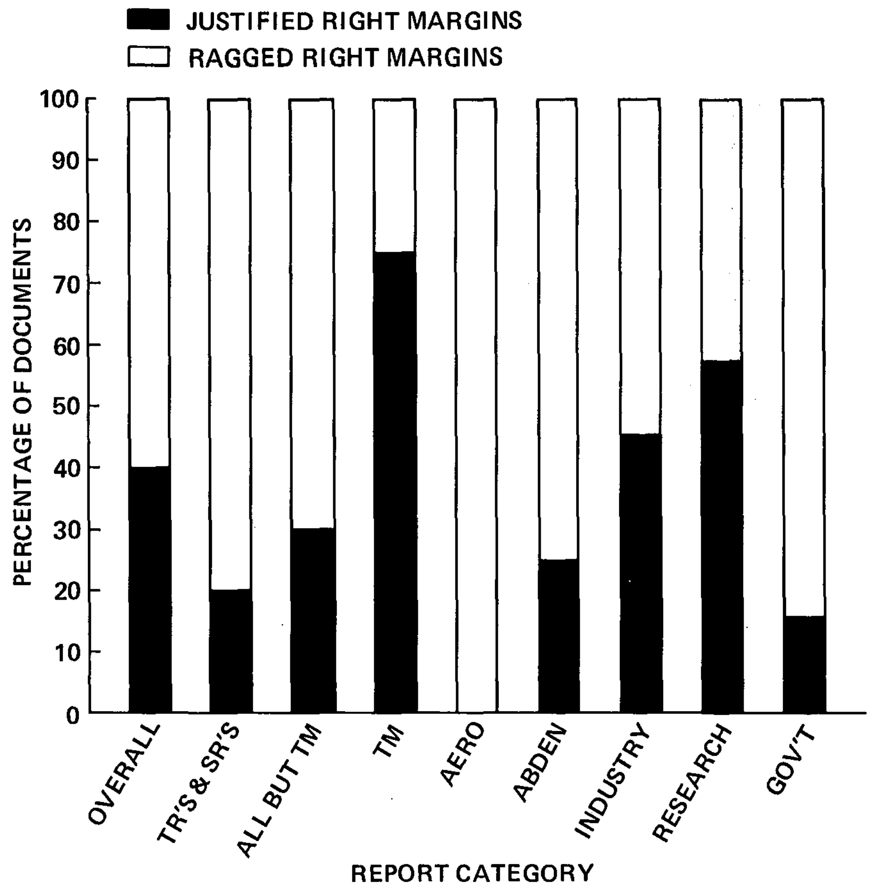

Figure 12. Use of justified and ragged right-hand margins in the survey documents

Williamson (1966) stated that unjustified (ragged) right margins do not adversely affect legibility. Experiments conducted by Fabrizio, Kaplan, and Teal at the U.S. Office of Naval Research (Spencer, 1969, p. 37), Gregory and Poulton (Poulton, 1970, p. 208); Hartley and Burnhill; Wiggins (Rehe, 1974, p. 32); and Zachrisson (1965, p. 155) all support this conclusion.

The NASA Publications Manual did not contain any guidelines for the form of the right margin. The sample NASA report had a ragged right-hand margin.

Paragraph indentation. - The survey reports were almost equally divided in the use and nonuse of paragraph indentation. These data are displayed in Figure 13. Slightly more than half of the overall survey indented paragraphs. When technical manuals were excluded, over 60 percent of the remaining documents used indentation. No data were extracted from the survey documents on line spacing between paragraphs.

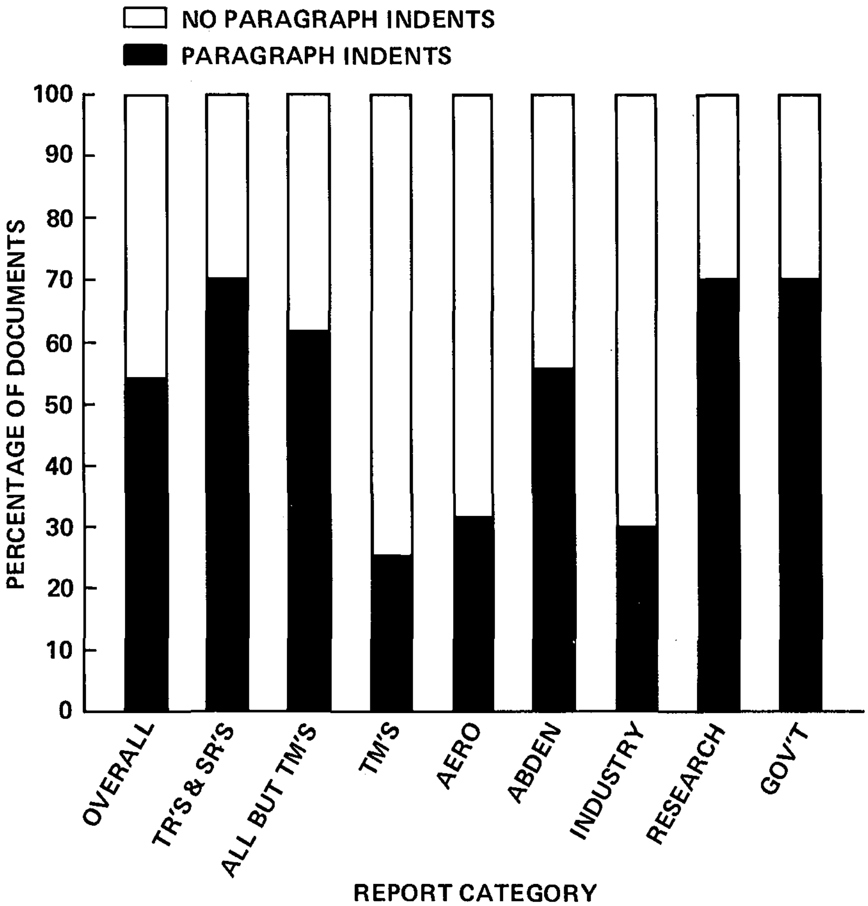

Figure 13. Use of paragraph indentation by survey documents

Some division existed in the literature concerning paragraph indentation. Morison (1951, p. 11) considered paragraph indentation to be the final subordinate. level of heading. Because of this, he proscribed the use of indents for the first line of text following any heading. He also suggested that if text type is set wide with no additional leading, some extra line space between paragraphs (in addition to the indent) be included. Williamson (1966, p. 123) agreed with the need for paragraph indentation, but recommended against the use of extra space between paragraphs unless it is in whole multiples of the text spacing. His chief reason for this was the prevention of "show through" of type from the backing page.

Burt and Tinker both conducted experiments in which the findings supported the hypothesis that indentation improves legibility. Spencer (1969, p. 44) questioned the validity of such interpretations based on the methodology of the testing procedure. Spencer (1969) and Rehe (1974) supported the position that extra space between paragraphs serves much the same function as indentation. Poulton (1970, p. 208-209) felt that adding half a line space between paragraphs not only looks better, but also probably improves performance characteristics.

The sample NASA report used paragraph indentation and extra line space between paragraphs, but the NASA Publications Manual provided no guidelines for their use.

Line length. - Table R summarizes recommendations from the literature regarding line length. These recommendations were made without reference to type size. A "most lenient" range of acceptable limits for line length (11 to 42 picas) was derived from this table using the lowest and highest values recommended by any sources.

The longest line on a given page was measured for each survey document. Averages were calculated for the survey as a whole and for the various report categories. The mean longest-line for single-column documents was 38 picas. Values ranged from 27 to 43 picas. The means varied only slightly (37 to 39 picas) for different report categories. The 12 two-column documents had an average longest-line of 20 picas per column, with a range of 19 to 21 picas. The single document set in three columns had a maximum line length of 14 picas per column.

Only one survey document exceeded the "most lenient" maximum line length of 42 picas. However, most documents were at the upper end of the acceptable line length range. The NASA sample report, whose longest line was 41 picas, was also at the upper end of the spectrum, but still within the acceptable maximum.

TABLE R

Line Lengths Recommended in the Literature

Line length (picas)			Type of literature	Reference
Minimum	Optimum	Maximum		
---	18	---	General	*Starch (Tinker, 1963, p. 233)
24	30	---	General	Lee (1965, p. 98)
---	42	---	Scientific/ technical	*Burnhill (1976, p. 13)
---	19	41	General	*Greene (1933, p. 727)
14	---	34	General	*Tinker (1963, p. 106-107)
20	27.5	35	General	Williamson (1966, p. 123)
21	25-26	30	Scientific journals	Survey data from journals (Tinker, 1963, p. 7)
11	17-18	20	Scientific journals	Survey data from journals (Tinker, 1963, p. 7)

*Experimental findings

The NASA Publications Manual (p. 7) defined the maximum image area as 6-5/8 inches in width. This is equivalent to 39-3/4 picas. The 41-pica line in the sample report slightly exceeded NASA's allowable maximum. The NASA prescriptive maximum of 39-3/4 picas is near the upper limit, but within the allowable range derived from literature sources in Table R. It is only slightly longer than the mean survey value of 38 picas.

Arnold (1972, p. 84-85) and Burt (1959, p. 13-14) made recommendations for line length in general literature based on type size. These recommendations appear in Table S.

TABLE S

Line Length Recommendations Based on Type Size

Type size (points)	Line length (picas)			Reference
	Minimum	Optimum	Maximum	
9	13.5	18	22.5	Arnold (1972, p. 84-85)
10	15.0	20	25.0	Arnold (1972, p. 84-85)
10	20.0	--	33.0	Burt (1959, p. 13-14)
11	16.5	22	27.5	Arnold (1972, p. 84-85)
13	19.5	26	33.0	Arnold (1972, p. 84-85)

Table T contains the results of the analysis of line lengths of survey documents as a function of type size. The mean and median values for all type sizes were above the ranges recommended by Arnold and Burt. The sample NASA report used 11-point type. Its 41-pica longest line exceeded the maximum acceptable length recommendations of Arnold and Burt, and it was also above the mean and median values for survey documents which used 11-point type. NASA guidelines did not discuss line length in terms of type size.

TABLE T

Line Length as a Function of Type Size for Single-Column Survey Documents

Type size (points)	No. of documents	Mean longest-line (picas)	Median longest-line (picas)	Range longest-line (picas)
9	7	39	39	36 - 43
10	17	38	37	34 - 42
11	12	37	38	27 - 42
13	1	39	--	-------

Tinker's work (1963, p. 106-107) was the only comprehensive study of the interaction of line length, leading, and type size found in the literature. His recommendations for "safety zones" for legibility are summarized in Table U.

TABLE U

Tinker's Recommendations* for Line Length and Leading for Various Type Sizes

Type size (points)	Line length (picas)	Additional leading (points)
6	14 - 28	1 - 4
8	14 - 36	2 - 4
9	14 - 30	1 - 4
10	14 - 31	1 - 4
11	16 - 34	0 - 2
12	17 - 33	1 - 4

*Tinker (1963, p. 106-107)

Figure 14 shows the proportions of survey documents within Tinker's limits for line length in relation to leading and type size. Only 30 percent of the survey publications fell within Tinker's recommendations. Technical manuals had

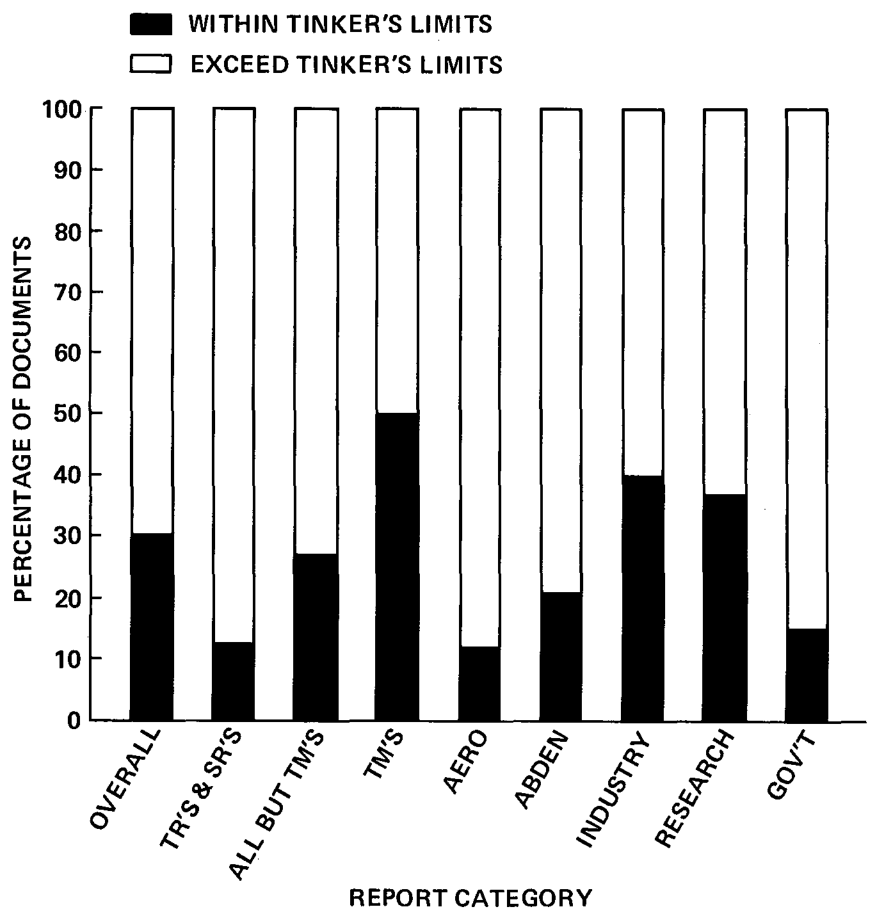

Figure 14. Percentage of survey documents within and exceeding Tinker's limits (Table U)

the highest proportion (50 percent) of documents conforming to Tinker's limits. No guidelines were available in the NASA manual in this area. The sample NASA report did not meet Tinker's criteria.

By selecting the lowest minimum and highest maximum specified by Arnold or Burt (Table S) or Tinker (Table U) for each type size, the most liberal limits of Table V were derived.

TABLE V

Most Liberal Limits from the Literature for Line Length as a Function of Type Size

Type size (points)	Line length (picas)	
	Minimum	Maximum
9	13.5	30
10	14.0	33
11	16.0	34
13	19.5	33

The means and medians of the single-column survey documents in all four type sizes exceeded the most liberal limits from the literature (shown in Table V). The sample NASA report with a 41-pica longest-line was even further above the maximum acceptable limit from the literature than were the mean and median values for the 11-point survey reports.

Character count. - Recommendations from the literature on minimum, maximum, and optimum character counts per line are listed in Table W. All were directed toward general literature rather than scientific/technical documents in particular. Taking the lowest and highest values cited by any sources gives a "most lenient" acceptable range of 50 to 80 characters per line.

The 37 single-column survey documents had a mean count of 74 characters per line and a median value of 72 characters per line. Individual values ranged from 58 to 110 characters per line. No documents were below the minimum limit of 50 characters per line established from Table W. Eight reports, or 28 percent of the one-column publications were above the upper limit of 80 characters per line. No statistics were prepared on the character counts of multi-column publications.

The NASA sample report had an average of 84 characters per line and thus was above the upper limit of 80 characters per line obtained from the literature. The sample NASA report was also above the mean and median values for the survey. The NASA guidelines did not treat the subject of character count.

Spencer (1969, p. 35) explained the underlying basis of the need for line length and character count limits. Short lines tend to increase the number of fixation pauses the eye must make, while long lines tend to increase the number of regressions the eye must make. Both situations decrease reading speed and increase errors in comprehension.

TABLE W

Literature Recommendations for Character Count Per Line

No. of characters per line			Reference
Minimum	Optimum	Maximum	
50	55-60	70	Lee (1965, p. 98)
54	-----	60	Dowding (1957, p. 6)
55	-----	80	*Burt (1959, p. 13-14)
--	60-70	--	Morison (1951, p. 9)
--	60-70	--	Spencer (1969, p. 35)

*Experimental findings

Leading. - Leading, the amount of extra space inserted between lines, is another factor that can affect legibility (Greene, 1933, p. 727 and Tinker, 1963, p. 233). As line length increases, there is a strong tendency for the reader to skip the next line after completing a line. Morison (1951, p. 9), Williamson (1966, p. 122), and Lee (1965, p. 99) stated that adding extra interlinear space can help to alleviate this problem. Burt found that the benefits of extra leading for 8-, 9-, and 10-point type stopped at 3 points of additional lead (Spencer, 1969, p. 35). Tinker (1963, p. 106-107) found 4 points to be the limit. Poultron (1970, p. 209), on the other hand, said that unleaded type can be read nearly as well as leaded type.

Table X shows the average additional leading used by survey publications employing various type sizes. Most survey documents used a generous amount of line leading, somewhat more than any of the literature sources recommended. This may represent an attempt by the compositors to compensate for relatively long line lengths. However, in the only study on the interaction of line length and leading, Tinker (1963, p. 106-107) found that additional lead did not reduce the decreases in legibility that long line lengths produced.

TABLE X

Additional Leading in Survey Documents

Type size (points)	Mean additional leading (points)
9	13
10	11
11	12
13	8

The NASA sample report, which used 11-point type for the text, used 1 point of additional leading between lines of successive prose, but 7 points of additional leading following lines containing mathematics. The NASA Publications Manual did not cover the topic of leading.

Mathematics. - Mathematical material was set in Roman type in 13 of the 21 survey documents (62 percent) containing mathematics. The other eight reports used Gothic style. In 16 reports, the mathematics was set in the same type style as the text. Four reports used Roman type for the text, but Gothic for the mathematics. One report employed Gothic type for the text and Roman for the mathematics.

The distribution of type sizes for mathematical material was: 9-point, 4 documents (19 percent); 10-point, 11 documents (52 percent); and 11-point, 6 documents (29 percent). Only three publications used a different type size for mathematical presentations than that used for plain text. All publications used the same type size and style for displayed mathematics and mathematics in text. The sample NASA report used the same type size and style (11-point Roman) for plain text, mathematics in text, and mathematics in display.

Two British sources (Chaundy, 1954, p. 23 and Burt, 1959, p. 17) recommended 11-point type with 1 or 2 points of additional leading for text composition containing mathematics. Two American authorities (William Byrd Press, 1954, p. 41 and Swanson, 1971, p. 15) recommended 10-point type with 2 points of extra leading. These differences in recommendations may be the result of differences in geographic availability of foundry matrices with large enough sorts.

Survey publications with mathematics in the text used an average of 145 percent additional leading. This compares with an average of 125 percent additional leading for the overall survey. There was an even more substantial difference when typeset reports containing mathematics were compared with typewritten reports containing mathematics. The typeset publications used an average of 90 percent additional leading compared with 175 percent for typewritten reports.

The NASA Publications Manual 1974 did not provide any guidance in regard to leading. The sample NASA report used two different leadings throughout the text. Successive lines of plain prose used nine percent additional leading (1 point). Lines which contained mathematics were followed by 64 percent additional leading (the usual 1 point of interline lead plus 6 extra points).

Analysis of the survey indicated that additional leading is commonly used for text containing mathematical notation. As long as this is done consistently throughout a publication, the adverse effect on legibility is relatively small. However, the practice of varying leading within a report to accommodate lines containing mathematics should be avoided (Chaundy, 1954, p. 26 and Swanson, 1971, p. 16). Not only is it considered bad style, but it seriously detracts from the legibility of the text because the reader's eyes have to make constant vertical and horizontal readjustments in order to find the next line of text.

The major cause of varying leading within a report is the presence of stacked fractions in the text. Literature sources (Strawhorn, 1978, p. I.4.5.1; Chaundy, 1954, p. 27; and Swanson, 1971, p. 16) recommended that mathematics in text should be linear. Chaundy (1954, p. 26) stated that linear arrangements of mathematics are more legible, and research by Tinker (1926, p. 465) confirmed this opinion.

Stacked fractions of the form $\frac{a}{b}$ can be expressed linearly as a/b by use of the solidus (/) or as ab^{-1} by use of the negative exponent (Swanson, 1971, p. 16; Chaundy, 1954, p. 26-27; and William Byrd Press, 1954, p. 32, 35).

Swanson (1971, p. 24) stated that radical signs should be avoided whenever possible. She and Chaundy (1954, p. 29) advocated substitution of fractional exponents in the form $a^{1/n}$ for roots of any power.

Seventy-six percent of the survey publications containing mathematics in the text used the solidus to eliminate stacked fractions. No roots of any form were located in the textual passages of these publications; therefore, it was not possible to assess the usage of fractional exponents to replace radicals in the text.

Oxford University (Chaundy, 1954, p. 29) and the American Mathematical Society (Swanson, 1971, p. 16) recommended that the solidus, negative exponents, and fractional exponents be used in displayed mathematics as well as mathematics in the text to replace fractions and roots.

Figure 15 shows the percentages of survey documents which used the solidus and fractional exponents in displayed mathematics. Almost half (45 percent) used the solidus; 35 percent used fractional exponents. A majority of reports published by government agencies and of ABDEN reports employed both conventions.

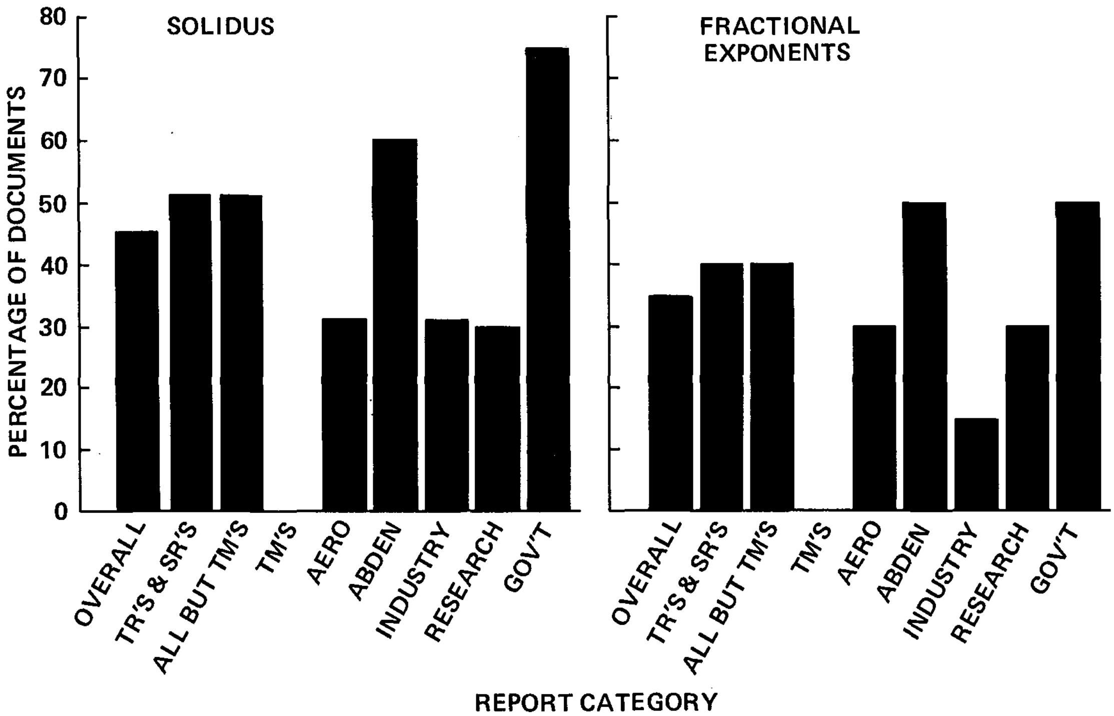

Figure 15. Use of solidus and fractional exponents in displayed mathematics of survey documents

The solidus was not used to replace stacked fractions in the NASA sample report although stacked fractions were present both in text and in display. The NASA Publications Manual 1974 did not include any references to use of the solidus, negative exponents, or fractional exponents for mathematical expressions either in text or in display. The sample NASA report did not contain any roots; therefore, use of fractional exponents to replace radicals in text or display could not be assessed. No data were collected on the use of negative exponents in the survey or in the sample NASA report.

Typography of tables. The majority of the survey publications containing tables did not group rows horizontally; although the practice was used by 29 percent of the overall survey and 38 percent of the technical and scientific reports with tables, as illustrated in Figure 16.

Literature sources, on the other hand, advocated this practice. Chaundy (1954, p. 68-69) recommended placing rows into horizontal groups of five, separated by additional leading. Tinker (1954, p. 442 and 1963, p. 208) produced experimental results which confirmed that grouping into sets of five or ten entries increases the legibility of tables.

The NASA Publications Manual made no mention of the practice of grouping in tables. The sample NASA report did not contain any tables.

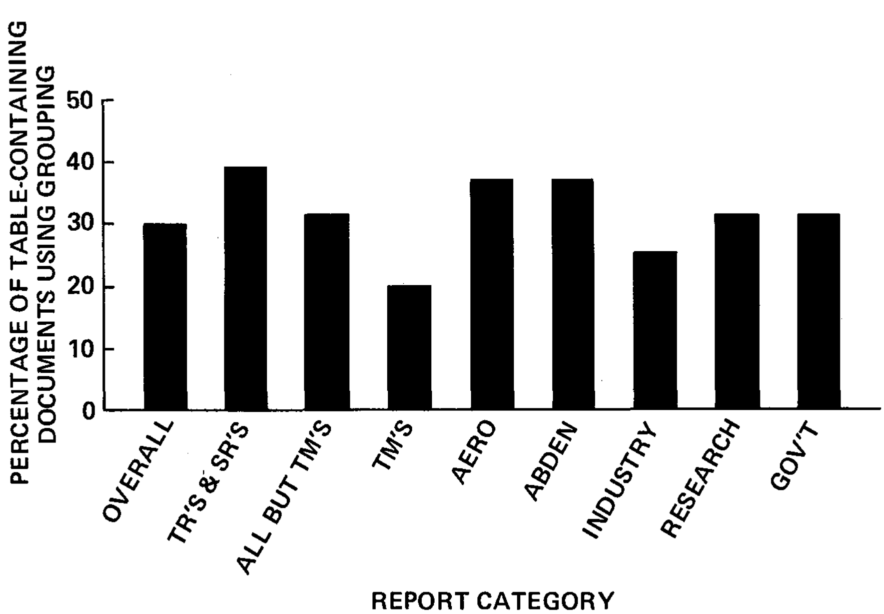

Figure 16. Use of horizontal grouping (rows grouped in sets of 5, 8, or 10 entries) in survey documents containing tables

As a result of his investigations of the legibility of tables, Tinker (1954, p. 442 and 1963, p. 205, 208) concluded that an excessive number of columns would hinder legibility. Ten was the average and eight was the median for the largest number of columns in survey tables. The NASA Publications Manual did not discuss an acceptable range of columns in tables.

Typography of displayed elements. Data were recorded and analyzed for four displayed elements of the text. The analysis is presented for the cover, title page, legends and captions, and headings.

Cover. - Figure 17 shows the relative use of Roman and Gothic type by survey documents for the title on the cover. Seventy-five percent used Gothic type as did a majority of every document category. No experimental findings or prescriptive recommendations could be found to support a hypothesis that either Roman or Gothic type is superior for displayed elements in regard to visibility, perceptibility, or legibility. The NASA sample report used a Roman type face for its cover

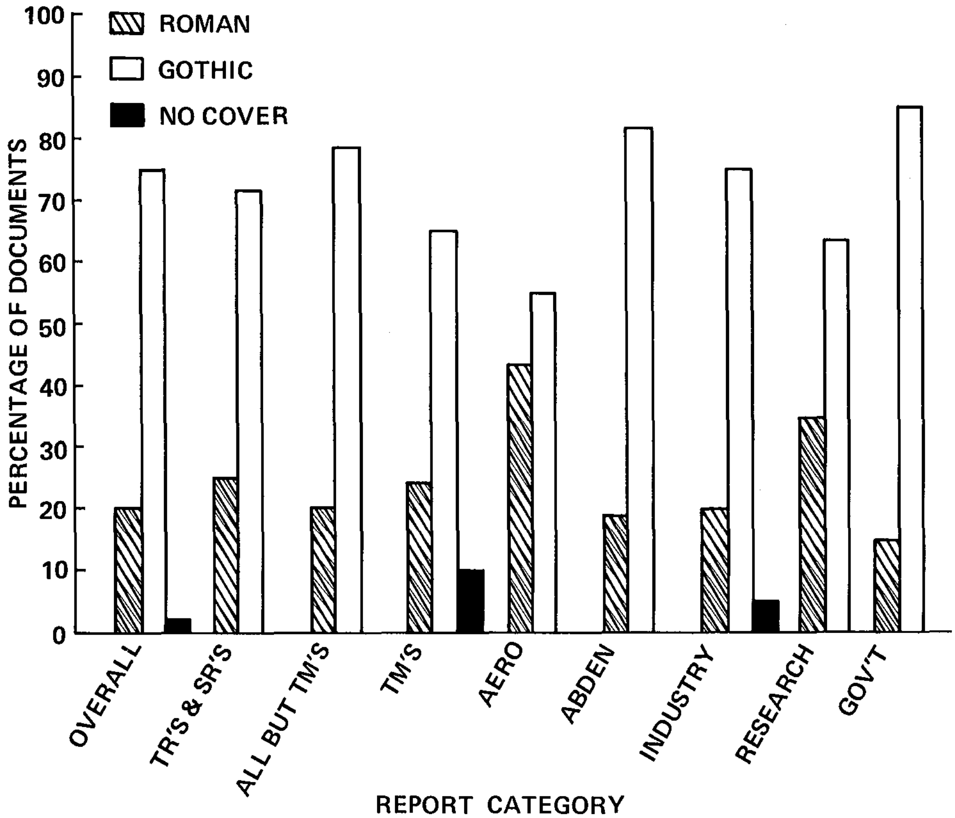

Figure 17. Type styles used by survey documents for the title on the cover

title. NASA guidelines provided no information on cover typography, presumably because cover pages are not prepared by authors.

Figure 18 shows the analysis of the survey publications regarding the use of all capitals versus upper and lower case type for the title on the cover page. There were no clear trends, although upper case was used more often in the overall survey.

The literature was mixed in opinion on this subject. Poulton (1970, p. 209) recommended that all upper case type be eliminated in nearly every display situation. His recommendation was based on four different legibility studies by Tinker, Brown, and himself. Bain (1970, p. 21) and Hvistendahl (1961, p. 227) agreed that all initial capital displays are to be avoided as archaic and less legible.

While acknowledging the difficulty of reading large blocks of copy in all capitals, Bain (1970, p. 24) advocated the use of all capitals in display if the copy is not excessively long. He pointed out that each arrangement can confer certain qualities that the other cannot. Capitals reinforce "monumental, formal and authoritative" qualities, while lower case arrangements are more informal and humanistic. As a purely practical consideration, Bain stated that lower case is more economical if width is a consideration for the arrangement of type; while the use of all capitals is more economical if the depth of the arrangement is critical. NASA used an upper and lower case type with all initial capitals for the title on the cover page.

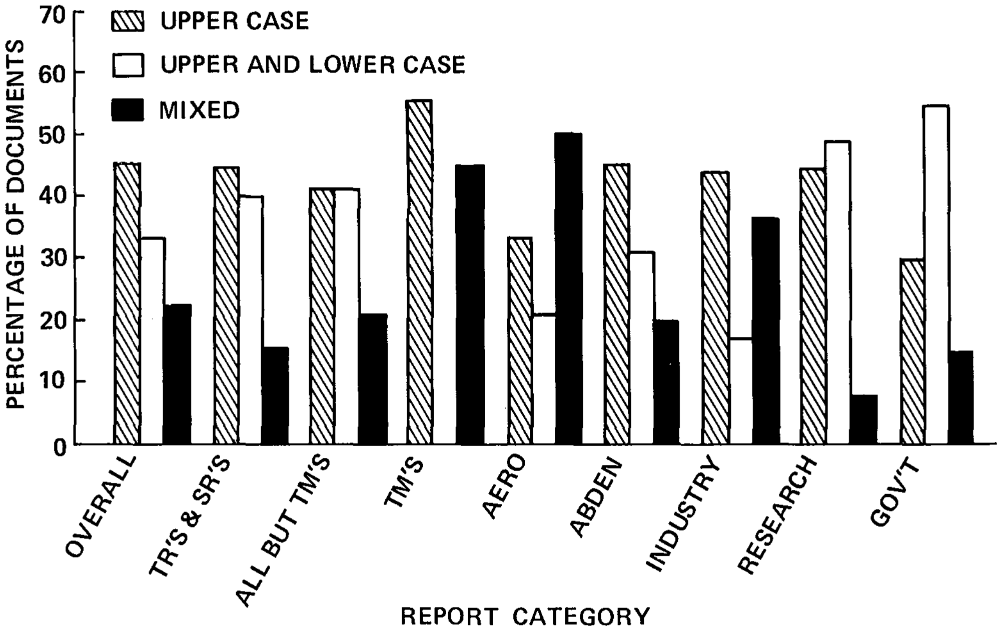

Figure 18. Use of all capitals versus upper and lower case for the titles on cover pages of survey documents

The mean type size for titles on cover pages in the survey was 25 points. Twenty-one points was the median value. NASA used 21 points for the title on the cover of the sample report.

Between one and six different type sizes were used for the cover elements of the survey publications. Most documents used two, three, or four sizes, as shown in Figure 19.

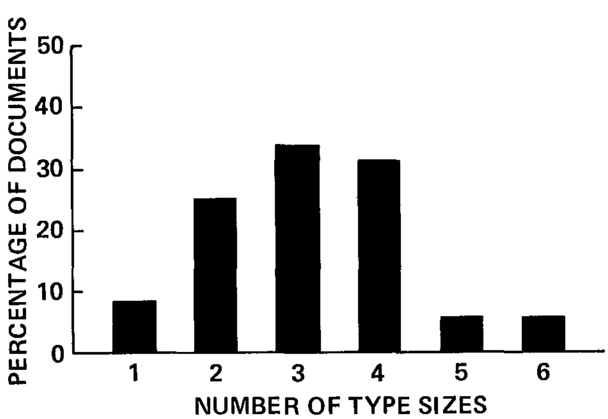

Figure 19. Number of type sizes on covers of survey documents

Bain (1970, p. 26) said that covers may become monotonous if there is no variation in type size and that variety of size makes it easier for the prospective reader to utilize the information on the cover. Tinker and Paterson (1946, p. 637), on the other hand, found that too much variation in type size and style can impede the reader. The NASA sample report used four type sizes on the cover.

Table Y shows the relative rankings for the type size of the elements appearing on the covers of survey publications. The elements are listed in order of decreasing size. The element with the highest average ranking relative to other elements was the title. The publisher had the second highest size ranking. The date, on the average, had the smallest size rating. The relative sizes of elements on NASA's sample report cover are also shown in Table Y. NASA used the largest type for the publisher and the second largest type for the title.

TABLE Y

Relative Size* of Cover Elements in the Survey Reports

Element	n	Mean size ranking in survey reports	Relative size ranking on NASA report cover
Title	45	1.60	2
Publisher	43	1.81	1
Sponsor	34	1.97	-
Subtitle	10	2.40	-
Author	33	2.70	4
Reference No.	32	2.90	3
Date	26	2.96	4

*1 = largest; 7 = smallest

Cover elements in the survey reports were also ranked by relative position on the page (1 = top; 7 = bottom). Table Z shows the mean rankings and indicates that reference number had the highest average positional ranking, and title had the second highest average ranking. The date, on the average, ranked in the lowest position. NASA's positioning of the cover elements is also shown in Table Z. NASA's practice of placing the reference number in the uppermost position and the title in second position was the same as the average practice in the survey documents. The title and subtitle showed the least variation in both size and placement of the cover elements in the survey documents.

TABLE Z

Relative Position* of Cover Elements in the Survey Reports

Element	n	Mean position ranking in survey reports	Relative position ranking on NASA report cover
Reference No.	36	1.83	1
Title	49	2.02	2
Subtitle	10	3.10	-
Author	36	3.19	3
Publisher	47	3.55	5
Sponsor	34	3.76	-
Date	29	3.79	4

*1 = First or uppermost position on cover; 7 = lowest position

Bain (1970, p. 28) stated that size, grouping, and position can be used to organize the information on the cover according to its importance. He suggested that elements such as the title be large and high and that the publisher's imprint be small and low on the page.

Title page. - Survey data on the type style used for the title on the title page are shown in Figure 20. Gothic type was used more often in the overall survey, but Roman type was used by more documents in the technical report, aero, ABDEN, and research categories and by NASA.

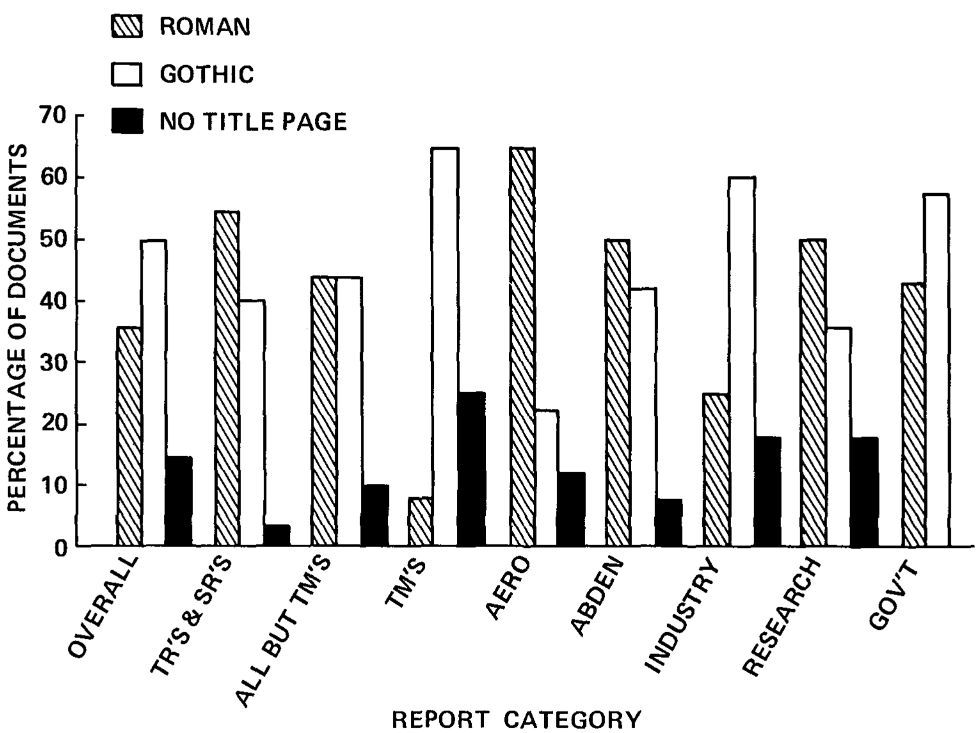

Figure 20. Type styles used by survey documents for the title on the title page

The survey used up to six type sizes for the different elements on a title page; however, the vast majority used between one and four sizes, as shown in Figure 21. Technical manuals and reports from industry tended to use more type sizes on title pages than did other document groupings. NASA employed four sizes for title page elements in the sample report. The NASA Publications Manual did not discuss typography of the title page.

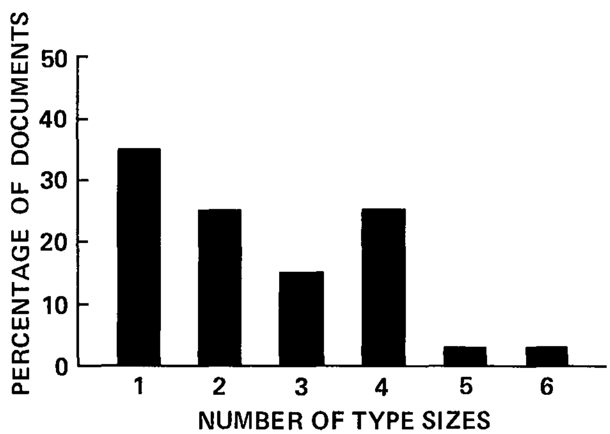

Figure 21. Number of type sizes on title pages of survey documents

The general findings of Bain (1970, p. 26) and Tinker and Paterson (1946, p. 637) regarding composition of the cover may also be applied to the title page.

Relative rankings for type size and position of elements on the title pages of survey documents are listed in Tables AA and BB, respectively. NASA's ordering of the elements on the title page was the same as the average relative positioning by the survey. In regard to size prominence, NASA used larger type for the publisher/sponsor than for the title. This practice varied from the survey results in which the document title had the largest mean size ranking.

TABLE AA

Relative Size* of Title Page Elements in the Survey Reports

Element	n	Mean size ranking in survey reports	Relative size ranking in NASA report
Title	45	1.60	2
Subtitle	9	2.33	-
Sponsor	23	2.43	1
Publisher	25	2.48	1
Reference No.	23	2.60	3
Date	24	2.70	-
Author	28	2.71	4

*1 = largest; 7 = smallest

TABLE BB

Relative Position* of Title Page Elements in the Survey Reports

Element	n	Mean position ranking in survey reports	Relative position ranking in NASA report
Reference No.	37	1.97	1
Title	43	2.05	2
Subtitle	11	2.90	-
Author	43	3.37	3
Date	40	3.82	-
Publisher	41	3.90	4
Sponsor	38	4.50	4

*1 = top, 7 = bottom

In both the cover and title page analyses, rankings for the title and the subtitle had the smallest standard deviations, indicating less variation in size and placement as compared with other elements.

Legends and captions. - Legends (titles) were used in 41 of the 43 survey documents containing tables. No publications used table captions (additional explanatory material). Of the 47 survey documents with figures, 45 used figure legends, 9 used figure captions along with the legends, and 2 documents employed neither legends nor captions for figures. All the captions were in upper and lower case. In five reports, the captions were typewritten; in four, they were typeset.

The data from the survey showed that both table and figure legends tended to be typeset rather than typewritten. The majority of documents in the overall survey and in all categories except aero (and technical reports in the case of figures) used typeset legends, as illustrated in Figure 22.

Figure 23 shows that, for the overall survey, the majority of documents set figure and table legends in upper and lower case rather than in all capitals. However, table legends were set in all capitals more frequently (40 percent of documents) than figure legends (25 percent of documents). In no document category did the use of all capitals prevail for figure legends, but slightly more than half of the technical reports, aero, ABDEN, and industry categories used all capitals for table legends.

The sample NASA report had no tables and thus no table legends or captions. The figure legends were typeset in upper and lower case. No figure captions were present. The NASA Publications Manual (p. 35-38, 43) recommended all capitals for table legends and upper and lower case for figure legends.

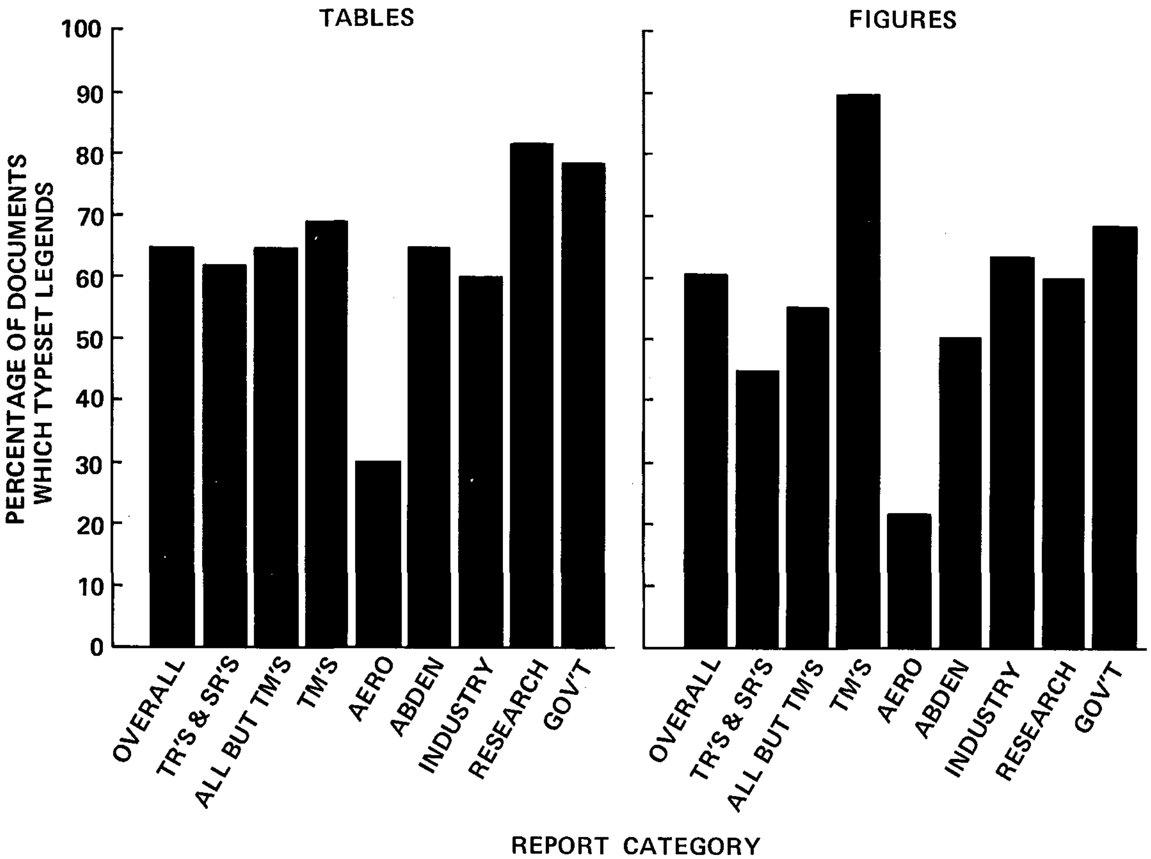

Figure 22. Percent of survey documents which typeset legends

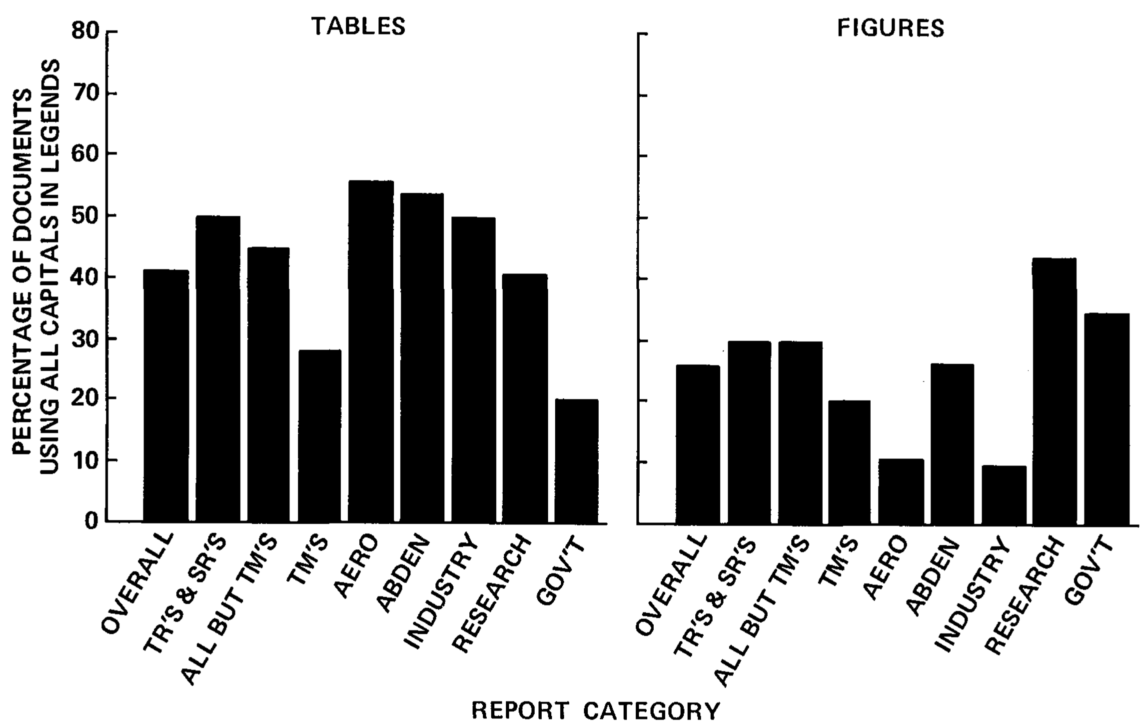

Figure 23. Use of all capitals in legends of survey documents.

Headings. - Authorities agreed that headings need to be set off from the text and that different levels of headings need to be distinguished from one another (Poulton, 1970, p. 209). Williamson (1966, p. 18, 139) and Morison (1951, p. 12) indicated that this could be accomplished by use of a different type style and/or size, all capitals, italics, underlining, boldface, relative positioning, or any combination of these methods.

Figure 24 shows the frequency of occurrence of the various heading levels in the overall survey and various categories. The maximum number of heading levels in any survey document was five. All the documents contained at least two heading levels, and 80 percent used a third level. Forty-one percent of the survey reports contained fourth level headings, but only 5 percent used a fifth level. With minor exceptions, the same general trend persisted throughout the various categories. The sample NASA report contained three heading levels. The NASA Publications Manual 1974 (p. 14) stated that headings are preferably limited to three levels, but up to six levels can be used as necessary.

Also shown in Figure 24 is the relative use of Gothic and Roman type styles for the heading levels by various report categories. The overall survey was about evenly divided in the use of the two type styles. Technical manuals, government reports, and industrial reports used Gothic more frequently than Roman for all heading levels. Other categories used Roman more often. NASA used Roman type for headings in the sample report. The NASA Publications Manual did not discuss type style or size of headings, but examples were in the same type size and style for all levels.

For the overall survey, headings decreased in average size through the first three levels, as shown in Table CC. The largest change occurred between first and second level headings. NASA report headings were the same size for all three levels.

TABLE CC

Type Sizes of Headings in Survey Reports

Heading level	n	Mean type size (points)	Decrease in size from next higher level (points)
First	50	14.60	----
Second	50	12.90	1.70
Third	40	12.25	0.65
Fourth	21	12.25	0.00

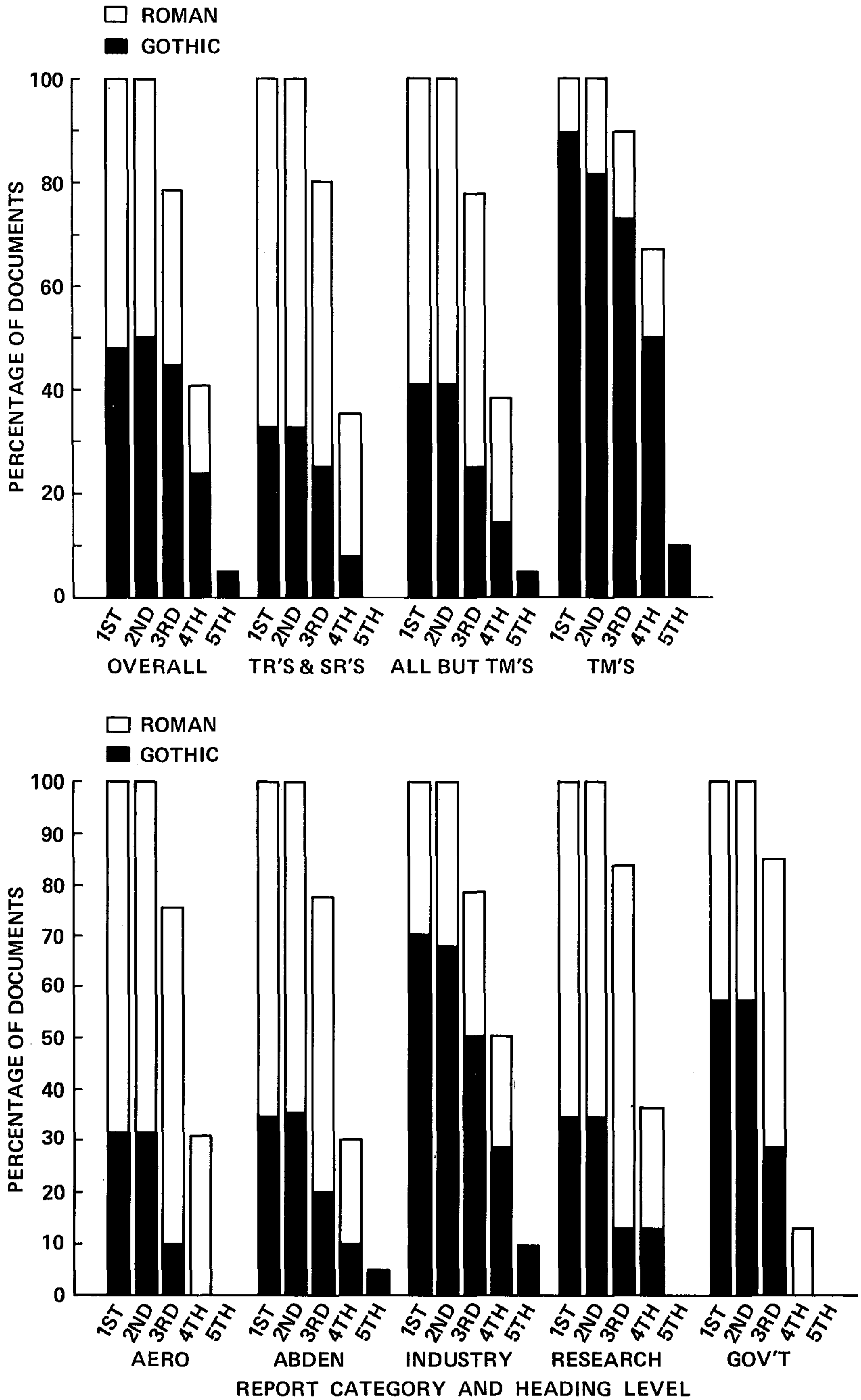

Figure 24. Frequency of occurrence and type style used for heading levels in the survey reports

Figure 25 shows the mean type sizes for heading levels by various document categories. Technical manuals and reports from industry decreased the type size through the third level of headings; however, other categories generally did not change type size significantly after the second heading level.

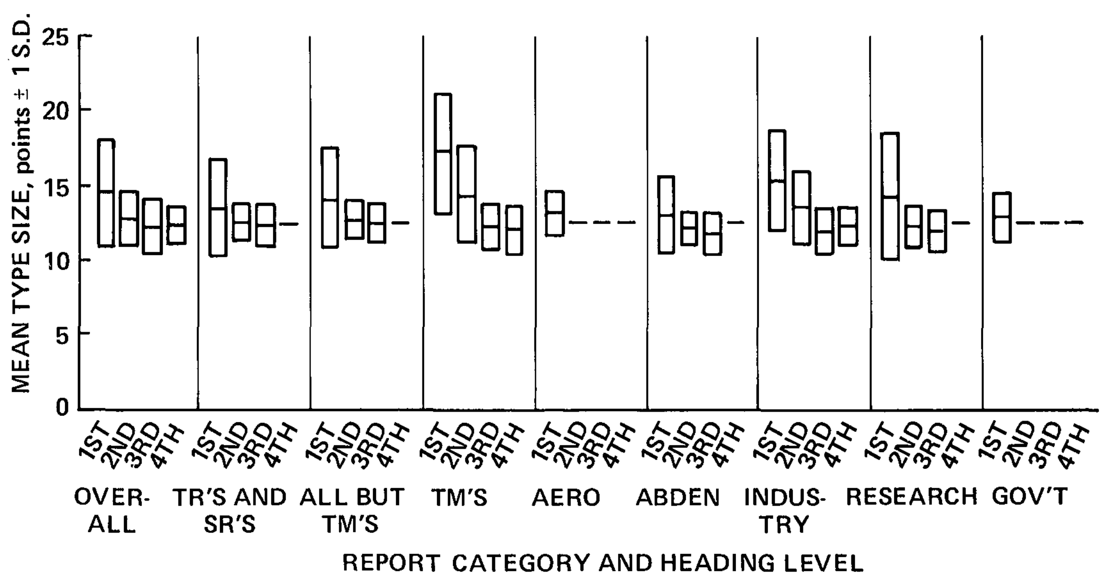

Figure 25. Mean type sizes of heading levels in the survey reports

The majority of the overall survey and all categories except technical manuals and reports published by industrial organizations used the same type size, style, and weight for headings as was used for the text. Figure 26 illustrates the data tabulated for this parameter. It is most likely that reports using the same type for text and headings were prepared by some type of "strike-on" typesetting system (typewriter, word processor, computer wheel, or chain printer). Technical manuals and reports from industry tended to use more sophisticated typographic techniques. NASA employed a "strike-on" composing system for the sample report.

Shown in Figure 27 is the percentage use of all capitals versus upper and lower case type for all heading levels in the survey. The ratio of all capitals to upper and lower case was highest in the first level of headings and decreased stepwise in the second and third heading levels. This trend was present in the overall survey and in all document categories. No clear tendency was observed for the fourth and fifth heading levels. Seventy-five percent of the survey used all capitals for first level headings, and fifty percent used all capitals for second level headings.

The sample NASA report used all capitals for the first two heading levels and upper and lower case for the third heading level. Although consistent with survey practice, this usage did not follow the guidelines of the NASA Publications Manual (p. 14) which called for all capitals for the first level heading and upper and lower case for the second and third level headings in reports containing three heading levels. An alternate sequence was suggested when more than three heading levels were necessary. In this sequence, the first and second heading levels were all capitals, and the third through sixth heading levels were set upper and lower case.

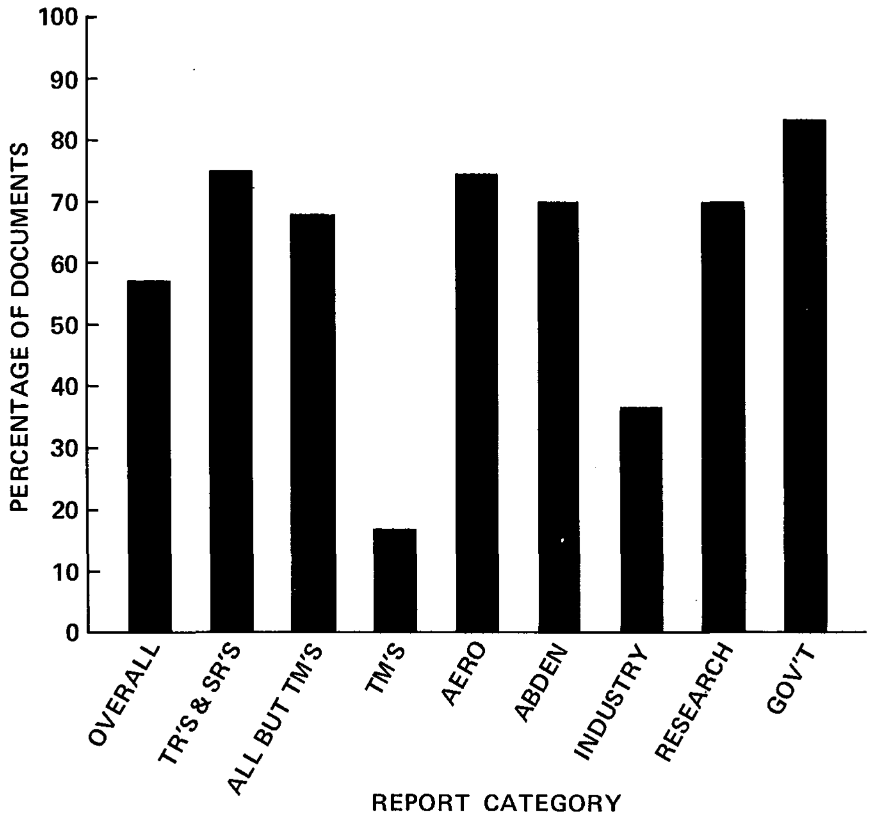

Figure 26. Percent of survey reports in which headings were the same type size, style, and weight as the text

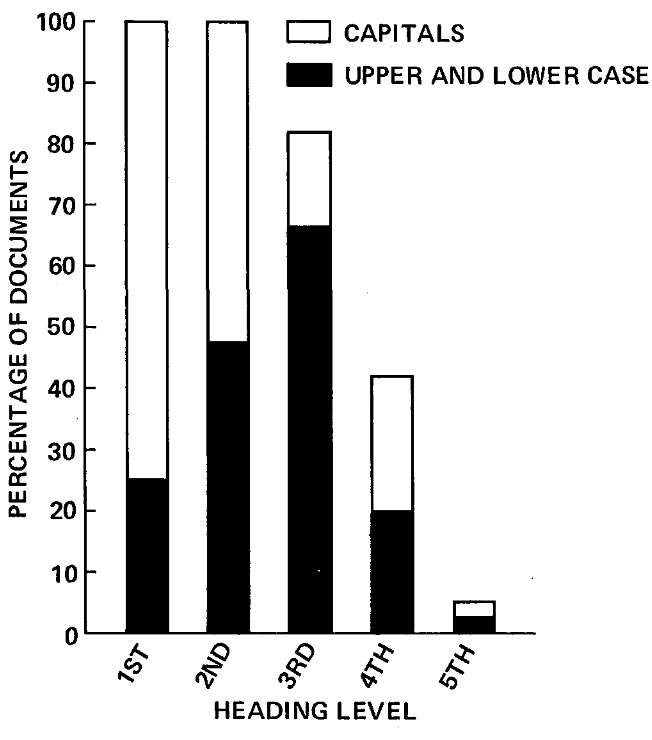

Figure 27. Use of capitals compared with upper and lower case type for headings in the survey reports

Italic headings were used very infrequently in the survey, and with no clear pattern. (See Figure 28.) Neither the sample NASA report nor the NASA Publications Manual mentioned or used italic or boldface type for headings.

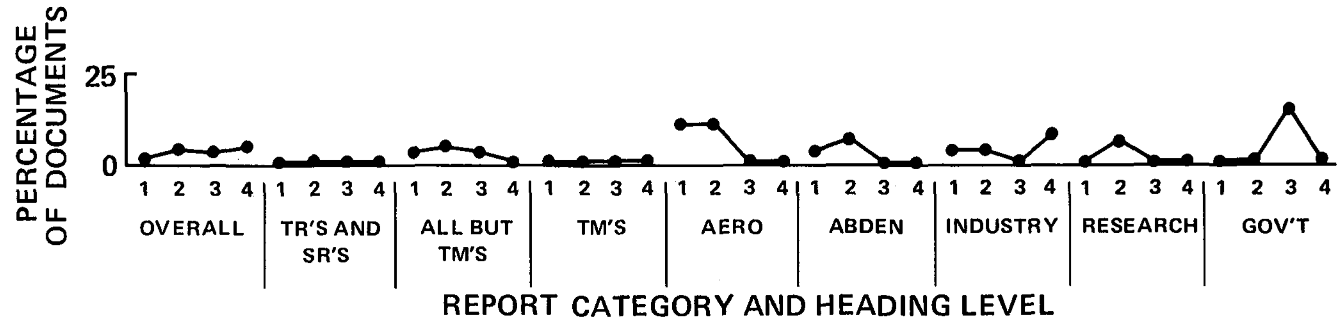

Figure 28. Use of italic type in survey report headings

Boldface type was used fairly often (approximately 45 percent of documents) for first and second level headings in the survey, as shown in Figure 29. Technical manuals and reports from industry again stood apart from other survey publications in that boldface major headings were used by a majority of documents in these categories (85 percent of technical manuals and 65 percent of reports from industry). When technical manuals were excluded, the use of boldface first and second level headings was only 35 percent in the remaining documents. In the overall survey and in most document subsets, the use of boldface headings declined markedly after the second heading level. Glanville (1946, p. 235) recommended, after conducting experiments, that a larger size and boldface version of type be used for headings if access (visibility) is a criterion.

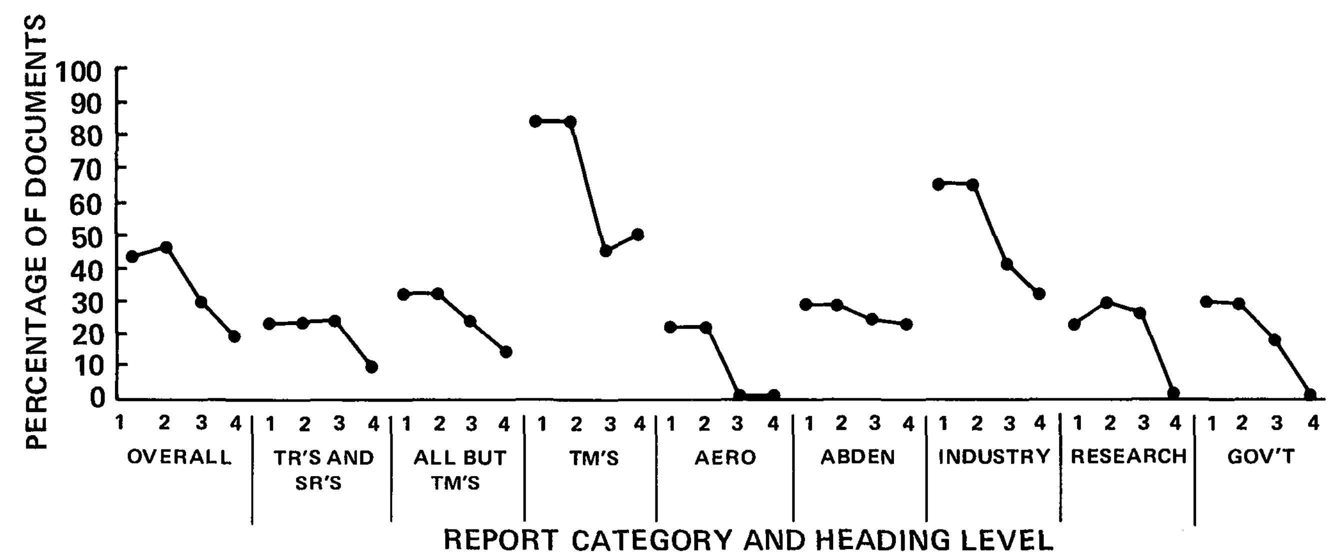

Figure 29. Use of boldface headings in the survey reports

In the survey, underscoring was generally used with increasing frequency as heading levels decreased in significance. (See Figure 30.) Technical manuals did not follow the same pattern as other survey documents. This category used virtually no underlining for headings, except that about 10 percent underlined second level headings. When technical manuals were excluded, 20 percent of the remaining survey documents underscored first level headings; 35 percent underscored second level headings; 50 percent underscored third level headings; and 60 percent, fourth level headings. Figure 30 illustrates the survey findings in regard to underscoring.

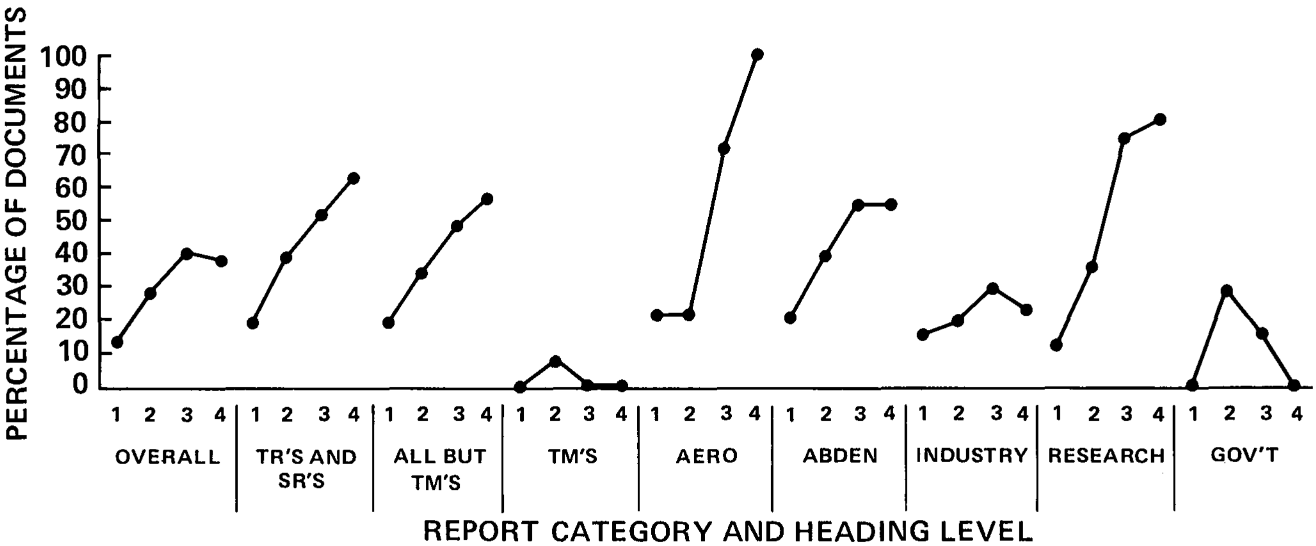

Figure 30. Use of underscored headings in the survey reports

The NASA Publications Manual (p. 14) recommended that only the third level heading be underscored in the three-level sequence, and the sample NASA report followed the guidelines. For the six-level sequence, levels one, three, and five were shown underscored.

Williamson (1966, p. 139) found that the general practice in publishing was to place headings in order of importance first at the center of the page (cross heading), then aligned with the left-hand margin above the text (shoulder heading), and finally run in with the text (side heading). The majority of reports in the survey followed the general center to left placement trend from major to minor headings. (See Figure 31.) The same pattern existed in all document categories. The sample NASA report used centered headings for all three heading levels, a practice at variance with the guidelines in the NASA Publications Manual (p. 14). For the three-level sequence (which should have applied to the sample report), the manual centered the first two levels and used a run-in heading for the third level. The six-level sequence centered the first four heading levels and used run-in headings for the fifth and sixth levels. NASA did not use or recommend any shoulder headings.

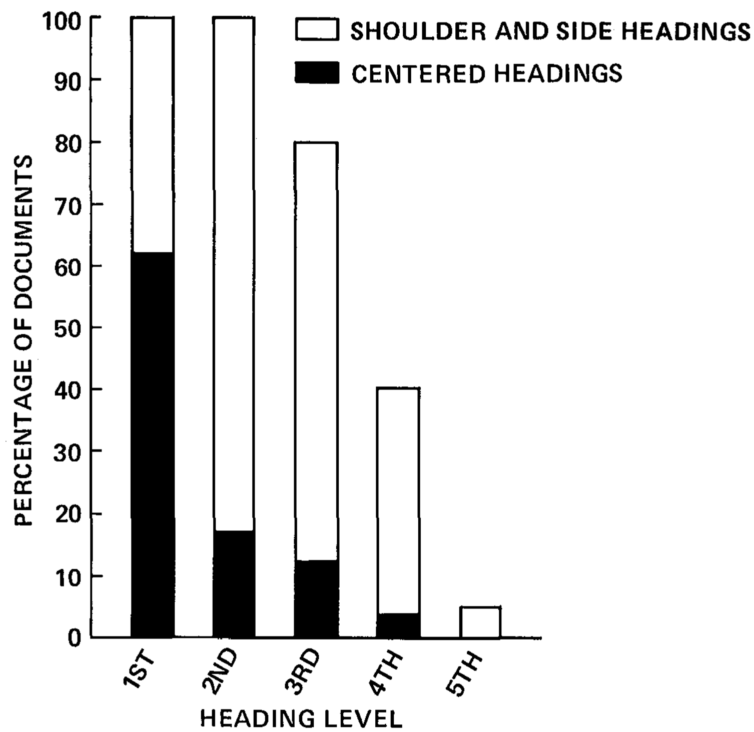

Figure 31. Heading placement in the survey reports

Graphic design. Data were recorded and analyzed for various aspects of graphic design and layout. The analysis is presented for line depth, character density, image area, gutter margins, folio placement, running heads, single and multiple column layouts, orientation of tables and figures, and color in figures.

Graphic design, or layout and imposition of printed material on the page, can affect both the economy of production and distribution as well as the facility of use by readers. Imposition is the placement of blocks of copy on a page and encompasses the dimensions of margins around and between them. Layout is the positioning of the report's elements (e.g., folios and running heads).

According to Rehe (1974, p. 14) and Baudin (1972, p. 274), a report's graphic design presents a message about the value of the report, its topic, the publishing organization, and the readers who use it. Hartley (1974, p. 20) stated that page shape, proportion, and size act as constraints on what is placed upon the page. Mathes and Stevenson (1976) stated that graphic design can enhance or impede access to the different types of information a report contains.

Table DD summarizes the average values of four graphic design variables in the survey and its subcategories. These data are discussed in the sections which follow.

TABLE DD

Average Values of Selected Graphic Design Variables in the Survey Reports

Survey category	Lines per page	Characters per page	Image area, % of page area	Gutter margin, % of page width
Overall survey	49	4060	64	10.0
TR's & SR's	46	3660	63	10.5
All but TM's	47	3860	64	10.2
TM's	53	4670	66	9.5
Aero	38	2940	64	10.4
ABDEN	47	3820	64	9.8
Industry	49	4180	66	9.5
Research	49	3920	61	10.4
Gov't	52	4500	68	9.5
Typeset	--	4910	65	9.2
Typewritten	--	3260	64	10.8
NASA sample report	39	3276	70	6.0

Line depth. - No data were found in the literature regarding the number of lines per page that would enhance or degrade the effectiveness of a report. As shown in Table DD, the survey documents contained an average of 49 lines per page. NASA's sample report contained 39 lines per page and thus was significantly below the survey average. The additional leading inserted after mathematics in the text of the sample report affected line depth. The NASA Publications Manual did not provide any limits or recommendations for number of lines per page.

Figure 32 shows the frequency distribution of line depth in the survey. Line depths in the 50-to-59 line per page increment occurred most commonly.

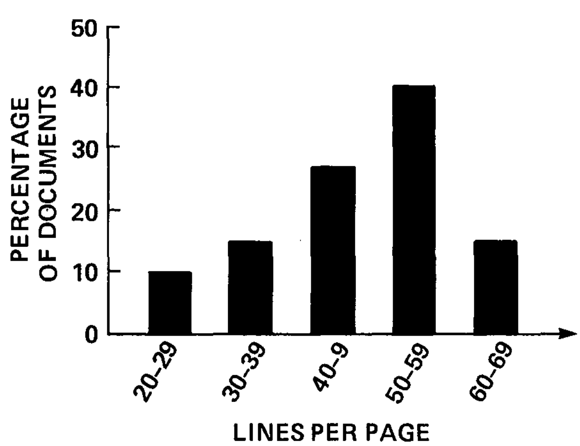

Figure 32. Distribution of line depths in the survey reports

Character density. - The mean character density for the survey was 4060 characters per page. No recommendations on character density were found in the literature. NASA's sample report contained 3276 characters per page. The NASA Publications Manual did not contain any recommendations on this subject.

Figure 33 shows the frequency distribution of character density in the report survey in 1000-character intervals. More documents had character counts in the 3000-3999 range than in any other interval. Typeset reports tended to have higher character densities than typewritten reports.

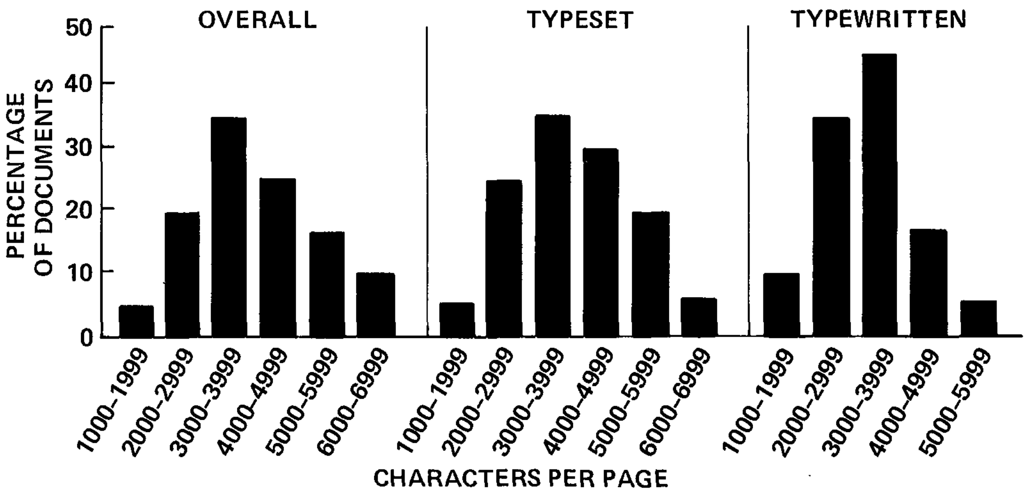

Figure 33. Character densities in the survey reports

Image area. - A rule of thumb in publishing is that textual material should occupy about 50 percent of the page. Tinker (1963, p. 110, 113-114) surveyed 928 subjects and found that 90.7 percent favored margins which met the 50 percent rule of thumb. The reasons were legibility (62 percent), aesthetics (27 percent), and tradition (1.7 percent). The 9.3 percent who did not favor the 50-percent guidelines for image area gave as their reason increased cost. Soar's survey of psychology journals published in 1920 found an average of 51.5 percent text, with a range of 44 to 69 percent text. His survey of 1950 journals showed an average of 60 percent text, with a range of 52 to 70 percent (Soar, 1951, p. 66). Most of this increase occurred during periods of material shortages, particularly in England during World War II.

In the present survey, the text occupied an average of 64 percent of the page. (See Table DD.) The range among various categories was relatively narrow. Reports published by research organizations comprised the lower limit with 61 percent text. Government reports, at 68 percent text, represented the upper limit. NASA's sample report had 70 percent text and thus was higher than the average for the overall survey and all the report categories.

The NASA Publications Manual (p.7-8) specified a maximum image area of 6-5/8 inches by 8-5/8 inches (57-square-inch area) on an 8-inch by 10-1/2-inch page (84-square-inch area). This is a maximum size-to-page ratio of 68 percent. The sample report with a size-to-page ratio of 70 percent exceeded this limit. As of October 1, 1981, the maximum image area was enlarged to 7-1/8 inches by 9-1/8 inches (65-square-inch area) on an 8-1/2-inch by 11-inch page (93.5-square-inch area). This is a maximum size-to-page ratio of 69.4 percent.

Figure 34 shows the range and frequency of occurrence of image areas in various categories of survey documents. The overall survey contained equal numbers of reports with size-to-page ratios in the 50-to-59 percent, 60-to-69 percent, and 70-to-79 percent increments.

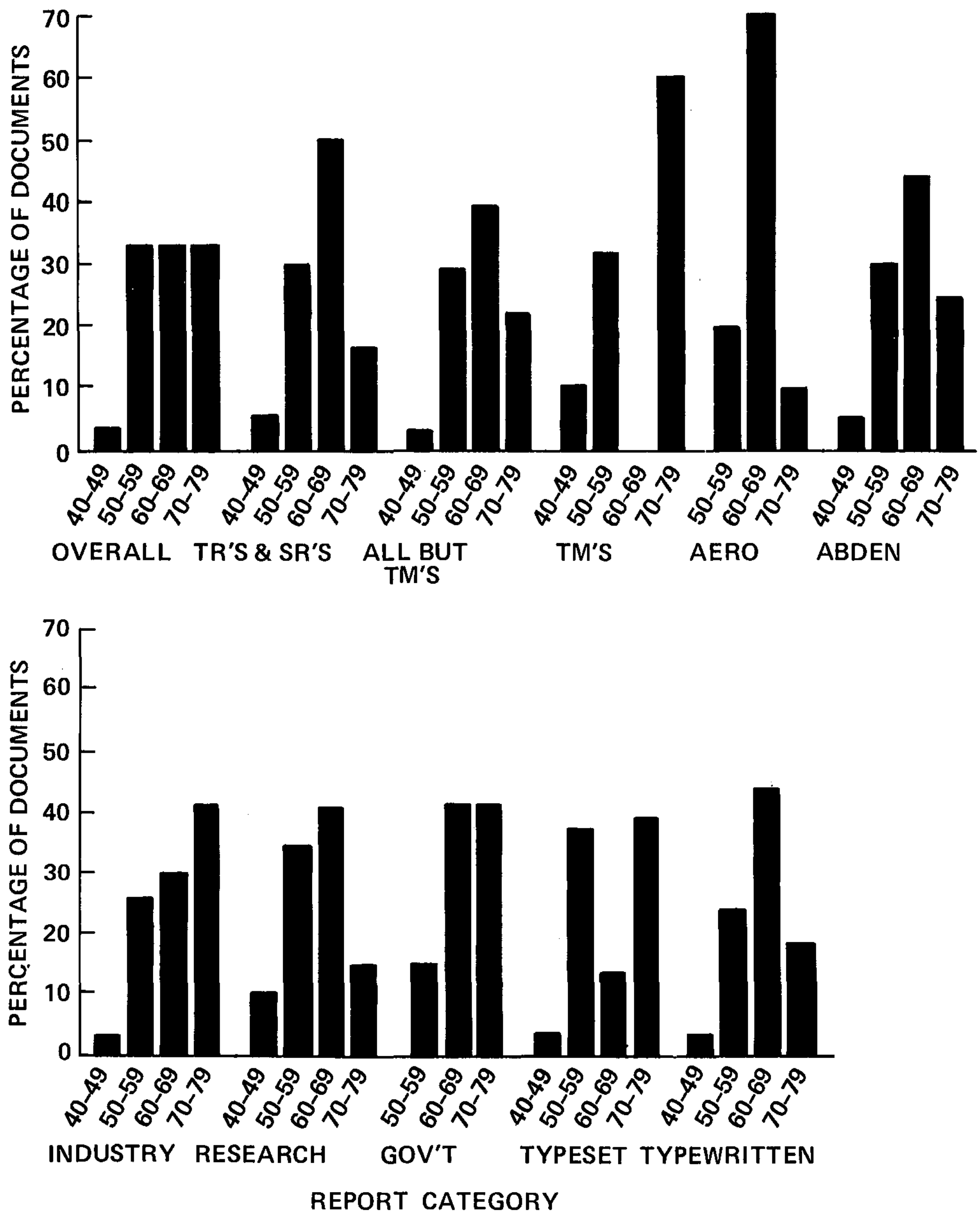

Figure 34. Image area as a percent of page area in the survey reports

Gutter margins. - Tinker (1963, p. 110, 114-115, 126) studied the effects of side margins on legibility. He found no difference in the speed of reading text in unbound documents with 7/8-inch side margins and with no side margins. In bound publications, however, Tinker found that as a page and the type on it approached the gutter margin, the increasing curvature of the page from nearly flat to nearly vertical significantly affected legibility. Burt (1959, p. 15) found that a gutter margin of 17.5 percent of the page width was the one preferred by most readers of both scientific and technical materials. Hartley (1974) noted that proportionally larger gutter margins facilitated the copying, punching, and clipping of material besides improving legibility and congeniality (compatibility).

The survey had an average gutter margin of 10 percent of the page width. Average values for the various categories varied only slightly. (See Table DD.) Individual report gutter margins varied from 4 percent to 19 percent of the page width; however, two-thirds of the individual documents in the survey and in all categories fell within the 6 to 14 percent interval. The NASA Publications Manual did not explicitly state a recommendation for the gutter margin; however, an 8.6 percent value was implied on page 8. In any case, the gutter margin in the NASA sample report was below the survey average of 10 percent, below the averages of all categories, and below Burt's recommendation of 17.5 percent.

Folio placement. - Literature recommendations on folio placement appeared to be based at least partially on assessments of readers' use of page numbers. Williamson (1966, p. 142) and Lee (1965, p. 279) stated that page numbers should be placed on the top side position on the page if the page numbers are necessary for reference purposes. Lee (loc. cit.) found that, as the folio is moved toward the center of the page, it becomes less effective. According to Morison (1951, p. 11), if the reader is not likely to need page numbers, the folio may be placed anywhere on the page. Williamson (1966, p. 143) noted that poor folio placement might cause confusion of page numbers with numerical data in the text.

Table EE shows the survey's placement of folios. In the overall survey and in most document groupings, page numbers were located at the center bottom most frequently. Technical manuals deviated from this preference, with more documents placing page numbers at the side bottom. (Side was defined as the outermost side, away from the gutter margin.) The NASA Publications Manual (p. 8) recommended side bottom placement of folios, and the sample report followed these guidelines.

TABLE EE

Placement of Folios in the Survey Reports

Survey category	Folio placement, percentage of documents			
	Center top	Center bottom	Side top	Side bottom
Overall survey	15	55	7	23
TR's & SR's	17	60	5	18
All but TM's	19	60	5	16
TM's	7	35	9	49
Aero	0	89	0	11
ABDEN	12	77	2	9
Industry	5	59	3	33
Research	31	55	5	9
Gov't	17	40	12	31

Running heads. - Williamson (1966, p. 141) noted the value of running heads for the reader especially if the pages become detached from the publication. As shown in Figure 35, running heads were used by only 20 percent of the survey. They were not used by a majority of any category. Technical manuals, with a 42 percent utilization rate, used running heads with the greatest frequency. The NASA sample report did not use running heads, and the NASA Publications Manual did not discuss their use.

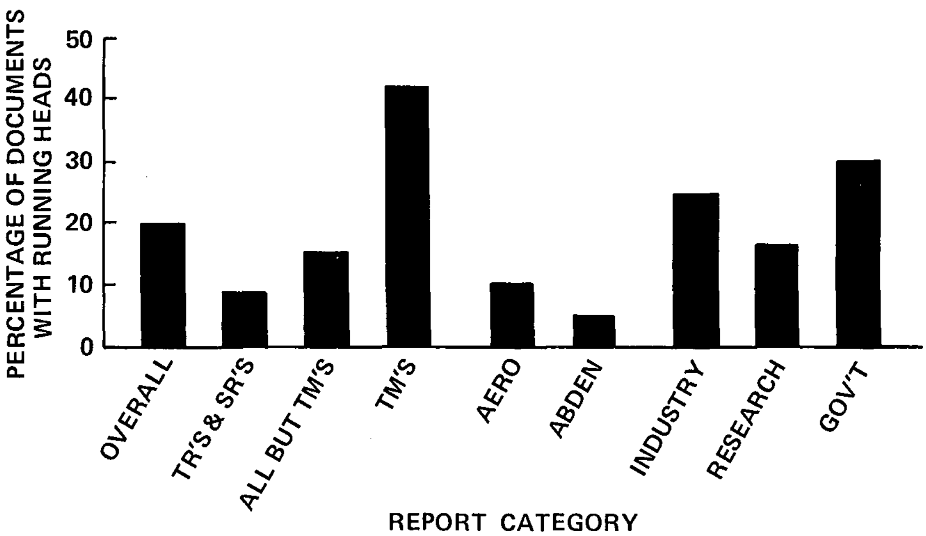

Figure 35. Use of running heads in the survey reports

Single and multiple column layouts. - In Figure 36, the usage rate of single and multiple column layouts in the survey is displayed. Seventy-five percent of the survey used a single column layout. For technical and scientific reports, the rate was 90 percent. Technical manuals employed double column layouts more frequently (42 percent) than any other category.

Tinker (1963, p. 116) listed five advantages of double column over single column layouts: (1) higher character/page density, (2) fewer pages, (3) more logical and economical placement of figures and tables, (4) fewer sideways visuals, and (5) elimination of foldouts and tip-ins. Results of experimental studies by Tinker (1963, p. 118), Foster (Rehe, 1974, p. 50), Poulton (1970, p. 208), and Williamson (1966, p. 117) have led many sources to recommend use of double column layouts in scientific and technical publications for reasons of increased legibility and readers' preference. Soar (1951, p. 65) and Tinker (1963, p. 116) reported a steady increase in the use of double column formats in scientific journals over a 60-year period.

Other researchers have questioned whether multicolumn layouts possess any advantages. Burt (1959, p. 17) felt that double column measures were too narrow for any publication with extensive mathematical material. Kat and Knight (1980, p. 296), Hartley (1974, p. 16), and Burnhill (1976, p. 13, 17-18) demonstrated that the narrow measures encountered in multicolumn layouts retarded the reading rate of scanners and speed readers significantly by as much as 200 words per minute. Hartley (op. cit.) and Burnhill (op. cit.) both recommended, as a result of their experiments, that if a figure is wider than a column, it should be placed at the top or bottom of the page. Burnhill went on to recommend that if more than 50 percent of the figures span more than one column in a multicolumn layout, a single column layout should be used instead.

The sample NASA report employed a single column format. The NASA Publications Manual did not explicitly comment regarding the number of columns on the page; however, sample pages had a single column layout.

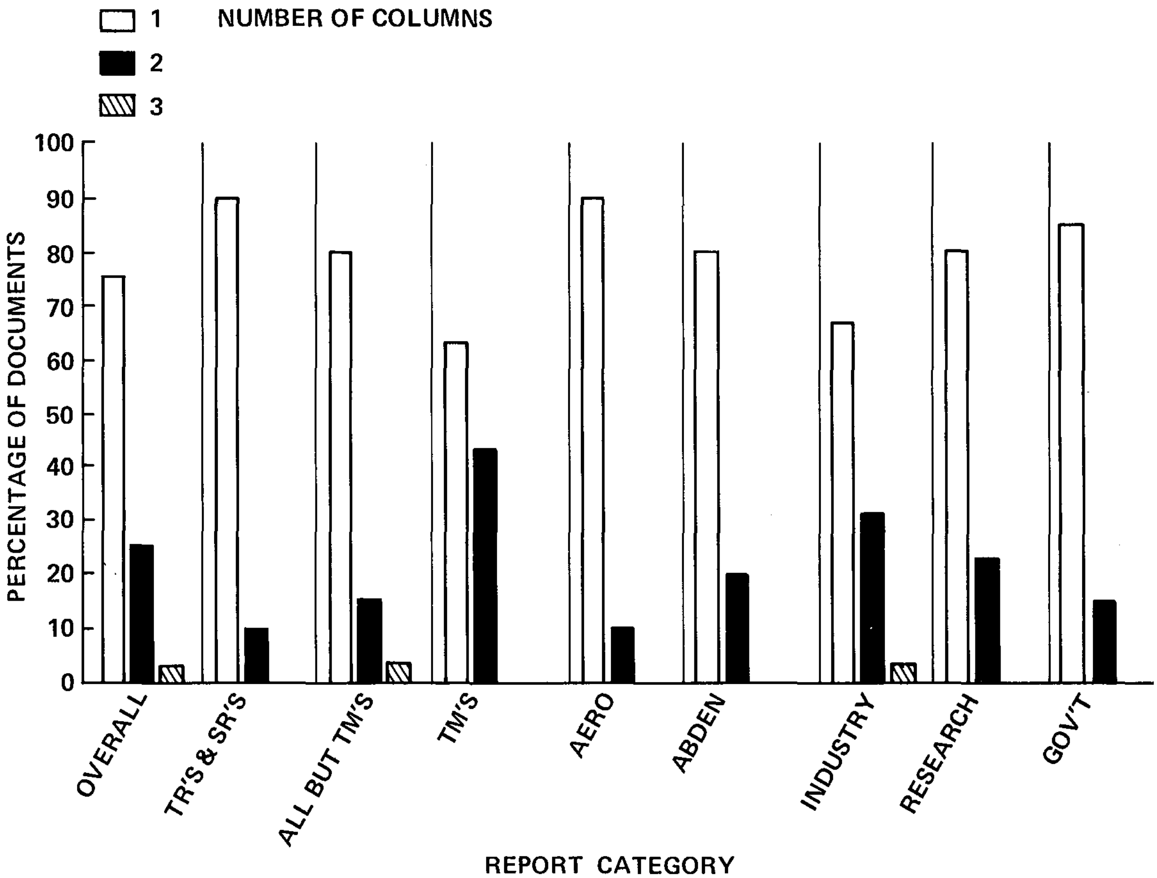

Figure 36. Number of columns in survey document layouts

Orientation of tables and figures. - Literature sources (e.g., Harvill, 1977, p. 17) strongly advocated that figures and tables be aligned with the text so that the reader does not have to rotate the publication to use them. Hartley (1974, p. 20) and Strawhorn (1978, p. I.3.5.2) stated that if there are a large number of tables and figures and it is not feasible to reduce them to fit the page, it may be preferable to alter the format and orientation of the entire publication.

Analysis of the survey showed that these recommendations were not observed in practice. The majority of the survey publications contained one or more tables or figures placed perpendicular to the rest of the text. (See Figure 37.) This observation held true for all survey categories except technical manuals and reports from industry. All government publications had at least one visual placed sideways. Only once had a report format been altered to accommodate oversized tabular material while maintaining text and table alignment.

The NASA Publications Manual (p. 37-38) stated that tables and figures are preferably placed upright on the page, but may be placed sideways. The NASA sample report contained one figure placed sideways.

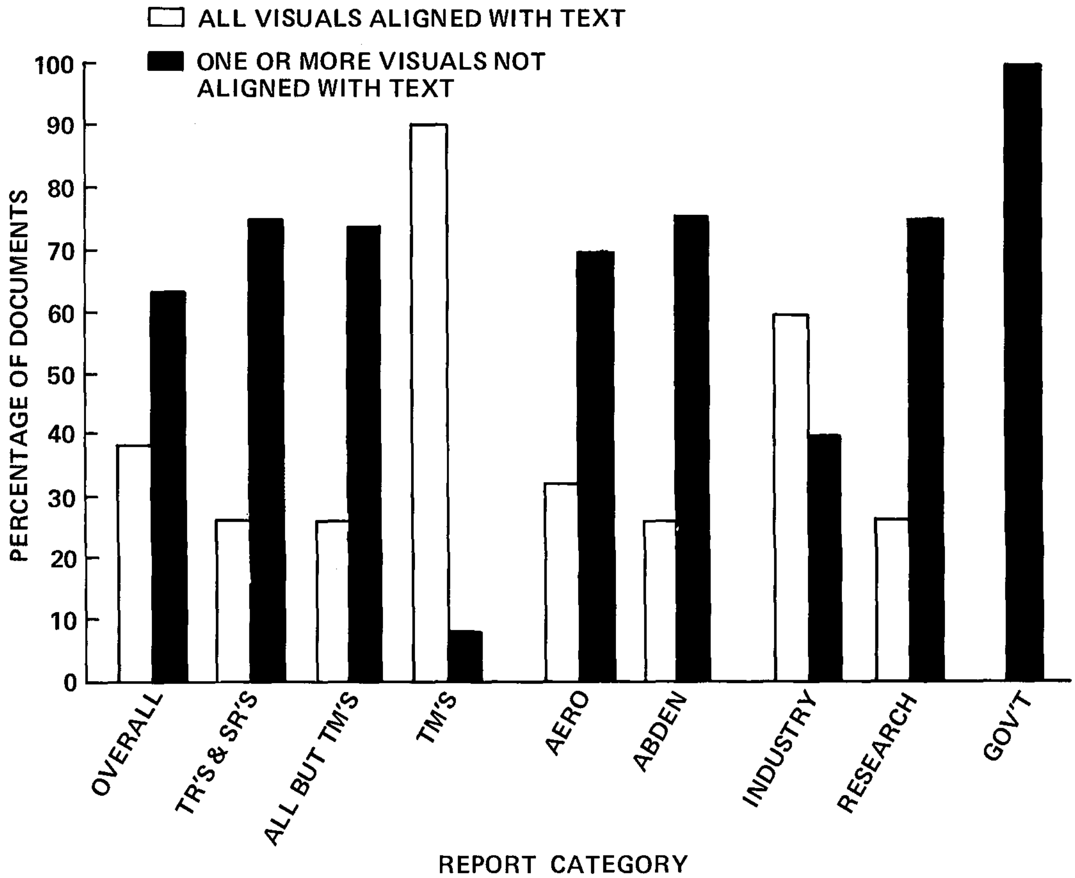

Figure 37. Orientation of tables and figures in the survey reports

Color in figures. - Only two technical reports out of the fifty in the survey used color in figures, and neither was printed. One report used color xerography for presenting information on a strip recorder chart. The other report included photographs of false color computer-generated maps.

In the literature, Harvill (1977, p. 36) proscribed the use of color in figures. Soar (1951, p. 65-66) found that indiscriminate use of color in typographic situations like covers seriously impeded legibility. Schutz (1961, p. 112) found that color could marginally improve the comprehension of well designed black and white figures which made optimal use of pattern and line differentiation.

The NASA Publications Manual (p. 9) stated that multicolor printing is prohibited except for classes of work in which additional colors provide a functional value. Because multicolor printing is costly and slow, justification must be provided and approval obtained prior to any use. The sample NASA report did not employ color.

Physical media. Data were recorded and analyzed for various aspects of physical media. The analysis is presented for paper and ink, binding, and re-imaged reproduction.

The media used to transmit reports can affect the reports' efficacy and efficiency in communicating information. The traditional medium for distributing multiple copies of written information has historically been printing. However, technological developments, especially in computer science and communications, are rapidly altering and reshaping the ways that written information is produced and disseminated. Technical reports are still printed, bound, and distributed; but many readers ultimately use the reports in other forms such as xerographic copy, microfiche-generated copy, digitally-generated copy, or microfiche viewed through a reader. So, in addition to traditional considerations such as paper color and finish, ink color, and method of binding (which are not the same in re-imaged copies as in originals), an analysis of physical media must also take into account the quality of printing in the original documents. The latter is particularly important because the quality of re-imaged documents is inherently dependent upon the quality of the originals and because the re-imaging processes of xerography, microfilming, and microfilm printout cause degradation.

Paper and ink. - Forty-nine of the fifty survey publications were printed on white or off-white paper using black ink. Eighty-four percent were printed on an uncoated or matte finished paper (as opposed to a coated or glossy paper), as shown in Figure 38. The highest use of glossy paper was by industrial reports (28 percent) and technical manuals (24 percent).

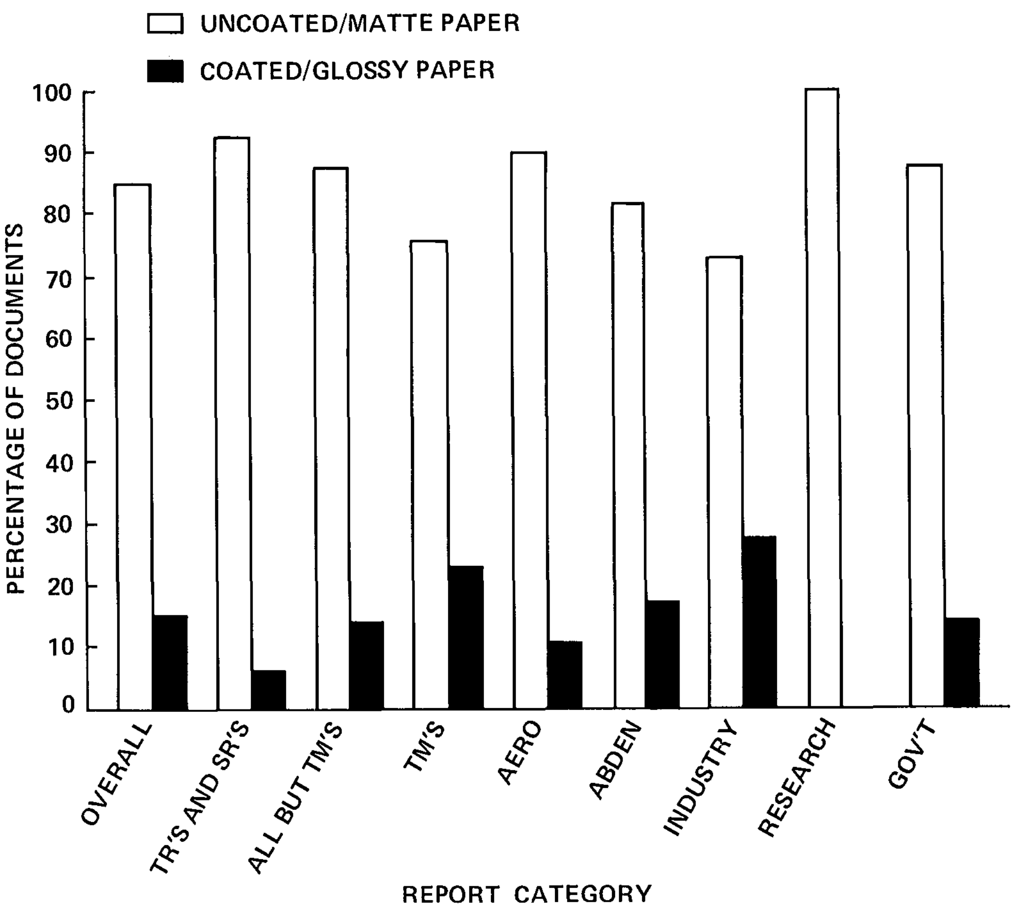

Figure 38. Type of paper used by survey documents

According to H. Spencer (1969, p. 14) and Strawhorn (1978, p. VI.4.5), an off-white paper on the yellow side was best for reading type. Tinker (1963, p. 158-160, 208) did not find any appreciable difference in legibility between white and off-white paper.

Bain (1970, p. 171) and Williamson (1966, p. 116) stated that the finish of paper can affect reproduction quality and legibility. Fine detail such as halftone dots and small type print better on a smooth coated paper. Tinker (1963, p. 159-160) reported that high gloss paper retarded reading by a small, but statistically significant, amount. Hawken (1966, p. 61, 65) noted that high gloss paper which is bound in such a way that pages may not be opened flat (i.e., sidewire binding) can create serious glare problems.

In regard to ink, Tinker (1963, p. 158-160) and Hovde (1929, p. 603) stated that black color should always be used and that a matte ink is superior to a glossy ink. The NASA sample report was printed in black ink on a smooth, matte finished white paper. The NASA Publications Manual did not specify any ink color, paper color, or paper finish.

Binding. - The frequency of use of various methods to bind survey documents is illustrated in Figure 39. For the survey as a whole, perfect binding was used most often (28 percent of publications), followed by saddle stitching (22 percent), and sidewire stitching (20 percent). All perfect bound documents used hot melt or glue; none were sewn. The most noticeable trend was the frequent use of ring binders for technical manuals (50 percent of category). Table FF shows the average length of survey documents bound by each of the six methods. Saddle-stitched publications had the shortest average length--50 pages. Documents using ring binders had the longest average length--250 pages.

The Monge survey of NASA report users revealed some dissatisfaction with the type of binding used. The chief complaint was that publications would not open and stay flat (Monge, 1979, p. 103, 139). The NASA Publications Manual did not discuss binding methods. Examination of eight NASA reports revealed that seven were

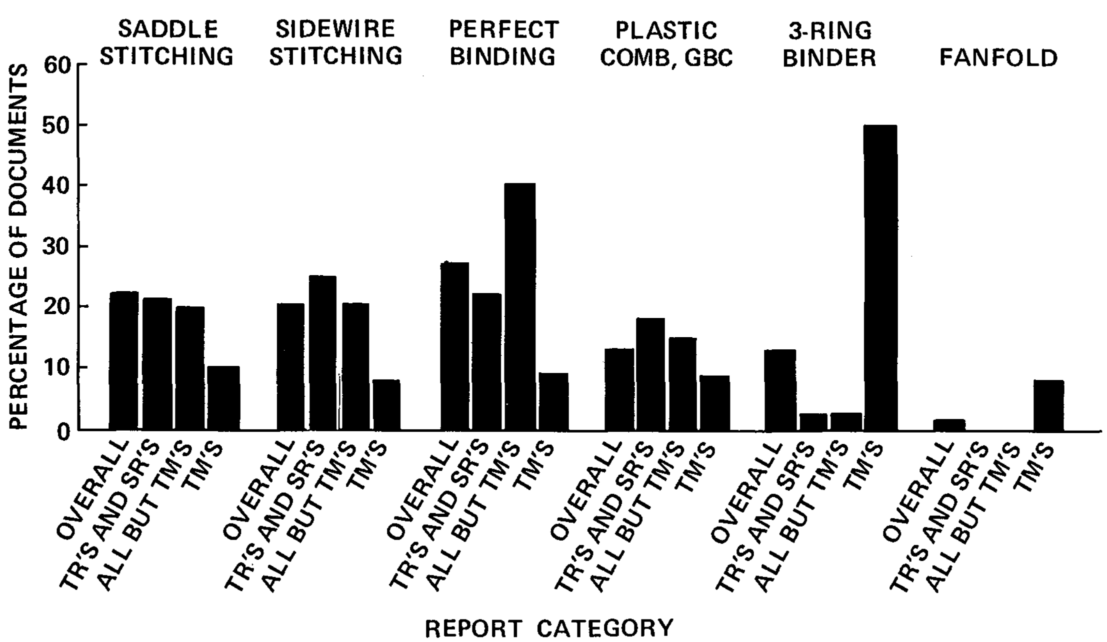

Figure 39. Binding methods used for the survey documents

TABLE FF

Average Length of Survey Documents Bound by Various Methods

Binding method	n	Average no. pages per document
Saddle stitching	11	50
Fanfold	1	70
Sidewire stitching	10	90
Plastic comb	7	112
Perfect binding	14	137
Ring binder	7	250

saddle stitched and one (a longer report) was sewn or perfect bound. None of these eight reports exhibited any evidence of the difficulties described in the Monge survey. One rather long, non-NASA survey report which used coated paper and hot melt perfect binding (not sewn) was observed to be disintegrating.

Re-imaged reproductions. - NASA's Technical Publications Program, A Working Guide (1979, p. 15) contained guidelines for copy preparation for microfiche and noted that 80 percent of NASA's scientific and technical documents are available only on microfiche. Those guidelines included the following:

1. Make every effort to have illustrations and tables appear on the page where they were first mentioned.

2. Do not use color.

3. Align figures with text because many microfiche readers do not permit rotation.

4. Use at least a 1-inch margin all around the image area; do not use paper larger than 8-1/2 by 11 inches.

5. Avoid the inclusion of previously reduced figures or type.

6. Place all footnotes and references on the page where they were introduced.

7. Number all pages in arabic numbers, beginning with the title page.

8. Where fidelity of a photo print is essential, include the source of photo availability.

9. Use a type size of at least 10 points.

These NASA guidelines generally corresponded with other literature prescriptives for preparing technical publications for microfiche. The sample NASA report met only the requirements for not using color, keeping page size smaller than 8-1/2 by 11 inches, using at least 10-point type, and not including previously reduced figures. Meeting the latter guideline caused one figure to be placed sidewise to the text, which violated the third guideline listed previously.

The Monge survey (1979, p. 101) of NASA technical literature users noted the disadvantage to microfiche users of reports in which tables and figures were not integrated with the text. As discussed in the section on sequential components, 82 percent of all survey publications had their tables and figures integrated with the text. The NASA sample report did not contain any tables, but the figures were grouped in the back matter.

Hawken (1966, p. 55, 63, 65) noted that narrow margins and consequent page curvature could cause degradation of type in documents that must be photographed or copied. The 1-inch minimum gutter margin specified in the NASA guidelines may be only barely adequate, and the sample report's margin was even less than the prescribed 1 inch.

Because the quality of a re-imaged document is almost wholly dependent upon the quality of the printing in the original document, printing quality in the survey documents was assessed. The results of this assessment are shown in Figure 40. The problem encountered most frequently in the survey was overdeveloping in prepress camera processes. This problem was evident in 45 percent of all survey publications. Underinking was the second most common defect, occurring in 35 percent of the survey. Other problems--slurring, offsetting, overinking, and underdeveloping--all occurred in about 20 to 30 percent of the documents. Technical manuals had a high occurrence (50 percent) of overinking.

Hawken (1966, p. 53, 82) mentioned several factors which caused difficulties in re-imaged documents: type filling in or breaking up and printing that is too light, uneven, or offset. The NASA Technical Publications Program, A Working Guide (1979, p. 15) mentioned similar factors. The sample NASA report had a very high quality of printing. No appreciable printing problems were detected.

Typographic factors must necessarily be considered beyond the printed page to the other forms in which a reader may use documents: microfiche viewed through a reader or viewer, microfiche-generated copy, xerographic copy, or a digitally-generated facsimile. The degree of degradation a type face will undergo can not be controlled by the publisher (H. Spencer, 1969, p. 7-10). Hawken (1966, p. 82) and Erdmann (1968, p. 408-409) reported that the typography can be severely degraded and yet still remain legible for most reading purposes because of the characteristic forms and structure of words and phrases. However, Hawken (1966, p. 83) added that difficulty in interpretation can occur for readers who encounter unfamiliar terms. Also, certain types of printed information containing numerals or codes cannot be interpreted by associations with surrounding characters.

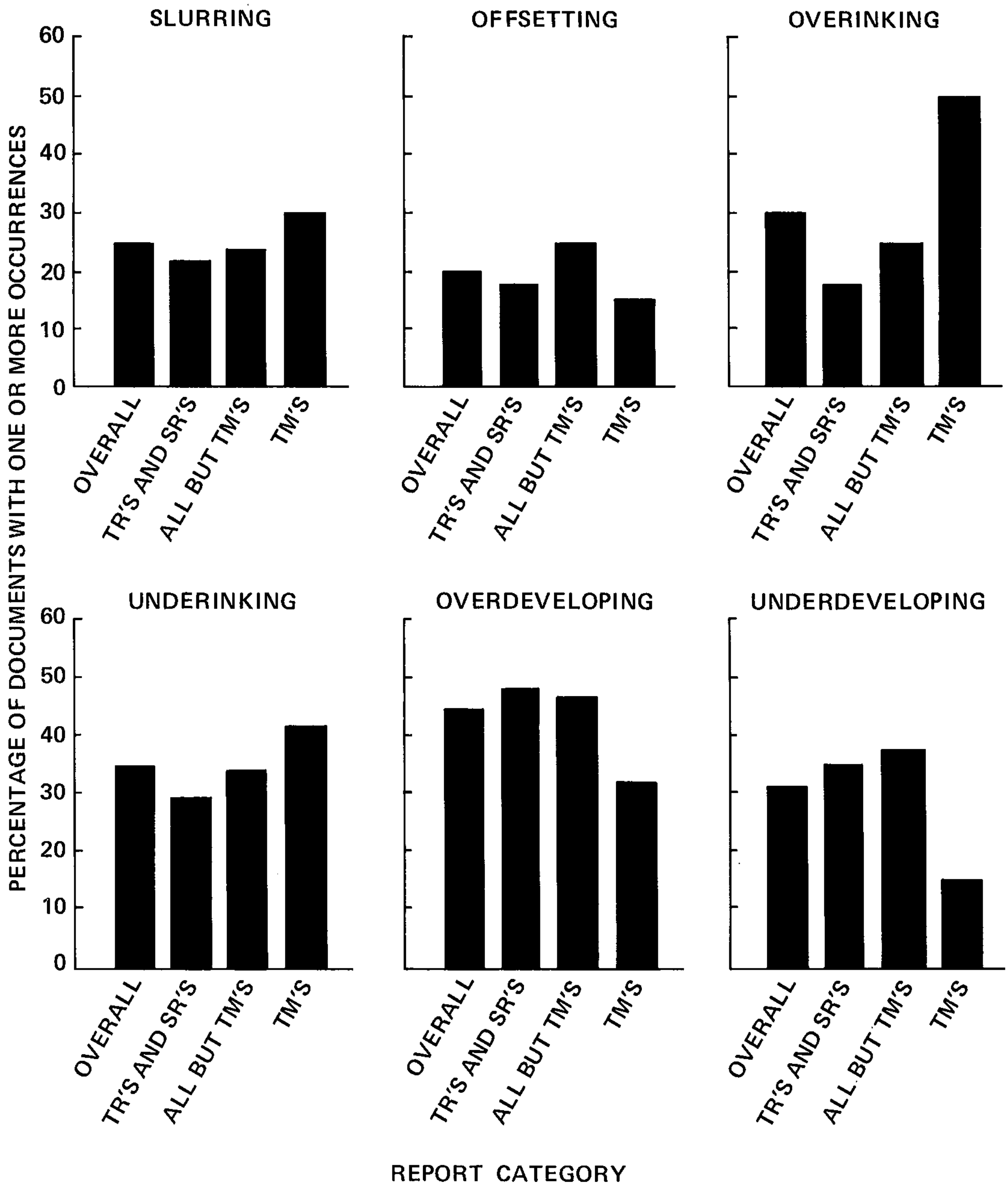

Figure 40. Frequency of occurrence of printing defects in the survey reports

The results of the perceptibility tests and subjective legibility ratings on degraded survey documents are shown in Table GG. Table GG shows that for both the xerographic and microfiche studies, the average subjective ratings of legibility increased as type size increased. Also, the subjects made fewer errors as type size increased, with the exception of the 10-point type in the microfiche tests.

TABLE GG

Results of the Typography Degradation Tests

Survey category	Mean errors per 10 words	Mean subjective rating; 0 = poor, 4 = most legible
Xerographic copy (10th generation)		
Overall survey	0.98	1.59
Documents set in:		
9-pt. type	1.60	1.07
10-pt. type	0.88	1.61
11-pt. type	0.52	1.87
NASA sample report	0	2.40
Microfiche printout (extremely underexposed)		
Overall survey	0.50	2.24
Documents set in:		
9-pt. type	0.55	1.60
10-pt. type	0.74	2.09
11-pt. type	0.28	2.63
NASA sample report	0	3.60

Many of the same factors that apply to normal typographic considerations of legibility are also factors which govern how well a recopied document can be read. Hawken (1966, p. 30, 34-35, 83) mentioned type size, brightness, height of the lower case "x," counters, and space. Erdmann (1968, p. 108) concluded that size was an accurate predictor of legibility for digitally reproduced characters. Hawken (1966, p. 34-35) stated that the height of the lower case "x" and not the absolute size of the type was the factor influencing reproducibility. He also cited the ratio of thin stroke width to thick stroke width in a letterform as one of the most important factors affecting legibility, with an even stroke ratio, 1:1, being the ideal for reproducibility. Hawken also stated that this ratio becomes more critical as the overall type size decreases. NASA guidelines (Technical Publications Program, A Working Guide, 1979, p. 15) stated that type size should be 10 points (approximately 3.5 mm) or larger.

The results of the typographic degradation study reported herein agreed with Erdmann's conclusions. As shown in Table HH, the "most legible" documents had larger average type sizes than the documents deemed "least legible" subjectively and by error count in reading. The "most legible" documents also had higher average values for all other variables measured and reported in Table HH, except that there was virtually no difference in the ratio of lower case "x" height to capital letter height between "least" and "most legible" type. The NASA sample type was in the mid-range for most typographic characteristics, between most and least legible documents, except that the thin stroke width of NASA's type was very low. This also resulted in a low thin stroke to thick stroke width ratio.

TABLE HH

Average Typography Characteristics of Survey Documents Which Scored as Most and Least Legible After Degradation

Characteristic	Least legible documents	Most legible documents	NASA sample report
Type size, mm	3.20	3.53	3.30
Capital letter height, mm	2.36	2.67	2.54
Lower case "x" height, mm	1.70	1.96	1.91
"x" height / capital height	0.72	0.73	0.75
Thin stroke width, mm	0.203	0.279	0.127
Thick stroke width, mm	0.279	0.355	0.381
Thin stroke width / Thick stroke width	0.73	0.79	0.33

CONCLUSIONS

The technical report has become a primary information product for the dissemination of scientific and technical information. As an information product, the technical report has been criticized for not meeting the rigors or criteria established for scientific journal publication and praised for its unique features such as timeliness, complete treatment, and inclusion of ancillary material.

Studies of the NASA technical report indicated that the reports were being used and that the perceived prestige of NASA technical reports was high. Users of NASA technical reports were specifically concerned with the inconsistent application of NASA publications standards, the absence of detailed summaries and abstracts, the policy of the Agency to exclude conclusions, the failure to relate research results to previous and/or existing work, insufficient tabular data, and the exclusion of negative data. The use of varied type sizes and styles, the absence of grids on graphs, and the type of binding used for certain NASA technical reports were specific concerns of the users.

Sequential Components

The survey reports showed wide variation in the number, kind, and placement of sequential components. The 99 reports surveyed used 96 different components. Only five components (cover, title page, table of contents, introduction, and appendixes) were common to half or more of the reports; however, strong agreement (82 percent or more) existed in regard to placement of these five components as front, body, or back matter.

The six style manuals and publications guides were not unified in the number and names of components recommended for inclusion in technical reports. Sixteen of twenty-four components were recommended by half or more of these sources; however, unanimous agreement for inclusion existed for only three components, the title page, the introduction, and the appendixes. The style manuals and publications guides were even more divided in the recommended sequence of the report components.

Textbooks showed the greatest agreement on which components should be considered for inclusion in technical reports. All six texts consulted recommended the following six components: memo/letter of transmittal, title page, abstract, contents, introduction, and appendix. Further, a consensus for inclusion existed for 17 of 20 components mentioned by one or more texts.

The number of components recommended by 50 percent or more of all three sources (survey reports, style manuals/publications guides, and textbooks) was limited by the poor consensus existing among survey reports. As previously mentioned, only five components were common to more than half of the 99 reports. Considering only textbooks and style manuals/publications guides, agreement existed in 50 percent or more of each source on including the following 12 components: cover, title page, abstract, contents, list of figures/illustrations, introduction, body (text), bibliography, references, appendix, list of symbols, and glossary.

The NASA Publications Manual agreed with the survey reports in both inclusion and placement of the five components for which a consensus existed. NASA included all three components (title page, introduction, and appendixes) recommended unanimously by the style manuals/publications guides. Of the 16 components recommended by half or more of these sources, 11 were mentioned by the NASA standards. The five not included were the foreword, list of tables, list of illustrations/figures, glossary, and index. The NASA Publications Manual included five of the six components recommended by all the textbooks (title page, abstract, contents, appendix, and introduction) and 13 of the 17 components mentioned by three or more of the six textbooks. Components omitted by NASA were the memo/letter of transmittal, list of illustrations/figures, recommendations, and glossary.

NASA's guidelines compared favorably, in general, with the survey usage and the recommendations of the style manuals/publications guides and textbooks where a consensus existed. However, no one recognized structure for the sequential components of technical reports was found to exist. This lack of a single agreed-upon organization is probably due to the wide variations in the content, purpose, and discipline of technical reports and to the varied audiences to which they are directed. Components present in a report, particularly in the body or text, will also be affected by the nature of the report--whether it is informative, analytical, or assertive.

NASA's major deviations from the mainstream of prescriptive guidelines and current practice were as follows:

1. NASA placed the symbols list as body matter following the introduction rather than as front or back matter. This location was viewed by several sources to interrupt the continuity from the introduction to the rest of the text and to be less accessible as a reference tool to the reader.

2. The NASA Publications Manual stated that tables and figures can be either integrated with the text as body matter or grouped together in the back matter after the appendixes and references. Examination of several NASA reports indicated that the latter treatment was often employed. Prescriptive sources and the survey reports were in strong agreement that figures and tables should be included in the text as soon as possible after first mention.

3. By placing the COSATI standard title page containing the abstract as the last page of reports, NASA, beginning in 1977, broke with the conventional placement of the abstract as front matter. This is evidenced by the fact that, of those survey reports containing an abstract, 85 percent placed it as front matter. The prescriptive sources also placed the abstract as front matter most commonly.

4. The NASA Publications Manual included both an abstract and a summary. Inclusion of both abstract and summary components was not recommended by a majority of the textbooks and commercial style manuals. The survey reports and prescriptive sources tended to favor an abstract rather than a summary.

5. NASA report guidelines did not call for lists of figures/illustrations or lists of tables favored by prescriptive sources. Presumably, the rationale for their omission is the same as that provided for usual omission of the table of contents. The NASA Publications Manual (p. 10) states that, "In reports of moderate length, front matter . . . is rarely advantageous and is omitted."

Language Components

The average readability scores of the survey documents ranged from grade 14 to grade 19 for the text and grade 17 to grade 21 for the summary section. Headings and captions scored between grade 12 and grade 15 on the Fog and Kincaid indexes. The text and summary of the NASA report fell within the ranges scored by the survey documents. Survey publications on NASA-related subject areas (ABDEN) scored as more difficult than the overall survey. The NASA sample report generally scored as easier to read (lower grade level) than the ABDEN reports. The levels obtained experimentally (14 to 19) for the texts of survey and NASA reports agreed fairly well with the general level of grade 16--college graduate--reported in the literature for scientific material. Summaries tested as somewhat higher--grades 17 to 21.

Eighty-eight percent of the survey reports used the third person in the text section. Fifty-six percent used the passive voice. Use of person and voice in summary sections was similar. In using third person, passive voice in both sections, the NASA report's usage corresponded to the consensus in the survey. The NASA Publications Manual did not contain any guidelines on use of person or voice. Literature sources, on the other hand, cautioned against excessive use of the passive voice as outmoded and less direct than the active voice.

Mathematical style books recommended that mathematical presentations should be punctuated by the same rules used to punctuate prose, whether the equations are in the text or displayed. The NASA Publications Manual stated that punctuation is omitted after displayed equations, but is included in introductory sentences leading into the equations. The NASA sample report did not, on the whole, follow the rules advocated by the commercial mathematics style manuals in punctuating displayed equations.

All three mathematics style books consulted recommended essentially the same methods for breaking equations which are too long to appear on a single line. The NASA Publications Manual made no recommendations on this subject, but did refer the reader to the GPO Style Manual. Broken equations in the sample NASA report followed the recommendations of the commercial style manuals.

Swanson (1971, p. 25, 41) stated that most authors tend to display too many equations and mathematical expressions. The NASA Publications Manual stated that "short mathematical expressions or equations can be treated as part of the text when it is convenient to do so." The sample NASA report displayed 93 percent of its equations.

The mean and median ratios of the number of tables to the number of pages of body and back matter in the survey reports were 16 percent and 9 percent, respectively. Values ranged from 0 to 66 percent. The NASA sample report did not contain any tables. Similarly determined figure-to-page ratios ranged from 0 to 203 percent for the survey documents, with a mean of 39 percent and a median of 28 percent. The figure-to-page ratio for the NASA report was 69 percent.

The majority of the survey documents contained one or more examples of each of these types of figures: functional/schematic diagrams, two-dimensional graphs, and orthographic illustrations. Functional/schematic diagrams appeared in more reports (65 percent) than any other type of figure. Two-dimensional graphs appeared in the second highest number of survey documents. When technical manuals were excluded, two-dimensional graphs became the most commonly used type of artwork, appearing in 75 percent of the remaining 38 documents.

The NASA Publications Manual contained some guidelines on the labeling and numbering of figures, but it did not contain any criteria that could be used in determing which types of artwork are most effective for various purposes. The sample NASA report contained two-dimensional Cartesian plots, orthographic illustrations, and isometric illustrations.

Further investigation of certain aspects of two-dimensional graphs showed that of survey publications containing this type of figure, only 25 percent used gridlines.

The NASA Publications Manual, by implication, made the use of gridlines optional. Gridlines were not used in the sample NASA report.

By a vast majority, two-dimensional graphs in the survey reports were hand-produced. Ninety-five percent of the reports containing two-dimensional graphs had one or more graphs produced by hand. Only 15 percent contained a strip/recorder-generated graph, and only 10 percent contained a computer-generated graph. The NASA guidelines did not address graph production methods, but examples provided therein were hand-produced as were all two-dimensional Cartesian charts in the NASA sample report. The figures for use of computer-generated charts were surprisingly low considering the sophisticated technology pioneered by NASA and other organizations and the number of organizations which now have computer graphics capabilities.

The maximum number of data paths plotted on one figure ranged from one to ten for the survey documents, with a median value of four and a mean value of five. The corresponding figure for the sample NASA report was eight. NASA guidelines did not set a maximum number, but eight types of lines (data paths) were presented and an order recommended for their introduction in figures. Literature sources and mean usage in the survey tended to limit multiple plots on a single figure to a lower number than NASA usage.

Literature recommendations varied regarding symbols for data points and data paths in multiple plots on single figures. No data were obtained from the survey documents on this subject. The first three data-point symbols recommended by the NASA Publications Manual agreed with those of Harvill (1977), but NASA suggested varying data paths, while Harvill used a straight line for all paths.

Presentation Components

The survey documents were evenly divided in composition method. Both typewritten and typeset composition were considered satisfactory by literature sources. The NASA Publications Manual stated that formal series reports other than Special Publications were prepared at originating centers as camera-ready copy, and further added that typewriters with proportional spacing were available. The NASA sample report was prepared using either a word processing system or a proportionally spaced typewriter.

Seventy percent of the survey (and NASA) used Roman type. The literature indicated that Gothic and Roman are equally suitable styles. Literature sources agreed that all capitals should not be used. All survey documents and the NASA report used capitals and lower case type. The NASA Publications Manual did not contain any recommendations or guidelines on type style, type size, leading, margin justification, paragraph indentation, character count, use of solidus to replace stacked fractions, or use of fractional exponents to replace radicals.

The majority of research cited on type size agreed that 9 points through 12 points can be used without adverse effect on legibility. The survey reports used 10-point type most frequently (21 of 50 reports) and 11-point type almost as often (19 reports). The NASA sample report was prepared in 11-point type.

Research reports showed that unjustified margins do not affect legibility. Sixty percent of the survey and the NASA report did not justify right-hand margins.

The survey was almost evenly divided on the use of paragraph indentation. The literature was also divided on use of indentation and/or extra space between paragraphs. The sample NASA report used indentation and extra space between paragraphs.

The NASA Publications Manual specified a maximum image width of 6-5/8 inches (which is 39-3/4 picas). The sample report with a 41-pica longest-line slightly exceeded the prescribed maximum. "Most lenient" limits of line length (11 to 42 picas) were established by taking the lowest minimum and highest maximum listed as acceptable by any literature sources. Only one survey document exceeded the upper limit; however, the longest lines of most survey documents and the NASA report were near the upper end of the acceptable range. These limits are rather crude because they do not take into account other factors which affect legibility and ocular performance. When "most lenient" line-length limits were established from the literature as a function of type size, the range was much narrower (e.g., 16 to 34 picas for 11-point type). The mean and median longest-lines of single-column survey documents exceeded the maximum acceptable literature limits for 9-, 10-, and 11-point type. The NASA sample report with a 41-pica longest-line was even further above the maximum limits than the survey averages. However, NASA's longest-line was only slightly longer than the survey average for single-column documents in 11-point type (38 picas).

"Most liberal" character count limits of 50 to 80 characters per line were obtained by taking the lowest and highest values acceptable to any references consulted. The single-column survey documents averaged 74 characters per line. The NASA sample report at 84 characters per line was above the literature maximum and the survey average. These literature limits were specified by publishing authorities rather than by scientific investigators. At most, they provide only a rough rule of thumb for general-reading type documents. Character limits appear practical only for typewritten composition where every character occupies the same width. Line length specifications made in terms of character count would still need to consider type size.

Most survey reports used a generous amount of leading, more than any of the literature sources recommended. The NASA sample report used two different leadings throughout. One point was used between successive lines of plain text. This was within the range specified by most authorities (up to 3 or 4 points); however, an extra 6 points was inserted after lines containing mathematics in text.

The majority of the 21 survey documents containing mathematics set the mathematics portion in Roman type. Most used the same type style and size for the mathematics as was used for the text. All used the same type size and style for all mathematics, whether in text or in display. The most common type size for mathematical material was 10-point (52 percent), with 11-point used in 29 percent of the reports. The sample NASA report used the same type style and size, 11-point Roman, for plain text and all mathematics, whether in text or displayed.

In the past, publishers who composed extensive amounts of mathematical copy were restricted to the use of a type style with a sort large enough to include all the symbols that might be needed. Linotype, strike-on composition, and film-based typesetting systems all imposed cost and style limitations. Recently, computerized photo-typesetting systems have become available employing digitally stored fonts that can eliminate many of these limitations.

Mathematics style books uniformly recommended use of the solidus and negative exponents to eliminate stacked fractions and the use of fractional exponents to eliminate radicals, especially in textual mathematics, but also in displayed mathematics. Seventy-six percent of the survey documents containing mathematical material in the text used the solidus to replace stacked fractions; forty-five percent used the solidus in displayed equations. No radicals were present in textual mathematics in the survey; however, thirty-five percent of the reports containing displayed mathematics employed fractional exponents to replace radicals. No data were collected on the use of negative exponents to replace stacked fractions either in the survey or in the NASA sample report. The NASA sample report did not use the solidus to replace stacked fractions which were present both in text and in display. The NASA sample report did not contain any roots; therefore, use of fractional exponents to replace radicals could not be assessed.

Because of the presence of stacked fractions, the NASA sample report employed 7 points (64 percent based on type size) of leading following lines of text containing mathematics, while using only 1 point (9 percent) between consecutive lines of plain prose. The survey reports containing mathematics in the text averaged 145 percent additional leading. Literature sources suggested 1 or 2 points of extra leading throughout for texts containing mathematics. Analysis of the literature and survey showed that the practice of adding extra leading is common for texts containing equations. However, literature sources stated that this should be done consistently throughout the text, and that leading should not be varied within a report to accommodate fractions and/or superior and inferior notation. The survey reports, while using larger amounts of extra leading (145 percent) as compared with the NASA sample report (64 percent), did use the leading uniformly throughout.

Literature sources advocated the horizontal grouping of rows of data in tables The majority (71 percent) of survey publications with tables did not adhere to this practice. One source cautioned that an excessive number of columns would hinder legibility. For survey reports with tables, the mean largest number of columns per table was ten, and the median, eight. The NASA Publications Manual did not discuss grouping or an acceptable range of columns per table. The sample NASA report did not contain any tables.

The literature did not show a clear preference for Gothic or Roman type for the title on the cover. Seventy-five percent of the survey used Gothic type. The NASA sample report's title was set in Roman type. The NASA Publications Manual provided no information on cover typography, presumably because cover pages are not prepared by authors.

The literature was mixed in opinion on the subject of capitals or upper and lower case for titles on covers. The survey reports used all capitals more often than upper and lower case. The NASA sample report used upper and lower case type with all initial capitals.

NASA's 21-point type size for the cover title was close to the average of 25-point type used by the survey reports. For all cover elements, the individual survey reports used from one to six type sizes. Eighty-five percent of the survey used either two, three, or four type sizes. NASA used four different type sizes on the cover. The literature was not specific on the number of type sizes recommended, but cautioned against extremes of too little variation (monotonous) or too much variation (impedes the reader).

The title had the largest average size ranking compared with other cover elements in the survey. Other elements in decreasing mean size rank were: publisher, sponsor, subtitle, author, reference number, and date. The NASA sample report used the largest cover type for the publisher, second largest for the title, third largest for the reference number, and smallest for the author and date.

In regard to relative position, the average survey ranking from top to bottom of the cover was: reference number, title, subtitle, author, publisher, sponsor, and date. NASA's order on the sample report cover was the same as the average survey ranking except that publisher and date were reversed, and no subtitle and sponsor appeared on the NASA cover. The survey reports and NASA agreed with a literature recommendation that the title be displayed large and high on the cover and that the publisher's name be low on the page. However, the literature source advocated small type for the publisher's name, whereas the survey reports made the publisher the second largest in average size ranking. In the NASA sample report, the publisher was the largest of any element on the cover.

For title pages, Gothic type was used more often than Roman to set the report title by the survey. NASA used Roman type for the title on the title page, as did the majority of documents in related categories (aerospace and ABDEN). The survey used up to six type sizes for elements on the title page; however, the vast majority employed between one and four sizes. Technical manuals and industrial reports tended to use more type sizes than other document categories. NASA used four type sizes for title page elements. The NASA Publications Manual did not discuss the typography of the title page.

In the survey, the title had the largest average size ranking of title page elements, followed in descending size rank by the subtitle, sponsor, publisher, reference number, date, and author. NASA used the largest type for the sponsor and publisher, followed by the title, reference number, and author.

The average positional rankings of title page elements in descending order from page top to bottom were: reference number, title, subtitle, author, date, publisher, and sponsor. NASA's title page followed this order exactly, except that no subtitle and date appeared on the title page.

Table legends appeared in 41 of the 43 survey publications with tables, and figure legends were used in 45 of 47 documents with figures. None of the survey reports used table captions, and only nine documents used a figure caption along with the figure legend. All captions were in upper and lower case. Their composition method was about equally divided. Legends were typeset rather than typewritten in the majority of the survey, and they were set in upper and lower case rather than in all capitals. The sample NASA report had no tables and thus no table legends or captions. Figure legends were typeset in upper and lower case. No figure legends were used. The NASA Publications Manual recommended all capitals for table legends and upper and lower case for figure legends.

The literature agreed that headings need to be set off from the text and that different heading levels need to be distinguished from one another. Authorities indicated that this could be accomplished by use of a different type style and/or size, all capitals, italics, boldface, underlining, relative positioning, or any combination of these methods.

Every survey document contained at least two heading levels, and 80 percent used third-level headings. Use dropped to 41 percent at the fourth level and to only 5 percent at the fifth level. Five was the maximum number of heading levels used by any document. NASA used three levels of headings in the sample report. The NASA Publications Manual stated that headings are preferably limited to three levels, but up to six can be used if necessary.

No clear preference was seen in the overall survey for either Gothic or Roman type in headings. Technical manuals, industrial reports, and government reports used Gothic type more often. Other categories (and the NASA sample report) used Roman type more often. The NASA Publications Manual did not discuss type size or style of headings, but examples of different levels were the same size and style.

Survey headings tended to decrease in average type size as they decreased in importance. First-level headings were clearly larger for all survey categories, and the largest change occurred between the first and second levels. NASA used the same type size for all three heading levels, and this was the same type size used for the text. Analysis of the survey indicated that the majority of the overall survey and most categories also used the same size, style, and weight type for headings as they used for text. Most likely these reports employed "strike-on" typesetting systems. Exceptions were technical manuals and industrial reports, which tended to use more sophisticated typographic techniques than the rest of the survey.

Seventy-five percent of the survey documents used all capitals for first-level headings, and fifty percent used all capitals for second-level headings. Use of all capitals declined at the third level. The same pattern existed in all document categories. No clear trend was observed for fourth- and fifth-level headings. The sample NASA report used all capitals for the first two heading levels and upper and lower case for the third heading level. Although consistent with survey practice, this pattern did not follow the guidelines in the NASA Publications Manual, which called for all capitals for the first heading level and upper and lower case for second- and third-level headings in reports containing three heading levels. An alternate sequence for reports requiring more than three heading levels used all capitals for levels one and two, and upper and lower case for levels three through six.

Italic headings were used very infrequently in the survey, and no pattern was evident. Boldface headings appeared in 45 percent of the survey; but when technical manuals were excluded, usage dropped to only 35 percent. Eighty-five percent of the technical manuals and sixty-five percent of the industrial reports used boldface for their first- and second-level headings. Use of boldface headings declined markedly after the first two heading levels. Authorities generally concluded that boldface type is desirable for increasing visibility of headings and facilitating the readers' access to information. The NASA Publications Manual did not mention italic or boldface headings, and the sample NASA report did not use them.

In regard to the underscoring of the headings, the opposite pattern was observed in the survey as that seen for use of boldface headings. Underlining was used with increasing incidence as heading levels decreased in significance. Again, technical manuals were different from the rest of the survey documents. The technical manuals used virtually no underscored headings. When technical manuals were excluded, the use rate for underscoring was 20 percent for first-level headings, 35 percent for second-level headings, 50 percent for third-level headings, and 60 percent for fourth-level headings. The NASA Publications Manual did recommend the use of underscoring, but only for the third heading level in the three-level preferred sequence. For the six-level sequence, levels one, three, and five were shown underscored.

The general practice in publishing was to place the headings in the order of importance first centered, then left shoulder, and finally run-in with the text. The majority of survey publications followed the general center-to-left position trend from major to minor headings. The NASA report centered all three headings, which is at variance with the guidelines in the NASA Publications Manual. For the three-level sequence, the manual centered heading levels one and two and used a run-in heading for the third level. The six-level sequence centered the first four heading levels and used run-in headings for the fifth and sixth levels. NASA did not recommend or use any shoulder headings.

The literature did not offer any recommendations on line depth or character density, nor did the NASA Publications Manual contain any relevant guidelines. The sample NASA report contained 39 lines per page and 3276 characters per page, about 20 percent lower than the survey averages of 49 lines and 4060 characters per page. Several factors contributed to the low character density in the sample report. These included type size, type proportion, low number of lines per page, and uneven leading between lines. If the character density in the NASA report were increased to the average of the survey, fewer pages would result, offering opportunities for significant increases in layout/printing personnel and equipment productivity, with corresponding cost reductions in supplies and materials. Ultimately, distribution and storage costs might also be decreased. The character density could be increased by: (1) reducing the size of the text type, while staying within guidelines established for legibility; (2) using a different text type style, one drawn in narrower proportions (but not condensed); and (3) reducing leading.

The text of the NASA sample report occupied 70 percent of the page area, compared with a maximum allowable ratio of 68 percent as calculated from the NASA Publications Manual. The average of the present survey for image area was 64 percent. Findings from other surveys varied from strongly substantiating a user preference for the 50 percent rule of thumb to documenting an increase in text-to-page ratios over 30 years (to 1950) from 52 to 60 percent for journals.

It is paradoxical that the NASA sample report had relatively few characters per page (less economical), yet the text-to-page ratio was quite high relative to all standards (less legible and less congenial). Increasing the image area is, in a sense, false economy. As mentioned above, there are several other ways of increasing character density which better maintain standards of legibility and reader preference.

The NASA sample report's gutter margin of 6 percent of the page width was low by all standards. The NASA Publications Manual implied a guideline of 8.6 percent of the page width, and the survey average was 10 percent. The literature cited a need for adequate gutter margins in bound publications. The only specific suggestion was 17.5 percent of the page width. Since the NASA sample report had a text-to-page ratio which was too high and a gutter margin which was too small, increasing the gutter margin, for example to 12 to 17 percent of page width, would rectify both situations.

In regard to folio placement, most literature sources that had a strong opinion argued for the side top position on the page. The survey, however, showed strong preference for center bottom folio placement. Folios were placed in the center bottom position most often by every category except technical manuals, which used the side bottom placement more frequently. The NASA Publications Manual recommended side bottom placement of folios, and the sample report followed this guideline.

Although recommendations for including running heads were found in the literature, they were present in only 20 percent of the survey. Technical manuals used running heads with greatest frequency (42 percent). The NASA sample report did not use running heads, nor were they mentioned in the NASA guidelines.

Literature sources were mixed in their recommendations concerning single or double column layouts. In the overall survey, 70 percent of all publications used a single column format. For technical and scientific reports, the usage rate increased to 90 percent. Technical manuals showed the most frequent use (42 percent) of double column layouts. The NASA Publications Manual, while not explicitly making a recommendation on the subject, showed all sample pages with a single column layout, and the sample report also employed a one column format.

Literature sources strongly advocated that figures and tables be aligned with the text so that the reader does not have to rotate the publication to use them. These recommendations were not followed by survey publications. A majority contained one or more visuals placed perpendicular to the text. The NASA Publications Manual stated that tables and figures are preferably placed upright on the page, but may be placed sideways. The NASA sample report contained one figure placed sideways.

Many visuals placed sideways in reports could be aligned with the text by a simple small reduction, which would not affect legibility or utility. When this solution is not feasible (e.g., numerous computer printouts), an alternative is to modify the publication format (e.g., 10-1/2 by 8 inches rather than 8 by 10-1/2 inches). Only one document in the survey followed this recommendation.

Readers are the primary beneficiaries of effective layout in reports. The disposition of the various elements on the page can make a report more or less comprehensible and easier or more difficult to use. In contrast to imposition factors such as character density, where there are opportunities for economic gains to publishers, layout improvements do not usually result in cost reductions. However, more satisfied readers may ultimately mean increased utilization of the publisher's product(s), particularly by marginal users.

White or off-white paper and black ink were recommended by all literature references and used by 49 of the 50 survey publications. Matte finished (uncoated) paper was heavily favored (84 percent of reports) over coated paper in the survey. The literature recommended coated paper only when extremely fine details needed to be reproduced very accurately. Otherwise, coated papers were noted to cause legibility problems. Additionally, although not mentioned in the references cited, high gloss paper is commonly known in the printing industry to be less suitable for archival purposes than uncoated paper because coated paper tends to embrittle, crack, and become detached from the binding as it ages. The NASA sample report was printed in black ink on matte finished white paper, in agreement with the literature recommendations and practice in the survey.

Binding methods used most frequently in the survey were perfect binding (28 percent of the publications), saddle stitching (22 percent), and sidewire stitching (20 percent). Other methods used less commonly were plastic comb, ring binder, and fanfold computer output. No evidence was found in the eight NASA reports examined of the difficulties described in the 1979 survey by Monge (i.e., reports would not open and stay flat). Of the eight NASA reports, seven were saddle stitched, and one longer report was sewn and perfect bound. Differences in the average length of documents bound by the various methods were noted. Saddle stitched publications were shortest (50-page average length), and documents using ring binders were longest (250-page average length). The NASA Publications Manual did not contain any guidelines on paper color or finish, ink color, or binding methods.

The NASA guidelines in the Technical Publications Program, A Working Guide for the preparation of copy for microfilming generally corresponded with literature recommendations on the subject. The NASA sample report did not comply with all of the internal guidelines. Notable lack of compliance was evident in the failure to integrate visuals into the text material and failure to align all visuals with the text, both of which cause problems for users, especially those reading documents on microfiche viewers. Another problem area for the NASA sample report was that the gutter margins were too narrow to comply with barely adequate internal standards.

A subjective assessment of printing quality in the survey revealed that over-developing occurred in a higher percentage (45 percent) of documents than any other defect. Other problems such as underinking, slurring, offsetting, overinking, and underdeveloping occurred in 20 to 35 percent of the reports. No appreciable printing problems were detected in the sample NASA report. Printing quality is particularly important for documents expected to be reproduced through xerography or microfilming because of the degradation inherent in these processes.

Under the particular test conditions of this degradation study, larger type tended to be more perceptible (fewer errors in reading) and was rated higher in subjective legibility tests than smaller type. The NASA sample report compared very favorably with the survey reports in these legibility tests on re-imaged type. Thus, the Agency's 10-point or larger guideline for type size is probably adequate.

The ratio of lower case "x" height to capital letter height did not vary substantially between "least legible" and "most legible" type, and thus does not appear to be an important factor in the typography of documents which will be re-imaged, contrary to statements of one literature source.

The brightness ratio, mentioned by some sources as important for successful re-imaging, was quite low for the sample NASA report. It was 0.33 compared with means of 0.73 and 0.79 for the least and most legible types, respectively. This did not appear to affect legibility, as the degraded NASA type scored quite high in both tests.

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National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia
23665

APPENDIX A

COVER LETTER AND DOCUMENT CONTROL FORM

NASA

Reply to Attn of:

Dear

The Langley Research Center, one of the leading national laboratories for research and development in the science of aeronautics and space technology, is conducting a comprehensive review and evaluation of the Langley scientific and technical information program. As part of this evaluation, a thorough review of the NASA scientific and technical report as an effective medium for transmitting information will be carried out. The review of the technical report will focus on an assessment of the overall organization of the report, the component parts, and their relationship within the total report context. Researchers will analyze a variety of report formats used by the government agencies; private industry; higher education; and trade, professional, and technical organizations.

We would like to include your organization as a producer/publisher of scientific and/or technical reports in the review. Specifically, we would like to secure from you the following:

1. Copies of typical reports published by your organization,

2. A copy of your style manual or the name of the manual if you use a commercially-prepared one (e.g., Chicago Manual of Style),

3. A copy of your publications or graphics manual or standards covering such factors as design, layout, typography style, illustrative material, printing, binding, and

4. A completed document control form which is enclosed.

Researchers will not concern themselves with report content; they will review the report medium only. The information, including copies of reports published by your organization, should be sent as soon as possible to the following address:

Mr. Robert A. McCullough
c/o Graffic Traffic Studios, Inc.
P. O. Box 6382
Norfolk, VA 23508

I understand the sensitive nature of our request and can assure you that the anonymity of your organization will be protected. Only Mr. McCullough and the research team will have access to the information you furnish. The actual tabulations will not contain the name of your organization. If you wish to contact Mr. McCullough, his telephone number is (804) 622-9479. He will be happy to answer any questions you might have.

We greatly appreciate your cooperation in helping with this project. The results of the study will enable NASA, and in particular the Langley Research Center, to develop a more effective medium for transmitting the results of our research.

Sincerely,

Thomas E. Pinelli
Assistant Chief
Scientific and Technical Information
Programs Division

Enclosure

DOCUMENT CONTROL FORM

NASA Technical Report Study

The information or documents you provide will be used to quantify current methods of producing scientific/technical reports.

- ☐ One copy of a typical report produced by your organization for distribution outside of the organization

- ☐ Style manual used by report writers and editors (Please check but do not send commercially available manuals)

  - ☐ Chicago Manual of Style
  - ☐ AP Style Manual
  - ☐ GPO Style Manual
  - ☐ Other commercially available manual (please indicate name)

    ____

  - ☐ Your organization's style manual
  - ☐ At present we have no manual of style

- ☐ Publications guide used for layout, type specification, and printing, etc

- ☐ We have no production guide

APPENDIX B

ORGANIZATIONAL AND

INSTITUTIONAL RESPONDENTS

Allergan Pharmaceuticals
American Association for the Advancement of Science
Argonne National Laboratory
ATARI, Inc.
Babcock and Wilcox
Battelle Memorial Institute
Baylor College of Medicine
The BDM Corporation
Bell Laboratories
Blue Cross/Blue Shield of Michigan
The Boeing Company
Boole and Babbage, Inc.
Brown and Root, Inc.
Burroughs Corporation
Calculon Corporation
Cameron Iron Works, Inc.
Canberra Industries, Inc.
Carrier
Coal Processing Consultants
Computer Sciences Corporation
Ken Cook Company
Core Laboratories, Inc.
Creare, Inc.
Data General
Digital Communications Corporation
Digital Equipment Corporation
Dravo Corporation
Eastman Kodak Company
Environmental Research Institute of Michigan
Ethyl Corporation
Exxon Company, U.S.A.
Foster-Miller Associates, Inc.
General Electric
General Motors Research Laboratories
Geolograph Pioneer
Frank Potter Graham Child Development Center
Hyster Company
IBM
INSLAW
Institute of Gas Technology
International Lead Zinc Research Organization
International Paper Company
Jet Propulsion Laboratory
Johnson Controls, Inc.
Journal of Technical Writing and Communications
Lawrence Livermore Laboratory
Lee-Norse Company
The MITRE Corporation
Mitsubishi Heavy Industries, Ltd.
NASA
National Cancer Institute
National Institute for Occupational Safety and Health (NIOSH)
National Safety Council
Naval Ocean Systems Center
Naval Surface Weapons Center
New Jersey Institute of Technology
The New York Public Library
Nickum and Spaulding Associates, Inc.
Nielsen Engineering and Research, Inc.
NL Industries
North Carolina Department of Labor
Northrop Corporation
Oak Ridge Associated Universities
OCLC, Incorporated
Omark Industries
Online Systems, Inc.
Perkin-Elmer
Pratt and Whitney Aircraft Group
Princeton Aqua Science
Pullman Swindell
Ranier National Bank
Rockwell International
SAS Institute, Inc.
Seybold Publications
Shure Brothers, Inc.
Sperry Univac
Teltone Corporation
Tennessee Valley Authority
Teradyne, Inc.
Texas Instruments, Inc.
Union Carbide
U. S. Army Corps of Engineers
U. S. Department of Agriculture
U. S. Department of Commerce
U. S. Department of Health, Education and Welfare
U. S. Department of Interior
United States Gypsum
United States Nuclear Regulatory Commission
University of Washington
WANG Laboratories, Inc.
Water Pollution Control Federation
Waukesha Engine Division
Westinghouse Electric Corporation

APPENDIX C

DATA CARDS

Card 1

Doc. No. | 1 Form No. | Org. Type | Activity | Doc. Type

Total Pages | Front Pages | Body Pages | Back Pages

% Front | % Body | % Back

Printing Method | Binding | Paper Color | Ink Color | No. of Colors, Text | Paper 0=Uncoated 1=Coated

No. Colors Cover | Cover Art 0 or 1

Slurring | Offsetting

Overdeveloping/Underexposed (Broken Char.) | Underdeveloping/Overexposed (Filled Char.)

Overinked | Underinked

Card 2

Doc. No. | 2 Form No. | Org. Type | Activity | Doc. Type

COVER

Title Set 0 or 1 | Title Style G or R | Title Size and Lead

1. Title | 2. Subtitle | 3. Author | 4. Date

5. Publisher | 6. Sponsor | 7. Ref. No.

TITLE PAGE

Title Set 0 or 1 | Title Style G or R | Title Size and Lead

1. Title | 2. Subtitle | 3. Author | 4. Date

5. Publisher | 6. Sponsor | 7. Ref. No.

Card 3

Doc. No. | 3 Form No. | Org. Type | Activity | Doc. Type

SUMMARY, CONCLUSION, OR INTRODUCTION

Voice A or P | Person 1,2,3 | No. Syllables Per 100 Words | No. of Sentences | No. Words 3 or More Syllables

Flesch | Kincaid | Fog

"TEXT" SAMPLE–

Voice A or P | Person 1,2,3 | No. Syllables for 100 Words | No. of Sentences | No. Words 3 or More Syllables

Flesch | Kincaid | Fog

HEADINGS (Include Title and Subtitle)

Voice A or P | Person 1,2,3 | No. Syllables Per 100 Words | No. of Sentences | No. Words 3 or More Syllables

Flesch | Kincaid | Fog

CAPTIONS (Tables and Figures as They Occur)

Voice A or P | Person 1,2,3 | No. Syllables Per 100 Words | No. of Sentences | No. Words 3 or More Syllables

Flesch | Kincaid | Fog

Card 4

Doc. No. | 4 Form No. | Org. Type | Activity | Doc. Type

TEXT–LEGIBILITY

Typeset 0 or 1 | Type-style G or R | Justified 0 or 1 | Indent 0 or 1 | Type Size and Lead

Line Length Picas | Char Per Line | Char Per Line | Char Per Line

Avg. Char. Per Line | Max Lines Per Page | Max Char Per Page | Gutter Margin As % of Page Width

LAYOUT, MISC.

% Image | No. of Columns | Folio Type T or S | Folio Place-ment | Table and Fig. Placement

HEADINGS, MISC.

Number Heads 0 or 1 | Heads Same as Text | Running Heads

1st LEVEL

Location | Style G or R | Size & Lead | Treat-ment: Caps U&Lc BF Ital Lined

2nd LEVEL

Location | Style G or R | Size & Lead | Treat-ment: Caps U&Lc BF Ital Lined

3rd LEVEL

Location | Style G or R | Size & Lead | Treat-ment: Caps U&Lc BF Ital Lined

4th LEVEL

Location | Style G or R | Size & Lead | Treat-ment: Caps U&Lc BF Ital Lined

5th LEVEL

Location | Style G or R | Size & Lead | Treat-ment: Caps U&Lc BF Ital Lined

APPENDIX C

Doc. No. | Form No. 5 | Org. Type | Activity | Doc. Type

APPENDIXES

Total Pages F+B+B | No. Pages Body | No. Pages Back | No. Pages Body + Back

Data Plots | As % B+B | As % of Back

Math Proofs | As % B+B | As % of Back

Computer Programs | As % BtB | As % of Back

Computer Printouts | As % B+B | As % of Back

Exp. Procedures | As % B+B | As % of Back

Related Lit. | As % B+B | As % of Back

Other | As % B+B | As % of Back | Describe Other

Total | Total As % B+B | Total As % Back | Total As % of Total Pages

Doc. No. | Form No. 6 | Org. Type | Activity | Doc. Type

LEGIBILITY–TEXT

Use Math 0 or 1 | Typeset 0 or 1 | Style G or R | Size & Lead

LEGIBILITY–DISPLAY

Use Math 0 or 1 | Typeset 0 or 1 | Style G or R | Size & Lead

Solidus

Text and Display | Text | Display

Radicals Expressed as $^{-1/n}$

Text and Display | Text | Display

Doc. No. | Form No. 7 | Org. Type | Activity | Doc. Type

Total Pages | Body Pages | Back Pages | Total Body + Back

Total Figures | Figures As % of B+B | Figures Body | % of Figures in Body

Figures Integrated with Text 0 or 1 | Figs. Back | % of Figures in Back

Figure Legends 0 or 1 | Legends Typeset 0 or 1 | Legends Caps or U&lc | Figure Captions 0 or 1 | Captions Typeset 0 or 1 | Captions Caps or U&lc

TYPES OF FIGURES

Charts

Scatter Dist. | Bar Pie | Polar | 2D Cartesian | 3D Cartesian

Diagrams

Org./Hierar-chal | Func-tional | Ortho Draw | Iso Draw | Perspec-tive Freehand | Model

Mixed Charts and Diagrams

Artwork

Illus. | Photos | Models

LEGIBILITY–CHARTS

Grid Used Charts | Max. No. Data Paths Per Figure | Use of Color-Charts | Use of Color, Other Art

PRODUCTION METHODS–CHARTS AND DIAGRAMS

Hand Drawn | Strip Record | Computer Output

Doc. No. | Form No. 8 | Org. Type | Activity | Doc. Type

Total Pages | Body Pages | Back Pages | Total Body + Back

Total Tables | Tables As % of B+B | Tables Body | % of Tables in Body

Tables Integrated with Text 0 or 1 | Tables Back | % of Tables in Back

Table Legends 0 or 1 | Legends Typeset 0 or 1 | Legends Caps, or U&lc | Table Captions 0 or 1 | Captions Typeset 0 or 1 | Captions Caps or U&lc

Max. No. Columns Per Table | Grouped Vertically 0 or 1 | Bold Face Data 0 or 1

APPENDIX D

COMPOSITION OF THE SURVEY SAMPLES

There were two survey samples used in this report. For the analysis of sequential components, the number of reports was 99. Table D-I below shows the composition of this sample (n = 99) by organizational type of the producer. The largest group was industrial organizations (54 of 99 documents), followed by research, trade, and professional organizations.

TABLE D-I

Composition of the n = 99 Survey Sample by Organizational Type

Organizational type	Number of reports
Industrial	54
Research, trade, and professional	22
Government	12
Academic	11
TOTAL	99

For the analysis of language and presentation components, the survey reports were reduced to 50 reports. Each report was categorized by type of publishing organization, by type of publication, and by principal activity or research area. Tables D-II, D-III, and D-IV show the composition of the reduced sample by each of these categories.

TABLE D-II

Composition of the n = 50 Survey Sample by Organizational Type

Organizational type	Number of reports	Percentage of sample
Industrial	25	50
Research, trade, and professional	14	28
Government	7	14
Academic	4	8
TOTAL	50	100

APPENDIX D

TABLE D-III

Composition of the n = 50 Survey Sample by Document Type

Document type	Number of reports	Percentage of sample
Technical reports	28	56
Technical manuals	12	24
Technical summaries	4	8
Scientific reports	3	6
Technical proceedings	1	2
Technical journals	1	2
Scientific journals	1	2
TOTAL	50	100

TABLE D-IV

Composition of the n = 50 Survey Sample by Principal Activity

Principal activity or research area	Number of reports	Percentage of sample
Aerospace	9	18
Basic research	3	6
Computing	9	18
Defense	2	4
Energy	7	14
Engineering	7	14
Manufacturing	5	10
Social sciences	2	4
Environmental sciences	3	6
Medicine	2	4
Publishing	1	2
TOTAL	50	100

APPENDIX E

EXHAUSTIVE LIST OF SEQUENTIAL COMPONENTS IN SURVEY REPORTS

Some material is either subordinate to or the same as other sections. This material has been grouped and added so that a clearer indication of position can be calculated.

Component	Percent of survey using component	Component location within survey reports, percent		
		Front	Body	Back
Cover	67.7	100.0	---	---
Inside front cover	2.0	100.0	---	---
	69.7	100.0	---	---
Disclaimers	11.1	90.9	---	9.1
Notices	24.2	83.3	4.2	12.5
Safety procedures	1.0	100.0	---	---
Warranty	1.0	100.0	---	---
	37.3	86.5	2.7	10.8
Title page	72.7	98.6	1.4	---
DD 1473	8.0	75.0	12.5	12.5
	80.0	96.3	2.5	1.2
Copyright	19.1	100.0	---	---
Approval page	2.0	100.0	---	---
DD 1473	8.0	75.0	12.5	12.5
Distribution list	13.1	15.4	---	84.6
List of distributors	1.0	---	---	100.0
Reproduction page	1.0	100.0	---	---
	44.4	68.2	2.3	29.5
Previous documents	5.0	60.0	---	40.0
Publications	1.0	---	---	100.0
	6.0	50.0	---	50.0
Abstracts	30.3	90.0	10.0	---
DD 1473	8.0	75.0	12.5	12.5
Library card abstract	1.0	---	---	100.0
	39.3	84.6	10.3	5.1
Preface	24.2	100.0	---	---
About the author	1.0	---	---	100.0
Acknowledgments	24.2	91.6	4.2	4.2
Author's notes	1.0	100.0	---	---
	50.5	94.0	2.0	4.0
Table of contents	68.6	100.0	---	---
List of effective pages	1.0	100.0	---	---
Page status summary	1.0	100.0	---	---
	70.7	100.0	---	---

APPENDIX E

Component	Percent of survey using component	Component location within survey reports, percent		
		Front	Body	Back
List of figures	17.1	94.1	---	5.9
List of illustrations	19.1	100.0	---	---
List of drawing & photos	1.0	100.0	---	---
Component drawing index	1.0	100.0	---	---
	39.3	97.4	---	2.6
List of tables	30.3	96.7	---	3.3
List of abbreviations	4.0	---	---	100.0
List of abbreviations & symbols	6.0	100.0	---	---
List of symbols	4.0	75.0	---	25.0
Nomenclatures	3.0	66.7	---	33.3
Symbols (NASA)	1.0	---	100.0	---
	18.1	61.1	5.6	33.3
Foreword	19.1	100.0	---	---
General information	2.0	50.0	50.0	---
Organization	1.0	100.0	---	---
	22.2	95.5	4.5	---
Summary	27.2	33.3	59.3	7.4
Executive summary	3.0	66.7	---	33.3
	30.3	36.7	53.3	10.0
Introduction	57.5	17.5	82.5	---
Organization	1.0	100.0	---	---
Objectives	1.0	---	100.0	---
Project administration	1.0	---	100.0	---
Input	1.0	---	100.0	---
Purpose	5.0	20.0	80.0	---
Statement of problem	1.0	---	100.0	---
System overview	1.0	---	100.0	---
Proposed program	1.0	---	100.0	---
	12.1	8.3	91.7	---
Text	35.3	---	100.0	---
Scope	3.0	---	100.0	---
Past & current research	2.0	---	100.0	---
Qualifications	1.0	---	100.0	---
Restrictions	1.0	---	100.0	---
Status	1.0	---	100.0	---
Theories	4.0	---	100.0	---
	12.1	---	100.0	---
Equipment	4.0	---	100.0	---
Materials	1.0	---	100.0	---
	5.0	---	100.0	---

APPENDIX E

Component	Percent of survey using component	Component location within survey reports, percent		
		Front	Body	Back
Experimental work	1.0	---	100.0	---
Methods	5.0	---	100.0	---
Operating instructions	1.0	---	100.0	---
Procedures	2.0	---	100.0	---
Sources of information	1.0	---	100.0	---
Work performed	1.0	---	100.0	---
	11.1	---	100.0	---
Installation	3.0	---	100.0	---
Maintenance	2.0	---	100.0	---
Preparation for use/ re-shipment	1.0	---	100.0	---
	6.0	---	100.0	---
Process	22.2	---	100.0	---
Data & interpretation	1.0	---	100.0	---
Description	6.0	---	100.0	---
Discussion	11.1	---	90.9	9.1
Output	1.0	---	100.0	---
Report samples and descriptions	1.0	---	---	100.0
Reporting	1.0	---	100.0	---
Results	4.0	---	100.0	---
Test evaluation	1.0	---	100.0	---
Time/Cost estimates	1.0	---	100.0	---
	27.2	---	92.6	7.4
Conclusions	22.2	---	100.0	---
Future work	1.0	---	100.0	---
Implications and limitations	1.0	---	100.0	---
Recommendations	7.0	14.3	85.7	---
	31.3	3.2	96.8	---
Appendixes	59.5	---	1.7	98.3
Diagrams	1.0	---	---	100.0
Illustrations	3.0	---	---	100.0
Tables	5.0	---	20.0	80.0
	68.6	---	2.9	97.1
References	36.3	---	2.8	97.2
Footnotes	1.0	---	100.0	---
Theory proof	1.0	---	---	100.0
Difference data sheet	1.0	---	---	100.0
	39.3	---	5.1	94.9
Bibliography	15.1	---	6.7	93.3
Glossary	23.2	8.7	4.3	87.0

APPENDIX E

Component	Percent of survey using component	Component location within survey reports, percent		
		Front	Body	Back
Indexes	23.2	4.3	---	95.7
Component drawing index	1.0	---	---	100.0
	24.2	4.2	---	95.8
Reader comment forms	7.0	14.3	---	85.7
User comment sheet	1.0	---	---	100.0
	8.0	12.5	---	87.5
Model designation	1.0	---	---	100.0
Back cover	3.0	---	---	100.0

APPENDIX F

COMMERCIALLY AVAILABLE STYLE MANUALS, PUBLICATIONS GUIDES, AND BOOKS COVERING REPORT PREPARATION AND PRODUCTION USED BY SURVEY RESPONDENTS

American Chemical Society. Handbook for Authors of Papers in American Chemical Society Publications. Washington, DC: ACS, 1978.

American Institute of Physics - Publications Board. Style Manual for Guidance in the Preparation of Papers for Journals. 3rd Edition. New York: AIP, 1978.

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16. Abstract

The results of Phase VI - The Technical Report: A Survey and Analysis are contained in this report. As part of the review and evaluation of the Langley Research Center's scientific and technical information (STI) program, the technical report was examined to determine the organization of the report (sequential components), the language used to convey the information (language components), and the methods used to present the information (presentation components). The examination included a survey of the literature pertinent to the subject and an analysis of current usage and practices of publishers of technical reports.

The purpose of the study was three-fold: (1) to survey and analyze current practice and usage using selected technical reports; (2) to survey and examine available literature relative to the sequential, language, and presentation components of technical reports; and (3) to compare the NASA technical report publications standards with the findings of the examination. The reported findings would permit NASA management to assess its publications standards and to initiate changes, as needed, to increase the effectiveness of the technical report as a product for information dissemination.

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