

NASA/SP—2006-6114



NASA Scientific and Technical Information Standards

*NASA Scientific and Technical Information Program
NASA Headquarters, Washington, D.C.*

The NASA STI Program Office . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program operates under the auspices of the Agency Chief Information Officer. Program responsibilities include collecting, organizing, providing for archiving, and disseminating NASA's STI. The NASA STI program provides access to the NASA Aeronautics and Space Database and its public interface, the NASA Technical Report Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- **TECHNICAL PUBLICATION.** Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers, but having less stringent limitations on manuscript length and extent of graphic presentations.
- **TECHNICAL MEMORANDUM.** Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- **CONTRACTOR REPORT.** Scientific and technical findings by NASA-sponsored contractors and grantees.

- **CONFERENCE PUBLICATION.** Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.
- **SPECIAL PUBLICATION.** Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.
- **TECHNICAL TRANSLATION.** English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include creating custom thesauri, building customized databases, and organizing and publishing research results.

For more information about the NASA STI Program, see the following:

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- Email your question via the Internet to help@sti.nasa.gov.
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NASA Headquarters, Washington, D.C.*

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The NASA Scientific and Technical Information (STI) Program thanks NCI Information Systems, Inc., for compiling standards for this document from a number of NASA Centers. We also thank the NASA Centers technical publications organizations for providing information from their internal procedures and manuals from which this document was compiled and for reviewing the draft publication. A special thanks goes to Elaine Firestone for performing a technical edit on the document.

In addition, we thank the professional writers, editors, graphics, and other publication personnel who for many years dedicated their efforts to ensuring that NASA STI Series Reports and other STI were well written, clear, and upheld a standard of excellence in scientific and technical documentation.

A special acknowledgment goes to Pearl I. Young for establishing an organization within the National Advisory Committee for Aeronautics (NACA), NASA's predecessor, which was the foundation for today's NASA STI Program.

TRIBUTE TO PEARL I. YOUNG



L-03247

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Pearl I. Young attended Jamestown College and the University of North Dakota, graduating in 1919 with honors, a Phi Beta Kappa key, and a triple major in physics, chemistry, and mathematics. After graduating, she was hired by the University to teach physics, which was a role that typically was held by men.

During this time, there were 21 female and 864 male physicists in the United States. Most of the women were college teachers, hired by women's colleges. There was only one woman physicist working for the Federal government at that time, and she worked for the National Bureau of Standards.

In 1922, Young was hired as a physicist by the National Advisory Committee for Aeronautics (NACA), and was assigned to the Langley Memorial Aeronautical Laboratory's (now NASA Langley Research Center) Instrument Research Division under the direction of Henry J. E. Reid.

In 1929, Reid appointed Young as Langley's Chief Technical Editor. She formed a "new" office, hired staff, and established the research reports and official documents that communicated the extraordinary technical accomplishments of NACA and later NASA.

Throughout her 28 years at the NACA and NASA, Young helped define the public image of the NACA and NASA and influenced the way aeronautical engineers throughout NACA and NASA communicated their ideas.

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PREFACE

NASA has a long, active, and well-recognized history of providing high-quality documentation of research and development (R&D) results through its Scientific and Technical Information (STI) Program. This Special Publication (SP), which is considered a companion to NASA SP-7084, “Grammar, Punctuation, and Capitalization: A Handbook for Technical Writers and Editors,” by Mary K. McCaskill, helps document and preserve the knowledge inherent in handling NASA’s STI.

We thank the many people who over the years have utilized their skills, knowledge, and professionalism to document and preserve NASA’s STI so that it will be available for use both now and in the future.

The information given in this document recommends general standards for a number of scientific and engineering disciplines. Adjust them as necessary to fit your specific disciplines or “house” style.

NASA STI Program Office
NASA Headquarters Office of the Chief Information Officer

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SECTION I

OVERVIEW OF NASA SCIENTIFIC AND TECHNICAL INFORMATION (STI) PUBLICATIONS: ELEMENTS AND FORMAT

1.1 NASA STI Report Series

1.1.1 Purpose

All significant scientific and technical findings derived from NASA activities are distributed or disseminated as appropriate, either in one of the NASA STI Report Series defined in this section or through suitable non-NASA scientific and technical channels. This section provides the standards for publication of NASA STI in the NASA STI Report Series.

1.1.2 Description of the NASA STI Report Series

1.1.2.1 Technical Publication (TP)

This series comprises reports of completed research or of a significant phase of research that present the results of NASA programs. TPs usually include extensive data or theoretical analysis, but they may also be compilations of significant scientific and technical data or information deemed to be of continuing reference value. TPs are the NASA counterpart of peer-reviewed formal professional papers but have less stringent limitations on manuscript length and extent of graphic presentations. In addition to reports that document research, the types of documents assigned to this series include the following:

- Bibliographies of STI literature in defined subject areas with abstracts and/or extensive annotation.
- Technical handbooks, critical tables, and extensive data compilations.
- Design standards. Authors should also document their design standards in the NASA Technical Standards Program, in accordance with NASA Policy Directive (NPD) 8070.6, "Technical Standards," as appropriate.
- Scientific and technical textbooks and manuals.
- State-of-the-art summaries, including critical reviews or surveys of a body of scientific or technical literature.
- Technical reports or monographs that provide complete and comprehensive treatment of significant contributions to scientific and technical knowledge or a critical evaluation of selected, previously published research.

1.1.2.2 Technical Memorandum (TM)

This series records scientific and technical findings that are preliminary or of specialized interest, e.g., reports for quick release, working papers, and bibliographies that contain minimal annotation. TMs do not contain extensive analysis. The types of documents that are assigned to this series include:

- Preliminary data (reports for quick release).
- Working papers for professional peers beyond the basic work unit or for external circulation.
- Individual papers prepared for presentation at or preprints for professional meetings or symposia that may or may not be published later in proceedings or journals.

- Preliminary proceedings of professional meetings or symposia sponsored or cosponsored by NASA. When the proceedings are not complete, the extent of the content, e.g., “abstracts only” or “primarily viewgraphs,” is indicated in the Supplementary Notes block of Standard Form (SF)-298, Report Documentation Page (RDP). (See Section 1.1.5.6 for information on the RDP.)
- Theses or dissertations that relate to Agency work, written by NASA employees only.
- Bibliographies that are written by NASA employees, contractors, or grantees and present listings of STI literature with minimal annotations.
- Computer program application documentation.
- Limited-use data compilations.
- Reports to other agencies or non-NASA-sponsored research results.

1.1.2.3 Contractor Report (CR)

This series comprises reports of scientific and technical findings by NASA-sponsored contractors, grantees, and cooperative agreement recipients and dissertations or theses by NASA contractors or grantees (if funded by NASA).

1.1.2.3.1 Content of CRs

CRs may contain findings of completed or significant scientific and technical work or findings of preliminary or specialized interest. All CRs are subject to the minimum review requirements listed in Section 8.2.3.

1.1.2.3.2 Publication of CRs in Other Series

A final report or non-required report authored by a contractor, grantee, or cooperative agreement recipient may be selected by the NASA Contracting Officer Technical Representative (COTR) or technical management for publication as a NASA CP, SP, or TP in lieu of publication as a CR. A given report may be published in one series only. Such reports must meet all criteria for the selected series and must be reviewed and approved at the level(s) required for that series.

1.1.2.4 Conference Publication (CP)

This series contains collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.

1.1.2.4.1 CP Preprints

Conference proceedings may be preprinted as a TM and distributed to attendees at conferences even though distribution as a CP is planned.

1.1.2.4.2 Publication of Conference Proceedings in Both Series

It is sometimes practical to publish conference proceedings in both series, i.e., preprinted as a TM and printed as a CP following the conference. For example, if a significant amount of time will elapse between presenting abstracts and illustrations as a TM and the full proceedings as a CP, or if handouts of the abstracts are needed for the conference and the papers have not yet been collected, publication in both series would be appropriate. When abstracts have been published as a TM and the proceedings are subsequently published as a CP, an entry in the Supplementary Notes block of SF-298, RDP, for the CP indicates that the CP supersedes the TM.

1.1.2.5 Special Publication (SP)

This series, which records scientific, technical, or historical information from NASA programs, projects, and missions, is most often concerned with subjects having substantial public interest. Examples of topics covered by this series and the ranges of numbers assigned to the various topics include the following:

- General series (numbered below 3000), e.g., NASA/SP—2006-2999.
- Handbooks and data compilations (numbered in the 3000 series), e.g., NASA/SP—2006-3000.
- History and chronology series (numbered in the 4000 series), e.g., NASA/SP—2006-4000.
 - 4000—Reference works.
 - 4100—Management histories.
 - 4200—Project histories.
 - 4300—Center histories.
 - 4400—General histories.
 - 4500—Monographs in aerospace history.
 - 4600—Electronic media (data compact disks (CDs) and digital video disks (DVDs)).
 - 4700—Historical conference proceedings.
- Numbers in the 5000 series were originally assigned to technology commercialization information, but this type of information is now published outside the STI Report Series.
- Management publications series (numbered from 6000 to 6999), e.g., NASA/SP—2006-6000. This series documents requirements, plans, theories, or techniques for management or administration of NASA-sponsored scientific and technical work. It includes NASA projects or programs that have application to more than one Center, to other Government agencies, or to partnerships with industrial or international organizations. Although reports that discuss methods of scheduling, funding, or staffing may be included, reports that contain specific costs or labor figures are not appropriate. When the primary content of a report is scientific findings or technical development, another series, such as TM or TP, should be used.
- Bibliographic series (numbered from 7000 to 7999), e.g., NASA/SP—2006-7000. Regularly published abstracts, continuing bibliographies, indexes, publication guides, and announcement journals.

1.1.2.6 Technical Translation (TT)

This series consists of English-language translations of non-English scientific and technical material pertinent to NASA's mission. A translation of material protected by copyright is a derivative work, and distribution is constrained by international copyright law. However, TTs are retained at the NASA Center for Aerospace Information (CASI) for U.S. Government use subsequent to the initial request for the translation. See Section 1.1.8.9 for more information on translations.

1.1.3 Assigning Publications to the NASA STI Report Series

1.1.3.1 STI Processing

NASA indexes and catalogues the STI Report Series documents into the NASA Aeronautics and Space Database and its public interface, the NASA Technical Report Server, as appropriate, and ensures (through NASA CASI) that these documents are archived at the National Archives and Records Administration (NARA). The STI Report Series also gains wide dissemination, as appropriate.

1.1.3.2 Electronic Copy

NASA requires that an electronic copy or Uniform Resource Locator (URL) (and requests that a hard (paper) copy) of all NASA STI Reports Series documents be submitted to NASA CASI through the NASA Center STI Manager or delegated Center organization. All NASA-funded STI must be reviewed via NASA Form (NF)-1676, or a Center equivalent form, prior to being published, disseminated, or presented external to NASA (or presented at internal meetings or conferences where foreign nationals may be present). NASA STI Report Series documents that are sent to NASA CASI without notification of a Document Availability Authorization (DAA, NF-1676) review will be held until appropriate release notification is received (for a maximum of 30 days). After several attempts to obtain a DAA or following the 30-day hold period, NASA CASI will process the documents without DAAs but limit them to NASA personnel only until a DAA is received.

1.1.3.3 Basis for Series Selection

Selection of the correct series in which a document is published is based on its content. Section 1.1.2 provides a description and guidelines on series selection. The author makes the preliminary determination in conjunction with technical management or the COTR (if applicable) and the Center Technical Publications Office. Selection is subject to approval as part of the Center review process.

1.1.3.4 Report Series Number Assignment

When the series is selected and approved, the publication is assigned a NASA report number. Authors contact their Center's Technical Publications Office to obtain a document number (that is received by the Centers from NASA CASI). The report number is prefixed by the Agency acronym and the two-letter abbreviation that indicates the series. Examples include NASA/CP—006-123456 and NASA/TM—2006-123456.

For documents that are published in English and another language, use the same NASA number but add the language in parentheses (e.g., NASA/TP—2006-123456 (in English); NASA/TP—2006-123456 (in Spanish)).

1.1.3.5 STI Work for Another Government Agency, Company, or University

When a NASA employee or person performing under a NASA contract or grant works with or undertakes work for another Government agency, they should also report their scientific and technical findings in the NASA STI Report Series. Appropriate indication of the joint project or sponsorship should be given on the cover, title page, and the RDP. Such publication does not preclude the other governmental agency from publishing the work in its own series.

In situations in which a NASA employee or person performing under a NASA contract or grant works with or undertakes work with a company or university and the company or university publishes the results, authors should indicate NASA's support on the title page or first page of the work.

1.1.3.6 STI-Related Work Funded by One Center and Performed by Another

When NASA work is sponsored or funded by one NASA Center and performed by another NASA Center, the scientific and technical findings should be reported in the NASA STI Report Series. The Center performing the work is responsible for approval, production, and issuance of the document. Appropriate indication of sponsorship is given on the cover, title page, and the RDP (SF-298).

1.1.4 Responsibility for the NASA STI Report Series

1.1.4.1 Policy

Responsibility for production and dissemination of all NASA STI publications is set forth in NPD 2200.1, "Management of NASA Scientific and Technical Information (STI)."

1.1.4.2 Responsibilities

The STI Program Office is responsible for the management of the Agency STI program and maintains control of the production and distribution of the six STI Report Series. This responsibility is carried out through the NASA Headquarters STI Program Director and the NASA Centers' STI Managers and Technical Publications Managers.

1.1.4.3 Preliminary Procedures

The author, technical management, and the Center Technical Publications Manager ensure that the necessary funds are available from the originating NASA Center or Headquarters office to cover the cost of production and printing of the report, if applicable. For reports that are to be printed, contact the Agency's or Center's Printing Officer and the Technical Publications Manager.

1.1.4.4 Reviews and Approvals

All NASA STI published or released by NASA, regardless of publication type or media used, must meet the review and approval requirements set forth in Section 8 before the STI is published, disseminated, or presented external to NASA or presented at internal conferences or meetings where foreign nationals are expected to be present. The author and his/her management ensure that the required reviews are completed and approved and signatures are obtained in cooperation with the COTR, if applicable (e.g., for CRs).

1.1.4.5 Special Procedures

NASA CRs (reports prepared by contractor, grantee, or cooperative agreement recipients) will be processed into an STI Report Series CR only after the cognizant Contracting Officer (CO) or COTR and NASA manager approve the report as an acceptable deliverable under the terms of the contract, grant, or cooperative agreement.

1.1.4.6 Submission of Reports

When specified in the contract, grant, or cooperative agreement, contractors, grantees, and cooperative agreement recipients must submit final reports to the NASA CO or COTR of record. For specifics, see the “NASA Federal Acquisition Regulations (FAR) Supplement” (updated February 3, 2003, <http://www.hq.nasa.gov/office/procurement/regs/>) Sections 1835.010, 1835.011, 1835.070, 1852.235-70, 1852.235-73, 1852.235-74, and their referenced sections, and the “Grants and Cooperative Agreements Handbook” (NPR 5800.1, Sections 1260.22, 1260.75, 1260.151, 1274.921, 1274.933, and their referenced sections). See Procurement Information Circular (PIC 03-03), entitled “Scientific and Technical Information,” dated February 3, 2003.

The use of electronic formats for submission is highly recommended. Contractors, grantees, and cooperative agreement recipients should provide NASA CASI with an electronic copy of the letter transmitting the final report to the NASA CO or COTR by sending it to mailto:eft_ftp@sti.nasa.gov, “attention acquisitions unit.” (For help, contact email: help@sti.nasa.gov.) Also submit an RDP for STI Report Series documents.

1.1.4.7 NASA Technical Translations

Translations of STI performed by and for NASA represent a resource investment; therefore, NASA CASI collects technical translations for inclusion in the NASA Aeronautics and Space Database.

1.1.4.8 Submission of NASA Technical Translations to NASA CASI

NASA activities arranging for translation services (e.g., through the award of a contract for translation services) should incorporate the requirement to submit one copy of each technical translation to NASA CASI in those arrangements (e.g., a contract clause), thereby relieving the requester of the responsibility to ensure that copies of translations are forwarded for input into the NASA Aeronautics and Space Database. If the producer of a translation is not required to submit one copy of each technical translation to NASA CASI, the requester must ensure that a copy of the translation is forwarded to NASA CASI for inclusion in the Technical Translations series.

1.1.4.9 Provision of Copyright Information

To assist NASA CASI in determining distribution limitations and to expedite future dissemination of a technical translation, the requester should ensure that information concerning copyright of the original source document accompanies the translation submitted to NASA CASI. This information is also entered on NF-1676. Such information includes, but is not limited to, the title of the book or article, the name of the book or journal in which the copyrighted information was originally published, the publisher’s name and address, the publication date, and any copyright notice appearing on the document, book, or journal in which the copyrighted information was originally published.

1.1.5 Standards for STI Report Series Publications

These standards apply to the STI Report Series regardless of the media (e.g., electronic, video, audio, compact disk – read-only memory (CD-ROM), Web site, etc.) chosen. While the data elements detailed here are required, the formatting of the STI may be adapted as necessary to fit the media. Publication of NASA STI in any media must also conform to NASA’s information technology standards and guidelines as specified in NPR (NASA Procedural Requirements) standard front and back covers and title pages are depicted in Section 1.3 of this document. Section 1.3 also illustrates the use of the standard elements (e.g., report number, title). Covers and title pages are available on the NASA STI Program home page (<http://www.sti.nasa.gov>, Publish STI). The use of the standard covers and title pages is required for printed STI. For electronic or alternative media, layouts may be adapted as needed.

1.1.5.1 Use of Color

1.1.5.1.1 Use of Color in Printed Versions of the NASA STI Report Series

The use of color in printed publications increases printing costs; therefore, color printing is used in printed versions of the NASA STI Report Series only when necessary to convey scientific and technical material in a clear and unambiguous fashion rather than when desirous to use decorative elements. The added design and production costs for the portrayal of information in color are justified and authorized by the NASA Headquarters or Center Printing Officer. The duplicating or printing requirements must be in accordance with NPD 1490.1, “NASA Printing, Duplicating, Copying, Forms, and Mail Management,” and must be approved by the Agency or Center Printing Officer for legality and necessity. Contact the Center Technical Publications Office or Graphics Coordinator to determine alternative methods to portray content (such as in charts and graphs) so that they do not require the use of color.

1.1.5.1.2 Use of Color in Electronic Versions of the NASA STI Report Series

If color enhances the content of NASA STI Report Series documents in electronic format, its use is appropriate. However, authors should not use color alone to indicate scientific data in charts and graphs. In situations where color is used, additional symbols (such as dots, crosshatch, etc.) should also be used to indicate the meaning of the color, or the actual color name should be indicated on the key. See Section 1.1.5.10 for additional considerations of Section 508 compliance for documents to be posted on Web sites.

The use of color increases the file size of electronic documents and may slow download from a Web site. Furthermore, because some users have black-and-white monitors and printers, the benefits of color may also be lost in those cases.

Publications using multimedia components are acceptable. Contact the Center Technical Publications Office and/or NASA CASI to find out if the specific multimedia format can be reproduced and archived by NASA CASI. If NASA CASI cannot reproduce or archive the multimedia format, authors may be required to send additional electronic copies.

1.1.5.2 Standard Front and Back Covers and Title Pages

The design and content of the front and back covers and title pages of NASA STI Report Series, except for SPs, are standardized in accordance with industry standards, such as American

National Standards Institute/National Information Standards Organization (ANSI/NISO) Z39.18, “Scientific and Technical Reports—Preparation, Presentation and Preservation,” and Agency standards, such as those detailed in NPD 1490.1, “NASA Printing, Duplicating, Copying, Forms, and Mail Management,” and NPR 1490.5, “NASA Procedural Requirements for Printing, Duplicating, and Copying Management.” This standardization provides a recognizable NASA image, speed, and economy of production and reproduction, consistency of cataloging information, and lowest recycling cost. Therefore, the front and back covers and title pages of NASA STI reports, except for SPs, must contain the standard elements listed below. See the report templates at <http://www.sti.nasa.gov/nasaonly/template/template.html> (NASA personnel) or <http://www.sti.nasa.gov/template/template.html>.

1.1.5.2.1 Standard Elements for Front Covers

- Report number(s). (If another agency’s, Center’s, or contractor’s report or document number is added to the NASA report number, it should be positioned to the right of or below the NASA report number.)
- NASA insignia (sometimes referred to as the NASA “meatball”); logos of other sponsors as appropriate (see Section 1.1.5.4.1).
- Title of report.
- Author name(s), affiliation, and location.
- Optional one-color line art or black-and-white photo or image.
- Distribution notices, if applicable. Distribution notices, including limitations and restrictions such as International Traffic in Arms Regulations (ITAR), Export Administration Regulations (EAR), Small Business Innovation Research (SBIR), proprietary information, or copyright notices must be placed on the cover, title page, and RDP.
- Conference information. Authors may choose to add conference information, such as conference name, location, dates, and sponsor.
- Joint project or sponsorship information, if appropriate.
- Rule (graphic straight line).
- Month/year.

1.1.5.2.2 Standard Elements for the Back of Front Covers

- NASA STI Program profile.

1.1.5.2.3 Standard Elements for Title Pages

- Cover elements (except artwork).
- Author name(s), affiliation(s), and locations.
- Editor name and affiliation, if applicable (for edited CPs, TPs, or TMs when the editor has contributed scientific and technical expertise and judgment).
- Agency name and address (corporate source).
- Contract statement and number, if applicable.
- Joint project or sponsorship information, if appropriate.
- Conference information (name of conference, location, dates, sponsors, etc.), if applicable.
- Distribution notices, if applicable (see Section 8).

1.1.5.2.4 Standard Elements for the Back of Title Pages

- Acknowledgment, if applicable.
- Disclaimers, if applicable.
- Statement announcing that the document is available from NASA CASI. In some cases, the document may also be available from the National Technical Information Service (NTIS). Documents that are marked to be available from NTIS must be unlimited, unclassified (i.e., no restricted-access, limited, Administratively Controlled Information (ACI) or Sensitive But Unclassified (SBU) data or information).
- International Standard Serial Number (ISSN), International Standard Book Number (ISBN), and/or Library of Congress Control Number (LCCN), if applicable.
- Level of technical or professional review (optional).

1.1.5.2.5 Standard Elements for Back Cover

The back cover is blank except for a rule (i.e., graphic straight line) at the bottom of the cover. If documents are printed, a mailing label that includes the addressee, the return address, and appropriate postage may be affixed to the center of the back cover. No text or images other than the rule may be placed below the last line of the address on the mailing label.

1.1.5.3 Standard Elements for Spines

- Report number.
- Title.

1.1.5.4 Artwork and Photography

NASA recommends the use of one-color line art and black-and-white photography on the front cover of the NASA STI Report Series only in the image area. Such one-color line art and black-and-white photographs must meet the graphics standards of the originating Center and must be approved by the Center Graphics Coordinator.

1.1.5.4.1 Cosponsor Logos

When NASA partners with or jointly funds work with another agency, noncommercial organization, or university, the logo or seal of the cosponsor may appear on the cover to the right of or below the NASA insignia and must be in accordance with the NASA guidelines for the use of logos and insignia at <http://www.hq.nasa.gov/office/pao/insignia> (see Section 1.1.5.4.2).

1.1.5.4.2 NASA Insignia

The NASA insignia cannot appear with the logos of private companies on publications. In rare exceptions, such as certain partnership situations, the Office of Public Affairs, Public Service Division at Headquarters, may approve a proposed use.

1.1.5.4.3 NASA Program Organizational Logos

NASA program organizational logos are not acceptable for use on covers.

1.1.5.5 Nonstandard Front Cover and Title Page

Sometimes a nonstandard design is needed for the front cover and title page of a NASA STI Report Series of particular note. Such designs must contain the standard elements indicated in Section 1.1.5.2. The use of a nonstandard design and the associated additional design labor cost are justified and authorized on a case-by-case basis using Center-specific procedures. The nonstandard design must be in accordance with NASA graphics standards and must be approved by the Center Graphics Coordinator. For duplicated or printed publications, the requirements are set forth in NPD 1490.1, “NASA Printing, Duplicating, Copying, Forms, and Mail Management,” and must be approved by the Center Printing Officer for legality and necessity.

1.1.5.6 Report Documentation Page (RDP)—SF-298

An RDP is required for all documents published in the NASA STI Report Series. It provides the information necessary to index and correctly categorize the report. Directions for preparation of the RDP are given on the back of the form. Except for NASA SPs, the completed RDP is positioned as the last page of the report. For documents that are to be printed, the RDP is printed so that it faces the back cover. For SPs, the RDP is forwarded to NASA CASI with, but not printed and bound in, the SP. For SPs in electronic formats, the RDP is a separate file. See <http://www.sti.nasa.gov/nasaonly/publish/SF298instr.pdf> NASA Supplementary Instructions To Complete SF-298 (Rev. 8/98 version).

Prior to dissemination, the information that is entered on the RDP must be verified against the information that is on the approved NF-1676 or Center implementation of this form.

For a classified report, the title and the abstract are followed by the classification of each in parentheses. Unclassified titles and abstracts are followed by a “(U).” Whenever possible, the title and abstract of a classified report are unclassified. Classified reports must be handled by the NASA Centers and are not sent to NASA CASI.

For information regarding how to indicate that a previously export-controlled or restricted-access document has subsequently been downgraded and has a new distribution requirement (see Section 1.1.5.12).

1.1.5.6.1 Funding Numbers

For information retrieval purposes, include the NASA Work Unit (WU) number, Work Breakdown Structure (WBS) number, or the Unique Project Number (UPN) on the RDP in block 5(f), if possible.

1.1.5.6.2 Supplementary Notes

For a symposium presentation that is preprinted as a TM or published as a CP, identify the meeting or symposium in the block designated for Supplementary Notes.

1.1.5.6.3 Abstract

The abstract included on the RDP should be informative rather than descriptive and should state the objectives of the investigation, the methods employed (e.g., simulation, experiment, or remote sensing), the results obtained, and the conclusions reached. Limit the abstract to a maximum of 200 words.

1.1.5.7 Handwritten NASA STI Reports

Handwritten elements of any kind are not acceptable. Publications included in the NASA STI Report Series must be professional in appearance (i.e., typeset or completed using word-processing equipment), and must be capable of electronic transmission.

1.1.5.8 Revised Reports, Errata, and Corrected Copies

A revised report must be issued in situations where the technical data need to be substantially changed or updated. The standard report number format to indicate this is the year and number of the original report followed by the REV extension, e.g., NASA/TM—2006-123456/REV1. The current month and year should be included on the report cover and title page. The Supplemental Notes section of the RDP should indicate whether or not the revised report supersedes the original report.

An errata should be issued if the errors are minimal but of sufficient importance to warrant correction. Minor typographical errors usually do not require correction. The distribution of errata is made in accordance with the original distribution.

A corrected copy should be issued if there are numerous errors that cannot be made clear in an errata. The standard report number format for a corrected copy is the year and number of the original report followed by “Corrected Copy” in parentheses. The report date is the same as the original report. Distribution is made in accordance with the original distribution.

The standards that apply to paper copy revisions also apply to electronic media. For example, a file on a Web site (such as on the NASA Technical Reports Server (NTRS)) should not be replaced with a revised file without indicating the appropriate revision elements and date of revision. It should be indicated on the cover that an errata, a corrected copy, or a revision has been added, along with the date of this action. In addition, a listing of the information that is being corrected should be inserted on page iii. Distribution of revised electronic media should be in accordance with the original distribution.

Other requests for correction are made to the Center’s STI Manager or to NASA CASI at email help@sti.nasa.gov. See also <http://www.sti.nasa.gov/qualinfo.html> for corrections under the “NASA Guidelines for Quality of Information.”

1.1.5.9 Special Factors for Document Legibility

It is important to produce publications that are legible in a variety of media.

For documents that may be printed, oversized image areas and foldouts to present oversized charts may show diminished quality in subsequent electronic formats.

We recommend 12-point typefaces when possible. Typefaces smaller than 10 points (or hard-to-read fonts online) on the original copy affect readability. Typefaces with small or delicate serifs may also affect readability.

1.1.5.10 Standards for Electronic and Alternative Media (Including Multimedia)

In considering electronic and alternative media forms of disseminating of STI, authors must meet the content requirements of Section 1.1.2, the data elements of Section 1.1.5, and the required reviews in Section 8, as well as the requirements of submittal to NASA CASI. Although content and data elements are required, actual formatting and presentation of the STI may be adapted, as necessary, to fit the specific media.

Information that is presented on a Web site must also comply with Section 508 requirements (PL105-220, Subsection 508(a), as amended). Authors should be cognizant that documents that extensively use a two-column format, that contain complex tables with table headers that span the column tables, or that use color (without supporting graphic symbols or indications in the text of what the color indicates) are difficult for visually impaired or other disabled persons to view or access with current assistive technology. In these situations, use of either a Hypertext Markup Language (HTML) or Extensible Markup Language (XML) version in addition to the Adobe[®] Portable Document Format (PDF) may be useful.

1.1.5.11 Sources for Standards

Style and format standards for NASA scientific and technical publications are provided in several sources. If you encounter conflicting guidance, the sequence of the following list governs selection of the appropriate standard.

- NPR 2200.2B, “Requirements for Documentation, Approval, and Dissemination of NASA Scientific and Technical Information (STI).”
- NASA/SP—2005-7602, “NASA Publications Guide for Authors,” and updated versions.
- Public Law 105-220, Title IV, Subsection 408(b), amended Section 508 of the Rehabilitation Act (29 U.S.C. 794d).
- NPR 2800.1, “Managing Information Technology.”
- Instructions issued by NASA Centers that implement the requirements of this NPR.
- *Government Printing Office (GPO) Style Manual*, latest edition.
- Industry-standard style manuals or specifications.

1.1.5.12 Previously Export-Controlled and/or Restricted-Access Documents

This section discusses re-marking and handling documents that were previously export-controlled and/or contain restricted-access information that has been downgraded. When NASA STI is no longer subject to restriction, NASA Centers' program officials, Export Control Administrators, and/or Patent or Intellectual Property Counsel, as appropriate, are responsible for re-marking (downgrading the restriction/limitation) the STI and notifying NASA CASI of the subsequent availability by sending the re-marked document and a copy of the new or modified DAA through the Center Technical Publications Office or STI Manager. Because NASA CASI is a contractor facility, it is not approved to change or alter dissemination information. See NPR 1600.1, "NASA Security Program Procedural Requirements."

The original marking should be electronically lined "through," and the new marking should be indicated next to or above the original marking by stating "restriction changed to...[insert new dissemination access], on date...[insert month, day, and year], by authority of... [insert originating office that is responsible for and has the authority to change the distribution notice]." Indicate this new information on the cover, the title page, and block 12 of the RDP. Do not simply change the access limitation and insert a new cover, title page, and RDP so that there is no record of the subsequent change.

1.1.6 Submitting Publications to NASA CASI

NASA requires that an electronic copy (and recommends that a hard copy) of STI be sent to NASA CASI or that NASA CASI be notified of the location of the STI if it resides on a Web site or in an existing document repository to which NASA CASI may gain access. If the document is in an internal NASA repository, the Center must provide a DAA or information on the required distribution or access. Submission to NASA CASI is accomplished by sending the document and a copy of the approved NF-1676 or Center implementation of this form through the Center's STI Manager or Technical Publications Office to NASA CASI. CASI recommends also sending a hard (paper) copy in addition to the electronic version as a reference to ensure that math and symbols have not been altered during electronic transmission. Electronic, alternative media, and hard copy reports and supplements to reports submitted to NASA CASI must conform to the standards below, depending on the medium (see Section 8.5). For information regarding submitting electronic copies of export-controlled or limited access information, see Section 1.1.6.5.

1.1.6.1 Electronic File Formats

Contact the Center's Technical Publications Manager or NASA CASI Help Desk (301-621-0390) to electronically submit reports to NASA CASI. The Help Desk will provide the Center's Technical Publications Offices with procedures.

NASA Centers can transfer unlimited/unclassified electronic files to CASI after the DAA review is completed via the NF-1676 or Center implementation of this form. Transfer of files to NASA CASI may occur via:

- File Transfer Protocol (FTP).
- The Center's Technical Report Server (TRS).
- Electronic media:
 - 3.5-in Microsoft® Disk Operating System (MS-DOS) diskettes.
 - CD-ROMs formatted to International Standards Organization (ISO) 9660 standards (for more information see URL http://www.yadagio.com/public/standards/iso_cdromr/tocont.htm).
 - Email attachment (up to 5 Mb in size).
 - Digital video disk (DVD).

Documents that are export-controlled, restricted, or limited must be encrypted prior to being sent to NASA CASI. Accepted encryption is established by the NASA Headquarters Chief Information Officer. Current encryption is by Entrust® public-key infrastructure (PKI) or SSL (secure socket layer), at a minimum. Remember that NASA CASI does not accept classified STI, which is handled by the cognizant Center's security office.

1.1.6.1.1 Acceptable Electronic File Formats

NASA CASI will accept the following electronic file formats, listed in order of preference:

- Adobe® PDF (Searchable Image Exact PDF is preferred).
- Adobe® Postscript® (PS) Levels 1 and 2.
- American Standard Code for Information Interchange (ASCII).
- Microsoft® Word or Corel® WordPerfect®.
- HTML (self-contained files only); files with links to external sources cannot be processed.

1.1.6.1.2 Submission Requirements for Electronic Formats

The submission requirements for electronic formats are as follows:

- Store a single document in one file.
- Store conference proceedings or other compilations of chapters, works, or papers in multiple files: one containing the complete document cover to cover and one file for each of the individual papers.
- Include the completed RDP as the last page of the document file. (For SPs, include the RDP as a separate file.) Note: If the RDP is not the last page of the document file but is stored in a separate file, it will not become part of the document when printed or part of the full-text files available through the NASA Aeronautics and Space Database.
- Send a copy of the DAA (NF-1676 or Center implementation of this form) but do not include it in the document. The DAA provides NASA CASI evidence of the DAA

approval process and enables NASA CASI to appropriately add the document to the NASA Aeronautics and Space Database and subsequently disseminate it.

- In order for NASA CASI to further distribute a document, provide the file in publication format. Publication format means that the file should include all pages required to output it as a print product (i.e., cover, front matter, RDP, and blank pages). This will ensure proper page positioning throughout the document if it is printed.
- Notify NASA CASI via email whenever files are transferred or loaded to the Center's Technical Report Server. Identify the file names of the reports and the full path or URL. NASA CASI requires the full path in order to locate the correct file. Address the email to: eft_ftp@sti.nasa.gov. NASA CASI has established aliases for this email address to ensure that it alerts appropriate staff that files are waiting to be processed.
- Forward NASA CASI a copy of the DAA allowing the document to be posted on the Center's Technical Report Server.

1.1.6.2 Alternative Media

NASA CASI requires two copies of alternative media containing STI (e.g., CD-ROM, videotape, audiotape, and DVD).

1.1.6.2.1 Computer Diskettes and CD-ROMs

NASA CASI will accept the following:

- 3.5-in MS-DOS diskettes.
- CD-ROMs formatted to ISO 9660 standards
(URL http://www.y-adagio.com/public/standards/iso_cdromr/tocont.htm).

Submission requirements: Two copies of the diskette or CD-ROM accompanied by a copy of the DAA (NF-1676) or Center-equivalent form in either electronic (a separate file from the alternative media) or print format.

1.1.6.2.2 Microfiche

NASA CASI can accept the following formats:

- 98 frames per 105 mm x 148 mm fiche.
- 24-to-1 reduction ratio.

Submission requirements: Silver master(s) accompanied by a copy of the DAA (NF-1676) or Center-equivalent form in either electronic (a separate file from the alternative medium) or print format.

1.1.6.2.3 Videotape and Audio Files

NASA CASI can accept the following videotape format: Sony Betacam SP[®].

Submission requirements: Two copies of the videotape accompanied by a copy of the DAA (NF-1676) or Center equivalent form in either electronic (a separate file from the alternative medium) or print format.

1.1.6.3 Compression Formats

NASA CASI can accept the zip compression format.

1.1.6.4 File-Naming Conventions

Name the file to clearly identify the contents using the report number or other identifying text, followed by a three-character extension that represents the application. See Section 7.1.3.5 for more information. We do not recommend including the use of a slash because it may make the file unusable.

1.1.6.5 Electronic Transfer of Restricted-Access Information

The following procedures for restricted-access information via the Internet and email (information whose publication or distribution is restricted by law, regulation, or policy as defined in Section 8.2.2) are in addition to procedures cited for unclassified/unlimited STI and procedures cited in Section 8.

STI containing restricted-access information (SBU or Sensitive But Unclassified) that is submitted via the Internet or email must be encrypted. The minimum level of required encryption is SSL. Currently, NASA uses Entrust PKI as the recommended method. See NPR 2810.1, “Security of Information Technology,” and NASA Technical Standard NASA-STD-2820, “Encryption and Digital Signature Standards.” Until such mechanisms and infrastructure are available, a paper copy or electronic file loaded to a CD-ROM will be accepted. Paper copies and CD-ROMs (including their internal electronic files) must be marked with the applicable restriction and mailed in an envelope that does not indicate the restricted nature of the content. For additional information, see NPR 1600.1, “NASA Security Program Procedural Requirements.” Export-controlled information is defined as ITAR—22 CFR 120-130 and EAR—15 CFR 730-744 information.

For information regarding the handling of documents that were previously classified as export controlled or restricted access but have subsequently been downgraded, see Section 1.1.5.12.

1.1.7 Electronic and Alternative Media Publications Availability

NASA STI publications are available from NASA CASI in the formats cited in the following list:

- Electronic formats. (PDF for NASA Aeronautics and Space Database registered users.)
- Computer diskette. (Computer diskette output is available in like-to-like MS-DOS, Microsoft® Windows, and Apple® Macintosh® formats.) When STI is provided to NASA CASI on computer diskette, NASA CASI can copy and distribute this medium on demand.
- Videotape. (Videotape output is available in Betacam SP, High-8, VHS, and Super VHS formats.)
- CD-ROM. (When STI is provided to NASA CASI on CD-ROM, NASA CASI can copy and distribute this medium on demand.)

1.1.8 Standards for Protection of Intellectual Property

1.1.8.1 Authorship

1.1.8.1.1 Author

With the exception of NASA histories, the authorship of NASA publications is generally reserved for persons who participate in the performance of the work from which the STI results and who can effectively defend the main technical content of the publication to a peer group. Because of the complexity of scientific and technical work, many publications have multiple authors. The authors' names should appear in a sequence that indicates their respective responsibility for the reported results; that is, the first author is the chief contributor and writer, and other authors follow in the order of their responsibility for the work.

1.1.8.1.2 NASA Coauthors

NASA employees may not be listed as coauthors of Contractor Reports. When NASA employees contribute to rather than monitor contract or grant work, such work should be published in another series.

1.1.8.1.3 Editor

Recognition of editorship is justified when the editor has contributed scientific and technical expertise and judgment.

1.1.8.2 Acknowledgment of Significant Input and Routine Support

It is appropriate to acknowledge significant contributions directly related to the substantive content or preparation of a NASA STI Report Series by individuals other than the authors. When an acknowledgment of contribution is warranted, it is included in a paragraph on the back of the title page.

1.1.8.3 References

1.1.8.3.1 Reference to Work by Others

Reference to work by others must be acknowledged in all NASA STI Report Series. Proper citation of references is the author's responsibility. The style and format of the reference list may follow accepted practice in the discipline of the report. When there is no preferred style, the name/date style of citation in text (e.g., Anders, 1971, 1972; Smith, 1974) with a corresponding reference list, alphabetized by name, is preferred.

1.1.8.3.2 Reference to Unpublished Work

Reference to unpublished work or information acquired through personal communication must be clearly identified as such and must not be represented as published information, even if publication is pending. Internal reports that have not been approved for publication outside the originating Center are considered unpublished. This identification should be included in a parenthetical note in the text and in the reference list with an appropriate notation such as "unpublished," "to be published," "personal communication," or "internal report." Under no circumstances should an author represent another's work as his or her own.

1.1.8.4 Inclusion of Copyrighted Material

Credit should be given for material taken from non-NASA publications and included in a NASA Report Series document. In the case of copyrighted source material, authors are responsible for securing permission from the copyright holder to use, reproduce, and distribute the copyrighted material as part of the NASA Report Series. Additionally, authors are responsible for ensuring that an appropriate copyright notice or acknowledgment (as directed by the copyright holder) is included within the text of the NASA Report Series. The author or initiator of the DAA review must enter the copyright status on the NF-1676 or Center equivalent form and provide information regarding NASA's permission to use copyrighted material (on NF-1676, check "Copyrighted" in Section 3.c and include a distribution limitation, if appropriate, in Section 3.d plus attach a copy of the permission obtained). Copyright status should also be entered on the RDP (block 12a). Any questions regarding obtaining such permissions or for acknowledging a copyright should be referred to the NASA Headquarters or the Center Patent or Intellectual Property Counsel (see Section 8.5.12).

When NASA is granted permission by the copyright holder to use copyrighted material in connection with a NASA-sponsored meeting or conference, the following copyright notice should be used:

“Copyright (c) (year of first publication) (Name of copyright owner). NASA has been granted permission to publish and disseminate this work as part of (name of conference publication). All other rights retained by the copyright owner.”

For copyright notices applicable to other situations or other rights granted (e.g., assignment or license for Government purposes only), contact the Center Patent or Intellectual Property Counsel.

1.1.8.5 Trade Names and Trademarks

The use of trademarks and trade names is discouraged because NASA considers it improper to advertise, endorse, or criticize commercial products or services in its publications. Use generic names whenever possible. Trademarks may be included if their use is the only way to specify material or equipment that is necessary to reproduce the results. However, in such cases, a trademark should be used as a proper adjective (i.e., capitalized and modifying the generic term) and on its first appearance in the text must be accompanied by the name of its registered owner. When trade names and trademarks are used in a publication, a disclaimer such as the following should be added in the publication on the back of the title page:

“Trade names and trademarks are used in this report for identification only. Their usage does not constitute an official endorsement, either expressed or implied, by the National Aeronautics and Space Administration.”

1.1.8.6 Copyright Status

1.1.8.6.1 Works Produced by Government Employees

No U.S. copyright protection is available for a work of the U.S. Government, i.e., a work produced by an employee of the U.S. Government as part of his or her official duties. (See 17 United States Code (U.S.C.) Section 105.) For works produced by a NASA employee that are published outside the U.S., NASA, as the employer, is the owner of any foreign copyright that can be asserted on the work. A publisher of a professional journal can republish a U.S. Government work, but the publisher cannot legally assert copyright on the U.S. Government work as published unless the publisher has added original, copyright-protected material. In such a case, the publisher's copyright protection extends only to the original material that has been added by the publisher. If a publisher publishes a U.S. Government work and does not add original, copyright-protected content, NASA may reproduce and disseminate an exact copy of the published work either in paper copies or on a NASA public Web site. If the publisher adds original materials such as a publisher-prepared abstract or peer review comments, the NASA author and/or Center must get permission to reuse or republish the article as published in the journal. However, NASA may use the U.S. Government work as originally submitted to the publisher for any purpose.

1.1.8.6.2 Works Copyrighted by NASA Contractors and Grantees

Unlike works of the U.S. Government, works produced under a Government contract or grant are protected under U.S. Copyright Law. The author or initiator of the DAA review must enter a contractor or grantee's ownership of copyright on the NF-1676 or Center equivalent form (on NF-1676, check "Copyrighted" in Section 3.c and include a distribution limitation, if appropriate, in Section 3.d). Also, the appropriate "Notice for Copyrighted Information" must be placed on the cover, title page, and RDP with any additional information shown on the back of the title page. See Section 8.

Unless provided otherwise in the contract, a contractor may assert, without prior approval of the CO, copyright in scientific and technical articles based on or containing data first produced in the performance of the contract and published in academic, technical or professional journals, symposia proceedings, or similar works. The contractor may not assert copyright in any other data produced under a Government contract, e.g., final reports or other deliverables, unless permission is granted in writing by the CO or by the terms of the contract. When copyright is asserted, the contractor must include a copyright notice and acknowledgment of Government sponsorship (including contract number) on any published reports; and the Government, and others acting on its behalf, must receive a license to reproduce, publish, or otherwise use the copyrighted work for governmental purposes. If copyright has not been asserted, the Government has unlimited rights in data first produced under the contract. Consult the NASA Headquarters or Center Patent or Intellectual Property Counsel with questions regarding permissible use of works copyrighted by NASA contractors and grantees.

In addition, whether or not a contractor has asserted copyright, the contractor may publish data produced or specifically used by the contractor in the performance of a Government contract in compliance with the data rights clause in the contract. Under the standard data rights clause (see FAR 52.227-14), contractors may use, release to others, reproduce, distribute, or publish such

data unless the data is subject to the export-control or national security laws or regulations or includes restrictive markings as described in Section 8. Contact the Center Patent or Intellectual Property Counsel for additional information.

Terms in grants are flexible but generally allow the grantee to assert copyright. All Federal agencies adhere to the Office of Management and Budget (OMB) Circular A-110 for works created under grants with colleges, universities, hospitals, and non-profit organizations, and to OMB Circular A-102 when the grantee is a state or local agency such as a state university. Circular A-110 provides that a grantee may assert copyright in any work that was developed under the grant. The Government obtains a license to reproduce, publish, or otherwise use the work for Federal purposes and to authorize others to do so. For cooperative agreements with commercial firms, see NPR 5800.1, “Grants and Cooperative Handbook, Sections 1274.208 and 1274.905. The terms of the particular cooperative agreement will specify respective rights of the parties. Contact the Center Patent or Intellectual Property Counsel to determine copyright terms in the cooperative agreement.

When an article produced under a NASA-funded contract or grant is published in a professional journal, the non-Government author often assigns copyright to the publisher. Under the contract or grant, NASA has a license to use and distribute such articles as submitted to the publisher; however, permission from the publisher should be obtained to reuse or republish the article as published in the journal. Additionally, other non-Government works in a journal may be copyrighted by their authors or assigned to the publisher, and the publisher may copyright the layout of the entire journal, i.e., the selection, coordination, or arrangement of articles in the journal. Thus, NASA should not reuse or republish entire publications such as conference proceedings or technical journals unless permission is obtained from all copyright owners involved.

1.1.8.7 Publishers’ Agreements

1.1.8.7.1 General

If a NASA-authored work is to be published by a commercial publisher, authors must consult the NASA Headquarters or Center Patent or Intellectual Property Counsel concerning any agreements with publishers. (Questions regarding whether a work was prepared as part of an employee’s official duties should also be referred to the NASA Headquarters or Center Patent or Intellectual Property Counsel.)

1.1.8.7.2 Standard Agreement

Generally, commercial publishers seek an assignment of copyright in works they publish. If requested to sign a publisher’s agreement, NASA employees should inform the publisher of their employment status and should not sign any document purporting to transfer a U.S. copyright as a prerequisite to publication. For papers authored only by Government employees, NASA authors should inform publishers that the paper is a U.S. Government work and is not protected in the United States under the U.S. copyright laws and that there is no U.S. copyright to be transferred. Additionally, a U.S. Government work may be protected under foreign copyright laws. If NASA approves transfer of a foreign copyright, an agreement to transfer the foreign copyright is executed by the NASA General Counsel and reserves a Government license in the work. Some

publisher agreements, such as for academic and scientific journals, include a signature block for the U.S. Government author. The Government author must certify in that block that the manuscript was prepared as part of that author's official duties. NASA authors may sign such signature blocks. If this signature block is missing, the following statement should be included either on the agreement or in a cover letter:

“The work entitled _____ was prepared as part of my official duties as an employee of the U.S. Government and, in accordance with 17 U.S.C. 105, is not available for copyright protection in the United States.”

Contact NASA Headquarters or Center's Patent or Intellectual Property Counsel for additional information on signing any copyright transfer form.

1.1.8.8 Coauthors Not Employed by the U.S. Government

If the work is a joint effort with a person whose contribution was not made as part of official duties as a U.S. Government employee, the statement should inform the publisher that the employee prepared the work as part of official duties as a U.S. Government employee in co-authorship with another person; identify the coauthor(s); and request that the publisher note that the U.S. Government contributed to the published work.

1.1.8.9 Translations

For works protected by copyright (i.e., not in the public domain), permission of the copyright holder is required before a work may be translated from one language to another. Such a translation is considered to be a derivative work under copyright law. Permission to translate a work and to make and distribute copies of the translation should be obtained from the copyright holder. Any questions regarding obtaining such permission should be referred to the NASA Headquarters or Center Patent or Intellectual Property Counsel.

1.1.9 Disclaimers

The use of disclaimers is acceptable. Avoid the use of disclaimers that call attention to unedited material or deny technical responsibility of the issuing Center. Disclaimers should be placed on the back of the title page.

1.1.9.1 Acceptable Disclaimers

A disclaimer may be employed to alert the reader that a particular publication:

- Is a presentation of preliminary findings, subject to revision as analysis proceeds.
- Is a formal draft or working paper, which is intended to solicit comments and ideas from a technical peer group.
- Is a preprint of a paper to be presented at a professional meeting.
- Uses a trade name or trademark for accurate reporting and does not intend endorsement.
- Gives acknowledgments.
- Gives availability of the document (from NASA CASI or NTIS).
- Indicates the ISSN.
- Indicates the level of technical or professional review (see Section 1.1.11).

1.1.9.2 Sample Disclaimer for Preprints

Include the following disclaimer, or a similar disclaimer, if applicable, on the cover and back of the title page:

“This is a preprint of a paper intended for presentation at a conference. Because changes may be made before formal publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.”

1.1.10 Distribution Notices

Distribution notices include limitations and restrictions, such as ITAR, EAR, SBIR, proprietary information, and copyrighted information, as discussed in Section 8. These designations are determined for STI via the NF-1676 or Center equivalent form.

1.1.11 Level of Review

Indicate (optional) on the back of the title page (or, in nontraditional media, in the introductory information that would equate to the back of a title page) the level of technical or professional review the STI has received. See Section 8.4 for specifics. Examples include:

“This material has been technically reviewed by (insert as appropriate: a committee of peers, expert single reviewer, technical management).”

For SPs, an example is:

“This material has been professionally reviewed by (insert as appropriate: the Headquarters (HQ) program office or NASA Center).”

1.1.12 Use of Metric Measurements

NPD 8010.2, “Use of the SI (Metric) System of Measurement in NASA Programs,” states, in part, that it is NASA policy to adopt the metric system of measurement, defined by ANSI/ASTM/IEEE SI-10, as the preferred system of weights and measures for NASA. Therefore, the use of metric measures is required in all NASA scientific and technical publications when the activities being documented or reported are performed using metric measurements. Scientific and technical activities performed using inch-pound measurements (U.S. customary units) should be documented or reported using inch-pound measures. The report must clearly state which form of measurements was used.

1.2 Other Forms of NASA STI

1.2.1 Journal Articles

Journal articles and similar periodicals produced by professional, technical, or academic organizations must also have NASA prior approval via NF-1676. Journal articles help ensure the timely dissemination of NASA scientific and technical findings to appropriate audiences. A TM number may also be obtained for a presentation; this allows distribution of copies to attendees and ensures that the article is included in the NASA Aeronautics and Space Database (NA&SD) and its public interface (if appropriate), the NTRS. “If appropriate” in the preceding sentence means unclassified, unlimited, and no copyright or distribution restrictions on the information.

1.2.2 Conference Publications

Conference Publications consist of collections of papers (not just abstracts and viewgraphs) from NASA-sponsored scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA. A preprint may be included in this series if it will not be published later as a collection of full papers.

1.3 Format and Page Mechanics

1.3.1 Page Mechanics and Layout

1.3.1.1 Page Size (For Printed Documents)

- Standard page size. The standard page size is 8-1/2 by 11 in (with 7-1/8 by 9-3/16 in being the maximum allowable space for text excluding page number), although other formats are produced.
- Foldouts. Deviation from the standard 8-1/2 by 11-in page size of a publication, such as foldouts to present oversize charts, is sometimes necessary. Foldouts should significantly enhance a report. Their use requires prior approval. Contact the Center publications office for Center-specific approval procedures.

1.3.1.2 Recommendations for Font Usage

- Font Size. 12-point type (font) is highly recommended. Do not use a point size smaller than 10-point type.
- Print resolution. Set a minimum of 300 dots-per-inch (DPI).
- Type style. Choose sans serif for titles, text of figures, tables, and graphics; choose serif for text. Try to use a standard font that is typical of most software packages, such as Times, Arial, Courier, Palatino, and Helvetica. Remember that Palatino and Helvetica are not cross-platform fonts. Symbol font is useful for Greek.

1.3.1.3 Requirements for Text Placement

A column of text may not end with a section heading alone, a heading and only one line of text, or a short line that is not the last line of a paragraph. A column may not begin with the last line of a paragraph. A page may not end with a hyphen. In Microsoft Word, use Widow/Orphan Control.

1.3.1.4 Page Numbering

- Use lowercase roman numerals for pagination of front matter. Reserve page i for the title page, but do not show the number on the page.
- Number main text pages sequentially throughout with Arabic numerals (preferred style). If a long report has multiple sections or parts, it may be necessary to number sectionally with sets of numbers that indicate both section and page (e.g., 1-1, 4-2).
- Number back matter (such as appendixes) sequentially with main text (preferred style). If necessary, appendixes may be numbered separately, with the appendix designator followed by a hyphen, then the page number (e.g., A-1, A-2).
- Assign an implied page number to blank pages or pages that have a special layout that prevents the number from being shown.

1.3.1.5 Layout Samples and Templates

NASA STI Report Series cover and title page samples can be found in NPR 2200.2, “Requirements for Documentation, Approval, and Dissemination of NASA Scientific and Technical Information.” The templates for the NASA STI Report Series can be accessed at <http://www.sti.nasa.gov/>, Publish STI. Although the basic elements of these templates must be used (such as cover and title page elements), the layouts may be adapted as needed for STI produced in alternative media (such as CD-ROM, DVD, or video).

1.3.2 Sections of a Report

1.3.2.1 Covers

Use the standard elements given on the NASA STI Report Series templates.

1.3.2.1.1 Front Cover

The following elements constitute the front cover:

- Report number(s). (If another agency’s, Center’s, or contractor’s report or document number is added to the NASA report number, it must be positioned to the right or below the NASA report number).
- NASA insignia (the “meatball”); other logos as appropriate.
- Title of report.
- Author name(s), affiliation, and location.
- Optional one-color line art or black-and-white photo or image.
- Distribution notices, if applicable. Distribution notices, including limitations and restrictions, such as ITAR, EAR, SBIR, proprietary information, NPR-2800.1 notice, and copyright notices, must be placed on the cover, title page, and the RDP.
- Conference information. Authors may choose to add conference information, such as conference name, location, dates, and sponsor.
- Joint project or sponsorship information, if appropriate.
- Rule (meaning a graphic straight line).
- Month/year.

When NASA partners with or jointly funds work with another agency, noncommercial organization, or a university, the logo or seal of the cosponsor may appear on the cover to the right of or below the NASA insignia and must be in accordance with the NASA guidelines for the use of logos and insignia at <http://www.hq.nasa.gov/office/pao/insignia>. The NASA insignia cannot appear with the logos of private companies on publications. In rare exceptions, such as certain partnership situations, the Office of Public Affairs, Public Service Division at Headquarters may approve a proposed use. NASA program organizational logos are not acceptable for use on covers.

1.3.2.1.2 Back of Front Cover

The following element comprises the back of the front cover:

- NASA STI Program profile.

1.3.2.1.3 Back Cover

The back cover is blank except for a rule (e.g., graphic straight line) at the bottom of the cover. If documents are printed, a mailing label that includes the addressee, the return address, and appropriate postage may be affixed to the center of the back cover. No text or images other than the rule may be placed below the last line of the address on the mailing label.

1.3.2.2 Front Matter

The subsections that follow identify standard elements for pages that precede the body, or text, of a NASA STI Report Series document.

1.3.2.2.1 Title Page

The following elements comprise the title page:

- Author name(s), affiliation(s), and locations.
- Editor name and affiliation, if applicable (for edited CPs, TPs, or TMs when the editor has contributed scientific and technical expertise and judgment).
- Agency name and address (corporate source).
- Contract statement and number, if applicable.
- Joint project or sponsorship information, if appropriate.
- Conference information (e.g., name of conference, location, dates, sponsors), if applicable.
- Distribution notices, if applicable.

1.3.2.2.2 Back of Title Page

The back of the report title page includes the following elements:

- Acknowledgment, if applicable.
- Disclaimers, if applicable.
- Statement announcing that the document is available from NASA CASI. In some cases, the document may also be available from the NTIS. Documents that are marked to be available from NTIS must be unlimited, unclassified (no restricted-access data). See the sample back of title page in NPR 2200.2, “Requirements for Documentation, Approval, and Dissemination of NASA Scientific and Technical Information.”
- ISSN, ISBN, and/or LCCN, if applicable.
- Level of technical or professional review.

1.3.2.2.3 Optional Front Matter Elements

The following items are optional front matter elements:

- Foreword (by someone other than the primary author) and/or preface (by the primary author). (SPs, CPs, and reference works may contain either or both.)
- Table of contents. (Short reports may not need a table of contents, but longer reports do.)
- List of tables.
- List of figures or illustrations.
- List of acronyms, symbols, and abbreviations used in text (may alternately be placed as an appendix or after introduction in text).

1.3.2.3 Body

1.3.2.3.1 Introduction

The primary function of an introduction is to define the subject, significance, purpose, objectives, and scope of the work. The introduction may also include background information. Introductions will vary to some extent, depending on the nature of the material in the report.

1.3.2.3.2 Symbols List

An alphabetical-order or logical-order symbols list (with definitions and units) may directly follow the introduction or may be placed as front matter or in an appendix. If the list includes symbols from both the Latin and Greek alphabets, the symbols in the Latin alphabet precede those in the Greek. The list of subscript and superscript symbols usually follows the main symbols list, but may be included in the main list (e.g., when a primary symbol and subscript or superscript are defined as a unit or when a symbol is used as both a primary symbol and a subscript or superscript).

1.3.2.3.3 Main Text

The central theme of a scientific and technical paper is developed in the main text. The overall organization of a report varies according to its subject and complexity. For example, experimental investigations contain comprehensive descriptions of specimens, apparatus, and procedures. Theoretical investigations, on the other hand, emphasize the application of new information to the state of the art. Typical report subsections are “Procedure,” “Tests,” “Discussion,” and “Results.”

1.3.2.3.4 Concluding Section or Summary

Most NASA STI Report Series publications have a concluding section, such as “Concluding Remarks,” “Conclusions,” “Summary,” or “Summary of Results.” This section should be self-contained because many people will read it first to determine whether to read the entire report. No material that has not already been presented in another section of the report should be presented in this section.

1.3.2.3.5 Abstract

An abstract should be informative rather than descriptive and should state the objectives of the work, the methods employed, the results obtained, and the conclusions reached. Limit the abstract to a maximum of 200 words.

1.3.2.4 Back Matter

1.3.2.4.1 Appendixes

Appendixes present supplementary information that might otherwise interfere with an orderly presentation of the text. Each appendix must be referenced in the text and given a title. When using more than one appendix, identify each by a capital letter in the order mentioned in the report. Appendixes may include a list of abbreviations and acronyms used in the text. When an appendix is written by someone other than the primary author of the main report, that person’s name and affiliation should appear after the title of the appendix proper and after the appendix

title on the contents page. A credit such as “With appendix [number and title] by [author]” should be placed on the report title page, in the contents, and in block 6 of the RDP.

1.3.2.4.2 Acronyms and Definitions

A list of NASA acronyms and definitions can be accessed at the following Web site:

<http://www.sti.nasa.gov/acronym/main.html>

1.3.2.4.3 References and Bibliography

- What to Cite. Cite all works consulted in the preparation of a paper, particularly those from which information is taken, in the text where appropriate and in the reference list.
- Responsibility for Citations. Styling and accuracy of references are the responsibility of the author.
- Style and Format. Follow accepted practice in the discipline, or contact the Center Technical Publications Office for examples of standard basic formats.
- References to Unpublished Information. Unpublished sources may include pending publications, oral meeting papers, interviews, email, or personal communications. Clearly identify these as such in the text of the report. Provide information that will make these sources as accessible as possible to the reader, either in a note to the text or in the reference list. Any of the citation methods used in various disciplines may be used. Always begin the reference list entry with the name of the source (person or entity), and provide as many reference citation elements as are available.
- References to Electronic Documents. At a time when electronic publication is on the rise, procedures and formats for citing electronic documents are still evolving.
- Limited Distribution. In publicly available works, citing documents with limited distribution is not recommended but permissible as long as the citation does not itself contain restricted information. However, the fact that a document is limited in distribution should not be mentioned in the reference citation. Place at the end of the citation the words “Available from” and the name of the organization responsible for the control and distribution of the document. Remember, however, that many readers will be unable to access the limited distribution references cited.

1.3.2.4.4 Report Documentation Page

The RDP is required for all reports published in the NASA STI Report Series, and is used for other types of information as determined by individual Center Technical Publications Offices. Directions for preparing the RDP are given on the back of the form. The information given here offers further guidance.

- Symposium Presentation Preprinted as a TM or Published as a CP. Identify the symposium in block 11, Supplementary Notes.
- Authors with Different Affiliations. The affiliation of each author should be listed in block 11, Supplementary Notes, unless they are identical. In this case, only one citing is required.
- Subject Categories Required. NASA CASI uses these categories to distribute reports to subscribers.

NASA STI Standards

- Abstract. Enter an abstract of no more than 200 words in block 13, Abstract. Compose the abstract to be informative rather than descriptive. Include the following elements:
 - Objectives of the investigation.
 - Methods used (e.g., simulations, experiment, or remote sensing).
 - Results obtained.
 - Conclusions reached.
- Subject Terms. This is required; please provide at least three. Select from the NASA Thesaurus and place them in block 14.
- Classified Reports. Ensure that all elements of the RDP are unclassified and marked as such. CASI does not receive classified STI.
- Placement of the RDP in the Report. Except for NASA SPs, position the completed RDP as the last page of the report, *facing* the inside back cover. For SPs, send the RDP to CASI as a separate file.

SECTION 2

FIGURES

2.1 Introduction

This section presents a possible style for figures in the Scientific and Technical Information (STI) Report Series and also discusses editing and preparing these figures.

The editing of figures can be a substantial task. Table 2-1 presents an exhaustive list of editorial functions related to figures (from *The Levels of Edit*, Van Buren and Buehler 1980). The style presented here provides a standard from which an author, editor, and illustrator can begin to work.

Table 2-1. Editing Tasks Related to Figures

- Identify each original figure with a figure number and ensure that figures are numbered consecutively.
- Ensure that any necessary permission to reproduce copyrighted figures is obtained.
- Ensure that all figures are cited in the text and that each text citation identifies an existing figure.
- Resolve any discrepancies between what is presented in a figure and what is indicated by the discussion in text.
- Ensure that all curves, data points, ordinates, and abscissas are fully identified in a manner that is appropriate to the content of the report.
- Arrange figures in a manner most appropriate to the significance of the data.
- Ensure that figure captions are present and correctly identify content of figures.
- Ensure that no two figure captions are identical.
- Delete titles (as in viewgraphs] from a figure with a caption.
- Ensure that figures are reproducible and have no hand-written or un-reproducible lettering.
- Ensure that spelling, grammar, punctuation, and usage (particularly of technical terminology) are correct in labels and captions and that all abbreviations, acronyms, and symbols are defined.
- Delete excessive detail from figures.
- Add scales to photographs when required.
 - Ensure that powers of 10 are used unambiguously.
- Ensure that the system of units is consistent and clear.
- Be sure to have the author review any potential changes to be sure that the content is not altered.

2.2 Policy for Figures

We strongly recommend that figures be in digital format. However, on those occasions when you work with figures that are not in electronic format, observe the following guidelines:

- Mark the tops of figures if orientation is not obvious.
- Obtain identification numbers or originals if figures have been previously prepared.
- Indicate crop marks on photographs if desirable image area is not obvious.
- Indicate positioning of figures in document.
- Indicate orientation of figures in document, i.e., sideways or upright.
- Specify style of captions.
- Specify overall size of original figures and lettering size and typeface.
 - Specify style of ordinate and abscissa scales.
 - Ensure appropriate and consistent style in labels used to identify curves, data points, scales, etc.
- Ensure that original photographs are not halftones (typical of older or previously published information).
- Indicate sizing of figures for reduction.

2.2.1 Copyright

Technical figures are routinely extracted from published books, reports, and journals and reprinted with acknowledgment of the original source of the figure. Such extraction and reprinting of copyrighted figures requires permission of the copyright holder unless the doctrine of fair use applies, which allows brief portions of a copyrighted work to be copied for certain purposes (see Section 2.2.1.2).

Methods of extracting the figure from the original document may differ, such as the figure may be electronically copied from the original document and may or may not be modified or redrawn. All these methods result in a figure that is essentially based on the original artwork; all infringe on the copyright.

2.2.1.1 Copyrighted Items

Fortunately, much of the material referenced in STI Report Series reports is in the public domain, i.e., it is not copyrighted. Work done by U.S. government employees who produce work in an official capacity is not copyrighted in the U.S; however, foreign copyright may pertain. Contractors to the Government normally either place material prepared under contract into the public domain or grant a license to the Government to use the material to distribute information to the public. Normally,

- When a figure is extracted from a reference, first determine whether the reference is copyrighted:
 - Were any of the authors affiliated with the Government?
 - Were any of the authors under contract to the Government?
- If the answer is “yes” to either of these questions, the reference is normally available to the Government without charge and no permission is required to reprint the figure. A parenthetical statement crediting the source should still be included in the caption, such as the one shown below:

Figure 14. Sound pressure levels measured during takeoff of six large transport aircraft. (From ref. 35.)

Because the area of copyrights can be complicated, check with your Center’s General or Intellectual Property Counsel for additional guidance on whether a document is copyrighted. If the answer to the above questions is “no” and the figure is copyrighted, check the copyright notice of the document to determine the copyright holder. Some journals grant permission to extract illustrations in the copyright notice.

2.2.1.2 Fair Use

Under the fair use provision, the copyright law has long been interpreted as allowing brief parts of a work to be copied for certain purposes. Extraction of a figure can be considered fair use if all of the following four criteria are met:

- The extracted figure is being used for nonprofit educational or research purposes.
- The extraction is a small part overall (both in amount and substantiality) of the original document (for example, one figure from a technical article).
- Extracting the figure would not damage the value of the original work.
- The figure represents technical data (for example, a graph) rather than artistic expression (for example, a photograph or drawing).

Thus, a single technical figure taken from an article of several pages could probably be reprinted under the fair use doctrine. However, extracting the only figure in a short article, extracting several figures from one article, or extracting a drawing, photograph, or artist’s rendering would be considered infringement.

It is a good approach to notify the copyright holder that you plan to use the figure in a NASA document under the fair use provision and to document your use of the figure so that the government can show that it was not negligent or willful in case the copyright holder questions the right to use the figure.

2.2.1.3 Requesting Permission

Requesting permission to reprint a copyrighted figure is the author's responsibility. All requests for permission to reprint should be in writing (email is acceptable), and written replies (email is acceptable) must be received before the report goes to press. The request should contain the following information, according to the *Chicago Manual of Style*:

- Complete citation of original work and identification, with page numbers, of what is being reprinted.
- Information about the publication in which the material will be reprinted: title, form of publication (book, report, journal), publisher, and projected date of publication.
- Explanation of what permission is being requested.

In the written permission, the copyright holder may require a particular form of citation of the original source, which should be included in the figure caption. For example:

Figure 14. Sound pressure levels measured during takeoff of 6 large transport aircraft. (From ref. 35; copyright American Institute of Aeronautics and Astronautics (AIAA); reprinted with permission.)

Occasionally, the copyright holder will charge a fee for reprinting. Contact your Center STI manager on how to handle charges for reprints.

2.2.2 Color

As stated earlier, color is used when it is necessary to convey scientific and technical material in a clear and unambiguous fashion. If possible, black and white is preferred over color. Color printing (hard-copy documents) must be approved by the Center Printing Officer. The following are guidelines for determining when color is necessary for the technical understanding of the material:

- Color terms are necessary in discussing the figure. For example, in a combustion study, temperature of flames may be discussed in terms of the colors in the flame.
- The results of the study can be portrayed only in color. For example, a study of displaying computational fluid dynamics calculations on a color graphics system would require display of the color results.
- Figures would become ambiguous if produced in black and white. For example, contour plots are often presented in color because the contour labels and/or the number of black and white shading patterns required would greatly reduce the effectiveness of the figure.

2.3 Relation Between Text and Figures

Figures should not be used in a document except to enhance understanding of the text. The author chooses a figure and cites it in the text for a particular purpose. Through the process of review, editing, figure preparation, and manuscript production, the original relationship between the figure and the text must be maintained.

2.3.1 Relevance of Figures

In writing a report, the author decides when technical illustration is needed, chooses the type of illustration, and provides data, photographs, drawings, and sketches necessary to produce these figures. In general, illustrations fulfill the following purposes:

- Describe mechanisms or principles that cannot be described well in text.
- Add emphasis to an important idea or fact.
- Show relationships between components of a system.
- Document authenticity, as in photographs of a test.
- Make comparisons.
- Present statistics in a meaningful way.
- Show step-by-step operations.

During the process of review, correction, and figure preparation, the relation between the text and figures can suffer. Also, the author may have selected illustrations that had been used for other documents or presentations and that may not match the text. Editors are the watchdogs in these matters; they are responsible for ensuring that:

- Each figure is cited in the text and numbered in order of its mention, unless the first mention is clearly incidental, for example, in the symbol list.
- Each text citation of a figure correctly identifies an existing figure.
- The discussion of a figure matches the information presented in the figure; for example, trends in data discussed in the text are obvious in the figure, specific data values cited in the text are borne out in the figure, parts of a drawing mentioned in the text are labeled in the drawing.
- The terminology and system of units used in the text are the same as in the figures.

2.3.2 Arrangement of Figures

In addition to the relevance of the figures to the text, the physical arrangement is also important. Figures should always be placed as close as possible to their initial discussion in the text. They may appear before they are mentioned but as much as possible should fall on the same or facing page. When the number of figures is so large that integration would interrupt the text, they may be placed at the end of the report.

The determination of when integrated figures are interruptive requires judgment and experience. Remember that flipping between text and figures placed in the back is interruptive. In deciding whether to integrate figures (as is preferred), consider the following:

- Whether figures can be grouped together on pages. Grouping two or more figures together on a page can make the task of integrating figures easier in areas of the text with a large number of figures mentioned.
- Whether the figures can be effectively integrated throughout most of the report. For example, if too many figures are cited in only one section, these figures can be grouped at the end of that section so long as they require under approximately 10 pages.
- Whether figures cited in the text can be integrated, while figures cited in appendixes are grouped at the back of each appendix. Whether appendix figures can be integrated, while text figures are grouped.

- How flexible is the final preparation of figures. Careful planning for preparation of figures can facilitate integration into the text. For example, if figures have less detail so that they can be reduced in size, then more figures can be integrated into the same length of text.
- Whether figures can be reduced more. Smaller figures are easier to integrate and often are more attractive. Even when grouped at the back, figures are unsightly if the font size is large compared with that of the caption. Of course, the figure must remain easily readable; complicated figures with many labels cannot be reduced as small as simpler figures.
- The capabilities of the manuscript preparation system. Some layouts in which there are runarounds and spanning columns with a figure may or may not be possible.

2.4 Size of Figures

Ideally, the final size of a figure in the publication should be based on its complexity and the number of labels.

To simplify the selection of overall original size and labeling size, three standard sizes are recommended for original figures (Figure 2-1):

- Full-page figure. Fills an entire page, preferably upright (portrait), but possibly sideways (landscape).
- Half-page figure. Fills approximately half a page, again preferably upright, but possibly sideways. If these figure types are drawn for sideways presentation, their height (i.e., the width dimension of the page) must be reduced to accommodate the caption.
- Column figure. Fills the column width in a two-column layout.

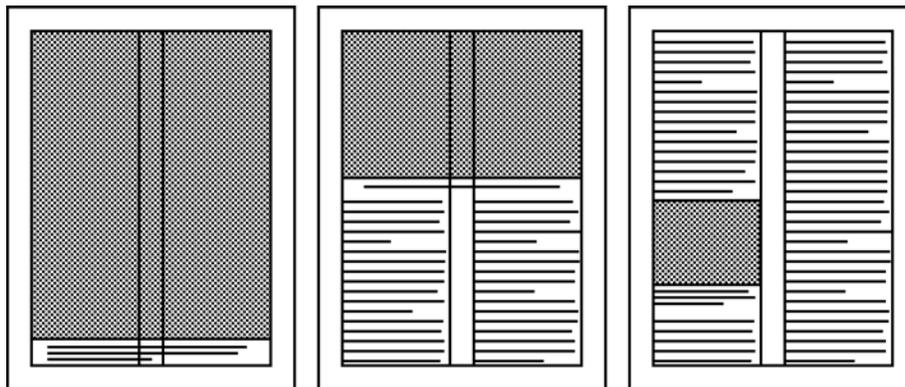


Figure 2-1. Recommended styles of figures.

2.5 Older Halftones

When digitizing figures that may involve older photographs, consult with the Printing Officer on standard techniques, because scanning a halftone can cause distortion.

2.6 Figure Style

This section presents one preferred style for figures. Captions are covered in a subsequent section. At times, for expediency or to be consistent with previously prepared figures, these preferences can be abandoned in favor of equally correct stylistic decisions.

2.6.1 Numbering

All figures should be cited in the text or an appendix by number in order of their mention in the text or appendix. Incidental mentions (for example, in the symbol list) may be out of order. Small figures that are very closely associated with the text, called “sketches,” may be unnumbered or given letter designations. Such sketches are especially appropriate when numbered figures must be placed in back of the report.

- Text figures, whether integrated into the text or in back, are numbered 1, 2, 3(a), 3(b), in order of their mention.
- If appendix figures are integrated into the appendix or appear immediately after the appendix text, they are numbered with the appendix designation A1, A2, B1, C1(a), C1(b). If appendix figures are grouped in the back with all report figures, they can be numbered without the appendix designation.
- Sketches (always integrated) may be unnumbered or may be designated A, B, C, in order of their appearance. Assigning a letter designation to a sketch adds flexibility to the layout of the final manuscript. Because the sketch can be cited by its letter, it can “float” conveniently to the end of the paragraph where it is mentioned or to the top of the next column.

2.6.2 Detail in Figures

Figures should not be excessively detailed, but sufficiently labeled to be clear. Preferred style calls for the following:

- Titles (at the top, for example, from viewgraphs) are omitted.
- Unnecessary lines, for example, boxes around figures, keys, and labels, are omitted. Often all four sides of a graph are drawn rather than only the sides with scale labels, resulting in a box around the data with the scale labels outside (Figure 2-2). Although not preferred, this format is acceptable.
- Supplementary notes about the figure in general and labels not identifying a specific part of the figure are included in the caption.
- Grids are kept as simple as possible. So long as the purpose of a figure is not compromised, ticks are preferred to coarse (i.e., sparse) grid lines, and coarse grid lines to fine (i.e., close) grid (Figure 2-3). The need to read data from a graph dictates the preferred type of grid needed:
 - Fine grids are used only in figures where values are to be read closely.
 - Coarse grids are used in figures where values need not be read so closely (quantitative graphs).
 - Tick marks are used only in figures where curves show trends (qualitative graphs).

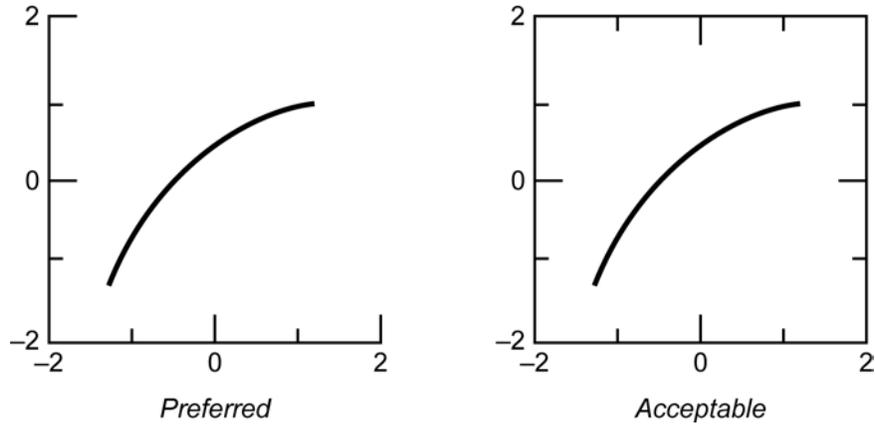


Figure 2-2. Scale lines on graphs.

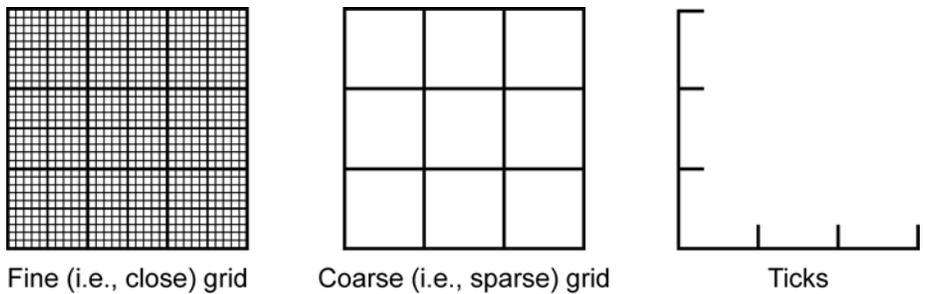


Figure 2-3. Three methods for indicating ticks.

2.6.3 Type Style and Size

In general, all labeling within a figure matches. To match type, three elements must be identical:

- Typeface.
- Type size.
- Leading, (i.e., the distance between baselines of succeeding lines of type).

Preferred style calls for the following:

- Within a single figure, the typeface of all labeling must match. Exceptions can be made when labels must be added to computer-generated plots. The computer-generated font should be matched as closely as possible, and added labeling should not be too random. For example, scale labels are often added, while computer-generated scale numbers are retained (Figure 2-4).
- Because of its wide availability, Arial is often used for figures.
- Final type size on figures should be no smaller than 10 points.
- Within a single figure, the type size and leading of all labeling should generally be uniform. Varying the type size is appropriate for subscripts and superscripts and to change the emphasis on a label. For example, on logarithmic scales, small numbers are commonly used to label minor ticks (Figure 2-5).

NASA STI Standards

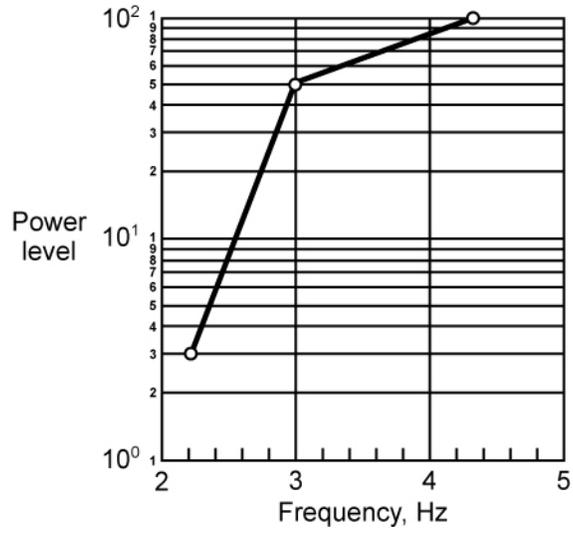


Figure 2-4. Arial scales added to computer plot.

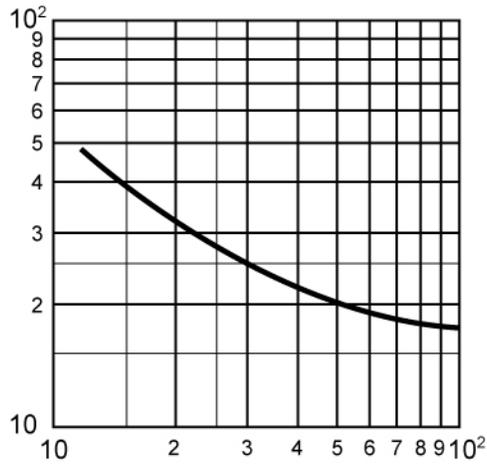


Figure 2-5. Small numbers used on logarithmic scale.

2.6.4 Labeling Style

In general, all labeling on figures is done in Arial (or another sans serif typeface). Boldface and italic (or oblique) font styles should be avoided except for special effects. For example, boldface font might be used for symbols representing vectors or matrices, italic (or oblique) font might be used for other symbols, or boldface font might be used to emphasize a particular label.

Horizontal labeling should read from left to right. Vertical labeling reads from bottom to top (Figure 2-6).

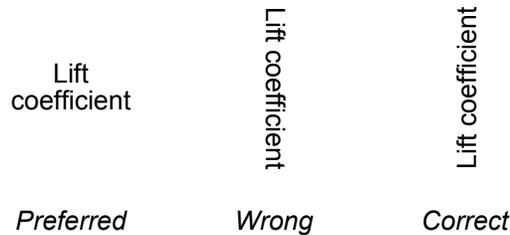


Figure 2-6. Vertical labeling reads from bottom to top.

No lines, whether they are data curves, grid lines, or leaders, may cross through labeling (Figure 2-7). If a label must cross a line, e.g., a grid line, the line is broken.

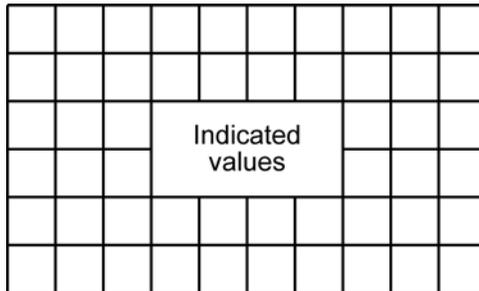


Figure 2-7. Broken lines accommodate labels.

Leaders are used to clarify the parts of a figure where labels apply. Leaders are fine lines, preferably drawn without arrowheads. (Dimension lines are drawn with arrowheads.)

Capitalization of only the first word of a label (sentence style) is preferred. All capital labeling or capitalization of all important words (headline style) is acceptable. The capitalization style should be consistent within a particular figure (Table 2-2).

Table 2-2. Capitalization Styles

Sentence style	Local chord, c, in
Headline style	Local Chord, c, in
All capital	LOCAL CHORD, c, in

Note that capitalization style of labeling does not affect the capitalization of either symbols or abbreviations.

Do not end a label with a period. If punctuation is necessary within a label, commas, semicolons, or colons are preferred to periods:

Incorrect	Correct
32 words per raster line. Each word can contain one slice of the character font.	32 words per raster line; each word can contain one slice of the character font

Standard abbreviations, particularly for units of measure, are encouraged to save space. A nonstandard abbreviation or a symbol in a figure must be defined either:

- In the symbol list of the report.
- In the figure caption.
- Within the figure itself.

Guidance on other symbols:

' symbol (for foot)	Do not use
" symbol (for inches)	Do not use
# symbol (for number or pound)	Do not use
% symbol	OK to use when necessary to save space

Spaces (preferably thin spaces) are used in numbers of five or more digits instead of commas. Four-digit numbers are closed up unless they appear in a column (e.g., in a key) with numbers of five or more digits:

10 000	4000	6 000
12 000	5000	12 000

Initial zeros at the beginning of a decimal number should appear only at the top of a column (as in a key) and after a relational sign, such as =. Typical style is to delete initial zeros elsewhere in figures (Figure 2-8). However, some authorities call for initial zeros; zeros may be left in a figure to avoid reworking it. Use of initial zeros must be consistent within a particular figure.

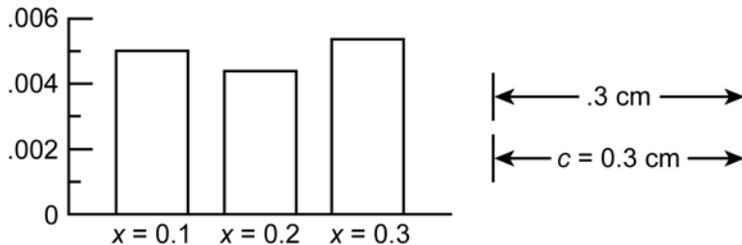


Figure 2-8. Use of initial zeros before decimal points.

Minus signs meaning negative values (as opposed to the binary operation, i.e., x-y) are closed up to the number, even in a key. Plus signs are not given to indicate positive values (Table 2-3).

Table 2-3. Use of Plus and Minus Signs

Incorrect	Correct
- 1.94	-1.94
- .87	-.87
- .64	-.64
+ .64	.64

2.6.5 Scales

It is the rare technical report that does not contain a figure with a scale. All graphs have scales: values of the independent variable (abscissa) run along the horizontal scale, and values of the dependent variable (ordinate) run along the vertical scale. Each scale consists of three parts, which are the:

- Ticks or grid.
- Scale numbers.
- Scale label.

The two basic types of scales are linear and logarithmic (Figure 2-9).

- Linear scales have equal spaces representing equal numerical values.
- Logarithmic scales have equal spaces representing powers of 10 and unequal spaces representing values between the powers of 10.

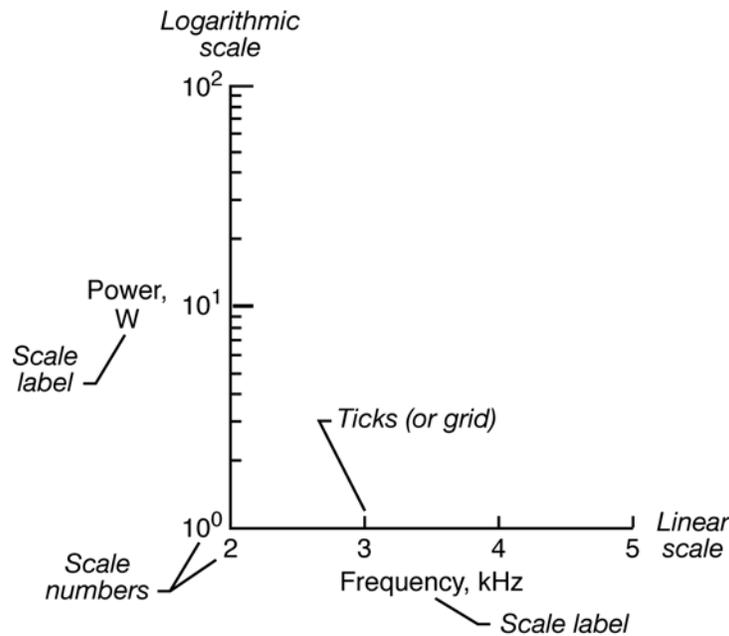


Figure 2-9. Linear and logarithmic scales.

2.6.5.1 Linear Scales

2.6.5.1.1 Scale Ticks or Grid

The need to read data from a graph dictates the type of grid needed. The most readable figures are free of unnecessary lines, so ticks are preferred to coarse grid lines, and coarse grid lines are preferred to fine grid.

- For linear scales, the ticks or grid lines should correspond to 1, 2, or 5 units of measurement multiplied or divided by 1, 10, 100, etc. (Figure 2-10). Use of other units would make interpolation between ticks difficult.
- Numbered ticks (major ticks) are longer than unnumbered ticks (minor ticks). (See Figure 2-11.) Zero lines are often drawn heavier on grids and extend across a graph with ticks.

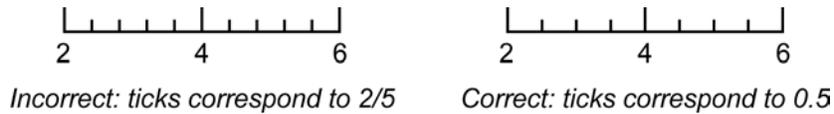


Figure 2-10. Tick ratios.

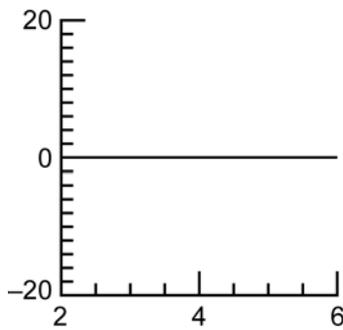


Figure 2-11. Numbered tick scales.

2.6.5.1.2 Scale Numbers

For linear scales, the scale numbers shown on the graph should correspond to 1, 2, 4, or 5 multiplied or divided by 1, 10, 100, etc. One scale increment would equal one of the following (Table 2-4):

Table 2-4. Linear Scale Increments

0.01	0.1	1	10	100	etc.
.02	.2	2	20	200	etc.
.04	.4	4	40	400	etc.
.05	.5	5	50	500	etc.
etc.	etc.	etc.	etc.	etc.	etc.

Typical style is to delete initial zeros before the decimal point in scales. Zeros, however, should be added to the right of decimal numbers so that all scale numbers have the same number of

decimal places. In vertical scales the scale numbers are aligned on the right except for zero (Figure 2-12).

When both the horizontal and the vertical scale begins with zero, only one zero is commonly given, aligned with both scales (Figure 2-12). Both zeros can be given.

Decimal points are not given after whole numbers (Figure 2-12).

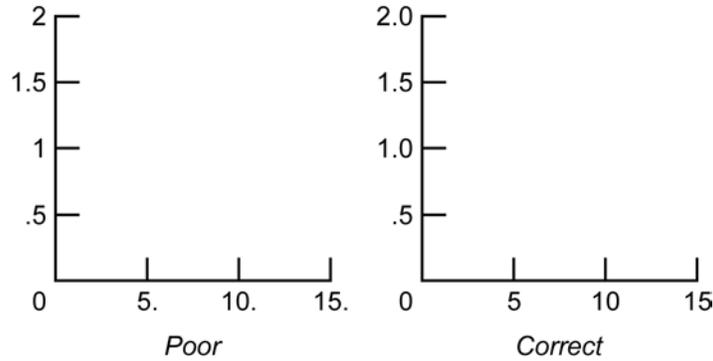


Figure 2-12. Use of decimal points and zeros in scale numbers.

When scale numbers are so large or small that they require several zeros that may crowd the scale, they are best shown with a multiplying factor. Typical style prefers that the factor be given with the scale itself, at the top of the vertical scale and at the right of the horizontal scale (Figure 2-13). This method of showing multiplying factors avoids the confusion of other standard methods of indicating a multiplying factor in the scale label:

$$\begin{aligned} &\text{Pressure} \times 10^{-5}, \text{ mmHg} \\ &\text{Pressure, mmHg} \times 10^5 \end{aligned}$$

Does this mean that a scale number of 2 indicates 200 000 mmHg or 0.00002 mmHg? Both of the above scale labels indicate pressure on the order of 100 000 mmHg.

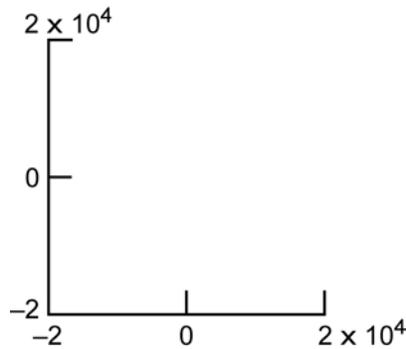


Figure 2-13. Multiplying factors on scale numbers.

2.6.5.1.3 Scale Labels

All scales must have a label that identifies what the scale represents in terms of words, a symbol, or both, plus the unit of measurement if not dimensionless:

- Pressure, p , μPa
- Lift-drag ratio, L/D
- α , deg

The preferred style for scale labels is to separate the word description, the symbol, and the unit of measurement with commas as shown above. Other styles call for parentheses around the unit, dashes instead of commas, or the word *in* before the unit:

- Pressure, p (μPa)
- Pressure- p - μPa
- Pressure in μPa

Authors and illustrators are strongly encouraged to use the preferred style.

If the vertical scale label is short or can be broken into a few short lines, it should be horizontal; otherwise, it may read vertically from bottom to top (Figure 2-14).

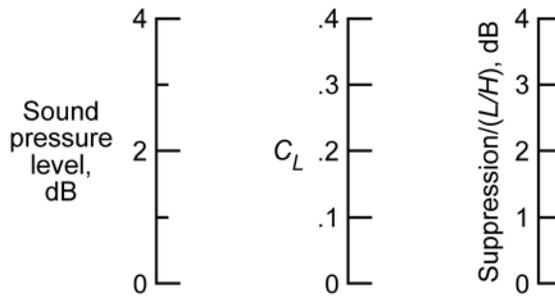


Figure 2-14. Horizontal scale labels.

2.6.5.2 Logarithmic Scales

2.6.5.2.1 Scale Ticks or Grid

A logarithmic scale should begin and end with a power of 10, particularly if it is labeled with powers of 10 instead of decimal numbers, i.e., with 10^0 , 10 , 10^2 instead of 1, 10, 100 (Figure 2-15).

The ticks at the power of 10 (major) are longer than the ticks between (minor). On logarithmic scales, some or all minor ticks may be left out.

The major ticks or grid lines on logarithmic scales may be numbered with powers of 10 or decimal numbers (Table 2-5 and Figure 2-15):

Table 2-5. Logarithmic Scale Numbering

10^{-2}	10^{-1}	10^0	10	10^2	10^3
.01	.1	0	10	100	1000

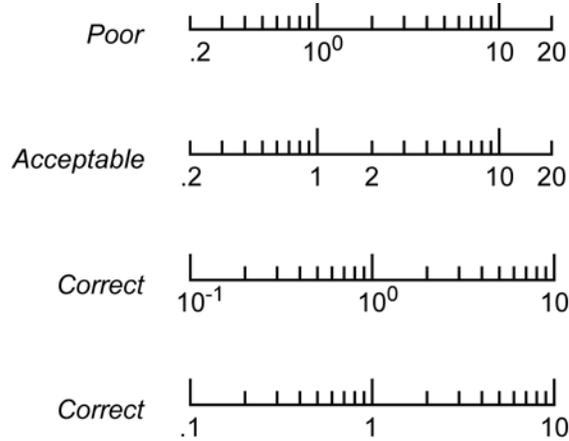


Figure 2-15. Logarithmic scale style.

When powers of 10 label the major ticks or grid lines, minor tick labels should be smaller, if possible, than other labels on the figure (Figure 2-16).

If all minor ticks between powers of 10 are drawn, they may or may not be labeled; if only some minor ticks are drawn, they should be labeled (Figure 2-16).

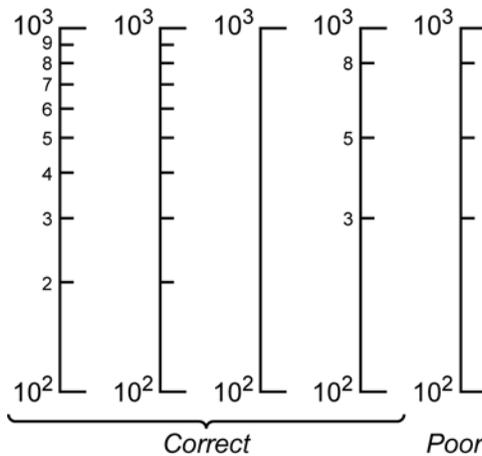


Figure 2-16. Ticks drawn with powers of 10.

When decimal numbers label the major ticks or grid lines, minor tick labels do not change size on a logarithmic scale (Figure 2-17).

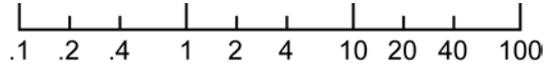


Figure 2-17. Logarithmic scale drawn with decimal numbers.

2.6.5.2.2 Scale Labels

Logarithmic scale labels identify what the scale represents and the unit of measurement just as linear scale labels do. The preferred style is also the same:

Frequency, *f*, Hz

An anomalous type of logarithmic scale (Figure 2-18) is actually a linear scale representing a logarithm. This method of displaying a logarithmic scale is not recommended, particularly when a unit of measurement must be given.

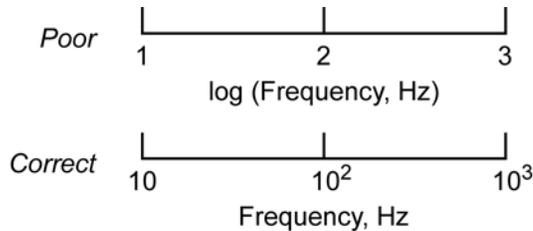


Figure 2-18. Anomalous logarithmic scale.

2.6.6 Keys and Curve Labels

When multiple curves or data sets are shown on the same plot, they must be made distinguishable by drawing them with differing line patterns, by using differing test point symbols, or by labeling each curve. When differing line patterns or test point symbols are used, a key to those line patterns or symbols is necessary.

Likewise, when information is distinguished by differing shading (e.g., on a bar chart) a key to the shading must be provided.

2.6.6.1 Keys

Keys should be placed near the top of a figure if possible (Figure 2-19), but never between a figure and caption. Keys should not be placed too close to the data in a figure and may extend outside the plot area of a graph or chart.

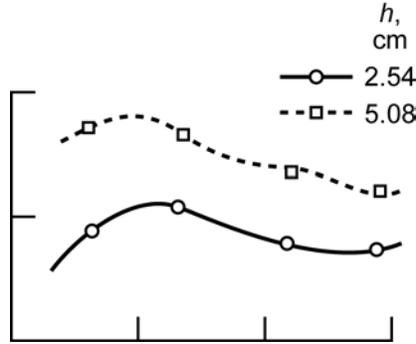


Figure 2-19. Preferred key position.

Keys are set up in a tabular format, but unlike tables, they are set up with no ruling or boxes. Alignment of keys is shown in Figure 2-20.

	<i>R</i>	<i>U, m/s</i>	<i>M</i>	
○	0.1×10^6	31.7	0.093	} Data
□	.8	9.6	.006	
◇	.9	71.3	.209	
—	.8	40.0	.117	Theory

Figure 2-20. Key alignments.

The line patterns, test point symbols, and/or shading patterns appear in the left column of the key with no heading above them.

The column or columns identifying the patterns and symbols are arranged as follows:

- If necessary, a heading identifying what the values represent and the unit of measurement is centered above the column.
- Columns of numbers are aligned on the decimal point with initial zeros and powers of 10 appearing only on the top number in each column.
- Columns of words and phrases are aligned on the left.

2.6.6.2 Curve Labels

If they do not interfere with or obscure the reading of the curves, curve labels are easier to understand than keys.

Curve labels should not cross curves, but be placed as close as possible to the curve (Figure 2-21). If necessary, a leader, preferably without an arrowhead, may be drawn from the label to the curve.

To shorten curve labels, they can be set up in a vertical or horizontal arrangement (Figure 2-22).

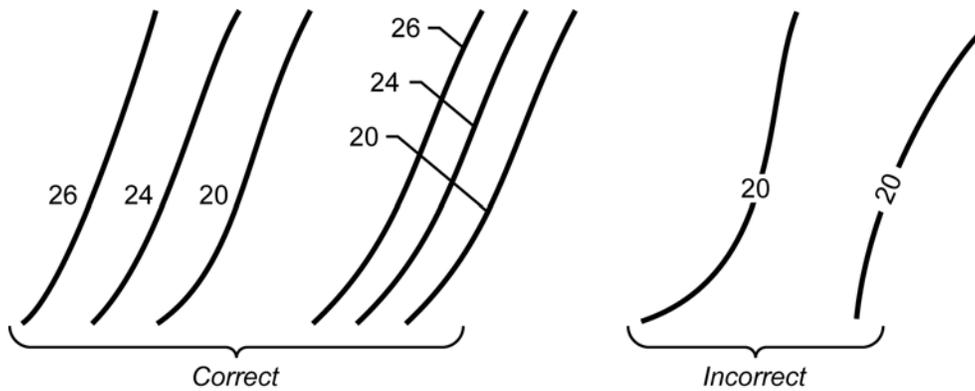


Figure 2-21. Curve label locations.

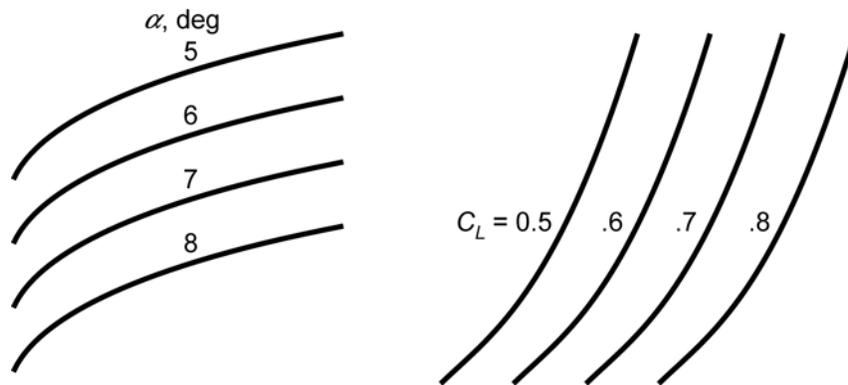


Figure 2-22. Curve label alignments.

2.6.7 Line Work and Symbols

All line work must be uniform and unbroken to reproduce accurately.

Heavier weight lines in a figure will receive emphasis. If line weights are varied in a figure, the following guidelines are recommended:

- Use the heavier line weight for drawings, graph curves, test point symbols, zero axis lines, and scale lines and ticks.
- Use the lighter line weight for grid lines, dimension lines, centerlines, and leaders.

The two basic data identifiers are test point symbols and line patterns. The same test point symbol and line pattern should be used to represent the same condition throughout a set of figures.

Figure 2-23 shows the traditional NASA line patterns and the recommended sequence for their use.

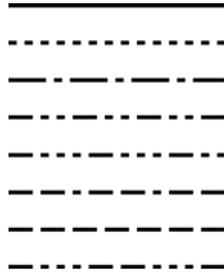


Figure 2-23. Traditional NASA line patterns.

Figure 2-24 shows the traditional NASA test point symbols and the recommended sequence for their use. In general, outline symbols (without shading) are recommended, particularly when test points are close together. When similar symbols are necessary for different sets of data, flags may be added to these symbols, or shading might be added (Figure 2-25). Always avoid the use of +'s, x's, or small dots for test point symbols because curves and grid lines obscure them.

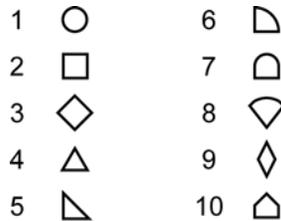


Figure 2-24. Traditional NASA test point symbols.



Figure 2-25. Methods of distinguishing similar test point symbols.

Shading patterns must be selected with care. They can be hard to distinguish from one another. Also, always be aware that the pattern may become too dense when the figure is reduced. Lines often do not reproduce well within shaded areas. Labeling should never cross the shading; the shading should be broken (Figure 2-26).

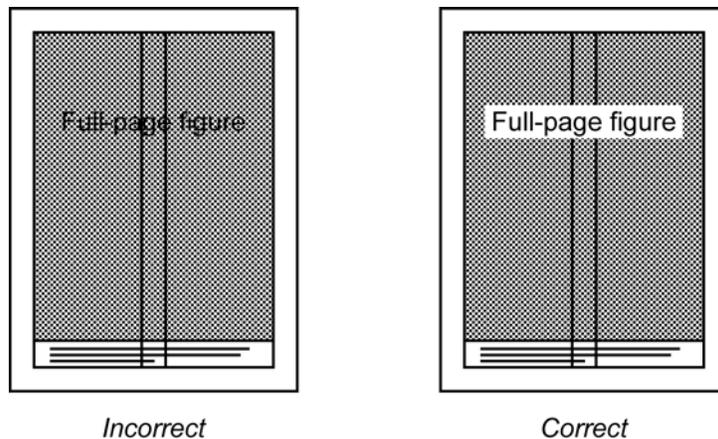


Figure 2-26. Shading examples.

2.7 Captions

The terms *caption* and *legend* are often used interchangeably. In this document, caption refers to the accompanying title or statement identifying, explaining, and describing the figure. It is placed below the figure. Legend means essentially the same thing.

All numbered figures must have captions. Sketches are considered part of the text, and do not have captions unless they are given a letter designation and then the caption, e.g., “Sketch A,” would accompany the sketch.

Each caption in a report should be unique. A series of similar figures in a report may be given a single number and unique caption with appropriate subcaptions, designated (a), (b), (c), and centered under the parts of the figure that they reference.

2.7.1 Content of Captions

Figure captions should be concise, but adequately descriptive. They should convey the basic idea of the figure without duplicating the information presented in the figure itself, e.g., the scale labels. A caption contains several elements:

- Figure number: Figure 1.
- A title or headline identifying the content of the figure. This “main caption” is rarely a complete sentence: Effect of penalty parameter on accuracy of total strain energy.
- A list of conditions necessary to describe the figure: $Pr_o/Eh^2 = 2.0$; $p_o = 0$.
- Supplementary notes and information explaining the figure: All linear dimensions are in millimeters.

The editor and author must ensure that the caption contains all the information necessary to understand the figure and distinguish it from the other figures in the report, i.e., a clear and unique main caption, a complete list of conditions, and all required supplemental notes:

Figure 1. Effect of penalty parameter on accuracy of total strain energy. $Pr_o/Eh^2 = 2.0$; $p_o = 0$. All linear dimensions are in millimeters.

Do not include keys in the caption, if possible. Keys often contain graphic characters (e.g., test point symbols and line patterns) that are much easier to produce as part of the figure than to typeset as part of the caption.

2.7.2 Style and Format of Captions

The style and format of figure captions vary with the publisher. One style follows, but variations are acceptable as long as you are consistent:

- Spell out the label “Figure 1.”
- Use sentence-style capitalization.

Figure 1. Curved beam and shell elements and sign convention.

Alternate: Figure 1—Curved beam and shell elements and sign convention.

Punctuate with periods after the figure number, after the main caption, after the list of conditions, and after any supplementary notes. Use semi-colons between conditions:

Figure 14. SPL measured during takeoff of six large aircraft. $T_o = 65$ °F; $\theta = 90^\circ$. (From ref. 35.)

When conditions are expressed with words rather than with symbols, either commas or equal signs may be used. Observe the preferred capitalization style for symbolic expressions if equal signs are used:

Figure 4. Airfoil coordinates. $y = 20.0$ in; $c = 35.702$ in

Figure 4. Airfoil coordinates. Span, 20.0 in; chord, 35.702 in

Figure 4. Airfoil coordinates. Span = 20.0 in; Chord = 35.702 in

Subcaptions are capitalized and punctuated in the same style. Lowercase letters in parentheses designate parts of figures. Sometimes subcaptions are simply a list of conditions:

(a) Right side view. (b) Top view.

Figure 2. Sketch of complete wind tunnel model. All dimensions are in inches.

(a) $y = 20.0$ in; $c = 35.702$ in (b) $y = 30.0$ in; $c = 31.433$ in

Figure 4. Measured and design airfoil coordinates.

When a figure appears on more than one page, the caption for the last page is:

Figure 2. Concluded.

and the captions on pages between the first and last appear as:

Figure 2. Continued.

One-line captions and subcaptions are centered. Captions with two or more lines extend the width of the column or page with the second and subsequent lines indented (hanging indentation), as shown in the above examples.

When figures are integrated into the text, the captions may be set in type smaller than the rest of the text; however, exercise caution that the caption remains legible and remember that authors frequently use figures in a variety of venues. When figures appear at the back or on pages by themselves, the captions appear in the same type size as the text.

2.8 Figure Layout

Talent and expertise are required to obtain a pleasing and correct layout of the text, figures, and captions. In general, a draft of the document, the original figures, and instructions for figure layout including anticipated figure reductions are given to those preparing the final manuscript for printing if the author does not do this. During manuscript preparation, figure reductions and other instructions may have to be adjusted. Essentially figures can be laid out in one of two ways: integrated with the text or in back of the text.

2.8.1 Figures in the Back

Figures in the back are generally the last pages of the report and are followed by references.

- Horizontally center figures on the page with their captions centered below them.
- Avoid crowding figures on a page. Some white space on figure pages leads to more attractive layout. Generally center the figures and captions vertically. Never leave more space above figures on a page than below.
- Whenever possible, group figures or parts of a figure together on a page. Such grouping saves space and printing costs and generally results in a more pleasing appearance.

When figures contain parts with separate subcaptions, part of one figure, (e.g., Figure 2(c)), should not be placed on the same page with part of another, (e.g., Figure 3 or 3(a)).

- More space should be left between figures on a page than between a figure and its caption.
- The space between figures and captions should be consistent throughout a document, even though more space may be available on some pages than on others.

2.8.2 Integrated Figures

Integration of figures is preferred for ease of reading. Integrated figures are placed as close to their discussion in the text as possible. Determining what is “as close as possible” requires judgment. Does “as close as possible” mean to place the illustration after the line where it is first mentioned? At the end of the paragraph? On the same page?

- Generally place a figure after the paragraph where it is first mentioned or at the top of the next page or column; this is sufficiently close to its discussion and does not interrupt the text. Never place a figure immediately before an equation.
- Do not place a figure in the middle of a paragraph unless it naturally breaks on the top or bottom of a page. Place a figure within a paragraph only if at least two lines of the paragraph appear both above and below the figure.
- To resolve layout problems, place a figure before it is mentioned as long as it appears on the same or facing page.
- When figures are integrated, be careful to keep parts of a figure clearly together. Cluster parts (a), (b), (c), etc., in a column, at the tops of columns, at the tops of facing pages, or on pages without text.
- Leave more space above the figure and below the caption than between the figure and caption.
- Do not leave space above a figure when it is placed at the top of a column or page.
- Remember that visual considerations are very important when integrating figures. The white space between text, figures, and captions, the overall appearance of facing pages, and precise sizing of the figures are very important.

**SECTION 3
TABLE DESIGN**

3.1 Introduction

Tables and graphs organize data into patterns so that large amounts of data can be interpreted and understood. Tables list exact data for comparison and computation, whereas graphs present relationships and trends. Tables and graphs are alike in that they usually contain a horizontal and a vertical scale, as indicated in the following figure taken from Buehler (1970) in *Report Construction: A Handbook for the preparation of Effective Reports*. (See Figure 3-1.)

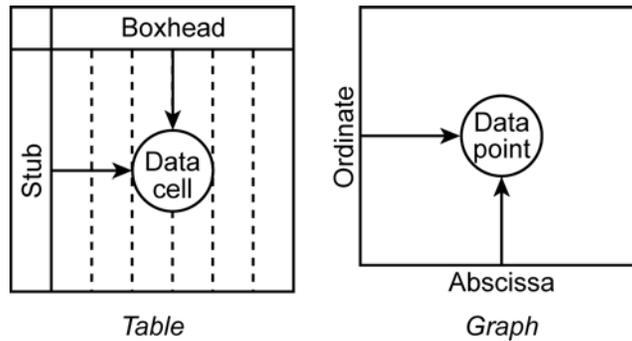


Figure 3-1. Horizontal and vertical scales.

The boxhead controls data that read down in columns; the stub controls data that read across in rows. One-dimensional tables that are missing either the stub or the boxhead (Tables 3-1 and 3-2) occur frequently and are perfectly correct.

Tables can be either informal or formal. Informal tables are integral parts of the text; thus, they must be simple and brief. Because they immediately follow an introductory statement, a title is usually unnecessary. They are unnumbered and thus cannot be referred to elsewhere in the paper. Formal tables are self-explanatory, have a unique title, and are referred to by number. Although formal tables are preferably integrated in the text near their first mention, they may be grouped at the back (after references or symbols and before figures).

Because of the wide variety of tables in NASA papers, we recommend flexible guidelines for table design, rather than specific rules. This section describes such guidelines.

Table 3-1. Sample Table Without Stub

Advantages	Disadvantages
Simple, fast Requires little storage Popular Does not require complete data set Accurate global mean Independent of R Respond to local discontinuity	Does not enhance high frequency Inaccurate regional values Inaccurate harmonic components

Table 3-2. Sample Partial Table Without Boxhead

Overall model length, m (ft)	0.93 (3.05)
Wing:	
Span, m (ft)	0.612 (2.007)
Area, m ² (ft ²)	0.124 (1.34)
Root chord (theoretical), m (ft)	0.33 (1.07)
Tip chord (theoretical), m (ft)	0.082 (0.27)
Mean geometric chord, m (ft)	0.228 (0.749)
Aspect ratio	3.0
Taper ratio	0.25
Sweepback of leading edge, deg	45
Airfoil section	NACA 64A series ^a
Horizontal tail (exposed each side):	
Span, m (ft)	0.113 (0.37)
Area, m ² (ft ²)	0.012 (0.133)
Root chord (theoretical), m (ft)	0.165 (0.54)
Tip chord (theoretical), m (ft)	0.055 (0.18)
Sweepback of leading edge, deg	50
Airfoil section	NACA 64-series
Vertical tail (exposed each panel):	
Span, m (ft)	0.146 (0.48)
Area, m ² (ft ²)	0.013 (0.138)
Root chord, m (ft)	0.137 (0.45)
Tip chord, m (ft)	0.037 (0.12)
Sweepback of leading edge, deg	36.57
Toe-out angle, deg.....	2
Airfoil section	NACA 64-series

^aAirfoil section has conical camber of design $C_L = 0.3$ on the outboard 20 percent of the local semispan.

3.2 Table Design

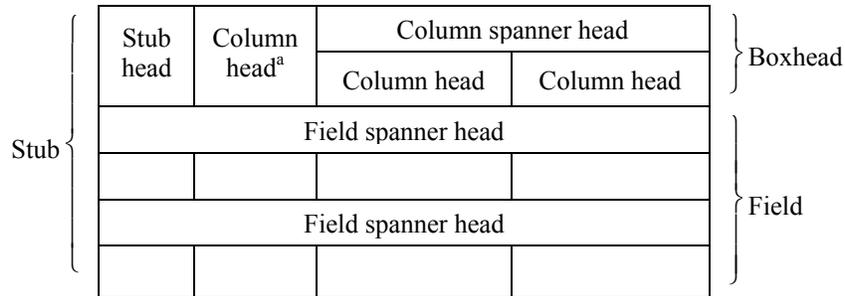
The *Government Printing Office (GPO) Style Manual (2000)* provides a thorough discussion of table design.

Buehler (1970) states, “There is not...a universally adopted nomenclature for the parts of a table.” In this section, we have chosen Buehler’s nomenclature (Figure 3-2). A glossary of terms appears at the end of this section.

TABLE X—TITLE

(Headnote)

(a) Subtitle



^aFootnote.

Figure 3-2. Parts of a table.

3.2.1 Title and Number

Each formal table has a unique title and is numbered in order of its mention in the paper. The title, typed in capitals, and the number are centered above the table. Subtitles, designated by lowercase letters in parentheses, are centered below the main title with only the first letter and proper nouns capitalized (i.e., sentence-style capitalization). For example:

**TABLE I—PHOTOCHEMICAL PROCESSES
FOR ONE-DIMENSIONAL MODEL**

(a) Kinetic process

Note that no punctuation follows the title or subtitle.

The title is not repeated on continued pages of a table. “TABLE I—Continued” replaces the title on the second and subsequent pages and “TABLE I—Concluded” on the last page.

Tables are numbered with Roman numerals (I, II(a), II(b)). If Roman numerals become too cumbersome (e.g., LXXVIII), then use Arabic numbers (1, 2(a), 2(b)). When tables appear in the appendix (either integrated or at the end), their numbers include the appendix designation (AII, A2). Appendix tables that are grouped with text tables in the back are numbered consecutively after the text tables, without the appendix designation.

The title should briefly describe the content of the table without giving background information, repeating results or headings, or commenting on the table. For example,

TABLE V—SOLUTIONS FROM SHAPE FACTOR, PARAMETER ESTIMATION, AND DECONVOLUTION TECHNIQUES

could probably be shortened to

TABLE V—SOLUTIONS FROM THE THREE TECHNIQUES

because the names of the techniques would be given in the boxhead. Also,

TABLE V—COMPARISON OF SOLUTIONS FROM THREE TECHNIQUES

would be inappropriate. The three solutions should be discussed and compared in the text; the title should be confined to facts.

3.2.2 Ruling Tables

NASA has traditionally published heavily ruled tables. Tables with a stub column and one data column (i.e., leaderwork tables, Table 3-3) are not ruled. Leaderwork tables with more than one data column can be published without rules (Table 3-3).

Because rules, particularly down rules, are difficult to handle on some word processing equipment, several manuals (e.g., the *GPO Style Manual* (2000) and *Words Into Type*) recommend no rules or cross rules only. Fully ruled tables are preferred because they are clearer, and the method of production does not make down-ruling particularly difficult.

Table 3-3. Sample Table Without Rules

TABLE I—MASS AND GEOMETRIC CHARACTERISTICS OF MODEL

Weight, N (lb)	296.92 (66.75)		
Moments of inertia:			
	Fuselage forebody-deflection angle of		
	0°	45°	78°
$I_x, \text{kg-m}^2$ (slug-ft ²)	0.845 (0.623)	0.944 (0.696)	1.335 (0.985)
$I_y, \text{kg-m}^2$ (slug-ft ²)	7.069 (5.214)	6.969 (5.140)	6.904 (5.092)
$I_z, \text{kg-m}^2$ (slug-ft ²)	7.862 (5.799)	7.854 (5.793)	7.513 (5.541)
Overall fuselage length, m (ft)	2.40 (7.88)		
Wing:			
Span, m (ft)	1.60 (5.25)		
Area, m ² (ft ²)	0.73 (7.88)		
Root chord, m (ft)	0.68 (2.23)		
Tip chord, m (ft)	0.24 (0.78)		
Mean aerodynamic chord, m (ft)	0.494 (1.62)		
Aspect ratio	3.5		
Taper ratio	0.35		
Sweepback of 0.25c, deg	20		
Sweepback leading edge, deg	26.6		
Dihedral, deg	-5		
Horizontal tail:			
Area (exposed), m ² (ft ²)	0.18 (1.91)		
Span (exposed), m (ft)	0.73 (2.40)		
Root chord, m (ft)	0.30 (1.00)		
Tip chord, m (ft)	0.18 (0.60)		
Sweepback of 0.25c, deg	38		
Taper ratio	0.6		

3.2.3 Boxhead

Column heads, column spanner heads, and the stub head make up the boxhead. On continued pages of a table, the complete boxhead is repeated.

Column heads apply to material below them; that is, they read down, never across. The following boxhead:

Target diameter	1 cm	2.54 cm
Minimum energy, keV	175.83	154.91
Maximum energy, keV	230.75	263.40

should be edited to:

Parameter	Target diameter	
	1 cm	2.54 cm
Minimum energy, keV	175.83	154.91
Maximum energy, keV	230.75	263.40

Note that when possible, a stub head is invented in a ruled table to avoid an empty box.

Headings in the boxhead are nouns or noun phrases. They should be as simple and brief as possible (commonly known abbreviations) with any necessary amplification in a footnote. Sentence-style capitalization is used. If possible, units of measurement are placed in the boxhead (or stub) rather than in the field. For clarity, multiplying factors are placed in the field, not in the boxhead. The symbol and unit of measurement are set off in the boxhead by commas. For example:

Orifice diameter, <i>d</i> , cm (in)	Injection angle, deg	Peripheral spacing, s/d
0.302 (0.119)	90	13.1
.302 (.119)	90	13.9
.241 (.99)	119	10.6

Note the use of parentheses to indicate a second set of values. (Also notice that the left parentheses are aligned, but the right parentheses follow the last character of the entries. This alignment of left parentheses is used only in uniform number columns.)

Column heads and stub heads are centered horizontally over the longest entry in the column and vertically in their boxes. (When a heading or entry is centered, leave any necessary extra space to the right of or below the heading or entry.) Column spanner heads are centered

vertically and horizontally in their boxes. They are often interrupted by a unit of measurement set off by commas. For example:

Root-mean-square lateral and vertical deviations, m, for configuration—					
1	2	3	4	5	6

Note the use of the dash to indicate that the spanner head reads into subsequent column heads.

Column spanner heads show similarities between columns and prevent repetition (Buehler 1970); however, to avoid confusion, the boxhead should be limited to three levels, i.e., two levels of spanners (*Chicago Manual of Style*). (See Table 3-4.)

Table 3-4. Sample Table with Three Levels of Spanners

Subject	Day	Root-mean-square lateral and vertical deviations for configuration—																	
		1		2		3		4		5		6		7		8		9	
		Δh	y	Δh	y	Δh	y	Δh	y	Δh	y	Δh	y	Δh	y	Δh	y	Δh	y
MM	1	9.1	32.2	9.1	16.2	9.1	24.3	6.8	48.7	9.1	24	6.8	2	3.3	3	2.3	9	3.2	7
	2	9.1	24.3	4.5	24.3	6.8	40.6	6.8	40.6	6.8	24	6.8	5	3.5	4	4.5	8	2.5	6
HB	1	9.7	31.2	4.1	26.2	7.1	34.3	6.8	28.7	2.1	24	2.8	7	1.3	3	5.3	7	3.2	4
	2	3.1	34.3	5.5	14.3	6.8	20.6	2.8	30.6	6.8	44	5.8	7	5.5	6	8.5	8	6.5	3

3.2.4 Stub

The stub, generally the left column of a table, may be difficult to distinguish. It always contains independent variables; in fact, more than one column may be required to define all the independent variables. In Table 3-4, the first two columns, headed “Subject” and “Day,” are the stub. In Table 3-1, there is no stub.

The stub may not have a stub head, even if there is a boxhead over the data field. In ruled tables, a stub head is preferred to avoid an empty box. If the stub entries are so diverse that no common heading is possible, leave the stub head box empty as in Table 3-5.

Table 3-5. Sample Table with Empty Stub Head Box

	α_{stall} , deg	α_{steady} , deg	V_{steady} , m/s	a_n , g units	* p , deg/s	q , deg/s	r , deg/s	h_p , m/s	Turn rate, s/turn
Ailerons with spin									
1 turn	13.5	23.0	46.3	1.6	29	18	31	12.3	7.8
3 to 6 turns	15.0	26.0	56.4	2.1	78	20	30	33.5	4.2
	19.0	23.0	54.9	2.6	71	21	30	51.8	4.5
	12.5	22.5	54.9	2.5	76	25	30	45.7	4.2
	14.0	26.0	55.5	2.5	67	23	30	43.6	4.7
Average	15.1	24.4	55.5	2.4	73	22	30	43.6	4.4

*Calculated.

Stub columns that number another stub column (see the “Test” column in Table 3-6) should be included only if the numbers are referred to elsewhere in the paper or are useful to the reader in some other way. Often such number columns are unnecessary.

If the stub is a word column, its entries should be consistent in grammar and punctuated and capitalized like column heads, i.e., symbols and units of measurement set off by commas and sentence-style capitalization. The word entries are usually aligned on the left, and runover lines are indented under the third character of the first line.

In a table without leaders, align a field entry with the first line of its stub entry. In a leaderwork table, align the field entry with the last line of a runover stub entry. Sometimes several field entries correspond to one stub entry.

Table 3-6. Sample Stub Column

Test	q_∞ , kPa	$T_{t,\infty}$, K	R_∞ , m^{-1}	α , deg	δ_u , deg	δ_l , deg	w_u , cm	w_l , cm	W , cm
Sealed spanwise gap									
1	61.9	1890	4.56×10^6	10	10	10	1.19	1.19	9.65
Maximum elevon-stub gaps									
2	62.6	1790	4.56×10^6	0	0	0	1.19 ↓	1.19 ↓	9.65 ↓
3	62.8	1830	4.72	0	10	10			
4	62.4	1890	4.59	10	0	0			
5	61.3	1870	4.56	↓	5	5			
6	61.7	1870	4.59		10	10			
7	62.6	1930	4.53		15	15			
8	62.2	1830	4.69	15	10	10			
9	61.8	1830	4.66	5	10	10			

3.2.4.1 Total and Mean Lines

Total, mean, and other similar stub entries are usually indented under the third character of other stub entries (Table 3-7). However, this indentation can be omitted to save space.

A cross rule is usually drawn above these types of entries, particularly if the stub head does not apply (Table 3-4) or if some columns must be ended (Table 3-7). A cross rule is not absolutely necessary (Table 3-5).

Table 3-7. Indented Stub Entries

Parameter	Case 1, data averaged over 5° regions	Case 1, data averaged over 10° regions	Case 1 minus case 2
Global radiant exitance, $W-n^{-2}$	235.19	235.09	6.30
Pole-to-pole gradient, $W-n^{-2}$	11.46	11.61	-.21
Equator-to-pole gradient, $W-n^{-2}$	-22.03	-22.27	.24
10° regional radiant exitance, $W-n^{-2}$:			
Pacific, tropical	266.03	265.50	.45
Pacific, high latitude	191.33	191.23	.10
Atlantic, subtropical	268.29	268.02	.27
Sahara	279.59	281.60	-2.01
Greenland	221.09	225.71	.38
South Pole	124.50	118.57	5.93
Area weighted mean of absolute zonal differences, $W-n^{-2}$			0.34
Area weighted mean of absolute 10° regional differences, $W-n^{-2}$83
Standard deviation of 10° regional differences, $W-n^{-2}$			1.44

3.2.4.2 Leaders

Leader dots are typed in the stub to lead the eye across to the field entry. It is preferable to minimize use of leaders. Leaders are usually used in:

- Two-column leaderwork tables (Tables 3-2 and 3-3).
- Ruled tables with units of measurement in the stub (Table 3-7).

Leaders begin two spaces after the stub entry and end at least two spaces before the field entry or down rule. More than two spaces may be left between the leaders and the field entry to avoid a ragged appearance (Tables 3-2 and 3-3).

The length of leaders depends on the overall length of a table. When the width of a table is larger than its length, 10 leader dots are sufficient between the longest stub entry and the longest data entry. In the following table, the leaders are unnecessarily long, and typed across a full-width page, the table is difficult to read:

TABLE II—SYSTEM DESIGN REQUIREMENTS

Frequency	1.08, 2.03, and 4.95 GHz
Antenna aperture	300 m/beam, 725 m total
Focal length	575 m
Gain	70 dB
Surface accuracy	^a λ/50
Orbit altitude	650 to 1000 km
Orbit inclination	60° and Sun synchronous
Lifetime	15 years, 3-year resupply
Pointing	0.01°
Slew rate	0.06 deg/s
Data rate	30 megabits/s

Its appearance is improved when the leaders are shortened:

TABLE II—SYSTEM DESIGN REQUIREMENTS

Frequency	1.08, 2.03, and 4.95 GHz
Antenna aperture	300 m/beam, 725 m total
Focal length	575 m
Gain	70 dB
Surface accuracy	^a λ/50
Orbit altitude	650 to 1000 km
Orbit inclination	60° and Sun synchronous
Lifetime	15 years, 3-year resupply
Pointing	0.01°
Slew rate	0.06 deg/s
Data rate	30 megabits/s

If this table were longer, longer leaders would have looked better.

When space is lacking in the stub column of a ruled table, the leader between the longest entry and the down rule can be as short as two single-spaced dots.

3.2.4.3 Stub Entries with Subordinate Entries

Entries in the stub read across unless they have subordinate entries (Table 3-2). A stub entry with subentries is usually followed by a colon, but if it reads into the subentries, it is followed by a dash. The subentries are indented under the third letter of the main entry, and leaders come from them rather than from the main entry.

3.2.4.4 Alignment of Stub Column

If the stub column is made up of numbers or symbols, it is aligned as usual (Tables 3-4 and 3-6). If the stub column is a word column, the entries are usually aligned on the left (Tables 3-2, 3-5, and 3-7).

3.2.5 Field

The field of a table contains the information identified by the boxhead and stub. The field may also contain field spanner heads if required to completely specify the information.

The field entries are arranged in columns that correspond to column heads and in rows that correspond to stub entries. Two or more field columns are usually separated by down rules. The widest entry in each column is centered under its corresponding column head. The rest of the entries in each column are positioned with respect to the widest entry. Alignment of the various types of columns is discussed in the following sections.

If no entry corresponds to a particular column head and stub entry, leave a blank in that column and row. *Words into Type* advocates using leaders to indicate that no entry is available and a blank to indicate that the column head is not applicable. It seems, however, that this distinction is not understood by most readers.

An entry appearing consecutively four or more times should probably be indicated by an arrow, centered, in the column (Table 3-6).

3.2.5.1 Number columns

3.2.5.1.1 Uniform Number of Columns

- Align a column of numerals representing values of the same quantity, called a uniform number column, on the decimal point or, if they are whole numbers, on the right.
- Omit decimals at the end of whole numbers.
- Place zero entries in the unit place (Table 3-8).
- In columns with five-digit numbers, leave a space in four-digit numbers (Table 3-8):

10 320		1320
2 962	But	2962
1 010		1010

- Omit initial zeros before decimal points except after cross rules (Table 3-8). (They are usually retained in a mixed number column.)

Table 3-8. Sample Table Omitting Initial Zeros

No.	Crew Motion	Input	Axis	τ_1 , s	ω_1 , rad/s	ρ_1	τ_2 , s	ω_2 , rad/s	ρ_2
1	Console operations 1	Force	X_c	18.2733	4.0291	0.5056	0	0	0
			Y_c	17.1199	2.8066	.5565	0	0	0
			Z_c	11.7578	4.7634	.5986	0	31.2563	.2357
		Moment	X_c	9.8581	4.4158	0.3196	0	0	0
			Y_c	17.3345	4.0384	.4683	0	0	0
			Z_c	4.0277	4.4132	.5589	0	0	0
2	Console operations 2	Force	X_c	27.7506	4.8027	0.6176	0	0	0
			Y_c	24.9955	3.9640	.4460	0	0	0
			Z_c	24.9720	5.3108	.7719	0	0	0
		Moment	X_c	18.7626	4.5882	0.4845	0	0	0
			Y_c	28.1691	4.3448	.6750	0	0	0
			Z_c	8.0293	5.3498	.7691	0	0	0

- Use a multiplying factor applying to an entire column only on entries below cross rules (Table 3-6).
- Place the unit of measurement in the column head, not in the field column.
- Close signs to numbers regardless of alignment (Table 3-7). Plus signs are usually not given.
- Align numbers in parentheses on decimals also and align left parentheses if no entries intervene between parenthetical entries:

Wire diam., mm (in) 1.27 (0.050) .660 (.026) .229 (.009) .190 (.0075) .165 (.0065) .140 (.0055)	But	Wire diam., mm (in) 1.27 (.050) .660 (.026) .165 (.0065)
--	-----	--

- Note that in the table on the right the longest parenthetical entry is centered in the column as well as the longest nonparenthetical entry.
- In a uniform number column consisting of entries with two numbers connected by \pm , “to”, or another connective, align the numbers on the decimal points and also align the connectives:

826 \pm 50
 1022 \pm 25
 3000 \pm 100
 2960 \pm 65

- Align a column of entries consisting of numbers connected by hyphens (indicating a range) on the hyphens. The numbers are always closed to the hyphen.
- Center an entry consisting of several numbers in a uniform number column:

Ref.		Ref.
13	But	13
14		16, 19, 23, 24
16, 19		30, 31, 32
24		21, 22, 23

If there are several multiple-number entries, align the column on the left for better appearance. Indent runover lines under the third character of the first line.

3.2.5.1.2 Mixed Number Columns

Align a column of numerals representing values of different quantities, called a mixed number column, on the right (Tables 3-2 and 3-3).

- Retain initial zeros before all decimal points unless space is a consideration.
- Place the units of measurement in the stub, not in the field column.

3.2.5.2 Word Column

A column consisting of words, phrases, or sentences is called a word column. In a word column, the entries should be uniform in grammar and punctuation. Sentence-style capitalization is used.

Center a word column in the field if the entries are short (Figure 3-3) and align it on the left if the entries are long (Table 3-9).

A stub word column usually aligned on the left.

NASA STI Standards

Tail configuration	Ventral fin	α' , deg	Ω , rps (s/turn)	Turns for recovery
	Off ^a	79	0.94 (1.06)	∞
	On ^a	46	.46 (2.2)	$2\frac{1}{2}$, 3, $3\frac{1}{2}$
		75	0.79 (1.3)	∞
	Off	47	0.46 (2.2)	2, $2\frac{1}{4}$, 3
	On			^b $\frac{1}{2}$
	Off ^a	81	0.79 (1.3)	^c ∞
	On	52	.50 (2.0)	2, $2\frac{1}{4}$, 3
		55	0.54 (1.9)	$1\frac{1}{2}$, $2\frac{1}{4}$, $2\frac{1}{2}$
	Off ^a	77	0.97 (1.0)	∞
	On	35	.45 (2.2)	1, $1\frac{1}{4}$, $1\frac{1}{4}$

^aTwo conditions possible.

^bRecovery attempted before final attitude reached.

^cNo recovery attempted because spin mode too steep to hold in tunnel.

Figure 3-3. Sample table displaying centered text.

Table 3-9. Sample Table Displaying Left-aligned Text

Event	Cell	Pilot action	Console operator	Test director action
Fire	Recover, fire	<ol style="list-style-type: none"> 1. Reduce lift 2. Throttle back to idle 3. Shut off engine 4. Shut off fuel 	<ol style="list-style-type: none"> 1. Switch WINCH AUTO/MAN to MAN 2. Switch EMERG SHUT OFF to OFF 3. Lower aircraft to ground 	Request crash and rescue equipment
Winch malfunction	Recover, winch	<ol style="list-style-type: none"> 1. Reduce lift 2. Throttle back to idle 	Push WINCH EMERG STOP	Instruct winch platform technicians to set manual brake on winch
Primary communication failure	Recover, com	<ol style="list-style-type: none"> 1. Reduce lift 2. Throttle back to idle 	<ol style="list-style-type: none"> 1. Switch to UHF 2. Switch WINCH AUTO/MAN TO MAN 	<ol style="list-style-type: none"> 1. Inform test team of communications failure with bull horn 2. Take appropriate actions as required
Test complete	Recover, test complete	<ol style="list-style-type: none"> 1. Reduce lift 2. Throttle back to idle 	Switch WINCH AUTO/MAN to MAN	Take appropriate actions as required
All other reasons for delaying or stopping test	Recover	<ol style="list-style-type: none"> 1. Reduce lift 2. Throttle back to idle 	Switch WINCH AUTO/MAN to MAN	Take appropriate actions as required

3.2.5.3 Symbol Column

Align a column consisting of abbreviations, designations, or chemical, mathematical, or computer symbol, called a symbol column, on the left (Figure 3-4).

Position in SPACE	FORTTRAN name	Variable name	Routine where variable is used	Description
1	C11	C ₁₁₁₁	LINSTF ↓	} Extensional stiffnesses
2	C12	C ₁₁₂₂		
3	C16	C ₁₁₁₂		
4	C22	C ₂₂₂₂		
5	C26	C ₂₂₁₂		
6	C66	C ₁₂₁₂		
7	F11	F ₁₁₁₁		} Stiffness interaction coefficients
8	F12	F ₁₁₂₂		
9	F16	F ₁₁₁₂		
10	F22	F ₂₂₂₂		
11	F26	F ₂₂₁₂		
12	F66	F ₁₂₁₂		

Figure 3-4. Sample table displaying symbol column alignment.

3.2.5.4 Summary of Alignment of Field Columns

As discussed in the previous sections, the preferred style for aligning field columns calls for:

- Align uniform number columns (unit in column head) on decimal points.
- Align mixed number columns (units in stub) on the right.
- Center word columns if entries are short, and align them on the left if entries are long.
- Align symbol columns on the left.

In a column that consists of a combination of numbers, words, and/or symbols, follow these guidelines:

- Center a word or symbol in a uniform number column.
- Align a word or symbol on the right in a mixed number column.
- Either align on the left or center a column consisting mainly of words, depending on the overall length of the entries.
- Align on the left a column consisting mainly of symbols.

You must first decide whether a particular column should be considered a uniform number, mixed number, word, or symbol column, and align it accordingly. Appearance should be the deciding factor.

3.2.5.5 Field Spanner Heads

Field spanner heads can be used to identify another independent variable (Buehler 1970). They do not affect the boxhead, but may require that the stub column be repeated. There must be at least two field spanner heads; the first appears directly below the boxhead (Tables 3-5 and 3-6). Note that the cross rules around the field spanner cross the entire table and the spanner head is centered across the width of the table.

3.2.5.6 Grouping Entries

At times, field entries must be grouped together to show their relationship with another field column or with the stub. This grouping can be done in three ways:

- Extra space can be left between rows. In a long list, leaving a double space every 5 or 10 entries makes a column easier to read (Table 3-10).
- Cross rules are the clearest way to group entries (Tables 3-4, 3-5, and 3-8; Figure 3-3). However, to avoid overly ruled tables, use cross rules only when grouping with space would be unclear.
- A brace is useful for showing a relationship between a single entry and a group of entries (Table 3-5 and Figure 3-4). Braces are always drawn to the right of any down rules.

Table 3-10. Sample Table Displaying Double-space in Columns

Frequency, MHz	-10 log y	Name	Frequency, MHz	-10 log y	Name
18017.33	45	Ammonia	18840.378	62	Dichloromethane
18045.525	69	Methyloxirane	18877.550	67	Dichloromethane
18048.920	69	Methyloxirane	18884.70	48	Ammonia
18102.23	65	Dichloromethane	18936.825	66	Ethanol
18103.616	62	Methyloxirane	19010.60	70	Methanamine
18127.10	54	Ammonia	19011.06	68	Methanamine
18142.445	66	Dichloromethane	19013.32	53	Methanamine
18143.273	68	Dichloromethane	19073.175	72	Dichlorodifluoromethane
18161.37	67	Methanol	19110.631	59	Methanamine
18162.35	54	Dichloromethane	19140.85	69	Methanol

If space or cross rules are used to group entries, the related entry (in another column) is aligned with the first entry in the group (Table 3-8).

If a brace is used to group entries, the related entry (in another column) is centered on the group (Table 3-5).

3.2.6 Headnotes

A headnote presents explanatory information applying to the entire table, e.g., conditions under which data presented in the table were measured or a reference source for the table.

Headnotes appear in brackets centered under the table title, or under the subtitle if the headnote applies to that part of the table. The brackets cover the entire headnote:

$$\left[\begin{array}{l} \text{Subscript c refers to converged results} \\ \text{and subscripts 1, 2, and 3 refer to} \\ m = 1, 2, \text{ and } 3 \end{array} \right]$$

Note that in a headnote with more than two lines, the second and subsequent lines are indented under the third character of the first line. The second line of a two-line headnote is centered:

$$\left[\begin{array}{l} \text{Subscript c refers to converged results} \\ \text{and subscript 1 to } m = 1, 2, \text{ and } 3 \end{array} \right]$$

No period ends a headnote; thus, punctuation marks other than periods should be used for internal punctuation.

3.2.7 Footnotes

Explanatory information that applies to particular elements of a table (e.g., title, heading, or entry) is presented in footnotes to a table.

3.2.7.1 Footnote Reference Marks

NASA has traditionally preferred superscript lowercase letters as reference marks for table footnotes.

- Superscript numbers or letters are satisfactory as footnote reference marks in a table that consists entirely of words.
- Superscript letters or symbols are better reference marks in a table that consists entirely or partly of numbers.
- Symbol reference marks are clearer on mathematical or chemical formulas. The following sequence should be used:

* asterisk	§ section mark
† dagger	∥ parallels
‡ double dagger	# number sign

The type of reference mark used (letter, number, or symbol) must be consistent within a table, and should be consistent within the tables of a paper; footnote reference marks can easily be ambiguous:

$$aP^2$$

Thus, clarity must always be examined.

Whatever the type of reference marks used, they begin anew for each table. The marks are introduced from left to right and from top to bottom within a table. They are typed after all punctuation marks, except a dash:

Mass,^a kg ... configuration^a

On a table title, place the reference mark after the title or after the word or phrase to which it applies.

In the boxhead or on an entry, place the reference mark before a number or symbol and after a word (Table 3-5 and Figure 3-3). If the reference mark replaces an entry, it appears in parentheses on the line of type.

3.2.7.2 Typing Footnotes

The footnotes themselves are typed directly below the table, never at the bottom of the page like text footnotes. They are repeated on each page of a continued table.

If the footnotes are long, they may all be typed on the last page of the table and may be typed on previous pages of the table.

Indent the first line of a footnote five spaces from the edge of the table.

Single space between the lines of table footnotes.

A period ends a footnote, and sentence-style capitalization is used.

3.3 Special Tables

Because of the variety of tables in NASA reports, specific rules are difficult to devise and follow. The following sections deal with several special problems.

3.3.1 Reducing Tables

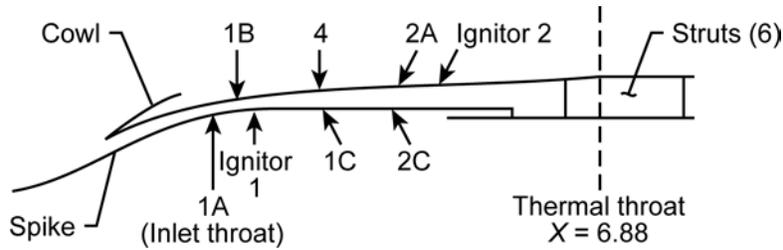
Oversize tables must be reduced to fit within the image area, and small tables should be reduced to fit together on a page. Tables should preferably be placed upright on the page, but they may be placed sideways. All elements of a table (title, headnote, footnotes) are reduced.

When tables are integrated in the text, a slight reduction (e.g., to 90 percent) differentiates them from the text.

3.3.2 Tables with Artwork

Occasionally a sketch is part of a table. If the sketch appears outside the rules of the table, it presents no special problems (Figure 3-5). When the sketch appears within the rules, it must be drawn and labeled so that it can be reduced, if necessary, to fit the table (Figure 3-3).

TABLE III—COMBUSTOR CONFIGURATION AND FUEL PARAMETERS
[Mach 6 design cowl position, $X_c = 3.872$]



Designation (a)	Number of Injectors	Orifice diameter, d , cm (in)	Injection angle, deg (b)	Peripheral spacing, s/d	X-location
Fuel injectors					
1A	37	0.302 (0.119)	90	13.1	4.50
1B	37	.302 (.119)	90	13.9	4.58
1C	37	.302 (.119)	106	13.5	4.94
4	37	.302 (.119)	90	14.2	4.94
2A	60	.241 (.095)	67	11.4	5.39
2C	60	.241 (.095)	119	10.6	5.17

^aDesignations used in all HRE documentation.

^bWith respect to AIM centerline in the view shown in the sketch.

Figure 3-5. Sample table with artwork.

3.3.3 Double-Up Tables

Extremely long, narrow tables can be divided in half and the halves typed side by side with a double rule between them (Table 3-10). The boxhead is repeated. The length of the two halves should be balanced as closely as possible. A stub entry may be continued from one column to the next, for example:

	Parameter	Case 1	Case 2
	Exitance, $W \cdot n^{-2}$ (cont.)		
	Sahara	279.59	281.60
	Greenland	221.09	220.71

Note that internal cross rules do not cross the double down rule.

3.3.4 Parallel Tables

A table may be so large that it must be typed across two facing pages. The title and headnote are centered across the two pages. Column spanner heads across columns on both pages are repeated; on the second page, “(Cont.)” is typed after the spanner head. Footnotes read across both pages. To make the table easier to read, the stub column may be repeated on the right of the second page. Cross rules must align. Because of the difficulties with alignment and centering on parallel tables, always try to divide large tables so that they may appear on separate pages.

3.3.5 Computer Tables

Tabulation of numbers is very easily computerized. Computer-produced tables result in less typing and better accuracy with a small sacrifice in appearance. Computer tables may or may not be ruled. Tables 3-10, 3-11, and 3-12 illustrate the variability in computer tables. Usually the title, subtitle, and headnotes are typed on the page, and the computer copy is reduced to fit in the remaining image area. The boxhead may or may not be typed.

Table 3-11. Sample Computer-generated Table

$M = 1.70, \delta_n = 0^\circ$				$M = 1.70, \delta_n = -10^\circ$			
α, deg	C_y	C_n	C_l	α, deg	C_y	C_n	C_l
-2.29	.0014	-.0002	.0002	-2.33	-.0447	.0551	-.0107
-1.28	.0010	-.0002	.0002	-1.29	-.0444	.0543	-.0106
-.32	.0012	-.0003	.0002	-.27	-.0438	.0537	-.0105
.72	.0009	-.0001	.0003	.73	-.0433	.0532	-.0102
1.70	.0006	0.0000	.0003	1.73	-.0432	.0528	-.0103
3.72	.0005	-.0001	.0004	3.72	-.0429	.0523	-.0100
5.71	0.0000	.0001	.0006	5.71	-.0429	.0524	-.0098
7.70	-.0003	.0001	.0006	7.71	-.0429	.0518	-.0097
9.73	.0002	-.0001	.0009	9.71	-.0424	.0509	-.0095
11.69	-.0004	.0002	.0010	11.67	-.0416	.0498	-.0090
$M = 2.16, \delta_n = 0^\circ$				$M = 2.16, \delta_n = 0^\circ$			
α, deg	C_y	C_n	C_l	α, deg	C_y	C_n	C_l
-2.24	.0009	-.0001	.0002	-2.27	-.0337	.0451	-.0097
-1.26	.0008	-.0002	.0002	-1.24	-.0334	.0443	-.0096
-.23	.0009	-.0001	.0002	-.23	-.0328	.0437	-.0095
.75	.0005	-.0001	.0003	.77	-.0323	.0432	-.0092
1.75	.0005	0.0000	.0004	1.79	-.0329	.0428	-.0093
3.79	.0003	.0001	.0005	3.74	-.0329	.0423	-.0090
5.77	0.0000	.0002	.0005	5.74	-.0329	.0424	-.0088
7.77	-.0005	.0003	.0005	7.78	-.0324	.0418	-.0087
9.76	.0009	-.0002	.0006	9.77	-.0316	.0409	-.0085
11.76	-.0011	.0002	.0005	11.76		.0398	-.0080

Table 3-12. Sample Computer-generated Table

M = 1.60							
ALPHA, DEG	CN	CA	CM	CLB	CNB	CY	ALPHA, DEG
-3.99	-.1723	.1547	.0639	-.0000	.0847	-.0160	-3.99
-1.99	-.0854	.1518	.0334	-.0001	.0865	-.0144	-1.99
-.00	-.0004	.1492	.0058	-.0004	.0623	-.0104	-.00
2.01	.0799	.1505	-.0179	-.0008	.0767	-.0129	2.01
4.03	.1731	.1542	-.0518	-.0013	.0737	-.0127	4.02
6.01	.2669	.1514	-.0864	-.0011	.0614	-.0106	6.01
7.61	.3491	.1474	-.1194	-.0014	.0750	-.0111	7.61
9.97	.5024	.1445	-.1983	-.0019	.0619	-.0136	9.97
12.01	.6651	.1380	-.2709	-.0024	.0099	-.0086	12.01
16.01	1.1402	.1202	-.5444	-.0028	-.1024	.0014	16.01

3.3.6 Others

NASA papers often contain tables that do not conform to the style established in this section. Spin tables (Figure 3-6), a rating system (Table 3-13), and a table of matrices (Figure 3-7) are examples. Authors, editors, and typists must use judgment in designing such tables; guidelines cannot be devised to fit every type of table.

	Spin block	Spin characteristics				Control deflection, deg			Turns for recovery
		α , deg	ϕ , deg	V, m/s (ft/s)	Ω , rps (s/turn)	For spin			
						δ_r	δ_H	δ_d	
254		75	12U 14D	85.0 (279)	0.33 (3.0)	30W 30A	10D 10D	5A 5A	$2\frac{1}{2}, 3, 3, \infty$
255		63 80	14U 10D	90.8 (298)	0.29 (3.4)	30W 30A	10D 10D	5A 5A	$1\frac{1}{2}, 1\frac{1}{2}, 1\frac{1}{2}, 2$
256		67 83	17U 17D	87.8 (288)	0.35 (2.9)	30W 30A	0 0	12A 12A	$1\frac{1}{2}, 2, 2, 2\frac{1}{2}$
257		49	6U 6D	99.1 (325)	0.18 (5.6)	30W 30A	0 0	7A 7A	$\frac{1}{2}, 1$
257		70	8U 10D	90.8 (298)	0.29 (3.4)	30W 30A	0 0	7A 7A	1, 1, 1
258		70	8U 4D	90.8 (298)	0.29 (3.4)	30W 0	0 0	7A 7A	>4, >6
260		45 68	6U 10D	96.3 (316)	0.19 (5.3)	30W 30A	28U 28U	7A 7A	$\frac{1}{2}, 1$
261		45 58	12U 14D	96.3 (316)	0.20 (5.0)	30W 30A	30U 30U	0 0	$\frac{1}{2}, \frac{1}{2}$
252		66	12U 14D	93.6 (307)	0.23 (4.3)	30W 30A	0 0	0 0	1, 1, 1
253		66	10U 6D	93.6 (307)	0.24 (4.2)	30W 30A	10D 10D	0 0	$1, \frac{1}{2}$
253		50	14U	101.8	0.16	30W	10D	0	...

Figure 3-6. Sample spin table.

Table 3-13. Sample Rating System Table

<p>CONTROLLABLE Capable of being controlled or managed in context of mission, with available pilot attention.</p>	<p>ACCEPTABLE May have deficiencies that warrant improvement, but adequate for mission.</p> <p>Pilot compensation, if required to achieve acceptable performance, is feasible.</p>	<p>SATISFACTORY Meets all requirements and expectations; good enough without improvement.</p>	Excellent, highly desirable.	1
		<p>Clearly adequate for mission.</p>	Good, pleasant, well behaved.	2
			Fair. Some mildly unpleasant characteristics. Good enough for mission without improvement.	3
	<p>UNSATISFACTORY Reluctantly acceptable. Deficiencies that warrant improvement. Performance adequate for mission with feasible pilot compensation.</p>	<p>Some minor but annoying deficiencies. Improvement is requested. Effect on performance is easily compensated for by pilot.</p>	4	
			<p>Moderately objectionable deficiencies. Improvement is needed. Reasonable performance requires considerable pilot compensation.</p>	5
			<p>Very objectionable deficiencies. Major improvements are needed. Requires best available pilot compensation to achieve acceptable performance in mission and is too high.</p>	6
	<p>UNACCEPTABLE Deficiencies that require improvement. Inadequate performance for mission even with maximum feasible pilot compensation</p>	<p>Major deficiencies that require improvement for acceptance. Controllable. Performance inadequate for mission, or pilot compensation required for minimum acceptable performance in mission is too high.</p>	7	
		<p>Controllable with difficulty. Requires substantial pilot skill and attention to retain control and continue mission.</p>	8	
		<p>Marginally controllable in mission. Requires maximum available pilot skill and attention to retain control.</p>	9	
	<p>UNCONTROLLABLE Control will be lost during some portion of mission</p>		Uncontrollable in mission.	10

TABLE VII—PREFILTER AND FEEDBACK GAIN MATRICES G AND F FOR DECOUPLED LATERAL AND LONGITUDINAL CONTROLS

(a) Lateral mode

$$[\omega_R = 2.298 \text{ rad/s}; \zeta_R = 0.80; P_R = 4.54 \text{ s}; (t_{1/2})_R = 0.38 \text{ s}]$$

$$G = \begin{bmatrix} -7.734535 & 1.588237 & 0.0 \\ 6.267414 & 0.714128 & 0.0 \\ 13.962874 & -1.067195 & 0.0 \end{bmatrix}$$

$$F = \begin{bmatrix} 0.868495 & 6.990785 & -21.222495 & 0.122524 \\ 0.273273 & 2.615730 & -2.238758 & -0.116009 \\ -0.374135 & -1.615966 & 33.748233 & -0.522822 \end{bmatrix}$$

(b) Longitudinal mode

$$[\omega_{sp} = 5.36 \text{ rad/s}; \zeta_{sp} = 0.79; P_{sp} = 1.93 \text{ s}; (t_{1/2})_{sp} = 0.16 \text{ s}]$$

$$G = \begin{bmatrix} 1.479356 & 3.424809 & 0.882762 & 0.0 \\ 2.638624 & 0.319423 & -7.582873 & 0.0 \\ 12.143196 & -4.229370 & -8.572163 & 0.0 \\ -11.227652 & 0.079126 & 6.239296 & 0.0 \end{bmatrix}$$

Figure 3-7. Sample table of matrices.

3.4 Editing and Marking Tables

While reviewing tables, the editor’s primary task is to format them according to NASA style.

The editor:

- Indicates where rules are to be drawn.
- Ensures that the boxhead is adequate and arranged properly.
- Indicates all capitalization and punctuation.
- Ensures that the stub (column(s) that contain independent variable(s)) is on the left.
- Indicates necessary indentions, leaders, grouping of entries (with space, braces, or cross rules), arrows, and initial zeros.
- Marks headnotes and footnotes for placement and indentation.
- Indicates the type (numbers, letters, or symbols) and placement of all footnote reference marks.
- Ensures that all heads and entries are legible, particularly on handwritten tables.

Any changes must be shown to the author. The author’s approval of major rearrangement of a table is important because major changes to a table in a final copy are very time consuming. When a table is rearranged or the boxhead must be heavily marked, a dummy copy that indicates the boxhead and ruling should be attached to the table. If a dummy is attached, mark out items on the table that are to be typed from the dummy.

The typist is not expected to add or delete material (e.g., rules or initial zeros), change the punctuation or capitalization, or change the type or position of footnote reference marks.

However, the typist:

- Aligns the field and stub columns according to the guidelines of this section.
- Centers heads over columns and may change the number of lines of the column head to improve appearance.

Editors should be aware of alignment of columns and may indicate their preference. Typists should use good judgment and question the editor if a table seems unattractive or ambiguous after being typed as marked. It is very difficult for an editor to visualize the final version of a table that is poorly typed or handwritten in the rough draft.

3.5 Glossary of Table Terms

Boxhead—Major part of a table that includes all column heads and the stub head.

Column head—Substantive heading that identifies material in columns of the field.

Column spanner head—Heading in boxhead that spans two or more column heads.

Cross rule—Line enclosing or dividing a table that runs across the table.

Double-up table—Long, narrow table with two halves that are run side by side with the boxhead repeated.

Down rule—Line enclosing or dividing a table that runs down the table.

Entry—Individual element of a column in the field or stub.

Field—Major part of a table that includes data and field spanner heads.

Field spanner head—Heading that cuts across the field and identifies data below it.

Footnote—Note that applies to a particular element of a table (e.g., title, head, or entry) and appears below the table.

Headnote—Note that applies to the entire table and appears below the title in brackets.

Leaders—Row of dots that lead the eye across the table.

Mixed number column—Column of numbers that represents different quantities (units of measurement in the stub); numbers are aligned on the right.

Number column—Column made up primarily of numbers that are aligned on decimal points or on the right.

Parallel table—Table that reads across two facing pages.

Overlay—Clear sheet with items that are repeated on several pages; the overlay is laid over the table when the print is prepared.

Runover lines—In an entry of more than one line, the second and subsequent lines that are indented under the third character of the first line.

Stub—Left column(s) of a table that contain independent variable(s).

Stub head—Heading for stub column.

Symbol column—Column made up primarily of abbreviations, designations, or symbols that are aligned on the left.

Uniform number column—Column of numbers that represents the same quantity (unit of measurement defined in the column head); numbers are aligned on decimal points.

Word column—Column made up primarily of words or phrases that are centered in the column or aligned on the left.

SECTION 4

SYMBOLS AND MATH

4.1 Introduction

Mathematics is a difficult type of technical copy to publish. Authors must choose symbols and notation to express their mathematical concepts and incorporate these expressions in a text along with necessary definitions of the symbology. Editors must ensure that symbology is standard, clear, and economical.

Consult with the author and noted authorities to determine the proper symbology and mathematical representation of the information. Unless the editor has an extensive mathematical background in the given discipline, no attempt should be made to change anything related to mathematical expressions without the knowledge of the author.

4.2 Symbols and Notation

Mathematical symbology should be:

- Standard where possible. Authors should not depart from currently accepted notation in their discipline. When no standard symbol exists, they should choose symbols that suggest the concept but do not conflict with other standards in the discipline.
- Clear in reference. Interpretation of a symbol should never be difficult. Conflicts should be avoided, and any symbol not familiar to the reader should be defined.
- Easily identified. Many numerals, letters, and signs are similar in appearance, e.g., zero and capital O.
- Economical in publication. The difficulty and cost of publishing symbols should be minimized.

4.2.1 Letter Symbols

A letter symbol for a physical concept should be a single letter on the line of type modified by subscripts and/or superscripts. It is distinguished from an abbreviation and is usually more than one letter on the line of type. A pair of symbols on the line of type is used to indicate increment (Δp), small perturbation (δp), or differential (dp , δp). Because these pairs denote a single physical quantity, one space is left around them in mathematical expressions unless they are enclosed.

Only letter symbols, not abbreviations, should be used in mathematical equations or expressions.

Secondary symbols, i.e., superscripts and subscripts, attached to a primary symbol are invaluable; however, they do complicate the typing of a manuscript. Subscripts and subscripts with more than one level are sometimes confusing and result in an unattractive copy when they appear in the line of type. Although multilevel subscripts and superscripts cannot be avoided, they should be chosen with care.

4.2.1.1 Subscripts

Subscripts modify the meaning of the primary symbol. They may be defined as subscripts or they may be previously defined abbreviations or primary symbols; however, a subscript should not be used as a primary symbol without further definition. For example, in a paper where σ is defined as standard deviation and M is defined as Mach number, σ_M could be used without defining M specifically as a subscript.

In aeronautics, multiple subscripts (and superscripts) have the following meaning:

- Adjacent subscripts (and superscripts) indicate that the second modifies the first (e.g., $\sigma_{\delta\epsilon}$) or that together they form an abbreviation (e.g., V_{rms}).
- Subscripts (superscripts) separated by a comma imply that they each modify the primary symbol.
- A subscript to a subscript denotes a derivative.

In disciplines other than aeronautics, multiple subscripts and superscripts have other meanings. For example, adjacent subscripts and superscripts have special meaning in tensor notation, and a subscript comma may indicate differentiation in structural analysis. Consult the author before changing the form of multiple subscripts or superscripts.

4.2.1.2 Superscripts

There are two types of superscripts: exponents and labels. An exponent raises the primary symbol to a power. A label superscript changes the meaning of the main symbol as a subscript does. Such labels may not be alphanumeric, e.g., prime (') or asterisk (*).

To avoid confusion with an exponent, enclose a superscript number that is a label, e.g.,

$f'(x)$ First derivative

$f''(x)$ Second derivative

$f^{(3)}(x)$ Third derivative

Enclose a symbol with a superscript label when it is raised to a power; or if enclosure is cumbersome, the exponent can be slightly higher than the label as long as clarity is not impaired:

Correct: $(u')^2$ or u'^2 or $[f^{(3)}]^2$

Incorrect: $u'2$ or $f^{(3)2}$

4.2.1.3 Alignment of Subscripts and Superscripts

When subscripts and superscripts are attached to the same primary symbol, they may be staggered (σ_M^2) or aligned (σ_M^2).

We recommend a staggered setup; however, there are situations that preclude staggering secondary symbols. Aligning superscripts and subscripts is also acceptable in some disciplines.

- Setup, whether staggered or aligned, should be consistent.
- A subscript is always closed to the primary symbol: never (σ_M^2).
- A nonalphanumeric superscript (e.g., ') is always closed to the primary symbol: M'_j .
- If either the subscript or the superscript is long, they are aligned: R_{ideal}^2 or D_i^{2N+1} .
- A subscript or superscript applied to an enclosure sign is typed at the same level as the lowest subscript or highest superscript within the enclosure:

$$\left(\frac{1-x^2}{2x}\right)^2 \quad (q_x - b_x)|_{x=2}$$

But $\left(\frac{\partial p}{\partial \rho}\right)_T$

4.2.1.4 Spacing In and Around Secondary Symbols

No spaces are left within subscripts and superscripts except around functional notation and function abbreviations, e.g.,

Correct: M_{j+1} $p_{t,\text{ideal}}$ $e^{2\pi i \cos \theta}$ $e^{2f(x)}$

Incorrect: M_{j+1} $p_{t, \text{ideal}}$ $e^{2\pi i \cos \theta}$ $e^{2f(x)}$

No space is required between a subscript or superscript and the next primary symbol unless readability is impaired or there is some other reason for a space:

1.19 $L_2\phi$ $\alpha_2^2\beta_1\beta_2$ $c_3e^{(1.19i)t}(1.19)$
 But 1.19 $L_2 \cos \phi$ $e^{(1.19i)t} t$

4.2.1.5 Accents

Another class of secondary symbols are those placed above (or below) the primary symbols. In the symbol list, these are sometimes grouped with superscripts (or subscripts), but in this section they are called “accents.”

For ease of typing, a subscript or superscript is preferred to an accent unless readability is impaired (\overline{M}_{ij} better than $M_{ij,av}$) or the accent is standard (\dot{x} and \ddot{x} for velocity and acceleration).

Multilevel accents are to be avoided.

4.2.2 Chemical Symbols

In many ways, chemical notation resembles mathematical notation; however, chemical symbols are treated differently:

- Symbols for chemical elements need not be defined; of course, they may be if the author wishes.
- Regular spacing, not double space, is left around chemical symbols or reactions in the text.

4.2.2.1 Symbols for Elements and Particles

Refer to appropriate references for your discipline, such as the *CRC Handbook of Chemistry and Physics* lists symbols or the *GPO Style Guide* for the elements and their atomic numbers and weights. Note that a regular lowercase l (el) is used in chemical symbols rather than script or italic. The mass number, atomic number, number of atoms, and ionic charge are indicated as shown in Table 4-1.

For example, ${}^{32}_{16}\text{S}_2^{2+}$ denotes a molecule with ionic charge of 2+ containing two sulfur atoms, each with mass number 32 and atomic number 16.

Note that ionic charge is indicated by A^{4+} rather than by A^{+4} .

Table 4-2 lists symbols for subatomic particles and quanta (*CRC Handbook*).

Table 4-1. Atomic Particle Designations

Mass number	Left	Superscript
Atomic number	Left	Subscript
Ionic charge	Right	Superscript
Number of atoms	Right	Subscript

Table 4-2. Symbols for Particles and Quanta

Proton	p
Neutron	n
Δ -particle	Δ
Σ -particle	Σ
Ξ -particle	Ξ
Deuteron	d
Triton	t
α -particle	α
Pion	π
K-meson	K
Electron	e
Muon	μ
Neutrino	ν
Photon	γ

4.2.2.2 Compounds

Element symbols can be combined along with necessary numbers and enclosures to denote the chemical formula for a compound.

Do not space between chemical symbols and numbers in a formula:



The symbols $-$, $=$, and \equiv can be used to denote line bonds; never space around them used this way.

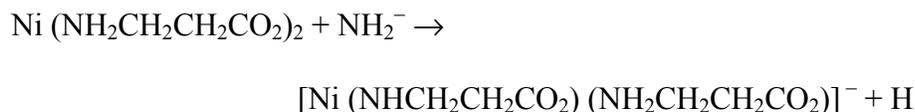
4.2.2.3 Reaction Equations

Reaction equations can be either displayed or run in the text. Displayed reactions may be numbered, but not consecutively with mathematical equations. Reaction equation numbers usually appear to the left of the reaction:



Space around + and \rightarrow in reaction equations.

A reaction equation is preferably broken after the arrow:



For more information on typesetting chemical formulas, reactions, bonds, etc., see the *American Chemical Society (ACS) Style Guide: A Manual for Authors and Editors*, Janet S. Dodd, Ed.

4.2.3 Computer Symbols

Computer symbols resemble abbreviations. They usually consist of several capital letters on the line of type, e.g.,

“Convergence is assumed to have occurred when the improvement is less than the parameter SERCV found in the COMMON block CONV of subroutine RDTITL.”

Regular spacing, not double space, is left around computer symbols in the text.

Computer symbols should not be used in mathematical equations, particularly if their use results in a mixture of computer and letter symbols.

There is nothing wrong with defining a letter symbol and a computer symbol for the same quantity. Computer symbols can be defined in several ways:

If use of computer symbols is confined to one place (e.g., appendix or table), define them there.

If computer symbols are used more extensively; they can be defined in the symbol list along with letter symbols, e.g.,

SYMBOLS

Symbols in parentheses are computer symbols.

a (VEL) sound speed, m/sec

d (DIF) percent difference between values

p (PRES) pressure, atm

R gas constant, 8.31435 J/mol-K

If few of the computer symbols correspond to letter symbols, they may be defined in a separate section of the symbol list.

4.2.4 Mathematical Notation

Simplicity must be considered when choosing notation. Equations can be cited by number rather than being retyped. A letter symbol can be assigned to an expression used repeatedly.

These relational and operational signs should always be used for the indicated concepts (Tables 4-3 and 4-4).

Table 4-3. Relational Signs

Symbol	Meaning
=	Equal to
≠	Not equal to
≡	Identical to, defined as
≈	Approximately equal to
∝	Similar to
∴	Perspective to
≅	Congruent to
∞	Varies as
<	Less than
>	Greater than
≤	Less than or equal to
≥	Greater than or equal to
<<	Much less than
>>	Much greater than
⋤	Not less than
⋥	Not greater than
→	Approaches as a limit

Table 4-4. Operational Signs

Symbol	Meaning
+	Plus
−	Minus
±	Plus or minus
∓	Minus or plus
÷	Divide by (rarely)
/	Divide by
×	Multiply by, cross product of vectors
•	Dot, or scalar, product of vectors

Notation requiring a backspace is more time consuming to type. Thus, staggering subscripts and superscripts is preferred to aligning them, subscripts or superscripts are preferred to accents, and multilevel accents above a symbol are to be avoided.

The considerations discussed above do not apply to standard mathematical notation. For example, a dot over a symbol is standard for derivative with respect to time, even though a superscript (e.g., ') may be more convenient to type.

4.2.4.1 Enclosure Signs

Parentheses (), brackets [], and braces { }, in that order, are used to enclose parts of a mathematical expression. Other types of enclosure signs (e.g., < > or | |) have meanings other than simply enclosure. They do not affect the usual order of enclosures.

If a standard enclosure sign has special meaning in an expression, that sign is not used simply to enclose within that expression. For example, if { } are defined with the function Im,

Correct: $2\pi(1 - \exp [-2 \operatorname{Im}\{\chi(b)\}])$

Incorrect: $2\pi\{1 - \exp [-2 \operatorname{Im}\{\chi(b)\}]\}$

Enclosure signs come in pairs. Editors must ensure that all necessary enclosures are present in the proper sequence. In general, overuse of enclosures is better than underuse, but too many can obscure meaning and cause waste of time and effort because large enclosures require handwork.

Enclosure signs are as high as the terms unless they enclose a term with only one subscript and one superscript level.

Regular-size enclosures can be used for one subscript and one superscript level.

If there are two or more sets of enclosures around an expression with one subscript and one superscript level, the second set, third set, etc., should be larger.

4.2.4.2 Operational and Relational Signs

Operational signs indicate a mathematical operation, e.g., addition (+). Relational signs indicate relation between mathematical expressions, e.g., equality (=).

In mathematical expressions, space around all operational and relational signs. Do not space around these signs in subscripts, superscripts, limits, and arguments of functional notation:

$$\alpha_{n+1} \quad e^{2\pi i(\gamma+1)} \quad \int_0^{x+2n} \quad f(x+1)$$

When no symbol precedes these signs, they are close to the symbols following them:

$$\pm 3 \quad \times 10 \quad \approx 1 \text{ GHz} \quad < N \quad a = -b + c$$

Exception: space after these signs at the beginning of lines of a multilinear equation that is broken.

Multiplication signs are used as follows:

- A times sign (\times) is used to indicate cross product of vectors or, with nabla, to indicate curl of a vector:

$$\vec{V}_1 \times \vec{V}_2 \qquad \text{curl } \vec{V} = \nabla \times \vec{V}$$

- To indicate multiplication when an equation must be broken at that operation.
- To indicate dimensions or magnification:

$$416 \times 416 \text{ matrix} \qquad \times 4 \text{ magnification}$$

A raised dot (\cdot) is used only to indicate the dot product of vectors or, with nabla, divergence of a vector:

$$\vec{V}_1 \cdot \vec{V}_2 \qquad \text{div } \vec{V} = \nabla \cdot \vec{V}$$

A raised dot or times sign is not used to indicate simple multiplication.

The division sign (\neq) is rarely used. A slash ($/$), horizontal bar, or negative exponent is preferred for indicating division.

4.2.4.3 Radicals

The radical sign ($\sqrt{\quad}$) sometimes may require handwork, so fractional exponents may be easier to type:

$$\frac{1}{\sqrt{a+b}} \qquad \sqrt[3]{2}$$

are equivalent to

$$(a+b)^{-1/2} \qquad 2^{1/3}$$

Within an expression or group of expressions, be consistent in the use of either radical signs or exponents.

4.2.4.4 Ellipsis

A series of three dots indicates elements left out of a continuous series:

$$n = 1, 2, 3, \dots \qquad x_2 + x_4 + x_6 + \dots + x_n$$

At least two, and no more than three, terms introduce the series.

The operational sign or comma that follows the introductory terms precedes the final term.

Space around operational signs and after commas, but not between ellipsis dots.

4.2.4.5 Integral, Summation, and Product Signs

Integral (\int), summation (\sum), and product (\prod) signs are centered on their arguments and are large enough to clear their arguments.

$$\int_0^T \left[-\frac{a^2}{4} + F(t) \right]^{1/2} dt \qquad \sum_{i=1}^{10} \left(\frac{a_{ij} - 4 \frac{M_g}{L}}{2} \right)^{1/2}$$

The argument of an integral usually ends with the differential of the variable of integration (dt above). (Note the space before the differential pair.) Integration variables are sometimes given before the rest of the argument. The argument of a summation or product includes terms containing the summation or product index (i above). Authors should ensure clarity in the arguments by adding enclosure signs if necessary.

Clear: $\int [1 - P(\vec{b})] b db$

Ambiguous: $\int dz \int d\xi \int dy \rho(b + z + y + \xi) \exp \left[\frac{-y^2}{2 B(e)} \right]$

Better: $\left[\int dz \int d\xi \int dy \rho(b + z + y + \xi) \right] \exp \left[\frac{-y^2}{2 B(e)} \right]$

Clear: $\sum_{k=1}^K x_k C_m(\phi_{k1}, \phi_{k2}) I_n^m(\theta_{k1}, \theta_{k2})$

Ambiguous: $\sum_{n=0}^{\infty} P_n(\cos \gamma) \sum_{m=0}^n (C_n^m \cos m\phi + S_n^m \sin m\phi)$

Better: $\sum_{n=0}^{\infty} \left[P_n(\cos \gamma) \sum_{m=0}^n (C_n^m \cos m\phi + S_n^m \sin m\phi) \right]$

In limits of integrals, products, and summations, no space is left around operational signs, and a slant is always preferred to indicate division. The limits on products and summations are centered above and below the sign in displayed equations and are typed as subscript and superscript to the sign in the text:

Displayed equation: $\sum_{n=1}^{\infty} A_j |\Delta M_j| = \Delta \bar{M}$

In text: “The sum $\sum_{n=1}^{\infty} A_j |\Delta M_j|$ is the average...”

The limits of an integral are typed to the right of the curls of the sign, which is slightly slanted to the right so that the lower limit begins one space before the upper limit:

$$\int_{\phi_1}^{\phi_2} X(\phi) \sin \phi d\phi$$

One space is left before the integral, product, or summation and between these signs and the argument if the limits do not extend beyond the sign. Otherwise, one space is left between the longest limit and the argument.

4.2.4.6 Mathematical Functions

4.2.4.6.1 Functional Notation

In functional notation, a function *f* of an argument consisting of one or more variables (e.g., *x*, *y*, and *z*) is denoted by *f(x,y,z)*. No spaces are left between the variables or around operational and relational signs in the argument:

$$F(t+\tau) \qquad P(a \leq x \leq b) \qquad F(x,y,s,t,\tau)$$

But $P_n^0(\cos \gamma)$

In mathematical expressions, a space is left before the function and after the argument:

$$A_t \sigma(e) I(\vec{b}) \qquad \frac{y-\eta}{2c(\eta)} \qquad g(\eta) I_j(\eta)$$

Subscripts and superscripts applying to the argument appear within the parentheses:

$$F(x^2)$$

Subscripts and superscripts applying to the function appear after the function symbol or with enclosure signs enclosing the function and its argument:

$$f^2(x,y,z) \qquad [f(x,y,z)]^2 \qquad g_j(\eta)$$

4.2.4.6.2 Abbreviations of Mathematical Functions

The following abbreviations for mathematical functions often appear in mathematical expressions set in roman type:

sin	sec	tan	log	Re	det
sinh	sech	tanh	ln	Im	tr
arcsin	arcsec	arctan	lim	div	adj
cos	csc	cot	min	curl	
cosh	csch	coth	max	grad	
arccos	arccsc	arccot	exp		

In mathematical expressions, these abbreviations are always followed by their argument.

Space before the function abbreviation and after the argument, and space after the abbreviation if it is not followed by an enclosure sign or superscript:

$$2a \cos \phi + a \cos 2\phi$$

$$\cos^{-1} \theta = \arccos \theta$$

$$\ln(\theta_0 - \theta_1)$$

$$\log_{10} A$$

Normal spacing (e.g., around operational signs) is used in the argument after these function abbreviations:

$$\ln \left(\frac{1 - n_1^2}{n_1^2 - n_1^4} \right) \quad \cos(-0.221 \chi_0 \cos 18.4t)$$

Do not space in limits appearing below the function abbreviations:

$$\lim_{x \rightarrow \infty} f(x)$$

After a function abbreviation, enclose an argument that begins with a minus:

$$\exp[-2\pi i(x + 1)]$$

Enclose an argument that continues past the first operational sign or the next function:

$$\cos 2\phi + \theta \text{ means } (\cos 2\phi) + \theta; \text{ not } \cos(2\phi + \theta)$$

$$\cos 2x_0 \cos t \text{ means } (\cos 2x_0) \cos t; \text{ not } \cos(2x_0 \cos t)$$

Enclose an argument if there is any ambiguity as to its extent:

$$\text{Poor: } \sin x/a \quad \sin \phi \dot{\phi}$$

$$\text{Better: } (\sin x)/a \quad (\sin \phi) \dot{\phi} \\ \sin(x/a) \quad \dot{\phi} \sin \phi$$

4.2.4.6.3 Exponential

The decision to use e to a power or the exponential function \exp must be based on readability:

$$\text{Poor: } e^{-c\omega t \pm i[-(c\omega)^2 + c\omega^2]}$$

$$\text{Better: } \exp\{-c\omega t \pm i[-(c\omega)^2 + \omega^2]\}$$

Be consistent. Do not use both e and \exp in the same expression or for similar arguments.

4.3 Symbols and Mathematics in Text

Symbols and short mathematical expressions and equations can be part of the text; these expressions in the text cannot be broken at the end of a line. If bringing the whole expression to the next line will result in a very short line, consider displaying the expression. Any mathematical expression, whether or not it is an equation, can be displayed. Numbered equations must be displayed. Items that require extra space above or below the line make for unattractive copy and should thus be avoided. For example, a slash should be used in the line of type rather than a horizontal bar:

$$(x + y)/xy \quad \text{rather than} \quad \frac{x + y}{xy}$$

Also, limits on summations and products in the line of type are typed as subscripts and superscripts rather than above and below the symbol:

$$\prod_{n=1}^{\infty} a_n \quad \text{rather than} \quad \prod_{n=1}^{\infty} a_n$$

Double-space around a letter symbol in the text except in the following instances. Do not double-space:

- After a symbol that is followed by a punctuation mark (“...values of α , β , and γ ”).
- Before a symbol attached to a word by a hyphen (“long the x -axis”).
- Around a symbol enclosed in parentheses (“the effective dihedral ($-C_{l\beta}$) decreases”).

You can also use italicized variables to help inline equations stand out. Note that parentheses used as grammatical punctuation around mathematical symbols should be regular size.

Double-space around mathematical expressions in the line of type, being sure to include words that are part of the expression; e.g.,

“At $C_L = 0.6$ and 0.8 for $\alpha = 20^\circ$...”

Not “At $C_L = 0.6$ and 0.8 for $\alpha = 20^\circ$...”

Do not double-space around chemical symbols and reactions, computer symbols, or abbreviations.

4.4 Displayed Mathematics

Any mathematical expression, equation, or relation can be displayed, i.e., typed on a separate line (or lines) and set off from the text by space. No punctuation follows displays, but introductory sentences leading into the display conform to correct punctuation practices. To display an equation,

- Triple-space between the text and the highest character in the display.
- Indent 10 spaces normally. To avoid breaking an equation or to leave room for the equation number, indent five spaces or type the equation flush or the left margin. You may also center an equation with a right-justified equation number.
- Triple-space between the lowest character in the display and the text.
- Double-space between one-line equations displayed together. If one or more equations are multilinear, double-space between lines of the same equation and triple-space between equations. For example,

$$E_2 = B + (DB + C) \cos xy + DC \cos 2xy$$

$$F_2 = -[(DB + C) \sin xy + DC \sin 2xy] - 2e^{-\xi x} \cos rx \sin xy (B - DC) \\ + e^{-\xi x} [B \sin 2xy + (DB + C) \sin xy]$$

Conditions applying to a displayed equation are typed not more than 10 spaces and not less than 5 spaces to the right of the equation and are usually enclosed in parentheses. Several conditions appearing together are aligned on the right. For example:

Initial conditions:

$$C = C' \quad (0 \leq r < \xi/2; t = 0)$$

$$C = C_o \quad (\xi/2 < r < L/2; t = 0)$$

Boundary conditions:

$$C = C_{\beta\alpha} \quad (r = \xi^-/2; t > 0)$$

$$C = C_{\alpha\beta} \quad (r = \xi^+/2; t > 0)$$

$$\frac{\partial C^\beta}{\partial r} = 0 \quad (r = 0; t \geq 0)$$

$$\frac{\partial C^\alpha}{\partial r} = 0 \quad (r = L/2; t \geq 0)$$

If there is not room for the condition on the line with the equation, type the condition below the equation flush with the right margin or three spaces to the left of the equation number:

$$P_n^m(\cos \phi_k) = N_n^m \left[C_n^m P_n(\phi_{k1}, \phi_{k2}) + S_n^m P_n(\phi_{k1}, \phi_{k2}) \right]$$

$$(n = 1, 2, 3, \dots, N; m = 1, 2, 3, \dots, n) \quad (23)$$

Authors sometimes want a series of related equations aligned on the relational sign. For example:

$$2x + 3y + (a^2 - 1)z = a + 1$$

$$(a^2 - 1)z = a + 1 - 2x - 3y$$

$$z = \frac{a + 1 - 2x - 3y}{a^2 - 1}$$

Although it is best that all concepts in an expression be represented by symbols, a word or phrase sometimes is used. The first letter of the word or phrase is capitalized:

$$C_m = \frac{\text{Pitching moment}}{q_\infty S \bar{c}}$$

$$\left\{ \begin{array}{l} \text{Area weighted} \\ \text{mean of} \\ \text{regional differences} \end{array} \right\} = A_g^{-1} \sum_{k=1}^K A_k |\Delta M_k|$$

$$A_{cyl} = (\text{Height}) \pi r^2$$

4.4.1 Multilinear Equations

Very often, long equations cannot be typed on one line. They must be broken on two or more lines with double space between the lines.

Break an equation before a relational sign (e.g., =). Align the relational sign with a previous relational sign, or indent the relational sign five spaces more than the first line:

$$\begin{aligned}
 & [\xi_R - i\xi_I][Q_R^T - iQ_I^T][Q_R + iQ_I][\lambda]\{\xi_R + i\xi_I\} \\
 &= [\xi_R - i\xi_I][Q_R^T - iQ_I^T] \left[-\left([A_{I,s}] + [A_{I,s}]^T + [A_{I,c}]^T [T] + [T^*]^T [A_{I,c}]^T \right) \right. \\
 & \quad + i \left(\frac{[B_c][T] - [T^*]^T [B_c]^T}{\pi \rho b^4 s} + [A_{R,s}] - [A_{R,s}] + [A_{R,c}][T] \right. \\
 & \quad \left. \left. - [T^*]^T [A_{R,c}]^T \right) \right] [Q_R + iQ_I] \{\xi_R + i\xi_I\} \\
 \\
 c_{ss}(nT) &= G_2 \left[\frac{e^{jnxy}}{2j} (e^{jxy} + D)(e^{jxy} B + C)(e^{-jxy} - e^{-\xi x} e^{jrx})(e^{-jxy} - e^{-\xi x} e^{-jrx}) \right. \\
 & \quad \left. - \frac{e^{-jnxy}}{2j} (e^{-jxy} + D)(e^{-jxy} B + C)(e^{jxy} - e^{-\xi x} e^{jrx})(e^{jxy} - e^{-\xi x} e^{-jrx}) \right] \\
 &= \frac{G_2}{2j} \left(\left[e^{jnxy} B + (DB + C)e^{j(n-1)xy} + DCe^{j(n-2)xy} \right] - e^{-\xi x} \left\{ Be^{j[(n+1)xy+rx]} \right. \right. \\
 & \quad + (DB + C)e^{j(nxy+rx)} + DCe^{j[(n-1)xy+rx]} + Be^{j[(n+1)xy-rx]} \\
 & \quad \left. \left. + (DB + C)e^{j(nxy-rx)} + DCe^{j[(n-1)xy-rx]} \right\} \right)
 \end{aligned}$$

If an equation cannot be broken at a relational sign, break before a plus or minus sign and bring the sign under the first character after the relational sign, as in the above examples. If there is no relational sign in above lines, indent the plus or minus five more spaces than the first line of the equation:

$$\pm i\omega \iint \left\{ c_6^{1/2} - \frac{\varphi_0^2}{2c_6^{1/2}} [0.675 \cos 2(18.4t) + 0.555 \cos 2(11.9t) - 0.742 \cos(18.4t) \cos(11.9t)] \right\} dt$$

If an equation must be broken somewhere other than before a relational, plus, or minus sign, type a times sign under the first character after the relational sign and continue with the equation. The author should be consulted before an equation is broken in this way:

$$\phi(x, y)_{z=0} = -\frac{1}{\pi} \iint_{S'} \frac{w(a, b) d\eta d\eta}{(x - \xi) - \beta(y - n)} \iint_{S''} \frac{\Delta p dZ}{q} dx$$

$$\times \iint_{S'} -\frac{2}{r} \left(\frac{\partial O}{\partial x} \right)_{z=0} dx dy$$

$$T_{\parallel} = T_Y \cos[-0.470 \varphi_0 \cos(18.4t) + 1.474 \varphi_0 \cos(11.9t)]$$

$$\cos[-0.221 \varphi_0 \cos(18.4t) + 0.221 \varphi_0 \cos(11.9t)]$$

Never break:

- Fractions.
- Radicals.
- Arguments in functional notation.
- Matrices.

Never separate sum, product, and integral signs from their arguments, or function abbreviations from their arguments.

Try to break before sums, products, integrals, and function abbreviations or after their arguments; and try to break before or after an enclosure sign.

When the left side of an equation before the relational sign is long and must be broken, the relational sign should fall at the beginning, not in the middle, of a line:

$$\begin{aligned}
 & -d_1e^{(18.4i)t}(18.4)^2 - d_2e^{(-18.4i)t}(18.4)^2 - d_3e^{(11.9i)t}(11.9)^2 - d_4e^{(-11.9i)t}(11.9)^2 \\
 & + 5.26 \frac{g}{L_2} \left[d_1e^{(18.4i)t} + d_2e^{(-18.4i)t} + d_3e^{(11.9i)t} + d_4e^{(-11.9i)t} \right] \\
 & = -c_1e^{(18.4i)t}(18.4)^2 - c_2e^{(-18.4i)t}(18.4)^2 - c_3e^{(11.9i)t}(11.9)^2 - c_4e^{(-11.9i)t}(11.9)^2
 \end{aligned}$$

Note that the relational sign (=) on the third line is indented three spaces so that it stands out from operational signs in the expression.

However, if the right side of an equation after the relational sign is very short, the relational sign, of course, falls near the end of the last line:

$$\begin{aligned}
 & -c_1e^{(18.4i)t}(18.4)^2 - c_2e^{(-18.4i)t}(18.4)^2 - c_3e^{(11.9i)t}(11.9)^2 - c_4e^{(-11.9i)t}(11.9)^2 \\
 & + 6.26 \frac{g}{L_1} \left[c_1e^{(18.4i)t} + c_2e^{(-18.4i)t} + c_3e^{(11.9i)t} + c_4e^{(-11.9i)t} \right] = 0
 \end{aligned}$$

Avoid breaking an equation from one page to another. In the rare instance that an equation must be continued on the next page, “(Equation continued on the next page)” is typed on the last line of the page flush with the right margin.

4.4.2 Reducing Equations

An equation may be reduced to avoid breaking it or to allow it to be broken at a convenient place. Very large equations sometimes must be reduced to fit on a page. Be sure that all fonts are legible after reduction.

4.4.3 Equation Numbers

All numbered equations must be displayed, but all displayed equations need not be numbered. Equations displayed in the text are numbered (1), (2), (3), and those displayed in an appendix are numbered (A1), (A2), (B1).

An equation is usually not assigned two numbers at different places in the text (if the equation is repeated). However, the same equation is sometimes given both a text number and an appendix number.

If an equation must be repeated, cite the number in the text, but it should not appear on the line with the equation. For example,

The Reynolds stress term is

$$q_1 = u^2 \frac{\rho_o}{\rho_j} - \left(1 - \frac{\rho_o}{\rho}\right) \rho' \quad (32)$$

Thus, the transformed pressure-density gradient source term does not change and can be expressed by equation (17):

$$q_2 = \rho' \frac{\partial}{\partial y_{ro}} \left(\frac{\rho_o}{\rho} \right)$$

Type equation numbers in parentheses flush with the right margin and centered on the last line of the equation. Leave at least three spaces between the last character in the equation and the number. If the equation number will not fit on the line with the equation, type it below the equation on the right margin.

A group of related equations are often assigned the same number. A large brace encloses the right sides of the equations and the number is centered on the group:

$$\left. \begin{aligned} A^2 &= (1-x)^2 + y^2 \\ B^2 &= x^2 + y^2 \\ k^2 &= \frac{1-(A-B)^2}{4AB} \end{aligned} \right\} \quad (A2)$$

If one equation of the group is cited separately (e.g., eq. (A2a)) or if the whole group does not fall on the same page, each equation in the group is assigned a lowercase letter:

$$A^2 = (1 - x)^2 + y^2, \tag{A2a}$$

$$B^2 = x^2 + y^2, \text{ and} \tag{A2b}$$

$$k^2 = \frac{1 - (A - B)^2}{4AB}. \tag{A2c}$$

4.4.4 Fractions

Fractions can be indicated in the following three ways:

- Built up $\frac{a+b}{c+d}$
- Slashed $(a + b) / (c + d)$
- Negative exponent $(a + b) / (c + d)^{-1}$

Built-up fractions are preferred for complicated fractions. This form is easy to read and unambiguous. However, the built-up fraction is hardest to type, requires the most space, and can become cumbersome when fractions occur within fractions. The built-up setup is usually preferred in displayed equations:

$$da = \frac{1}{2\pi(\theta_0 - \theta_1)} \left(d\theta_0 - \frac{\theta_0 - \theta_2}{\theta_1 - \theta_2} d\theta_1 \right)$$

In running text, in subscripts, in superscripts, and in limits, slashed fractions are most convenient in terms of space and appearance:

“Maximum error with $c_{\theta_0}/\theta_0 = 0.707$ is...”

$$e^{2\pi i/3} \quad x_{i+(1/2)} - x_{i-(1/2)} \quad \int_0^{\pi/2} \quad \lim_{a/b \rightarrow 0}$$

Slashed fractions can easily be ambiguous:

$$\begin{aligned} a/b/c & \text{ means } (a/b)/c \text{ or } a/(b/c) \\ 1/2 x & \text{ means } (1/2)x, x/2, \text{ or } 1/(2x) \\ \cos x/y & \text{ means } (\cos x)/y \text{ or } \cos(x/y) \end{aligned}$$

Slashed fractions are also ambiguous with plus or minus signs:

$$a + b/c \text{ means } a + \frac{b}{c}$$

If space is not a concern, it may be wise to insert parentheses:

$$a + (b/c)$$

Parentheses are necessary in the following slashed fraction:

$$(a + b)/c \text{ means } \frac{a + b}{c}$$

In the numerator or denominator of a built-up fraction, a slashed fraction is often better than another built-up fraction:

$$c \frac{\omega}{\omega'} = \frac{\ln(\theta_1/\theta_n)}{\pi n} \qquad \frac{c(c+1)}{a+b+c}$$

Do not use a built-up fraction in the numerator or denominator of a slashed fraction:

$$\frac{1}{2\pi(\theta_0 - \theta_1)} \left(d\theta_0 - \frac{\theta_0 - \theta_2}{\theta_1 - \theta_2} d\theta_1 \right) \frac{1}{\ln \left(\frac{\theta_0 - \theta_2}{\theta_1 - \theta_2} \right)}$$

Never: $\frac{1}{2\pi(\theta_0 - \theta_1)} \left(d\theta_0 - \frac{\theta_0 - \theta_2}{\theta_1 - \theta_2} d\theta_1 \right) \Big/ \ln \left(\frac{\theta_0 - \theta_2}{\theta_1 - \theta_2} \right)$

To avoid the possible ambiguity of slashed fractions, a negative exponent can be used:

$$R^{-2} = 0 \text{ rather than } 1/R^2 = 0$$

$$a(1+a)^{-1/2} \text{ rather than } a/\sqrt{1+a}$$

$$\cos^{-2}\theta \text{ rather than } 1/\cos^2\theta$$

Remember that the exponent -1 has special meaning on trigonometric functions:

$$\cos^{-1}\theta = \arcsin \theta \neq 1/\cos \theta$$

A negative exponent is also very useful when slashing a fraction within a built-up fraction would be awkward:

$$\frac{1}{2\pi(\theta_0 - \theta_1)} \left[d\theta_0 - \left(\frac{\theta_0 - \theta_2}{\theta_1 - \theta_2} \right) d\theta_1 \right] \left[\ln \left(\frac{\theta_0 - \theta_1}{\theta_1 - \theta_2} \right) \right]^{-1}$$

The disadvantage of a negative exponent is that it is easily overlooked by editors, typists, and readers.

In short, built-up fractions are best for complicated fractions in displays. Slashed fractions are best for simple fractions in the text, in secondary symbols, within built-up fractions, and in limits; but they are sometimes ambiguous. Negative exponents are best for more complicated fractions in the text and within built-up fractions.

Watch for inconsistency in the form of fractions. Do not mix slashed and built-up fractions unnecessarily:

$$c \frac{\omega}{\omega'} = \frac{\ln \theta_1}{\pi n} \lim_{x \rightarrow \infty} ; \text{ not } c(\omega/\omega') = \frac{\ln \theta_1}{\pi n}$$

If an expression, e.g., $d\theta_1 [2\pi(\theta_0 - \theta_1)]^{-1}$, appears in an equation, it should not be expressed differently in the next equation, e.g., as

$$\frac{d\theta_1}{2\pi(\theta_0 - \theta_1)}$$

4.4.5 Vectors, Matrices, and Determinants

A vector is usually typed vertically and enclosed in braces with elements centered in a column and double space between them:

$$\left\{ \begin{array}{c} \xi_c \\ \xi_F \\ \xi_G \end{array} \right\} \quad \left\{ \begin{array}{c} x_{\beta_1} \\ x_{\beta_2} \\ \vdots \\ x_{\beta_N} \end{array} \right\} \quad \left\{ \begin{array}{c} \xi_c \\ S\xi_c \\ S^2\xi_c \\ \xi_G \\ S\xi_G \\ S^2\xi_G \end{array} \right\}$$

When typed vertically, a vector must be displayed; however, the vector can be run in the text by typing its transpose horizontally as follows:

$$[\xi_c \ \xi_F \ \xi_G]^T$$

Note that brackets enclose the vector in this form.

The elements of a matrix are enclosed by brackets and centered above each other in vertical columns with at least three spaces between adjacent elements and at least a double space between rows:

$$z = \begin{bmatrix} A & -BR^{-1}B' \\ -H'QH & -A' \end{bmatrix}$$

Note that more space may be left between elements and rows so that the matrix appears balanced.

Determinants resemble matrices, but are enclosed by || rather than by [].

In large matrices and vectors, ellipsis dots are used to avoid repeating elements:

$$A = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \cdots & \alpha_{1n} \\ \alpha_{21} & \alpha_{22} & \cdots & \alpha_{2n} \\ \vdots & \vdots & & \vdots \\ \alpha_{m1} & \alpha_{m2} & \cdots & \alpha_{mn} \end{bmatrix} \quad \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \vdots \\ \alpha_n \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_n \end{bmatrix}$$

$$A(\text{adj } A) = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \cdots & \alpha_{1n} \\ \alpha_{21} & \alpha_{22} & \cdots & \alpha_{2n} \\ \vdots & \vdots & & \vdots \\ \alpha_{i1} & \alpha_{i2} & \cdots & \alpha_{in} \\ \vdots & \vdots & & \vdots \\ \alpha_{n1} & \alpha_{n2} & \cdots & \alpha_{nn} \end{bmatrix} \quad \begin{bmatrix} A_{11} & A_{21} & \cdots & A_{j1} & \cdots & A_{n1} \\ A_{12} & A_{22} & \cdots & A_{j2} & \cdots & A_{n2} \\ \vdots & \vdots & & \vdots & & \vdots \\ A_{1n} & A_{2n} & \cdots & A_{jn} & \cdots & A_{nn} \end{bmatrix}$$

$$A(\text{adj } A) = \begin{bmatrix} |A| & 0 & \cdots & 0 \\ 0 & |A| & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \cdots & 0 & |A| \end{bmatrix} = |A|I_n$$

Dashed lines within matrices and vectors indicate partitioning:

$$A = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} & \alpha_{14} & \alpha_{15} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} & \alpha_{24} & \alpha_{25} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & \alpha_{34} & \alpha_{35} \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & \alpha_{44} & \alpha_{45} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \end{bmatrix}$$

The same rules apply for displaying matrix equations as for displaying other mathematical equations.

Break matrix equations preferably at a relational or operational sign; never break a matrix:

$$\{y\} = [\Phi] \left\{ \dot{x}_{F_2}^* \right\} = -[\Phi][\tilde{M}]^{-1} \left[[\tilde{K}] \middle| [\tilde{D}] \middle| [I] \middle| [I] \middle| \dots \middle| [I] \right] \left\{ \begin{array}{c} x_{F_1}^* \\ x_{F_2}^* \\ x_{\beta_1}^* \\ x_{\beta_2}^* \\ \vdots \\ x_{\beta_L}^* \end{array} \right\}$$

$$+ q[\Phi][\tilde{M}]^{-1} \left[-[\hat{A}_0]_C \middle| -[\hat{A}_1]_C \left(\frac{c}{2V} \right) \middle| [\hat{A}_2]_C \left(\frac{c}{2V} \right)^2 \middle| -[\hat{A}_0]_G \middle| -[\hat{A}_1]_G \left(\frac{c}{2V} \right) \middle| [\hat{A}_2]_G \left(\frac{c}{2V} \right)^2 \right] \left\{ \begin{array}{c} \xi_C \\ \dot{\xi}_C \\ \ddot{\xi}_C \\ \xi_G \\ \dot{\xi}_G \\ \ddot{\xi}_G \end{array} \right\}$$

Because of its size, a matrix equation must sometimes be displayed separately from the text by introducing it like a figure integrated in the text. Cite the equation by number and direct the reader to it.

4.5 Spacing Guidelines

The following lists summarize spacing discussed in previous sections (numbers in parentheses are section numbers in this section):

There is no space:

- Between a primary symbol and its subscript: t_1 .
- Between a primary symbol and its nonalphanumeric superscript: M'_j .
- Around operational signs in subscripts, superscripts, and limits: t_{1+2} .
- Between multiple subscripts or superscripts: t_{ji} .
- Between a subscript or superscript and the next symbol unless there is some other reason for a space.
- After an operational or relational sign not preceded by a symbol except at the beginning of lines of multilinear equations: $\langle N$.
- Between variables or around operational signs in the argument of functional notation.
- After a function abbreviation followed by an enclosure or superscript.

- Within a formula for a chemical compound.
- Between ellipsis dots.

There is one space:

- Around an operational or relational sign preceded by a symbol or at the beginning of lines of multiline equations: $N < K$
- Around summation, product, and integral signs.
- Around functional notation.
- Around a two-letter symbol denoting one quantity, e.g., dx , ΔU , δp
- Before a function abbreviation and after its argument.
- Between a function abbreviation and its argument not enclosed or preceded by a superscript.
- Around + and \rightarrow in chemical reaction equations.

There is a double space:

- Around letter symbols and mathematical expressions in the text.

There is no double space:

- Around a letter symbol that is enclosed in the text, before a symbol attached to a word by a hyphen, or after a symbol followed by a punctuation mark. See also use of italicized variables in Section 4.3.
- Around chemical symbols or reactions in the text.
- Around computer symbols in the text.
- Around abbreviations in the text.

There is at least a triple space:

- Between an equation and its number on the same line.
- Between adjacent elements of a matrix.

4.6 Marking Mathematical Copy

The goal of marking mathematical copy with an author is to make it clear, accurate, and professional.

The editor's task includes ensuring that:

- Characters that are easily confused (Table 4-5) should be identified at least the first time they appear.
- Spacing must be marked only when desired spacing is different from the typed draft. Double space around symbols in the text need not be marked.
- Subscripts and superscripts must be identified if the manuscript is not clear; alignment of subscripts and superscripts need be indicated only if desired alignment is different from the typed draft.

However, if the mathematics are handwritten, more marking is required:

- Identify handwritten symbols that are easily confused (such as Greek lettering or editorial markings).
- Mark all spacing except around operational and relational signs in the line of type and around summation, product, and integral signs. Double space around symbols in the text need not be marked.

Table 4-5. Typewritten Characters That May Be Misread

Character	Identification
l	lc el
1	one
°	deg
o	lc oh
O	cap oh
0	zero
Π	cap pi
∏	product
Σ	cap sigma
∑	sum
x	lc ex
X	cap ex
×	times
χ	lc chi
θ	lc theta
Θ	cap theta

Identify all Greek letters (Table 4-6).

Table 4-6. Greek Alphabet

Alpha	A	α	Nu	N	ν
Beta	B	β	Xi	Ξ	ξ
Gamma	Γ	γ	Omicron	O	o
Delta	Δ	δ	Pi	Π	π
Epsilon	E	ϵ	Rho	P	ρ
Zeta	Z	ζ	Sigma	Σ	σ
Eta	H	η	Tau	T	τ
Theta	Θ	θ	Upsilon	Υ	υ
Iota	I	i	Phi	Φ	ϕ
Kappa	K	κ	Chi	χ	χ
Lambda	Λ	λ	Psi	Ψ	ψ
Mu	M	μ	Omega	Ω	ω

4.7 Mathematical Text

A mathematical paper or section of a paper cannot consist only of a list of equations. Text must guide the reader through the derivation. The mathematical expressions and equations, even if displayed, are integral parts of the text, acting as nouns, phrases, and clauses. Thus, mathematics in the text must be punctuated according to its grammatical function:

“If $[(1 - \sigma)/\sigma] \cos \theta_0 < 1$, we may approximate...”

“If $[(1 - \sigma)/\sigma] \cos \theta_0 < 1$ is the limiting condition,...”

In some disciplines, no punctuation appears after displayed mathematics; in other disciplines, it does. Be consistent. Text introducing displays conforms to correct punctuation practices.

Displays are a part of the text and require an introductory statement or phrase that appears with the equation, not on the previous page. This introduction could be a complete sentence followed by a colon, a short phrase such as “for example,” or a subject and verb (in which case the display is the predicate of the verb). However, a display should not be introduced by a dangling participial phrase (*AIP Style Manual*) such as:

“Substituting equations (1) and (2) in equation (3),”

or

“By substituting equations (1) and (2) in equation (3), the term becomes...”

This construction can be improved by providing a subject for the participle to modify, i.e.,

“Substituting equations (1) and (2) in equation (3), we obtain...”

or by changing the participle to a gerund, i.e.,

“Substituting equations (1) and (2) in equation (3) yields...”

The many symbols appearing in mathematical text present special problems with wording and punctuation. A symbol cannot begin a sentence. This can be avoided by introducing an adverb (such as “thus” or “then”) as the first word of the sentence or by replacing the symbol with its definition. Often symbols appear immediately after their definitions; the commas around the symbol are usually omitted

“The stretching parameter A is related to...”

on the spatial distribution of the source terms q_1 and q_2 .”

Commas (or parentheses) can enclose the symbols to prevent the sentence from being misread.

A well-written text can make a complicated mathematical derivation straightforward and clear by defining symbols, relating a series of equations to one another, and describing the physical reality represented by the mathematics.

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SECTION 5

UNITS OF MEASURE

5.1 Policy on the International System of Units (SI)

Section 1.1.12 gives NASA's preferred policy regarding SI and U.S. customary units. Remember that regardless of which set of units you use, be consistent and indicate which you use in the text, figures, and tables.

There are many excellent references available, as noted below. As with other references cited in this document, if you encounter a conflict among the references, choose the reference most pertinent to your scientific or engineering discipline, and be consistent in following its guidance.

- National Institute of Standards and Technology (NIST) Special Publications 811, 1995 Edition, "Guide for the use of the International System of Units (SI)," Barry N. Taylor.
- American Society of Testing and Materials (ASTM) Standard for Metric Practice.
- "Scientific Style and Format: The CBE Manual for Authors, Editors, and Publishers," Council of Science Editors, 6th edition.

5.2 Use of SI and U.S. Customary Units

When both systems of units are used, SI must be the primary system; i.e., SI values appear first in the text, tables, and drawings and nearer to the axis in plots, unless the U.S. units were used in the original research.

When both systems are used, a statement indicating the system of units where measurements and calculations were made appears in a paragraph at the beginning of Symbols. When no symbol list is used, the statement appears in the Introduction, Preface, or Foreword.

Sample statement:

"Dimensional quantities are presented in both the International System of Units (SI) and U.S. Customary Units. Measurements and calculations were made in U.S. Customary Units."

5.2.1 Text

In the text, values of SI units are normally given first, and those in U.S. customary units are given afterward in parentheses. The decision to use SI units alone or both SI and U.S. customary units should be followed throughout a paper. If U.S. customary units are given for some quantities in some parts of a paper, they usually are given for all quantities throughout the paper. The *GPO Style Manual* is a good resource.

Hyphenation of the quantity in parentheses should be consistent with the preceding SI quantity:

Incorrect: “The 0.3-m (1 ft) model...

Correct: “The 0.3-m (1-ft) model...

Never interrupt a hyphenated quantity with the U.S. customary unit quantity in parentheses:

Incorrect: “The 0.3-m-(1-ft) long model...

Correct: “The 0.3-m (1-ft) long model...

Or

“The 0.3-m long (1-ft) model...

Note that quantities expressed in compound units or in degrees Celsius are not hyphenated:

2 kW/m² curve

180 °C flame

A particular value should be converted only once within a paragraph:

“The two plates studied were 2.5 cm (1 in) thick and 1.2 cm (0.5 in) thick. The 2.5-cm thick plate was....

5.2.2 Tables

In leaderwork tables, the U.S. customary units are given in the stub in parentheses after the SI units:

Area, m ² (ft ²)	0.093 (1.00)
Thickness, m (ft)	0.3 (1.00)

In column heads, the U.S. customary units may be given in parentheses after the SI units or in a separate column after the SI column:

Length, cm (in)
1.27 (0.5)
2.54 (1.0)
5.08 (2.0)

Length	
cm	in
1.27	0.5
2.54	1.0
5.08	2.0

5.2.3 Figures

To avoid clutter in drawings, dimensions in U.S. customary units can be given in parentheses after the SI value and the units explained in the legend (Figure 5-1).

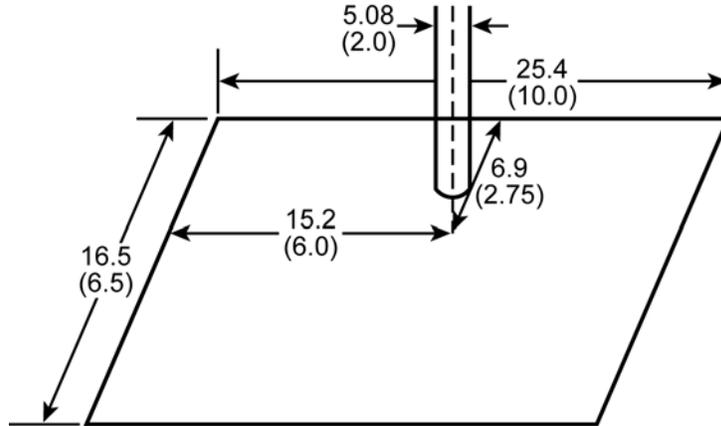


Figure 5-1. Dimensions displayed in figures.

In plots, the scales may be arranged as follows for SI units (Figures 5-2 and 5-3). SI units appear on the left and bottom scales and the SI scale ends at a tick (Figure 5-2). If the research was conducted in the U.S., then the U.S. scale should end at a tick.

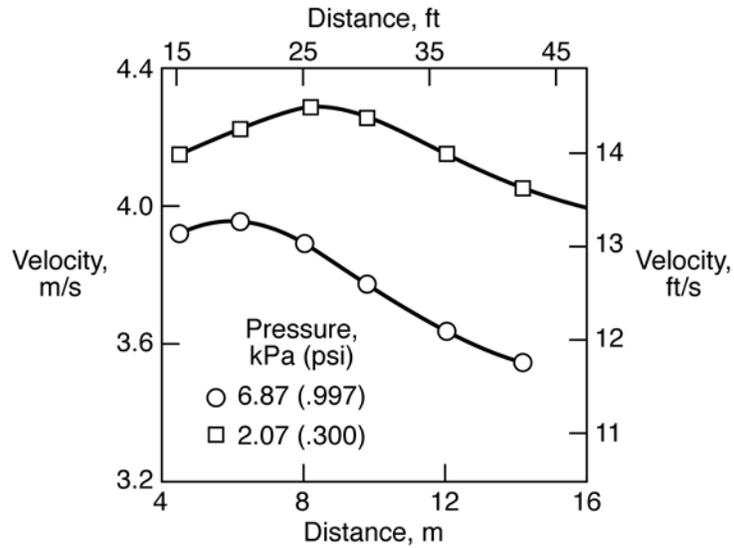


Figure 5-2. SI units on left and bottom scales.

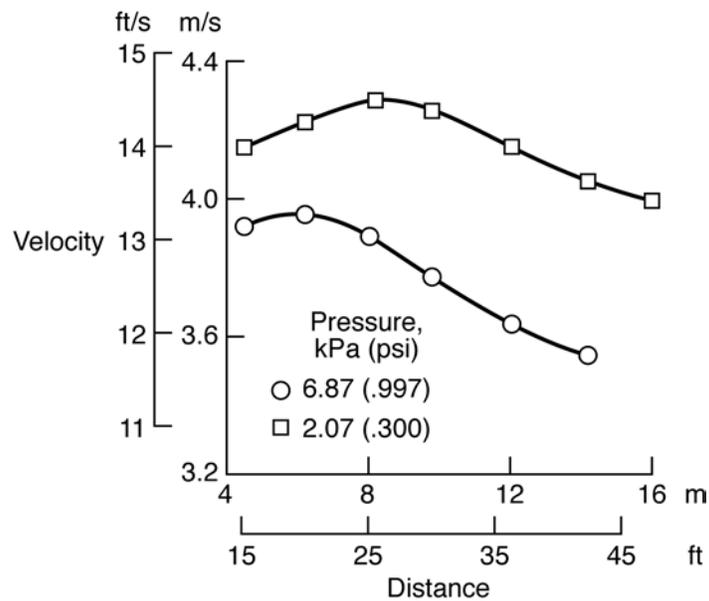


Figure 5-3. SI scale nearer to plot.

5.3 SI Practice

The ASTM Standard for Metric Practice (ASTM E 380-79) and the NIST Guide for the Use of the International System of Units (NIST SP 811, 1995) have excellent sections on the use of SI prefixes, non-SI units in use with SI, and rules for conversion and rounding.

5.3.1 SI Units and Abbreviations

In this section, three tables (from the ASTM Standard for Metric Practice) list the units, prefixes, and abbreviations approved as part of SI by the General Conference on Weights and Measures (GCWM). The base and supplementary units in Table 5-1 are the fundamental units in SI. By combining these units, compound (or derived) units are formed (e.g., m/s). Table 5-2 lists derived units that have been given special names. These derived units are generally used rather than their formulas, e.g.,

J not N/m for energy (but N/m is used for moment)

Pa·s not (N/m²)s for viscosity

To form decimal multiples and submultiples of SI units, the prefixes listed in Table 5-3 are attached to the unit name or abbreviation.

Table 5-1. SI Base and Supplementary Units

Quantity	Unit	Abbreviation
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd
Plane angle	radian	rad
Solid angle	steradian	sr

Table 5-2. SI Derived Units with Special Names

Quantity	Unit	Abbreviation	Formula
Frequency	hertz	Hz	S^{-1}
Force	newton	N	$m \cdot kg \cdot s^{-2}$
Pressure, stress	pascal	Pa	N/m^2
Energy, work, quantity of heat	joule	J	$N \cdot m$
Power, radiant flux	watt	W	J/s
Quantity of electricity, electrical charge	coulomb	C	$s \cdot A$
Electrical potential, potential difference, electromotive force	volt	V	W/A
Electric capacitance	farad	F	C/V
Electric resistance	ohm	Ω	V/A
Conductance	siemens	S	A/V
Magnetic flux	weber	Wb	$V \cdot s$
Magnetic flux density	tesla	T	Wb/m^2
Inductance	henry	H	Wb/A
Luminous flux	lumen	lm	$cd \cdot sr$
Illuminance	lux	lx	lm/m^2
Activity (of radionuclides)	becquerel	Bq	S^{-1}
Absorbed dose	gray	Gy	J/kg

Table 5-3. SI Prefixes

Power of 10	Prefix	Abbreviation
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^2	hecto ¹	h
10^1	deka ¹	da
10^{-1}	deci ¹	d
10^{-2}	centi ¹	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	
10^{-24}	yocto	

¹Use only when necessary except for centimeters.

5.3.2 Prefixes

SI prefixes are directly attached to the names or abbreviations of SI units (e.g., kilopascal or kPa) to eliminate leading zeros in decimals and nonsignificant digits. They replace powers-of-10 notation.

Powers of 10 should generally not be used with SI units. Exceptions are:

- Physical quantities that are customarily given in powers-of-10 notation; e.g., Reynolds number is usually given in terms of 10.
- Logarithmic scales that are clearer when powers of 10 are used as scale labels.
- Computational purposes where powers of 10 are preferred because errors are easily made when using multiples or submultiples of base units; e.g., input and output of computer programs are usually in exponential notation.

Only one prefix is attached to a compound unit, preferably to the numerator, unless the base unit, kilogram, is one of the units:

N/m, not mN/mm
GN/m, not MN/ μ m
km/s, not m/ms

also C/kg MJ/kg

Two or more prefixes are not placed side by

Incorrect: μ s 141m

Correct: ns pm

If a value is outside of the range of the prefixes, delete all prefixes and use a power of 10.

Prefixes should be selected so that numerical values will be between 0.1 and 1000. Take care not to confuse readers by careless application of prefixes.

The number of prefixes attached to a unit within a paper should be limited.

If the range of a particular quantity is not too large, it should be expressed in the same unit multiple throughout a paper. For example, a scale in kilopascals in a figure should not be discussed in terms of pascals in the text.

A particular value should always be expressed in the same unit multiple. A reference length given as 10 cm, e.g., should not be expressed as 100 mm elsewhere.

5.4 Non-STI Units in Use with SI

Minimum use of non-SI units with SI ensures the integrity and thus the advantages of this coherent system of units. However, it is impractical to disallow (or require conversion of) all non-SI units. NASA recognizes that in some scientific disciplines, both SI and U.S. customary units are used as primary measurements in research and in the field. It is suggested that the first time a non-SI unit is used, for which the conversion to SI units would be unwieldy within the text, the conversion should be defined in a footnote on the page the unit is first used. Examples of non-SI units with lengthy conversions are the footcandle and the einstein, used in photosynthesis and irradiance studies, respectively. In this section, policies concerning non-SI units used with the primary system are presented. (This section refers to units used with the primary system and not to U.S. customary units used as a secondary system).

5.4.1 Units Approved for Use with SI

Some non-SI units are approved for use with SI; conversion to the corresponding SI unit is therefore not necessary. These units are listed in Table 5-4.

Table 5-4. Units Approved for Use with SI

Quantity	Unit	Abbreviation
Time	minute	min
	hour	h
	day	d
	year	yr
	week	wk
	month	mon
Plane Angle	degree	¹ deg and °
	arc minute	arc min
	arc second	arc sec
Temperature	degree Celsius	°C
Volume	liter ²	L
Mass	metric ton ³	t
	atomic mass unit	amu
Distance	nautical mile ⁴	n. mi
Speed	knot ⁴	(⁵)

¹ With a number, the degree sign () is always used.

² Liter is used to measure liquids and gases. Usually the only prefixes used with liter are milli- and micro-.

³ Metric ton should be restricted to commercial or meteorological usage. Prefixes should not be attached to its abbreviation.

⁴ These units are standard for aerial navigation.

⁵ Not abbreviated.

Nominal dimensions that name an item need not be converted to SI units:

2-in pipe 2 × 4 lumber

Logarithmic measures, such as pH and decibel (dB) are acceptable. The reference quantity for decibel should be given in SI:

Sound pressure level, dB (re 20 pPa)

Power level, dB (re 0.1 pW)

5.4.2 Units Accepted for Limited Use

Several non-SI units are accepted with SI because of existing practices. Sometimes a unit is used only in a specific field. Table 5-5 lists some of the units that are acceptable for limited use. Such use should not be encouraged, but rather tolerated (or sometimes discouraged). Give SI equivalents of these units once in a paper in the symbol list or at their first appearance.

Table 5-5. Units Accepted for Limited Use

SI equivalents of these units are given once in a paper.

Quantity	Unit	SI Equivalent
Absorbed dose	rad	1 rad = 0.01 Gy
Acceleration	g unit ^a	g – 9.066 650 m/s ²
Activity	curie	1 Ci = 3.7 × 10 ¹⁰ Bq
Area	hectares ^b	1 ha = 1 hm ²
Energy	electron volt kilowatt-hour ^c	1 eV = 1.602 19 × 10 ⁻¹⁹ J ^d 1 kWh = 3.6 MJ
Length	angstrom astronomical unit parasec	0 1 Å = 0.1 nm 1 AU = 1.495 979 × 10 ¹¹ m 1 pc = 3.085 678 × 10 ¹⁶ m
Pressure	atmosphere ^b bar ^e millimeter of mercury ^b torr ^b	1 atm = 101.325 kPa 1 bar = 100 kPa 1 mm Hg = 133.322 Pa 1 torr = 133.322 Pa

^a The symbol g is defined as acceleration due to gravity, which is 9.086 650 m/s².

In a paper, g may be used both as a symbol, e.g., $dp = -gp dZ$ and as a unit, e.g., "...experience acceleration of 2 g" "Acceleration, g, units 2."

^b The hectare should be restricted to large areas of land and water.

^c The kilowatt-hour is used only to measure electric energy.

^d The abbreviation kWh commonly appears and is preferred by ASTM. Also, kWh should be used if h is used for hour.

^e The millibar is widely used in meteorology.

5.4.3 Deprecated Units

Table 5-6 lists units that are deprecated and should not be used with the primary system of units.

Table 5-6. Units That Are Deprecated

These units should not appear without being converted to SI units.

Unit	Corresponding SI unit	To convert to SI unit, multiply by
barn	m ²	10 ⁻²⁸
calorie	J	4.184
dyne ^a	N	10 ⁻⁵
erg ^a	J	10 ⁻⁷
fermi	fm	1
gamma	T Pg	10 ⁻⁹ 1
gauss ^a	T	10 ⁻⁴
kayser	m ⁻¹	10 ²
Maxwell ^a	Wb	10 ⁻⁸
mho	S	1
Micron	μm	1
oersted ^a	A/M	7.957 747 × 10 ⁻¹
poise ^a	pa·s	10 ⁻¹
roentgen	C/kg	2.58 × 10 ⁻⁴
Stokes ^a	m ² /s	10 ⁻⁴

^a These units belong to the centimeter-gram-second (cgs) system of units, and should be avoided.

5.5 Writing Unit Names and Abbreviations

Units of measurement should be presented clearly, concisely, and consistently in a paper. Obviously, the most concise way to express measured quantities is with abbreviated units, but consideration must also be given to clarity and whether the intended audience will be familiar with the unit abbreviations. As always, consistency is also important. For example, authors often intend to use s for second, but lapse into using sec. This section presents guidelines for when and how to write and abbreviate units.

5.5.1 When and When Not to Abbreviate

Editors must use judgment in determining whether units should be spelled out or abbreviated. Generally, units are abbreviated in a technical paper, but in a paper receiving more general distribution, units may have to be spelled out to ensure audience understanding. The presentation of units should be consistent in a paper. Usually, all units are either abbreviated or they are all spelled out; however, consistency can be taken to extremes. For example, even though several simple units (kilogram, meter) have been spelled out, spelling out a complicated unit (kg/Pa-s-m) is probably not desirable. Also, time units such as year, day, and hour should often be spelled out for sake of appearance, even though second is abbreviated. This section presents guidelines for writing and abbreviating units.

Units are to be spelled out when they appear without a number:

“Pressure is given in pascals.”

“Figure 1. Test plate. Dimensions are in centimeters (inches).”

Units without numbers are usually abbreviated in Symbols. To avoid ambiguity in complicated units, abbreviations are preferred.

In tables and figures, units are abbreviated because of space limitation.

5.5.2 Unit Name Spelled Out

The following are guidelines when spelling out unit names:

- Unit names are common names and are not routinely capitalized:
pascal kelvin newton joule
- Plurals are formed according to standard rules of English:
meter, meters
hertz, hertz
henry, henries
- Product of units is indicated by a centered dot:
newton·meter
Plural is formed on the last unit:
pascal·seconds
- Quotient of units in text is indicated by per, not a solidus:
meter per second, not meter/second
Plural is formed on the numerator:
liters per second
- Powers are indicated by “squared” or “cubed:”
meters per second squared
Exceptions are when area and volume are involved:
square meter cubic foot watt per square meter

The American spelling of meter and liter is preferred to the European spelling (metre and litre).

5.5.3 Unit Abbreviations

The following are guidelines when abbreviating units:

- Standard rules for capitalization do not apply to abbreviations of SI units; the abbreviations are always as they appear in Tables 5-1, 5-2, and 5-3. Exceptions are not made in capitalized titles, headings, or slide labels.
- Unit abbreviations are not changed in the plural:
20 lb, not 20 lbs
- Periods do not follow unit abbreviations:
2.54 cm in/hr lb/in
- Prefix abbreviations are directly attached to the unit abbreviation.
- A space is left between a number and unit:
35 mm, not 35mm
Exceptions are the symbols for plane angle and temperature degrees:
46010130" 67°C
- Product of units is indicated by a centered dot or thin space:
ft·lb J/mol·K
- Quotient of units is indicated in the following three ways:
m/s m·s⁻¹ $\frac{m}{s}$
- More than one solidus cannot appear in a unit without parentheses:
(J/mol)/K, not J/mol/K
- Powers are denoted by superscript numbers:
kg/m³
- Abbreviations should not be mixed with spelled-out units in the same expression:
kJ/mol, not kJ/mole
Gy/s, not gray/s

SECTION 6

REFERENCES (TYPES AND SETUP)

6.1 Book Number References

6.1.1 Required NASA STI Report Series Numbering

Authorized NASA Headquarters or Center personnel may obtain NASA STI Report Series numbers by:

- Telephoning the NASA STI Help Desk at 301-621-0390.
- Sending a fax to the NASA STI Help Desk at 301-621-0134.
- Sending an email via Internet to help@sti.nasa.gov.
- Writing to the NASA STI Help Desk, NASA Center for AeroSpace Information, 7121 Standard Drive, Hanover, MD 21076-1320.

6.1.2 Options Items

The International Standard Serial Number (ISSN):

- Used for serial titles (periodicals, annuals, and other publications regularly issued under the same title).
- Available from the Library of Congress, National Serials Data Program, Washington, D.C. 20540.

The International Standard Book Number (ISBN):

- Used by libraries and bookstores as an aid in book publishing.
- Available from the U.S. ISBN Agency, 630 Central Ave., New Providence, NJ 07974; URL: <http://www.isbn.org/standards/home/isbn/us/isbnus.asp>.
- NASA maintains a block of ISBN numbers; for additional information on how to assign an ISBN number for an STI document contact the STI Program office or the Help Desk at help@sti.nasa.gov.

The Library of Congress Card Control Number (LCCN):

- Used for monographic publications selected and cataloged by the Library of Congress.
- Available from the Library of Congress, Cataloging in Publication Division, Washington, DC 20540, URLs: <http://www.copyright.gov/faq/html#q51>; <http://cip.loc.gov/cip/cipfaq.html#control>.

6.2 Metric Measurements References

The following can be used as metric measurement references:

- IEEE/ASTM-S1 10 “Standard for Use of the International System of Units (SI)—The Modern Metric System.” http://standards.nasa.gov/NPTS/main_menu.taf.
- Artusa, Elisa A. “SI (Metric) Handbook.” National Aeronautics and Space Administration, John F. Kennedy Space Center. NASA TM—109197. Baltimore, MD: NASA Center for Aerospace Information, 1994. Provides information for an understanding of SI units, symbols, and prefixes, as well as style and usage in documentation in both the U.S. and in the international business community; conversion techniques; limits, fits, and tolerance data; and drawing and technical writing guidelines.

Also provides information on SI usage for specialized applications like data processing and computer programming, science, engineering, and construction. Related information in the appendixes includes legislative documents, historical and biographical data, a list of metric documentation, rules for determining significant digits and rounding, conversion factors, shorthand notation, and a unit index.

- *Conversion Factors*. Northridge, CA: U.S. Metric Association (USMA). A comprehensive one-page table that provides conversion factors from both inch-pound units to metric system units and from metric system units to inch-pound units. Shows the conversion factors for length, area, volume, torque, mass, energy/work, power, pressure/stress, force, speed, and temperature. Order from USMA Web site: <http://lamar.colostate.edu/~hillger/>.
- Institute of Electrical and Electronics Engineers. *American National Standard Illustrations for Publication and Projection*. ANSI Y15.1M. New York: ANSI, 1979 (1986).
- *Metric Editorial Guide*, Fifth Edition. Bethesda, MD: American National Metric Council, 1993. Explains and illustrates proper use of SI metric units, terms, and symbols. Provides standard spelling, punctuation, and usage for metric terms, abbreviations, and symbols.
- Pedde, Lawrence D., et al. *Metric Manual*. U.S. Bureau of Reclamation. GPO S/N 024-0003-00129-5. Washington, DC: U.S. Government Printing Office, 1978. Presents the basics of SI (International System of Units), metric conversion techniques and examples of engineering problems associated with metric conversion.
- *USMA's Guide to the Use of the Metric System [SI Version]*, 15th ed., 2000.
- *STI Metric Style Manual for Written and Computer Usage*, <http://lamar.colostate.edu/~hillger/supplies.htm>.

6.3 Acknowledging Contributors

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Following are general guidelines for transferring copyrights and citing copyrighted material. For more specific information, contact the NASA Headquarters Chief Intellectual Property Office or the Patent Counsel at the Center.

6.4.1 Transferring Copyright

No U.S. copyright protection is available for a work produced by the U.S. Government, that is, work produced as an employee of the U.S. Government as part of official duties. All works authored as part of official duties as a NASA employee must include a statement that the work is not available for U.S. copyright. For works produced by a NASA employee that are published outside the United States, NASA, as the employer, is the owner of any foreign copyright that can be asserted on the work.

Some publishers' copyright transfer forms include a statement and signature block in which the author, as the Government author, certify that the manuscript was prepared as part of official duties. If this statement and signature block are missing, the following statement should be included either on the form or in a cover letter:

The work entitled _____ was prepared as part of my official duties as an employee of the U.S. Government and, in accordance with 17 U.S.C. 105, is not available for copyright protection in the United States.

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6.5 Electronic Document References

Citations of electronic documents appear in the “References” section of the report along with citations of paper documents. The citation should include

- Name of author.
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- Paragraph numbers, if applicable.
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In addition, both formal and informal documents are published electronically. Formal documents include scholarly information such as NASA formal reports. Informal documents include email and discussions groups. Because such documents are difficult, if not impossible, to access, reference to informal documents is discouraged. If the information must be referenced, it should be treated similar to an informal personal communication in paper documents. Clearly identify the reference as such and place the following identification in a parenthetical note in the reference list, with an appropriate notation: “unpublished,” “to be published,” or “personal communication.” Personal communications should include name and affiliation of person doing the communicating.

The following references are cited in the suggested style. Information in quotation marks should be italicized. Some line returns are forced to illustrate concepts for breaking lines.

1. Quinion, Michael B.: Citing Online Sources, Advice on Online Citations Formats. *World Wide Words*, June 21, 1996. <http://www.quinion.demon.co.uk/words/citation.htm> Accessed June 30, 1997.
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3. Walker, Janice R.: *MLA-Style Citations of Electronic Sources*, Vers.1.1, Rev. Aug. 1996. <http://www.cas.usf.edulenglish/walkermla.html> Accessed June 30, 1997.
4. Guide for Citing Electronic Information, based on *Electric Style: A Guide for Citing Electronic Information*, by Li, X and Crane, N. (1993). Westport: Meckler, Prepared by K. Wagner, Aug. 1995. Sarah Byrd Askew Library, William Person College of New Jersey. <http://www.wilaterso.edu/wcpagesllibra Icitin.htm> Accessed June 30, 1997.
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10. Information and documentation-Bibliographic references-Electronic documents or parts thereof, *Excerpts From Final Draft International Standard ISO 690-2*. International Organization for Standardization. <http://www.nlc-bnc.ca/isolte46sc9IstandardI690-2e.htm> Accessed July 14, 1997.

6.6 GPO Style Manual and Chicago Manual of Style

The *United States Government Printing Office (GPO) Style Manual* (<http://www.gpoaccess.gov/stylemanual/browse.html>) and the *Chicago Manual of Style* can be used as companion references to this style guide. Both provide extensive coverage on matters of grammar and punctuation. In addition, the *GPO Style Manual* discusses symbols, tables, figures, and numbering issues that are encountered when writing government documentation. If you encounter a conflict among references, choose the reference most appropriate to your discipline and be consistent following its guidance.

SECTION 7

ELECTRONIC DOCUMENTS

7.1 Guidelines for NASA Personnel

For guidance about publishing NASA Scientific and Technical Information (STI), see NPR 2200.2B, “Requirements for Documentation, Approval, and Dissemination of NASA Scientific and Technical Information.” NASA strongly encourages the use of electronic formats and recommends a paper copy also be sent to help ensure that math and symbols have not been transposed due to font substitution during transmission. Suggested fonts are Courier, Helvetica, Arial, Palatino, or Times. (See Section 7.3.3.2.) Guidelines for acceptable file formats are given below. NASA STI should be submitted to the Center’s STI or Technical Publications Manager, who will provide a copy of it and the approved NASA Form (NF)-1676 (or the Center’s version of this form) and Standard Form (SF)-298, if appropriate, to the NASA Center for Aerospace Information (CASI). CASI is NASA’s contract facility to acquire STI, organize it into the NASA Aeronautics and Space Database, and distribute it. Contact the NASA Center STI or Publications Manager if further guidance is needed on electronic file formats.

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Electronic files of limited/restricted or export-controlled STI must not be sent via the Internet or email unless they are encrypted. NASA’s policy to electronically submit limited/restricted and export-controlled STI via the Internet and email is summarized below:

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- File Transfer Protocol (FTP).
- NASA Center's Technical Report Server (TRS).
- Electronic media.
- 3.5-in Microsoft Disk Operating System (MS-DOS) diskettes.
- CD-ROM's formatted to ISO 9660 standards.

NASA CASI will accept the following electronic file formats, listed in order of preference.

- Adobe Portable Document Format (PDF). Do not apply security, user password, or user ID to the PDF (listed under Document Security when you create the PDF; if security is applied, then ID and password are needed to view the document).
- Adobe Postscript (PS) Levels 1 and 2.
- Native formats. Native refers to the source application (e.g., Microsoft[®] Word, PowerPoint[®], and Excel[®]; Corel WordPerfect; Adobe[®] Photoshop[®]). Files in their native format must be self-contained, including all graphics.
- Hypertext Markup Language (HTML). Files must be self-contained; do not use links (electronic pathways) to external documents or Web sites because files can be disabled or links "broken," resulting in loss of information.
- Tagged Image File Format (TIFF).
- Extensible Markup Language (XML).
- American Standard Code for information Interchange (ASCII) text-only files.

The submission requirements for electronic formats are as follows:

- Store single documents in one file.
- Store conference proceedings or other compilations of chapters, works or papers in multiple files: one containing the complete document cover to cover and one file for each of the individual papers.

Contact your Center STI or Technical Publications Manager for their requirements regarding RDP SF-298 submission. The submitted report must include the completed RDP as the last page of the document file (except for NASA Special Publications SPs), or supply a printed RDP. For SPs, send the RDP as a separate file. Also supply a copy of the approved Document Availability Authorization (DAA NF-1676) form. The DAA provides NASA CASI evidence of the approval process and enables CASI to process the document. The DAA should be a separate file. CASI will add it as an attachment to the metadata separate from the document file. The DAA is

required. Without it, CASI will contact the NASA STI or Publications Manager for documentation of release information.

Verify that the information on the RDP corresponds to that on the DAA. If the RDP is not the last page of the document file, but is stored in a separate file, it will not become part of the document when printed or part of the image files available through the NASA Aeronautics and Space Database.

Provide the file in “publication format” in order for CASI to further distribute the document. This means that the file should include all pages required to output it as a print product, e.g., cover, title page and front matter, RDP, and blank pages. This will ensure proper page positioning throughout the document when and if it is printed.

Your STI or Technical Publications Manager will notify CASI via email whenever files are transferred either to the FTP site or your Center’s Technical Report Server.

7.1.3. Additional Media

NASA CASI requires two copies of any nonprint media containing STI, e.g., CD-ROM, videotape, audiotape, along with a printed SF-298 and NF-1676.

7.1.3.1 CD-ROMs and 3.5-in Diskettes

CD-ROMs should be formatted to International Standards Organization (ISO) 9660 standards and diskettes should be MS-DOS compatible.

7.1.3.2 Microfiche

CASI can accept the following formats:

- 98 frames per 105 mm x 148 mm fiche.
- 24-to-1 reduction ratio.

Submission requirements include silver master(s), accompanied by a printed SF-298 and NF-1676.

7.1.3.3 Videotape and Audio Files

CASI can accept the following videotape formats:

- Betacam SP.

Submission requirements include two copies of the videotape, accompanied by a printed SF-298 and NF-1676.

7.1.3.4 Compression Formats

NASA CASI can accept the zip compression format.

7.1.3.5 File Naming Conventions

CASI currently accepts electronic files regardless of naming convention. It is suggested that the name identify the file perhaps by using the report number and the file format by using the appropriate file extension. DAA files should be named using the root name of the document file and underscore DAA (_DAA). Examples include the following:

- NASA/TM-2002-123456 submitted as one PDF—TM-2002-123456.pdf.
- NASA/TM-97-245678/Vol2 submitted as one PDF—TM-2002-24567v2.pdf.
- NASA/CP-2000-209555 submitted as one PDF—CP-2002-209555.pdf and each conference paper submitted as a separate file. The name should identify each individual paper or work followed by the appropriate extension. Example: for paper one, 01CP-20955501.pdf.
- The DAA submitted with NASA/CP-2000-209555 should be named CP-2000-209555_DAA.

7.2 Guidelines For NASA-Funded Contractors

NASA-funded contractors who elect or are required by their contract to submit a final report to NASA should transmit the final report of STI to the appropriate NASA Center contracting officer. Also send a copy of the letter that is sent to the NASA contracting officer to:

NASA Center for AeroSpace Information (CASI)
 Attn. Acquisitions
 7121 Standard Drive
 Hanover, Maryland 21076-1320

See NPR 2200.2B, “Guidelines for Documentation, Approval, and Dissemination of NASA Scientific and Technical Information” for stylistic information and recommended formats for final contractor reports.

7.2.1 Final Report Submission Requirements

NASA prefers that you submit an electronic version of a final report. Recommended fonts include Courier, Helvetica, or Times. It is recommended that a paper copy also be submitted to ensure data integrity (e.g., that the file has not been compromised and that no font substitution occurs in math, equations, and symbols).

If STI contains limited, restricted, or export-controlled STI, do not electronically submit it via the Internet or email unless it is encrypted in a format appropriate to NASA. For the purposes of encryption, limited/restricted information is defined as competitively sensitive information, such as trade secret, proprietary, SBIR and Small Business Technology Transfer Pilot Program (STTR), confidential commercial, and patent (prior to formally filing a patent application) information. Export-controlled information is defined as ITAR (International Traffic in Arms Regulations—22 CFR 120-130) and EAR (Export Administration Regulations—15 CFR 730-744) information. NASA CASI does not handle classified documents. If appropriate encryption is not available at time of transmittal, NASA will accept a paper copy or an electronic copy on CD-ROM. The paper copy or electronic file loaded to the CD-ROM and the CD-ROM itself must be marked with the appropriate restriction. Do not add the restrictive marking to the

exterior mailing envelope. For additional information, contact the NASA contracting officer or the NASA Center STI or Technical Publications Manager.

7.2.2 Required Forms

Include the RDP as the last page of the report file (available at www.sti.nasa.gov). Click on Publishing Information on the home page or go to https://pollux.hq.nasa.gov/nef/user/form_search.cfm).

7.2.3 Electronic File Submittal Guidelines

The following guidelines may help in creating acceptable files.

7.2.3.1 Electronic File Formats and Media

NASA and its contractor-run facility, the NASA Center for AeroSpace Information (CASI), will accept electronic files in the following formats:

- Adobe PDF (preferred format).
- Adobe Postscript.
- Native formats. Native refers to the source application (Microsoft Word, PowerPoint, Excel; Corel WordPerfect; Adobe Photoshop, etc.); files in their native format must be self-contained, including all graphics.
- HTML. Files must be self-contained; do not use links (electronic pathways) to external documents or Web sites because files can be disabled or links “broken,” resulting in the loss of information.
- TIFF.
- XML.
- ASCII (text-only files).

Electronic files can be submitted via:

- Disk (3.5-in, CD-ROM, formatted to ISO 9660 Standards, 100 or 250 Mb Zip).
- Email attachment up to 5 Mb.
- Internet download.

If none of these methods work, please contact the Contracting Officer’s Technical Representative (COTR) for instructions.

CASI uses WinZip to uncompress files.

7.2.3.2 Organizing Electronic Files

The electronic file must contain the complete camera-ready cover-to-cover report, including the SF-298 (RDP).

- Store report and/or supplements to a report as a single, cover-to-cover product; CASI WILL NOT combine multiple files to create the necessary single-file document. In the case of compilations, in addition to a single, cover-to-cover file, also provide a separate file for each individual section or paper in the document. This facilitates cataloging at CASI.

- Include all pages required to output or store it as a camera-ready, cover-to-cover report (i.e., cover pages, front matter, text, graphics, RDP, and blank pages) to ensure proper page positioning throughout the report when it is printed.
- It is not necessary to provide an “interactive” PDF file (such as contents page numbers linking to those sections), as that utility is not needed and will not be used or retained when CASI downloads the file to the storage area for online access.

7.2.3.3 Converting Files to PDF

We recommend that native files be printed to Postscript format before creating PDF files. This creates a searchable PDF file.

PDF files generated from a scanned image should be converted from the scanned image to PDF Searchable Image Exact (PDF image plus text) whenever possible. This creates a searchable PDF file while maintaining the integrity of the original report. Other modes of conversion that are available in conversion programs may alter the contents of the original file.

For assistance in creating PDF files, additional information can be obtained from the Adobe Web site at <http://www.adobe.com>. Adobe® Acrobat® Reader® can be downloaded free from <http://www.adobe.com/support/downloads/main.html>.

7.3 Guidelines For NASA-Funded Grantees and Cooperative Agreement Personnel

NASA-funded grantees and cooperative agreement personnel who either elect or are required by their grant or agreement to submit a final summary of research or final report to NASA should transmit the STI to the appropriate NASA Center’s grants officer, who will submit it (after NF-1676 approval) to the following:

NASA Center for AeroSpace Information (CASI)
Attn. Acquisitions
7121 Standard Drive
Hanover, Maryland 21076-1320

7.3.1 Final Report Submission Requirements

NASA strongly recommends submitting an electronic version of the final summary or report. A paper copy should also be submitted to ensure data integrity (e.g., that the file has not been compromised and that no font substitution occurs in math, equations, and symbols, if applicable).

The grantee or cooperative agreement organization is responsible for appropriately marking information that is restricted/limited or export controlled. If STI contains limited/restricted or export-controlled STI, do not electronically submit it to NASA or NASA CASI via the Internet or email unless it is encrypted in a format appropriate to NASA. For additional information, contact the grants officer or the NASA Center’s STI or Technical Publication Manager. If no appropriate encryption package is available at time of submission, NASA will accept a paper copy of the STI or an electronic copy on CD-ROM. The paper copy or electronic file on CD-ROM and the CD-ROM itself must be marked with the appropriate restrictive marking. Do not add the restrictive marking to the exterior mailing envelope.

7.3.2 Recommended Forms

NASA recommends including the SF-298 RDP as the last page of the report file (available at www.sti.nasa.gov, Click on Publish STI or go to https://pollux.hq.nasa.gov/nef/user/form_search.cfm). This helps ensure the appropriate indexing of information.

7.3.3 Electronic File Submittal Guidelines

The following guidelines will help in creating acceptable files.

7.3.3.1 Electronic File Formats and Media

NASA and its contractor-run facility, CASI, will accept electronic files in the following formats:

- Adobe PDF (preferred format) (see Section 7.2.3.3).
- Adobe Postscript.
- Native formats. Native refers to the source application (Microsoft Word, PowerPoint, Excel; Corel WordPerfect; Adobe Photoshop, etc.); files in their native format must be self-contained, including all graphics.
- HTML. Files must be self-contained; do not use links (electronic pathways) to external documents or Web sites because files can be disabled or links “broken,” resulting in the loss of information.
- TIFF.
- XML.
- ASCII (text-only files).

Electronic files can be submitted via:

- Disk (3.5 in, CD-ROM formatted to ISO 9660 Standards, 100 or 250 Mb Zip).
- Email attachment up to 5 Mb.
- Internet download.

If none of these methods work, please contact the COTR for instructions.

CASI uses WinZip to uncompress files.

7.3.3.2 Organizing Electronic Files

The electronic file must contain the complete camera-ready cover-to-cover report, including the RDP. Suggested fonts for best results are Times, Arial, Courier, Palatino and Helvetica. (Palatino, and Helvetica are not cross-platform fonts.)

- Store report and/or supplements to a report as a single, cover-to-cover product; CASI does NOT combine multiple files to create the necessary single-file document. In the case of compilations, in addition to a single, cover-to-cover file, also provide a separate file for each individual section or paper in the document. This facilitates cataloging at CASI.
- Include all pages required to output or store it as a camera-ready cover-to-cover report (i.e., cover pages, front matter, text, graphics, RDP, and blank pages) to ensure proper page positioning throughout the report when it is printed.

- It is not necessary to provide an “interactive” PDF file (such as contents page numbers linking to those sections), as that utility is not needed and will not be used or retained when CASI downloads the file to their storage area for online access.

7.3.3.3 Converting Files to PDF

When converting files to PDF, the preferred mode is “PDF Normal,” in which the PDF is created directly from a postscript file. Postscript files generated from native formats can be converted to “PDF Normal” using Adobe® Acrobat® Distiller®. Native files should be printed to postscript format before creating PDF files. This creates a searchable PDF file.

PDF files that are generated from a scanned image should be converted from the scanned image to PDF Searchable Image Exact (PDF image plus text). This creates a searchable PDF file while maintaining the integrity of the original report. Other modes of conversion that are available in conversion programs may alter the contents of the original file.

For assistance in creating PDF files, additional information can be obtained from the Adobe Web site at www.adobe.com. Adobe Acrobat Reader can be downloaded free from <http://www.adobe.com/support/downloads/main.html>.

SECTION 8

REVIEW OF DOCUMENTS PRIOR TO PUBLICATION

8.1 Purpose

This section provides the review and approval policies that NASA uses to ensure the quality and integrity of its Scientific and Technical Information (STI) to the greatest degree practicable, provides for the widest practicable and appropriate dissemination of its STI, and protects information that based on statute, regulation, or policy, cannot be disseminated to various audiences.

8.2 Policy and Legal Requirements

8.2.1 Distribution of NASA STI

The NASA STI Program is responsible for providing the distribution of information produced by and for NASA to the public. This function fulfills the mandate of Section 203(a) of the National Aeronautics and Space Act of 1958, which requires NASA to “provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof.” Reinforcing this Space Act requirement, the Office of Management and Budget (OMB), in Circular A-130, establishes the clear policy that the Agency is responsible and expected to disclose information to the public consistent with the Agency’s mission.

8.2.2 Protection of Certain STI

Pursuant to law, certain types of information are required to be protected from public disclosure. The Freedom of Information Act (FOIA) provides guidance regarding categories of information that are exempt from mandatory release under the FOIA. Dissemination of information may also be restricted under other laws, regulations, or policy.

As used in this Special Publication (SP), restricted-access information means information whose publication or distribution is restricted by law, regulation, or policy. Restricted-access information includes national-security-classified information, export-controlled information, personal information subject to the Privacy Act, and proprietary information of the Government or others, such as “Limited Rights Data” and “Small Business Innovation Research (SBIR) Data” received under a contract, trade secret/confidential commercial information other than “Limited Rights Data” or “SBIR Data,” information developed under agreements and subject to Section 303(b) of the National Aeronautics and Space Act of 1958, as amended, copyrighted information, and documents disclosing inventions. Public access to restricted-access information may be prohibited or restricted. Unless a determination is made that public release of information must be prohibited or restricted, NASA STI is made available to the public.

In addition, certain types of information are further restricted from dissemination via NASA public Web sites (NPR 2810.1 and NPR 2800.1). Any questions regarding whether or not certain types of information must be protected from public disclosure should be referred to the NASA Headquarters or Center Patent or Intellectual Property Counsel and the Export Control Administrator for information on handling documents that contain export-controlled or restricted-access information but have subsequently been downgraded.

8.2.3 Review of NASA STI

Before NASA STI may be published or otherwise disseminated external to NASA (or presented at internal meetings or conferences where foreign nationals may be present), it must be reviewed to determine whether public access to the information must be prohibited or restricted. The NASA review, referred to as the Document Availability Authorization (DAA) review, is implemented via NASA Form (NF)-1676 (or a Center implementation of this form). The DAA review process is intended to ensure that NASA does not inappropriately release information to which public access may be prohibited or limited.

Although NASA STI may be produced either directly by NASA or under NASA contracts, grants, and agreements, the NASA DAA review process applies only to the publication and dissemination of NASA STI by NASA or for NASA. The DAA review process is mandatory for all NASA STI disseminated by or for NASA, including on Web sites or presented at internal meetings or conferences where foreign nationals may be present.

The NASA DAA review is required in situations in which NASA publishes, disseminates, or presents STI external to NASA or presents it at internal meetings or conferences where foreign nationals may be present, including STI that has been received from NASA-funded contractors or grantees. Unless otherwise specified in the contracts or grants, NASA does not restrict its contractors and grantees from publishing NASA-funded information themselves. In situations where the contractor or grantee independently publishes STI, NASA is not considered to have published, disseminated, or presented the information, so the DAA review by NASA is not required. However, contractors or grantees are still required by U.S. laws and regulations to review their information and ensure that it:

- Conforms with laws and regulations governing its distribution, including intellectual property rights, export control, national security, and other requirements.
- To the extent the contractor or grantee is given access to data necessary for the performance of the contract or grant that contains restrictive markings, complies with such restrictive markings.

NASA may, on a voluntary basis if requested by the contractor or grantee, perform a DAA review of STI published or disseminated by contractors or grantees.

NASA STI subject to review is reviewed through the DAA review process to:

- Verify its adherence to NASA STI publications policy, if appropriate.
- Ensure its conformance to standards for professional reports and technical accuracy, if appropriate.
- Determine whether public access to the information must be prohibited or restricted.

The DAA review is applicable whether publication is accomplished through printing, submission to external channels for publication through any media, or published electronically on systems accessible by persons or institutions outside NASA. This review is also applicable to presentations that are to be made before professional audiences, whether or not the presentation is accompanied by written material.

8.3 Review for Adherence to Publications Policy

The review for adherence to publications policy is required to ensure that NASA technical reports meet the requirements of NPD 2200.1, “Management of NASA Scientific and Technical Information (STI),” and this NPR.

8.4 Professional and Technical Reviews

Professional reviews (also called editorial and content reviews) are performed by individuals or groups with technical knowledge or background tempered by interdisciplinary expertise in history, education, and program management. Such reviews assess the quality of the document content in terms of its readability, communication of information, and suitability for a particular audience without particular focus on content.

Technical reviews are performed by peers having expertise within the technical discipline of the activity or research being documented. Such reviews assess the technical integrity and merit of the activity or research being performed and the results being documented without regard to the effectiveness of the document at communicating the information.

See “Guidance for Peer Review of NASA STI,” <http://www.sti.nasa.gov/nasaonly/publish/publish.html> and “Professional, Technical, and Data Quality Reviews for NASA STI Documents,” <http://www.sti.nasa.gov/publish/proftech.html>.

8.4.1 Responsibilities

Professional and technical reviews are required to ensure that NASA STI reports conform to NASA Headquarters and Center standards for professional reports and technical accuracy and meet data quality standards. The officials in charge of Headquarters Offices and Directors of Centers are responsible for ensuring the appropriate review and approval of the content of NASA-sponsored STI resulting from work conducted under their authority for presentation or publication through any channels and in any media, including electronic dissemination. Implicit in this approval is the approval for the preparation, printing, and appropriate dissemination of the STI as a work of NASA.

8.4.2 Review Requirements

The officials that are referenced in Section 8.4.1 will ensure that the appropriate minimum review of the NASA STI Report Series and other STI is completed, as indicated by the following levels of NASA STI Report Series professional and technical review requirements:

NASA STI Report Series	Professional and technical review requirements
TP	Technical review by committee of peers or expert single reviewer
TM	Review by technical management
CR	Review by NASA technical management or expert reviewer(s)
CP	Review by technical management
SP	Professional review controlled by originating Headquarters Office or NASA Center
TT	No technical review; some printing authorization; permission to use copyrighted information must be obtained
Other STI	Review by technical management

8.4.3 Peer Review

NASA accepts and encourages technical review by qualified external reviewers or committees of external reviewers. The Agency also accepts technical review by qualified internal reviewers or committees of internal reviewers who are selected on the basis of technical expertise and who do not have (or have disclosed) prior situations or personal or funding issues that would affect their technical review.

Peer reviews must be conducted in an open and rigorous manner. Peer reviews must also ensure that the data are reliable, unbiased, accurate, complete, and have full documentation, and they must ensure that circumstances that could affect data quality are identified and disclosed.

8.5 DAA Reviews

The DAA review is NASA’s compliance review for the publication, dissemination, and presentation of NASA STI by or for NASA through any channel or media. The DAA review is implemented via NF-1676 (or a Center specific implementation of this form). The DAA review not only determines technical approval but also specifies reviews for restricted-access STI, such as national-security-classified information, export-controlled information, proprietary STI, and documents disclosing an invention. NASA STI may be subject to one or more of the restrictions described below. Documents containing restricted-access STI must include Notices applicable to all valid restrictions (see Exhibits throughout this section) as well as one of the document distribution limitations listed in Section 8.5.13, along with any appropriate expiration date. Copying and disseminating of such documents must be done in compliance with applicable notices.

8.5.1 Administratively Controlled Information (ACI) – Sensitive But Unclassified (SBU)

Guidelines for determining and marking administratively controlled information (formerly referred to as “For Official Use Only (FOUO)” information) and referred to as Sensitive But Unclassified (SBU) are given in NPR 1600.1, “NASA Security Program Procedural Requirements” and via NF-1686. For more information about this category of information, contact the NASA Headquarters Office of Security and Program Protection.

8.5.2 National Security Review

NASA Headquarters and Center originating offices are responsible for the review of STI to determine whether the information is subject to security classification. Final security classification rests with NASA Headquarters Office of Security and Program Protection, and documents containing information subject to security classification are addressed in NPR 1600.1, “NASA Security Program Procedural Requirements,” and NPR 2810.1, “Security of Information Technology.” NASA Headquarters and Center originating offices, in conjunction with Headquarters and Center Export Administrators, are also specifically responsible for the review and approval of policy and plans for the intended release of NASA technical and programmatic information to a foreign government. The NASA Headquarters and Center originating offices are also responsible for the review and approval of all material intended for publication, dissemination, and presentation when such material contains information that pertains to the Department of Defense (e.g., aeronautics programs, space launches, or space operations), regardless of the source of the materials.

8.5.3 Publicly Available Documents

All NASA STI not meeting any of the criteria for distribution limitations described herein will be considered approved for public release. Information approved for public release will be made available by NASA CASI to any and all pertinent distribution channels, in keeping with the policy set forth in OMB Circular A-130.

8.5.4 Export Control Reviews

Export control limitations are applied to information subject to:

- Arms Export Control Act, 22 U.S.C. 2778 et seq.
- Export Administration Act of 1979, Pub. L. 96-72 Stat. 503, 50 U.S.C. app. 2401 et seq.
- International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120-130.
- Export Administration Regulations (EAR), 15 CFR Parts 730-774.

These regulations establish lists or categories of technical data subject to export control that may not be exported or disclosed to foreign nationals without proper authority. The term *exported* includes providing information or making information available to a foreign national (including a U.S. citizen representing a foreign national if that individual intends to provide the information to a foreign national) either within the United States or abroad. Information placed on the Internet in an unrestricted manner is deemed an export.

8.5.4.1 Review Requirements

The export control review is required to ensure that the NASA STI Report Series; conference, meeting, and symposia presentations; abstracts; and external publications containing information subject to control under pertinent U.S. export laws or regulations are suitably protected. Each such report, presentation, abstract, or publication must be reviewed and approved by or in conjunction with the Headquarters or Center Export Administrator prior to dissemination, in any media, to audiences that may include foreign nationals. Examples are:

- Presentations at internal meetings that foreign nationals are likely to attend.
- Presentation at “open” meetings in the U.S. that may include foreign nationals.
- Presentations at meetings held in foreign countries.
- Publications intended for public dissemination and/or distribution.
- Unrestricted electronic releases over the Internet.

The abstract, complete report, and presentation must be approved prior to release.

Under certain conditions, officials who oversee specific contracts or projects may, on a case-by-case basis, be granted limited delegations of authority to approve publications when the contracts or projects are restricted to topics exempt from export controls. These limited delegations are coordinated through the NASA Office of External Relations and the cognizant NASA Headquarters Mission Directorate.

8.5.5 International Traffic in Arms Regulations (ITAR—22 CFR 120-130)

8.5.5.1 Definitions

The ITAR implements the Arms Export Control Act and contains the United States Munitions List (USML). The USML identifies articles, services, and related technical data that are designated as “Defense Articles” and “Defense Services,” pursuant to Sections 38 and 47(7) of the Arms Export Control Act. The ITAR is administered by the U.S. Department of State. “Technical Data,” as defined in the ITAR, do not include information concerning general scientific, mathematical, or engineering principles commonly taught in schools, colleges, and universities or information in the public domain (as that term is defined in 22 CFR 120.11). It also does not include basic marketing information on function and purpose or general system descriptions. For purposes of the ITAR, the following definitions apply:

- a. “Defense Article” (22 CFR 120.6). A “Defense Article” is any item or “Technical Data” on the USML (22 CFR 121.1). The term includes "Technical Data" recorded or stored in any physical form, models, mockups, or other items that reveal "Technical Data" directly relating to items designated in the USML. Examples of "Defense Articles" included on the USML are:
 - (1) Launch vehicles, including their specifically designed or modified components, parts, accessories, attachments, and associated equipment.
 - (2) Remote-sensing satellite systems, including ground control stations for telemetry, tracking, and control of such satellites, as well as passive ground stations if such stations employ any cryptographic items controlled on the USML or if they employ any uplink command capability, all components, parts, accessories, attachments, and associated equipment (including ground support equipment) that

is specifically designed, modified, or configured for such systems. (See 22 CFR 121.1 for the complete listing.)

- b. “Technical Data” (22 CFR 120.10). Information that is required for the design, development, production, manufacture, assembly, operation, repair, testing, maintenance, or modification of “Defense Articles.” This includes information in the form of blueprints, drawings, photographs, plans, instructions, and documentation.
- c. Classified information relating to “Defense Articles” and “Defense Services.”
- d. Information covered by an invention secrecy order (35 U.S.C. 181 et seq.; 35 CFR Part 5).
- e. Software directly related to “Defense Articles,” including, but not limited to, system functional design, logic flow algorithms, application programs, operating systems, and support software for design, implementation, test, operations, diagnosis, and repair.

8.5.5.2 Notice of Availability Limitation

If NASA STI contains “Technical Data” or “Defense Articles” as defined above, it is restricted by ITAR, and all copies must bear the “ITAR Notice” shown in Figure 8-1. Release or distribution of the same information by NASA contractors is subject to the same notice. The restriction marking must appear on the cover, title page, and the Report Documentation Page (RDP).

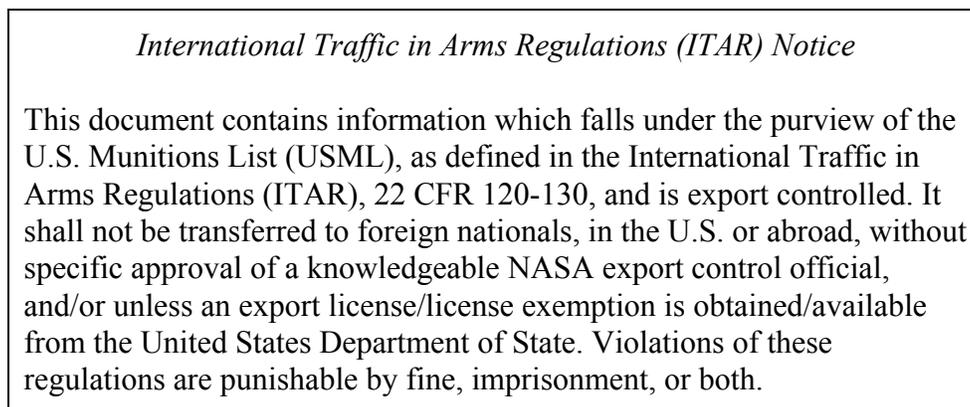


Figure 8-1. ITAR Notice.

8.5.6 Export Administration Regulations (EAR—15 CFR 730-774)

8.5.6.1 Definitions

The EAR implements the Export Administration Act and contains the Commerce Control List (CCL). The CCL lists commodities, technology, and software subject to the export control authority of the U.S. Department of Commerce. The items on this list are export controlled for reasons of national security, foreign policy, proliferation, and/or short supply. These regulations are administered by the U.S. Department of Commerce. Information subject to EAR export restrictions includes that specific “Technology” identified in the CCL (15 CFR 774).

- a. “Technology” (Supplement 2 to 15 CFR 774). Specific information necessary for the development, production, or use of a product on the CCL. The information may be in the form of technical data or technical assistance.
- b. “Technical Data.” Information that may take the form of such as blueprints, plans, diagrams, models, formulae, tables, engineering designs and specifications, manuals, and instructions written or recorded on other media or devices such as disk, tape, or read-only memories.
- c. “Software.” A collection of one or more computer or microcomputer programs fixed in any tangible medium of expression.
- d. “Development Information.” Specific information necessary for any stage prior to serial production, such as design, design research, design analyses, design concepts, assembly and testing of prototypes, pilot production schemes, design data, transformation of design data into a product, configuration design, integration design, and integration design layouts.
- e. “Production Information.” Specific information necessary on any production stage, such as product engineering, manufacture, integration, assembly (mounting), inspection, testing, and quality assurance.
- f. “Use Information.” Specific information necessary for operation, installation (including onsite installation), maintenance (checking), repair, overhaul, and refurbishment.
- g. Information not subject to export control under the EAR. Examples of such information include:
 1. Information that is publicly available via literature, library, patent, or seminar.
 2. Fundamental basic and applied research in which the resulting information is ordinarily published and shared broadly within the scientific community, as well as university-based, corporate, or Federally Funded Research and Development Center-based (FFRDC) research that has no restrictions on publication of the resulting information.
 3. Educational information taught in a college catalog course.
 4. Information contained in patent applications that are not subject to 37 CFR Part 5 secrecy orders.
 5. Basic marketing information on function or purpose or general system descriptions that the producer would make available to its closest competitors at no more than the cost of reproduction.

8.5.6.2 Notice of Availability Limitation

If NASA STI contains “Technology” controlled by EAR, the cover, title page, and RDP of all copies must bear the “EAR Notice” shown in Figure 8-2 at the end of this section. Release or distribution of the same information by NASA contractors is subject to the same notice.

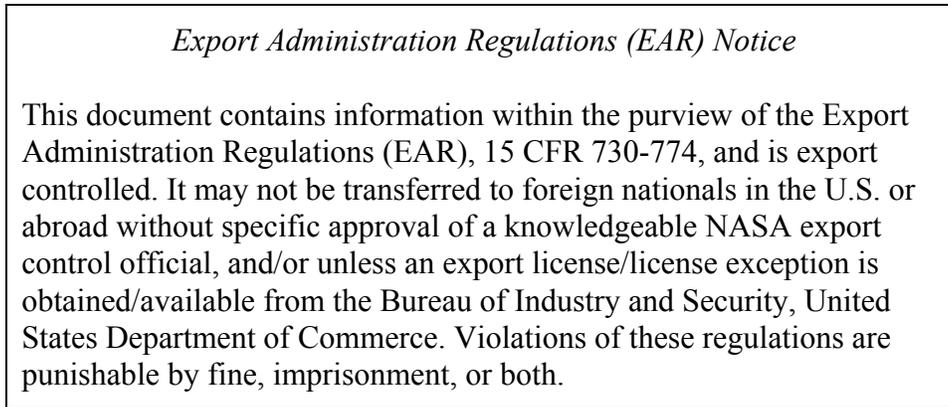


Figure 8-2. Export Administration Regulations Notice.

8.5.7 Proprietary/Sensitive STI

Proprietary information refers to information that is owned by someone. The owner has proprietary rights (i.e., a legal property right) in the information that allows the owner to exclude others from using, selling, reproducing, displaying, or distributing the information. As defined in NPR 1600.1, “NASA Security Program Procedural Requirements,” sensitive information is information that is determined to have special protection requirements to preclude unauthorized disclosure; to avoid compromise of or risks to facilities, projects or programs; to avoid threat to the security and/or safety of the source of information; or to meet access restrictions established by laws, directives, or regulations.

For the purposes of the DAA review and this NPR, proprietary STI is STI that contains “Limited Rights Data” received under a contract; “SBIR Data” received under a SBIR contract; trade secret/confidential commercial information other than “Limited Rights Data” or “SBIR Data;” data subject to Section 303(b) of the National Aeronautics and Space Act of 1958, as amended; copyrighted information; or information disclosing inventions. Additionally, STI may include sensitive information that is unclassified but must be restricted from the Web based on NPR 2800.1.

8.5.8 “Limited Rights Data”

8.5.8.1 Definition

“Limited Rights Data” are data developed at private expense that are delivered to the Government under a government contract and embody trade secrets, or are commercial or financial and confidential or privileged, or that pertain to items, components, or processes developed at private expense. Information that constitutes “Limited Rights Data must be marked with a “Limited Rights Notice” in accordance with FAR clause 52.227-14 when delivered to the Government. If such data are not marked with the “Limited Rights Notice,” the Government has no obligation to withhold the data from public release. Any questions regarding what constitutes

“Limited Rights Data,” or regarding its marking, use, or dissemination, should be referred to the NASA Headquarters or Center Patent or Intellectual Property Counsel.

8.5.8.2 Notice of Availability Limitation

Documents containing “Limited Rights Data” must bear the “Limited Rights Notice” shown in Figure 8-3 and one of the document distribution limitations listed in Section 8.5.13. Copying and disseminating of such documents must be done in conformance with this notice. Any questions regarding appropriate markings or legends and applicable document distribution limitations should be referred to the NASA Headquarters or Center’s Patent or Intellectual Property Counsel.

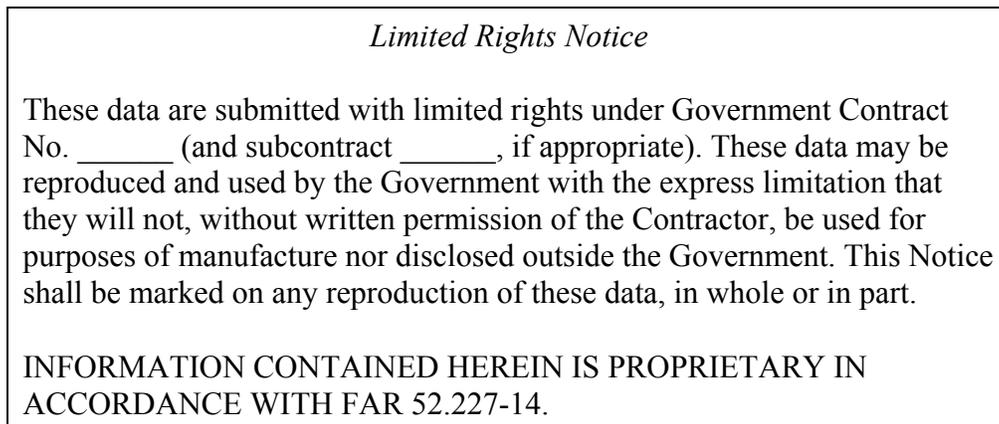


Figure 8-3. Limited Rights Notice.

8.5.9 “SBIR Data”

8.5.9.1 Definition

“SBIR Data” are defined as data first produced by an SBIR contractor that are not generally known, have not, without obligation as to its confidentiality, been made available to others by the contractor, or are not already available to the Government. Data developed under an SBIR contract, if marked with the “SBIR Rights Notice” specified in the contract, must be withheld from public release in accordance with the SBIR contract, usually for four years. If such data are not marked with the “SBIR Rights Notice,” the Government has no obligation to withhold the data from public release. Any questions regarding what constitutes “SBIR Rights Data,” or regarding its marking, use, or dissemination, should be referred to the NASA Headquarters or Center Patent or Intellectual Property Counsel.

To provide a commercialization incentive to SBIR contractors, it is NASA policy to restrict all SBIR program reports from public disclosure for the period specified in the contract for “SBIR Data” unless the contractor has granted permission to publicly release the report sooner. If a letter of permission from the contractor is on file, SBIR program reports may be made publicly available immediately.

8.5.9.2 Notice of Availability Limitation

Restricted SBIR program documents must bear the “SBIR Rights Notice” shown in Figure 8-4 and one of the document distribution limitations listed in Section 8.5.13, along with the appropriate expiration date. Copying and disseminating of such documents must be done in conformance with this notice. Any questions regarding appropriate markings or legends and applicable document distribution limitations should be referred to NASA Headquarters or the Center’s Patent or Intellectual Property Counsel.

<p><i>SBIR Rights Notice</i></p> <p>These SBIR data are furnished with SBIR rights under Contract No. _____. For a period of 4 years after acceptance of all items to be delivered under this contract, the Government agrees to use these data for Government purposes only, and they shall not be disclosed outside the Government (including disclosure for procurement purposes) during such period without permission of the Contractor, except that, subject to the foregoing use and disclosure prohibitions, such data may be disclosed for use by support Contractors. After the aforesaid 4-year period the Government has a royalty-free license to use, and to authorize others to use on its behalf, these data for Government purposes, but is relieved of all disclosure prohibitions and assumes no liability for unauthorized use of these data by third parties. This Notice shall be affixed to any reproductions of these data, in whole or in part. Date for public release: _____.</p> <p>INFORMATION CONTAINED HEREIN IS PROPRIETARY FOR 4 YEARS IN ACCORDANCE WITH FAR 52.227-20.</p>

Figure 8-4. SBIR Rights Notice.

8.5.10 Trade Secret/Confidential Commercial Information

Under certain limited circumstances, NASA employees may be provided access to third-party trade secret or confidential commercial information other than “Limited Rights Data” or “SBIR Data” for inclusion in NASA STI. A “trade secret” is information that:

- Is used in a business.
- Is secret.
- Gives a competitive advantage to the person with knowledge of it.

The party delivering such information must include a proprietary notice that indicates the restricted nature of the information when delivered to the Government. If such information is properly marked by the originator, NASA agrees to handle the information in accordance with the markings. When NASA STI that contains trade secret or confidential commercial information is published or otherwise disseminated by or for NASA, the cognizant program or project office is responsible for ensuring that such data are properly identified and marked to indicate restricted dissemination. Any questions regarding what constitutes trade secret or

confidential commercial information, or regarding its marking, use, or dissemination, should be referred to NASA Headquarters or the Center Patent or Intellectual Property Counsel.

8.5.10.1 Notice of Availability Limitation

If NASA STI is restricted due to trade secret or confidential commercial information other than “Limited Rights Data” or “SBIR Data,” all distributed copies must contain the marking or legend supplied by the originator of the information and, if applicable, one of the document distribution limitations listed in Section 8.5.13. In accordance with the NPR 5800.1E, “Grants and Cooperative Agreements Handbook,” Section D (see Rights in data clause at 14 CFR 1274.905), in limited circumstances information that is first produced by a recipient under a cooperative agreement with a commercial firm may be marked as trade secret/commercial confidential information and its use limited for a period of up to 5 years. In such cases, an appropriate expiration date of the limitation must be included. Copying and dissemination of marked information must be consistent with its markings or legends and any applicable document distribution limitations. Any questions regarding appropriate markings or legends and applicable document distribution limitations should be referred to NASA Headquarters or the Center’s Patent or Intellectual Property Counsel.

8.5.11 Information Subject to Space Act Section 303(b)

Under certain limited circumstances, NASA employees may produce technical information that may be treated as trade-secret information. Section 303(b) of the National Aeronautics and Space Act, as amended, provides that information or data produced by NASA employees, in carrying out NASA’s participation in an agreement entered into under the Space Act, may be protected for a period of up to 5 years if such information would constitute a trade secret or confidential commercial information if it had been produced by the non-Government party. This provision is generally applicable to agreements that have the objective of developing commercial products or processes. Such data should be properly marked by the cognizant NASA project office. NASA agrees to protect the data for the period of time established in the agreement between NASA and the other party, up to 5 years.

8.5.11.1 Notice of Availability Limitation

If NASA STI is restricted due to information subject to Section 303(b) of the Space Act, all distributed copies must contain one of the document distribution limitations listed in Section 8.5.13 along with the appropriate expiration date of the limitation. Copying and dissemination of marked information must be consistent with its markings or legends and any applicable document distribution limitations. Any questions regarding appropriate markings or legends and applicable document distribution limitations should be referred to NASA Headquarters or the Center’s Patent or Intellectual Property Counsel.

8.5.12 Copyright

8.5.12.1 General

A copyright owner is the owner of the exclusive rights comprised in a copyright. A copyright provides the copyright owner the exclusive right to, or authorize others to: reproduce the copyrighted work; prepare derivative works based upon the copyrighted work; distribute copies of the copyrighted work to the public; perform the copyrighted work publicly; and display the

copyrighted work publicly. Others are restricted from exercising the exclusive rights reserved to the copyright owner without the copyright owner's permission.

Contracts, grants, and agreements often permit the contractor, grantee, or recipient to assert copyright in reports and other publications first produced in the performance of the specified activity, e.g., works containing or based on data first produced under a NASA contract, grant, or agreement and published in academic, technical or professional journals, symposia proceedings, or similar works. When copyright is asserted, the contractor or grantee must include a copyright notice and acknowledgment of Government sponsorship (including contract or grant number) of the work when it is published. Ordinarily, the Government receives a government purpose license (also called federal purpose license) in the copyrighted work. The cognizant program or project office provides written notification to the responsible Center Technical Publications Office of instances where documents containing a copyright notice are provided without a license authorizing public distribution.

Under most contracts, grants, and agreements, a government purpose license includes the right to use, modify, reproduce, release copies to the public, perform publicly, and display publicly a copyright work or authorize others to do so for governmental purpose. Under a government purpose license, the Government may use the work within the Government without restriction and may release or disclose the work outside the Government for government purposes. Under Section 203 of the Space Act, it is a governmental purpose to provide for the widest practicable and appropriate dissemination of information concerning NASA's activities and their results. Thus, public distribution of the results of work funded by NASA is a governmental purpose. Although NASA may publicly release copyrighted works for which it has a government purpose license, these works are still protected by copyright, and recipients of the works must comply with the Copyright Law (e.g., they may not further copy or distribute the copyrighted work without permission of the copyright owner).

Documents produced by Government employees in the performance of official duties are not subject to copyright protection in the United States. However, the U.S. Government may obtain copyright protection in other countries depending on the treatment of government works by the national copyright law of the particular country. For additional information, contact the NASA Headquarters or Center Patent or Intellectual Property Counsel. (See the CENDI (<http://www.cendi.gov>) Frequently Asked Questions about Copyright, available from <http://www.cendi.gov/publications/04-8copyright.html>).

8.5.12.2 Notice of Availability Limitation

If NASA STI is restricted due to copyrighted content, all distributed copies must bear the appropriate "Notice for Copyrighted Information" notice shown in Figure 8-5 at the end of this section. Release or distribution of the same information by NASA contractors is subject to the same notice.

(a) Notice for Copyrighted Information (Contractor/Grantee-Prepared Works)

Notice for Copyrighted Information

This manuscript has been authored by employees of _____ under Contract/Grant No. _____ with the National Aeronautics and Space Administration. The United States Government has a nonexclusive, irrevocable, worldwide license to prepare derivative works, publish or reproduce this manuscript, and allow others to do so, for United States Government purposes. Any publisher accepting this manuscript for publication acknowledges that the United States Government retains such a license in any published form of this manuscript. All other rights are retained by the copyright owner.

(b) Notice for Copyrighted Information (Government Works)

Notice for Copyrighted Information

This manuscript is a work of the United States Government authored as part of the official duties of employee(s) of the National Aeronautics and Space Administration. No copyright is claimed in the United States under Title 17, U.S. Code. All other rights are reserved by the United States Government. Any publisher accepting this manuscript for publication acknowledges that the United States Government retains a nonexclusive, irrevocable, worldwide license to prepare derivative works, publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes.

(c) Notice for Copyrighted Information (Joint Works)

Notice for Copyrighted Information

This manuscript is a joint work of employees of the National Aeronautics and Space Administration and employees of _____ under Contract/Grant No. _____ with the National Aeronautics and Space Administration. The United States Government may prepare derivative works, publish or reproduce this manuscript, and allow others to do so. Any publisher accepting this manuscript for publication acknowledges that the United States Government retains a nonexclusive, irrevocable, worldwide license to prepare derivative works, publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes.

Figure 8-5. Copyright notices.

8.5.13 Document Distribution Limitations

Document distribution limitations determined during the DAA review and indicated on the NF-1676 are:

- U.S. Government Agencies and U.S. Government Agency Contractors Only.
- NASA Contractors and U.S. Government Agencies Only.
- U.S. Government Agencies Only.
- NASA Personnel and NASA Contractors Only.
- NASA Personnel Only.
- Available Only with Approval of Issuing Office (Program Office or NASA Center).

When STI is no longer subject to restriction (or following the date cited in “Limited until...”), the cognizant NASA Center (program officials and Export Control Administrators or Patent or Intellectual Property Counsel, as appropriate) must re-mark the STI and provide the NASA CASI with a copy of the new or modified DAA through the Center’s Technical Publications Office or STI Manager. Because NASA CASI is a contractor facility, it is not approved to change or alter authorization categories.

8.5.14 Subject to NPR 2800.1

Prior to loading a NASA document to a public Web site, refer to NPR 2800.1. If restrictions apply based on this document, use the appropriate restriction indicated in the exhibits at the end of this section.

8.5.15 Documents Disclosing Inventions

8.5.15.1 General

Information that is otherwise approved for public release may be withheld if it discloses an invention. The publication of information disclosing an invention by any party before the filing of a patent application may create a bar to a valid patent. Accordingly, under 35 U.S.C. 205 and implementing regulations, agencies are to withhold from release to the public documents that contain information about an invention that the Government owns or may own a right, title, or interest (including a nonexclusive license). This applies to inventions made and reported by NASA employees, contractors, and grantees. Release is delayed in order for a patent application to be filed or, if a decision not to file is made, until release is approved by NASA Headquarters or the Center Patent or Intellectual Property Counsel.

When STI discloses an invention, the invention must also be formally disclosed to NASA via eNTRe, the NASA electronic New Technology Reporting Web site at <http://invention.nasa.gov>, or using NF-1679, “Disclosure of Invention and New Technology,” also available at the eNTRe Web site.

8.5.15.2 Notification

The party making and disclosing or reporting the invention is responsible for notifying the Agency as to the nature of the information and the related invention. In the case of reports submitted under contract or grant, notification should be made to the Contracting Officer or Grant Officer, the designated Patent Representative, and the STI Manager. In the case of

NASA-prepared documents, notification should be made to the Project Officer, the Center Patent or Intellectual Property Counsel, and the STI Manager.

8.5.15.3 Notification Response

Regardless of availability category and any blanket availability authorization that may have been granted, all documents that disclose an invention (except security-classified documents that disclose an invention) for which notification has been made must be withheld by the originating office, with notice to the Center Technical Publications Manager, until the patent application process is complete (i.e., an application is filed with U.S. Patent and Trademark Office or a decision not to file an application is made, and release is approved by the Center Patent or Intellectual Property Counsel). Such withholding does not require NASA Program Office approval. Security-classified documents that disclose an invention must be withheld until approved for release under applicable security guidelines.

8.5.16 Nonstandard Restrictions

Use of restrictions other than those specified in this section must receive prior approval by the Headquarters Office of General Counsel. Requests for use of nonstandard restrictions must include the following information:

- Clear statement of who can and cannot receive the document.
- Time limit for the restriction.
- Reason for the restriction.
- Copy of the legal citation the proposed restriction is based upon.

8.5.17 Delegations

The DAA process is based on statutory requirements for NASA and is coordinated with the Headquarters Office of General Counsel, External Relations, and Security and Program Protection. The responsibility held by the OICs of Headquarters Offices is delegated to NASA Center Directors (with the exception of policy and standards information requiring review by the Office of External Relations).

8.5.18 Documentation of DAA Review and Approval

Approvals should be documented on NF-1676 or the Center-specific implementation of this form. The DAA also documents which restrictions, if any, must be applied to the distribution of the publication or presentation. Individuals originating STI in any form may consult with the NASA Headquarters or Center DAA representative and, as appropriate, the Headquarters or Center Export Administrator, who can explain the availability categories and authorization requirements, and with their NASA Program or Project Manager, COTR, and Contract Technical Monitor, as applicable.

Copies of NF-1676 are available from the Center or Headquarters Forms Manager and are also accessible via the NASA Forms Web site (<http://www.hq.nasa.gov/office/codec/codeci/help/forms/forms.htm>) and the NASA STI program home page (<http://www.sti.nasa.gov>, Publish STI, Required Approvals). Use of the form in other media and in other formats is permitted as long as the data elements contained on NF-1676 are retained.

8.6 Special Concerns

8.6.1 Grants and Cooperative Agreements

In accordance with NPR 5800.1, “Grant and Cooperative Agreement Handbook,” the widest practicable dissemination should be made of results of a NASA grant or cooperative agreement, subject to the restrictions noted above. If the results of a NASA grant or cooperative agreement are published as a NASA CR, they must meet the requirements for CRs as specified in Section 4.5. The DAA review of grant reports published in the NASA STI Report Series should be initiated by the Technical Officer or by the applicable Headquarters Program Office.

8.6.2 Reports Funded by Other Agencies

NASA STI Report Series that result from efforts fully funded by other Government agencies, e.g., the Department of Defense or the Department of Energy, do not require a specific NASA DAA review if the report has been subject to the review process of that agency. Such reports will carry the limitations assigned by the other Government agency. If a review has not been made by another Government agency, a DAA review initiated by the appropriate NASA program is required. Reports resulting from efforts funded in part by NASA require a NASA DAA review.

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SECTION 9

PRINTING AND DISSEMINATION

9.1 Purpose

To ensure the widest practicable and appropriate dissemination of the results of NASA Scientific and Technical Information (STI) activities, NASA maintains an electronic and alternative media duplication capability, adheres to printing regulations that direct printing and reproduction procedures, and maintains a variety of distribution mechanisms that ensure easy access to the NASA STI Report Series, as well as other STI-related products and services.

9.2 Responsibilities

- General distribution requirements for the NASA STI Program are determined by the NASA STI Program director.
- Distribution and dissemination requirements for individual publications are determined by the author and his or her management in coordination with the general requirements of the NASA STI Program director.
- If applicable, all duplicating or printing of NASA STI is performed in accordance with NPD 1490.1, “NASA Printing, Duplicating, Copying, Forms, and Mail Management,” and NPR 1490.5, “NASA Procedural Requirements for Printing, Duplicating, and Copying Management.”
- NASA Center for AeroSpace Information (CASI) is responsible for the primary dissemination of NASA STI, which is done electronically. NASA Centers may elect to also disseminate unclassified/unlimited STI by placing it on their Center Technical Report Server once it has undergone a NASA Form (NF)-1676 or Center version of this form review. Documents on a public Web site must also meet requirements in NPR 2800.1.

9.3 Duplication/Printing, Including for Secondary Distribution

9.3.1 Print Media

NASA disseminates STI electronically. On occasion, a Center may also require hard copy duplication/printing. The duplication or printing of publications in the NASA STI Report Series in hard copy, if a Center elects to do so, is accomplished through Center Publications Offices using NASA Headquarters or Center duplicating/copying facilities and/or a Government Printing Office (GPO), in accordance with NPD 1490.1 and NPR 1490.5. Special handling is required for limited or restricted STI.

9.3.2 Electronic and Alternative Media

The dissemination of STI in electronic or alternative media, which may or may not be issued jointly with a print version, in the NASA STI Report Series must be made in accordance with the standards in Section 1.1.6.

9.4 Archiving of NASA STI

The NASA STI Report Series are scanned or converted into Adobe Portable Document Format (PDF) Searchable Image Exact format (if they are not received in this format) for submission to the National Archives and Records Administration (NARA) for archiving requirements. This process is in accordance with NASA's Records Retention Schedules (NPR 1441.1).

9.5 Duplication for Secondary Distribution

NASA CASI is responsible for subsequent requests for NASA STI. This is called secondary distribution. NASA CASI fulfills requests for STI in electronic formats.

9.6 Dissemination/Distribution of NASA STI Report Series

NASA has four types of dissemination/distributions of its STI:

- Initial (primary).
- Center.
- Author.
- Secondary (i.e., requests on demand).

9.6.1 Initial (Primary) Dissemination/Distribution

Initial or primary dissemination/distribution is made at the time the report is first produced.

NASA CASI is responsible for the initial distribution of STI that is made in electronic formats. For STI in alternative media formats (video, compact disk – read only memory (CD-ROM)) and for alternative media format supplements to electronic STI, the Center must provide to NASA CASI the number of copies necessary for distribution. If a Center elects to do a hard-copy printing, the Center is still required to send an electronic file to NASA CASI.

9.6.2 Dissemination/Distribution of Unclassified/Unlimited Documents

NASA CASI provides the widest practicable dissemination of publications in the NASA STI Report Series. If the document is unclassified/unlimited, NASA CASI sends a copy to NASA Centers, domestic and international organizations, corporations, and universities that are registered with NASA CASI to receive NASA STI publications in any or all of the 11 broad subject divisions. This includes other government agencies, NTIS, the Superintendent of Documents/GPO, and the Federal Depository libraries (unclassified/unlimited STI only).

9.6.3 Distribution of Restricted Documents

NASA CASI makes the appropriate distribution based on the approved registration. The National Technical Information Service (NTIS), the Superintendent of Documents/GPO, and the Federal Depository libraries do not handle restricted information. Centers are not approved to distribute restricted documents other than to NASA CASI and to authors (who are approved to receive them). Any distribution by an author must be reviewed by the appropriate Center's personnel (e.g., export control, general counsel).

9.6.4 Submittal of STI to NASA CASI

NASA STI Managers and Contracting Officer's Technical Representatives (COTRs) ensure that copies of all unclassified publications are forwarded to NASA CASI once the publications have been approved via the NF-1676 (or Center implementation of this form). Electronic formats are strongly recommended. See <http://www.sti.nasa.gov>, Publish STI, Electronic File Formats for NASA STI, for appropriate types of electronic formats. Such STI should be electronically transferred in encrypted format as approved by NASA or sent in hard copy or electronic form on CD-ROM if encryption is not available.

Two copies (1 electronic (required) and 1 hard copy (recommended)) of NASA STI Report Series are to be sent to NASA CASI. The hard copy may be used to validate that math and other symbols have not encountered a font substitute during transmission. For NASA STI reports that are in an alternative media that NASA CASI cannot accommodate, contact NASA CASI to determine the number of copies that must be provided so that they can make the appropriate distribution.

Documents provided to NASA CASI are processed into the NASA Aeronautics and Space Database and announced in a variety of published bibliographies and other external resources.

9.6.5 Center Dissemination/Distribution

A Center may elect to distribute copies of the STI internally to appropriate approved personnel, such as to their records management office, export control office, or other specific organizations. The Center is responsible for this distribution.

9.6.6 Author Dissemination/Distribution

Authors may also request that their Center provide a supplementary distribution of NASA STI publications in addition to the initial distribution. The author distribution may include known authors in the field, conference registrants, members of organizations or groups known to have an interest in the field, and/or persons who have requested similar prior papers. This distribution may also contain the names of persons included in lists obtained from contractors and other agencies. For restricted-access STI, authors must ensure that the names of potential recipients for this distribution have been approved by the Center management prior to the Center or the author making this distribution. Distribution of restricted-access STI requires additional approvals.

9.6.7 Secondary Dissemination/Distribution

Secondary distributions are sent to authorized requesters on demand. This distribution is the responsibility of NASA CASI.

9.6.8 NASA STI Help Desk

For additional information concerning announcement and dissemination/distribution, contact the STI Help Desk as follows:

- Telephone the NASA STI Help Desk at 301-621-0390.
- Send a fax to the NASA STI Help Desk at 301-621-0134.
- Send an email via Internet to help@sti.nasa.gov.

- Write to the NASA STI Help Desk at the NASA Center for AeroSpace Information, 7121 Standard Drive, Hanover, MD 21076-1320.

9.7 Use of Commercial or Nonprofit Publishers

The decision to use commercial or nonprofit publishers (e.g., society and nonprofit publishers) for printing NASA STI involves the following considerations:

- When appropriated funds have been used to create information to be published, printing services must be provided by the GPO, and the information shall not be made available to a private publisher for initial publication.
- If appropriated funds have not been used, other factors (e.g., type and content of the publication, audience, statutory requirements, past practice, and distribution to depository libraries) must be taken into consideration, and both the Office of the General Counsel and the office responsible for the preparation of the work must be consulted.
- The contractual arrangement with the publisher would not be a procurement or assistance transaction, but rather a Space Act agreement.

SECTION 10
ABBREVIATIONS AND ACRONYMS

ACI	Administratively Controlled Information (See SBU)
AIAA	American Institute of Aeronautics and Astronautics
AIP	American Institute of Physics
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
ASTM	American Society of Testing and Materials
CASI	Center for Aerospace Information
CCL	Commerce Control List
CD	Compact disk
CD-ROM	Compact disk – read-only memory
CO	Contracting Officer
COTR	Contracting Officer’s Technical Representative
CP	Conference Publication
CR	Contractor Report
DAA	Document Availability Authorization
DPI	Dots per inch
DVD	Digital video disk
EAR	Export Administration Regulations
FAR	Federal Acquisition Regulations
FFRDC	Federally Funded Research and Development Center
FOIA	Freedom of Information Act
FOUO	For official use only
FTP	File Transfer Protocol
GCWM	General Conference on Weights and Measures
GPO	Government Printing Office
HQ	Headquarters
HTML	Hypertext Markup Language

NASA STI Standards

IBM	International Business Machines
IEEE	Institute of Electrical and Electronics Engineers
ISBN	International Standard Book Number
ISO	International Standards Organization
ISSN	International Standard Serial Number
ITAR	International Traffic in Arms Regulations
LCCN	Library of Congress Control Number
MS-DOS	Microsoft Disk Operating System
NA&SD	NASA Aeronautics and Space Database
NARA	National Archives and Records Administration
NF	NASA Form
NISO	National Information Standards Organization
NIST	National Institute of Standards and Technology
NP	NASA Publication
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
NTIS	National Technical Information Service
NTRS	NASA Technical Reports Server
OMB	Office of Management and Budget
PDF	Portable Document Format
PIC	Procurement Information Circular
PKI	Public-key infrastructure
PS	Postscript
RDP	Report Documentation Page
SF	Standard Form
SBIR	Small Business Innovation Research
SBU	Sensitive but unclassified
SI	International System of Units
SSL	Secure socket layer
STC	Society for Technical Communication

NASA STI Standards

STI	Scientific and Technical Information
STIPO	Scientific and Technical Information Program Office
STTR	Small Business Technology Transfer Pilot Program
TIFF	Tagged Image File Format
TM	Technical Memorandum
TP	Technical Publication
TRS	Technical Reports Server
TT	Technical Translation
UPN	Unique Project Number
URL	Uniform Resource Locator
USC	United States Code
USMA	U.S. Metric Association
USML	United States Munitions List
V&PSB	Visual and Printing Services Branch
VHS	Very high frequency
WBS	Work breakdown structure
WU	Work unit
XML	Extensible Markup Language

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