Naval Research Laboratory

Washington, DC 20375-5320

NRL/FR/5230--97-9869

NRL Report Formats

Timothy D. Calderwood
Patricia E. Staffieri

Publications Branch
Technical Information Division

December 1, 1997

REVIEWED AND APPROVED
December 1997

Peter H. Imhof
Head, Technical Information Division

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave Blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	1 December 1997	Informational

4. TITLE AND SUBTITLE

NRL Report Formats

5. FUNDING NUMBERS

PE - 63270N

6. AUTHOR(S)

Timothy D. Calderwood and Patricia E. Staffieri

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Research Laboratory
Washington, DC 20375-5320

8. PERFORMING ORGANIZATION REPORT NUMBER

NRL/FR/5730--97-9869

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

This is the revised edition of NRL/PU/5320--93-0241 of 10 December 1993.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

NRL Report Formats was prepared to provide information to those at the Naval Research Laboratory (NRL) who write technical reports and for those who typeset and lay out reports for reproduction. This publication provides easy-to-follow instructions, given in the order of a report's construction. Written explanations are given for each section,and figures are shown for each component. The points of contact are given for each of NRL's three locations: Washington, D.C. (NRL-DC), Stennis Space Center, Mississippi (NRL-SSC), and Monterey, California (NRL-MRY), from whom additional report preparation assistance may be obtained.

14. SUBJECT TERMS

Format
Report

15. NUMBER OF PAGES

41

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std 239-18
298-102

CONTENTS

NRL REPORT FORMATS

INTRODUCTION

This *NRL Report Formats* publication provides authors and those who prepare reports with a concise reference guide to NRL's format requirements. The *NRL Format Guide,* updated in 1997, is also available for your reference. It is available in printed form from your Site Technical Information Office (STIO) (see below) or electronically on the TID Web site at **tid.nrl.navy.mil/5230.html.**

HOW TO USE THIS PUBLICATION

This publication is organized in the same way as an NRL Report, starting with the front cover and ending with an appendix at the back. Each component is illustrated with a sample and explanatory text on facing pages. Note that the sample formats are shown in a reduced version; the measurements are accuate for an 8½ in. by 11 in. page. Information is provided in a generic way so it can be used with any word processing or page layout software program.

> Units of measure are given in inches (and typographic points where appropriate). The illustrations have boxed notes. The bold boxes apply to the overall page; the lighter boxes apply to specific items.

FEEDBACK

We solicit your comments on the material presented in this document. Contact your local STIO with any questions or suggestions you may have.

SITE TECHNICAL INFORMATION OFFICES

Listed below are the STIOs for each NRL location.

NRL Washington—Fax (202) 404-8681

Tim Calderwood	Publications Branch	Code 5230	(202) 767-2379
Kathy Parrish	Editorial Section	Code 5231	(202) 767-2782
Judy Kogok	Graphic Arts Section	Code 5232	(202) 767-2850

NRL Stennis—Fax (601) 688-4502

Maria Banker	Technical Information	Code 7032.1	(601) 688-5429

NRL Monterey—Fax (408) 652-4769

Sandra Huddlesten	Publications Section	Code 7502	(408) 656-4708

FRONT COVER

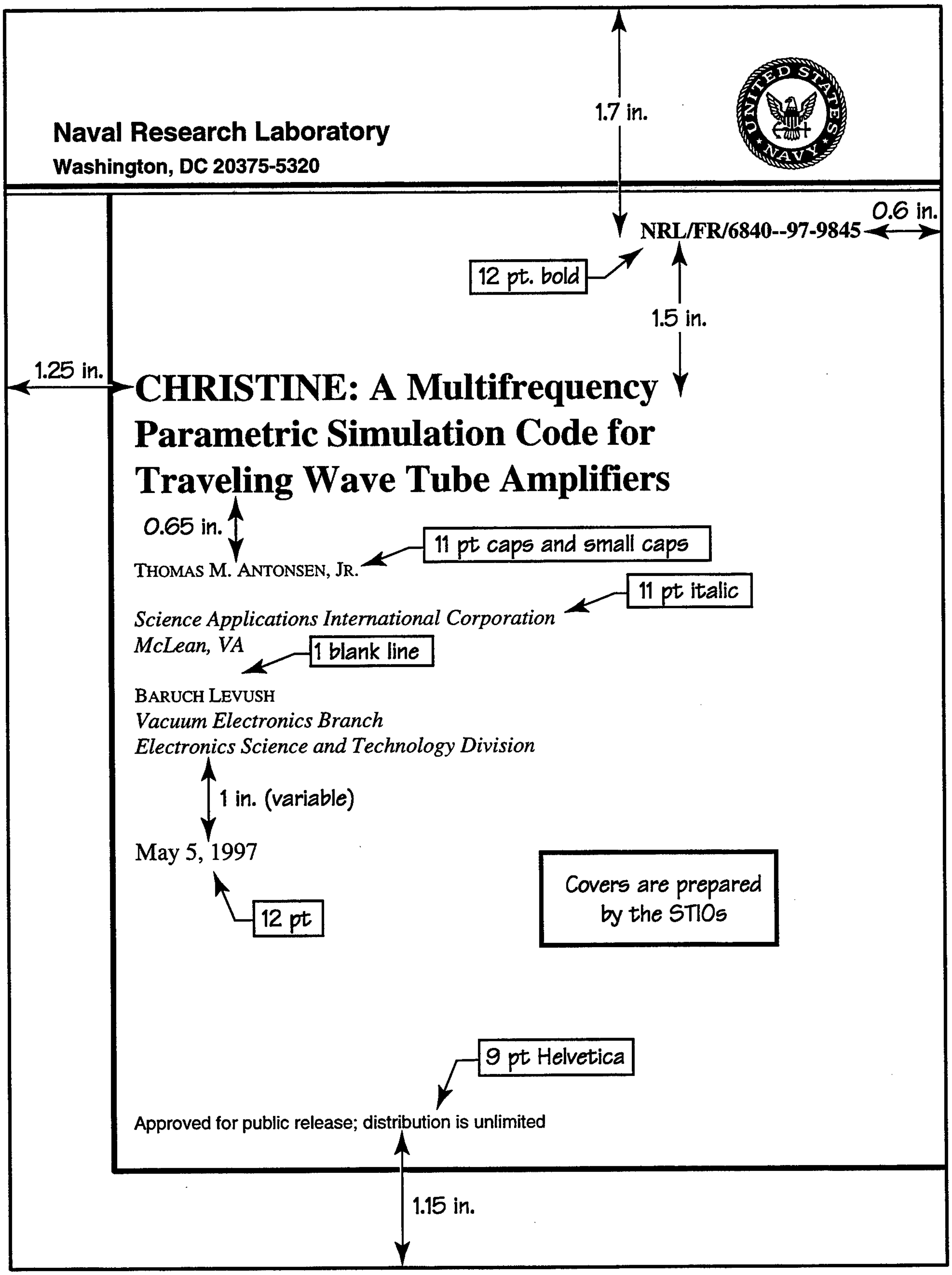
To ensure uniformity of all NRL Reports, FRONT COVERS are prepared by STIO production personnel.

The thick-thin double rule on the cover and the information above it meet the requirements of the Navy Graphic Design Standards (SECNAVINST 5600.20) for official publications. The site location and ZIP Code are added to designate the location of the originator.

The ruled line down the left margin and across the bottom are design elements added by NRL.

Report numbers are assigned by the STIO.

See Section 2 of the *NRL Format Guide* for details concerning the various cover elements.


Naval Research Laboratory
Washington, DC 20375-5320
1.7 in.
NRL/FR/6840--97-9845
0.6 in.
12 pt. bold
1.5 in.
1.25 in.
CHRISTINE: A Multifrequency Parametric Simulation Code for Traveling Wave Tube Amplifiers
0.65 in.
11 pt caps and small caps
THOMAS M. ANTONSEN, JR.
11 pt italic
Science Applications International Corporation
McLean, VA
1 blank line
BARUCH LEVUSH
Vacuum Electronics Branch
Electronics Science and Technology Division
1 in. (variable)
May 5, 1997
12 pt
Covers are prepared by the STIOs
9 pt Helvetica
Approved for public release; distribution is unlimited
1.15 in.

Front cover

REPORT DOCUMENTATION PAGE, SF 298

The REPORT DOCUMENTATION PAGE, SF 298, is the first right-hand page. It is part of the front matter and is numbered with a Roman numeral one "i." The SF 298 is prepared in final form by the STIO. The STIOs are responsible to ensure that the SF 298 is filled out correctly for submission to the Defense Technical Information Center (DTIC).

For those who want to prepare a draft of the SF 298, the STIOs have this form available in electronic form. (Contact your STIO for details.) The text of the form is set in 9-point type. The page number is set in 11-point type and is centered at the bottom with a 0.5-in. margin.

General instructions for completing the SF 298 are found on the reverse side of the form.

The number in Block 15 is the count of all printed pages in the report, including covers.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	May 31, 1993	Interim Report

4. TITLE AND SUBTITLE	5. FUNDING NUMBERS
Electron Beam Quality Limitations and Beam Conditioning in Free Electron Lasers	PE - 9987N45J PR - 128NJ90M1 WU - DN879-00
6. AUTHOR(S) Philip Sprangle, B. Hafizi,* Glen Joyce, and Philip Serafim†	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Research Laboratory Washington, DC 20375-5320	8. PERFORMING ORGANIZATION REPORT NUMBER NRL/MR/6183--93-7166
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Naval Research Arlington, VA 22217-5660	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

*Icarus Research, Bethesda, MD 20814
† Northeastern University, Boston, MA 02115

12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
Approved for public release; distribution is unlimited.	

13. ABSTRACT *(Maximum 200 words)*

The operation of free electron lasers can be severely limited by the axial velocity of the beam electrons. In this report we propose methods for reducing the axial velocity spread in electron beams by redistributing the electron energy via interaction with an axially symmetric, slow, TM waveguide mode. In the first method, the energy redistribution is correlated with the electrons' betatron amplitude, while in the second method it is correlated with the electrons' synchrotron amplitude. Reductions of more than a factor of 40 in the rms axial velocity spread have been obtained in simulations.

SF 298 forms are prepared by the SITOs

14. SUBJECT TERMS	15. NUMBER OF PAGES
Free electron laser; Axial velocity spread; Emittance; Beam conditioning	14
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500 i Standard Form 298 (Rev. 2-89) Prescribed by ANSI Std 239-18 298-102

Report Documentation Page, SF-298

CONTENTS

The CONTENTS page is set up as shown in the sample. There is no header on this page.

Margins—1st Page

	Inches
Top	2
Bottom	0.75
Left	1
Right	1

Margins—Following Pages

	Inches
Top	1
Bottom	0.75
Left	1
Right	1

Fonts

Title	**TIMES ROMAN BOLD 12-POINT FULL CAPS**
Text	Times Roman 11 point
Page numbers	Times Roman 11 point

Double space between levels of headings. Try to limit the number of headings to two levels in the CONTENTS, but do not use more than three levels in any case. See the Appendix for alternative typefaces.

Page Numbers

Text Items

Individual text entries indicate the page on which they are found in the body of the text. The page numbers are placed flush right with dot leaders.

Page

The CONTENTS page(s), as part of the front matter, is numbered with a lowercase Roman numeral(s) beginning with "iii."

Lists of Figures and Tables

Lists of figures and tables are optional. However, if the report contains a large number of figures and/or tables, such a listing might be desirable. These lists are given the centered titles of FIGURES and TABLES. They immediately follow the CONTENTS page.

If both lists are used, they do not have to be on separate pages; use two blank lines to separate them.

No header on this page

2 in.

12 pt bold centered

Text: 11 pt

CONTENTS

2 blank lines

1 in. 1 in.

iii

0.75 in. 0.5 in.

Contents

EXECUTIVE SUMMARY

The EXECUTIVE SUMMARY (if used) follows the CONTENTS and precedes the first page of text of the body of the report. The EXECUTIVE SUMMARY is set up as shown in the sample. There is no header line on this page.

Margins—1st Page

	Inches
Top	2
Bottom	0.75
Left	1
Right	1

Margins—Following Pages

	Inches
Top	1
Bottom	0.75
Left	1
Right	1

Fonts

Title	**TIMES ROMAN BOLD 12-POINT FULL CAPS**
Text	Times Roman 11 point
Headings	See Regular Text Page sample (page 12).
Page numbers	Times Roman 11 point

Page Numbers

The EXECUTIVE SUMMARY is numbered beginning with page E-1 and continuing with E-2, E-3, etc.

Headers and Footers

There are no headers or footers in the EXECUTIVE SUMMARY.

No header on this page

2 in.

12 pt. bold centered

Text: 11 pt

EXECUTIVE SUMMARY

2 blank lines

INTRODUCTION

1 blank line

←1 in.→ ←1 in.→

Formal methods are mathematically based techniques, often supported by reasoning tools that can offer a rigorous and effective way to model, design and analyze computer systems. This report summarizes the results of an independent study of 12 cases in which formal methods were applied to the construction of industrial systems. A major conclusion of the study is that formal methods, while still immature in certain important respects, are beginning to be used seriously and successfully by industry to design and develop computer systems.

Canada's Atomic Energy Control Board (AECB), the U.S. National Institute of Science and Technology (NIST), and the U.S. Naval Research Laboratory (NRL) commissioned this study to determine the industrial track record of formal methods to date and to assess the efficacy of formal methods for meeting their needs. The study had three main objectives:

1. To better inform deliberations within industry and government on standards and regulations;
2. To provide an authoritative record on the practical experience of formal methods to date; and
3. To suggest areas where further research and technology development are needed.

These objectives have been accomplished through the publication of this report. The report consists of two volumes and this Executive Summary. The first volume is the analysis of the supporting data contained in the second volume. Volume One includes a discussion on formal methods and a brief characterization of the formal and related methods used in the cases, a summary of the 12 cases, a description of the methodology used in the survey, a cluster-by-cluster analysis of the data, a discussion on the key events and timing associated with each case, and an analysis of our formal methods R&D summary; it concludes with the findings, observations, and conclusions. The appendixes to Volume One contain brief biographies of the authors, brief characterizations of 11 formal methods used in the cases, the initial questionnaire, the questionnaire used in our structured interviews, and acknowledgements. Volume Two contains detailed supporting data on the 12 cases.

Through these means, the sponsors have been provided with an organized body of systematic information, assessments, evaluations and observations that interpret and extrapolate useful data on cases of significant industrial scale and applicability to real-world products.

This Executive Summary presents the following:

1. A summary of the major findings of the study.
2. Recommendations for continuing R&D in formal methods.

FINDINGS AND RECOMMENDATIONS

The following conclusions are the result of applying the expertise of the authors in analyzing the cases.

E-1

0.75 in.

0.5 in.

Executive Summary

FIRST PAGE OF TEXT

The FIRST PAGE OF TEXT is different from the succeeding text pages. The page number for only the first page is centered 0.5 in. from the bottom and is set in 11-point Times Roman using as Arabic "1." (Page numbers on succeeding pages are contained in the headers.) There is no header on this page.

Margins—1st Page

	Inches
Top	2
Bottom	0.75
Left	1
Right	1

Fonts

Title	**TIMES ROMAN BOLD 12-POINT FULL CAPS**
Text	Times Roman 11 point
Heading Level 1	**TIMES ROMAN BOLD 11-POINT FULL CAPS**
Heading Level 2	**Times Roman Bold 11-point Initial Caps**
Heading Level 3	*Times Roman 11-point Italic*
Heading Level 4	**Times Roman Bold 11-point Initial Caps Indented**
Heading Level 5	Times Roman 11-point Indented Initial Caps—run in with paragraph.
Heading Level 6	Times Roman 11-point Indented Initial Cap of 1st word—run in with paragraph.

Headers

There is no header on the first page of text.

Footer

The "Manuscript approved [date]" footer appears at the bottom of the first page of text. It is preceded by a 0.007-in. thick horizontal hairline. This line is 0.75-in. long followed by a hard return. The text is 9-point Times Roman flush left under the line and is followed by two hard returns. Turn this footer off after page 1 for the remainder of the document.

The "Manuscript approved [date]" is taken from the Publication Approval Form and is the date the Division Superintendent signed off on the manuscript.

Vertical Spacing

There are two blank lines between the title and the start of the text. There is one blank line between paragraphs.

There is one blank line between headings levels1, 2, 3, and 4 and the text following these headings. The text begins on the same line after heading levels 5 and 6.

2 in.

No header on this page

Text: 11 pt

12 pt. bold centered

AN INTERNATIONAL SURVEY OF INDUSTRIAL APPLICATIONS OF FORMAL METHODS

VOLUME 1
PURPOSE, APPROACH, ANALYSIS AND CONCLUSIONS

2 blank lines

INTRODUCTION

1 blank line

1 in. Formal methods are mathematically based techniques, often supported by reasoning tools that can offer a rigorous and effective way to model, design and analyze computer systems. The purpose of this study is to evaluate international industrial experience in using formal methods. The cases selected are, we believe, representative of industrial-grade projects and span a variety of application domains. The study had three main objectives: 1 in.

- To better inform deliberations within industry and government on standards and regulations;
- To provide an authoritative record on the practical experience of formal methods to date; and
- To suggest areas where future research and technology development are needed.

This study was undertaken by three experts in formal methods and software engineering: Dan Craigen of ORA Canada, Susan Gerhart of Applied Formal Methods, and Ted Ralston of Ralston Research Associates. Robin Bloomfield of Adelard was involved with the Darlington Nuclear Generating Station Shutdown System case. Brief biographies of the authors are included in Appendix A.

Support for this study was provided by organizations in Canada and the United States. The Atomic Energy Control Board of Canada (AECB) provided support for Dan Craigen and for the technical editing provided by Karen Summerskill. The Naval Research Laboratory (NRL), Washington, DC, provided support for all three authors. The U.S. National Institute of Standards and Technology (NIST) provided support for Ted Ralston.

This final report consists of two volumes. This first volume describes the study, formal methods, the cases that were studied, our approach to performing the study, and our analysis, findings, and conclusions.

The second volume of the final report provides the details on the case studies. For each of the case studies, we present a case description, summarize the information obtained (from interviews and the literature), provide an evaluation of the case, highlight R&D issues pertaining to formal methods, and provide some conclusions. Earlier drafts of the case studies were reviewed by the relevant participants.

From the authors' analysis of the 12 cases and the stated R&D needs from those we interviewed, other areas are suggested for future R&D. These areas are drawn from the particular set of cases that we studied

---

Manuscript approved March 31, 1993.

1 in.

1

0.5 in.

First page of text

LEFT-HAND TEXT PAGE

A LEFT-HAND TEXT PAGE is shown on the facing page.

Margins

	Inches
Top	0.75
Bottom	0.75
Left	1
Right	1

Header for Left-Hand Pages

The header for left-hand pages contains the page number (flush left) and the last name(s) of the author(s) (flush right) followed by a hard return (or 3 points to ensure that descenders do not run into or touch the horizontal line).

If there is one author, use the author's full name. If there are two or three authors, use the first author's last names only, followed by "et al." (example: Craigen et al.). Note that there is no comma in front of et al.

Text is 10-point Times Roman italic.

A full-width horizontal line is placed under the header text. This line is 0.014-in. thick and 6.5-in. long. There should be a vertical space of 0.025 in. after the line.

Vertical Spacing

There are two blank lines between the title and the start of the text. There is one blank line between paragraphs.

There is one blank line between headings levels1, 2, 3, and 4 and the text following these headings. The text begins on the same line after heading levels 5 and 6.

1.3 in. 0.875 in.

2 *Craigen, Gerhart, and Ralston*

FORMAL METHODS Level 1

1 in. Before proceeding, we provide an historical perspective, explain the term "formal methods" and introduce the broad spectrum of formal methods techniques that are represented in the survey. 1 in.

Historical Perspective Level 2

For over two decades, researchers have explored topics in the mathematics of program synthesis and analysis. The article "Assigning Meaning to Programs" [Floyd 1968] stated the goal of both (1) semantics of programming languages, and (2) specification and reasoning about individual programs. This goal evolved into the key idea of inductive assertions then defining both language semantics and program meaning by relationships among preconditions, program statements, and postconditions. The intriguing possibility of mechanical proof of programs, or alternatively, heuristic generation of programs, yielded many exploratory systems and theoretical insights. Two barriers to practical application arose: (1) it was difficult to capture the full semantic content of programming languages and operating environments, and (2) it was a constant challenge to express the functional and nonfunctional intent for a program in its context of use.

Important Concepts Level 3

Research led to many important concepts: formal definitions of complex language features and identification of pitfalls of unnecessary and overly complex features; specification languages for abstract data types, concurrent processes, and abstract machines; a theory of abstraction behind hierarchical system structures; mechanizable logics that permitted computational reasoning about program properties; and theories of domains such as security, synchronous clocks, microprocessors, and compiling. Practical applications were found in these domains and small-to-medium scale examples were worked out. Industrialization began in the U.S. about a decade ago through the government mandate of certification of security properties.

Practice went a different route. Verification was achieved (and defined) through case-based reasoning (i.e., testing) with numerous criteria and strategies for good testing practice (primarily functional and structural coverage). Reviews provided the primary means of intellectual control: mental checking of desirable properties of systems under development and the concomitant communication among stakeholders (such as managers, designers, testers, and documenters). Heuristic methodologies for structured requirements analysis and design offered additional guidance toward systems that captured the conventional wisdom of good structure and provided a common means of communication.

Verification Level 4

Researchers developed a theoretical base for testing and the results, although mostly negative, suggested various heuristics for testing that more closely approximated an ideal where each test case meant something with some chance of revealing errors or demonstrating new evidence of correctness. The following paragraphs elaborate on this information.

Level 5 *Heuristic Methodologies*—Heuristic methodologies from practice never gained much research attention although abstract data types gave rise to object-oriented languages and methods to add even more structure and support to heuristic system development. Effort in this area is somewhat limited and should be expanded for additional analysis. A number of important concepts and their interrelationships need to be explored.

0.75 in.

Left-hand text page, also showing heading levels

RIGHT-HAND TEXT PAGE

A RIGHT-HAND TEXT PAGE is shown on the facing page. It differs from the left-hand text page only in its header.

Margins

	Inches
Top	0.75
Bottom	0.75
Left	1
Right	1

Header for Right-Hand Pages

The header for right-hand pages contains a brief or abbreviated version of the report's title (flush left) and the page number (flush right) followed by a hard return (or three points to ensure that descenders do not run into or touch the horizontal line).

Text is 10-point Times Roman italic.

A full-width horizontal line is placed under the header text. This line is 0.014-in. thick and 6.5-in. long. After the line should be a vertical space of 0.25 in.

Vertical Spacing

There are two blank lines between the title and the start of the text. There is one blank line between paragraphs.

There is one blank line between headings levels 1, 2, 3, and 4 and the text following these headings. The text begins on the same line after heading levels 5 and 6.

1.3 in.

International Survey of Industrial Applications–Vol. I 3

←1 in.→ ←1 in.→

Theoretical results—Theoretical results have also played a role in system development (e.g., data compression, error correction, and encryption algorithms for disk and network storage and data structures permit representation and searching of data bases and processing of visual images).

Other complexities—Especially demanding are theories and strategies for managing distributed computation and data on both physically distributed resources and multiprocessor computing systems.

No matter what technical approach is applied in software development, common information processing needs arise: maintaining consistency among, and intelligibility of, an interwoven mass of documents expressing the points of view of many stakeholders, with constant change in content and often change in structure of that mass, while the set of stakeholders also changes over what may be many years of a system's life. Programming environments have evolved to address this need: structured editors, configuration management, database representations, graphical interfaces, and ways of coordinating work flow among, as well as work products of groups of system stakeholders. Particularly important are those assets that are viewed as worthy of use beyond their project context (e.g., software components, document templates, review guidebooks, error and productivity data). More research will be done in this area in the future.

Thread in Practice

Yet another thread in practice has been the greater attention forced onto the process aspects of system development: how an organization manages and improves its infrastructure and specific procedures. While the logic-based form of mathematical approaches to system description was maturing, so was another form: statistical reasoning about errors and growth of reliability over time, with the objective of introducing industrial quality control and assurance practices.

Thus we have the setting for this study and the present report: mathematical techniques have been maturing for 25 years while non-mathematical techniques and general concerns for process have driven the practice. In the past five years, sparse anecdotal evidence indicated that formal methods were beginning to be used in industrial practice, leading to sponsorship of the present study to determine systematically and factually where these applications were occurring, why, and how the methods were being used.

What Are Formal Methods?

Definitions of formal methods abound. In the FM89 report (Craigen and Summerskill 1989), formal methods were defined as:

> "Methods that add mathematical rigor to the development, analysis, and operation of computer systems and to applications based thereupon."

> "...are nothing but the application of applied mathematics—in this case, formal logic—to the design and analysis of software-intensive systems."

In more concrete terms, there has been a tendency, on the part of the formal methods community, to define formal methods in terms of a Hilbert-style axiomatization. For example, Robin Bloomfield has defined formal methods as follows:

> "A software specification and production method, based on a mathematical system, that comprises the following:

0.75 in.

Right-hand text page

FIGURES

Place figures as close as possible to where they are first mentioned. Figures that are full-page in size are optically centered (a little above actual center). Avoid landscape and fold-in figures if possible. See your STIO for details on how to handle these special-case figures.

Placement

Center the figure horizontally. Place it 0.5 in. below the baseline of the last line of text. There is 0.25 in. between the bottom of the figure and the baseline of the first line of the caption. Allow 0.5 in. between the baseline of the last line of the caption and the top of the next line of text. Labels and callouts are set in Helvetica and no smaller than 9 points after final reduction.

Captions

Center the figure caption below the figure. The baseline of the first line of the caption is 0.25 in. below the bottom of the figure. Type is 9-point Times Roman. The first word is capitalized—the others are not (unless it is a formal title). The caption does not end with a period (even if it is a complete sentence) unless it is followed by other sentences. If space below the figure is limited, captions may be placed beside the figure if there is room. The word figure is abbreviated as Fig. There is an em-dash between the figure number and the first word of the caption. An em-dash is equal in length to the type size.

Type Size

Text figures are set in 10-point Times Roman.

TABLES

Place tables within the text as close as possible to where they are first mentioned.

Placement

Center the table horizontally. Place it 0.5 in. below the last line of text, starting with the first line of the table title. Allow one hard return (0.17 in.) between the last line of the title and the top of the table. Allow 0.5 in. between the bottom of the table and the next line of text.

Titles

Center the table title 0.25 in. above the table. Type is 11-point Times Roman. Words in the title (except for articles) are initial caps. The title does not end with a period (even if it is a complete sentence) unless it is followed by other sentences. Place an em-dash between the table number and the first word of the title. An em-dash is equal in length to the type size. In this case, the em-dash is 10-points long because the type is 10 points in size. If the title is more than one sentence, only the first words are capitalized.

Type Size

Tables are set in 11-point Times Roman. Keep tables within the image area of the page (6.5 × 10 in.). To fit the area, tables may be set in a smaller type size (but no smaller than 8 points).

8 *Craigen, Gerhart, and Ralston*

PATTERN RECOGNITION ALGORITHM

Suppose we have a digitized $I \times J$ image g and that this is convolved with a mask or kernel k of size $(2N+1) \times (2N+1)$ to form an unscaled image h. The variables involved are defined by Table 1. The process of optimization, as shown in Fig. 1, comprises a search for the mask k_{opt} in a domain, or set of acceptable masks, K for which $f(G, k)$ is maximum.

3 blank lines

0.5 in.

11 pt

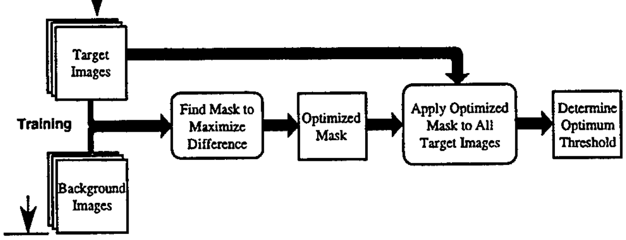
0.25 in.

Table 1 — Definitions of Variables

Object	Format	Class*	Domain†
Original Image	$g = g(i, j)$	$g, i, j \in Z$	$0 \leq g \leq G$ $1 \leq i \leq I$ $1 \leq j \leq J$
Convolution Mask	$k = k(m, n)$	$k \in R$ $m, n \in Z$	$-K \leq k \leq K$ $-N \leq m \leq N$

*Z represents the set of all integers and R the set of all real numbers
†G is the maximum grey level in g, and K is the maximum absolute value for an element of k.

0.5 in.



0.25 in.

Fig. 1 – Schematic diagram of autonomous target-detection system

9 pt

0.5 in.

The convolution operation $h = g + k$ is commonly defined by

$$h(i,j) = \sum_{m=-N}^{N} \sum_{n=-N}^{N} g(i+m, j+n). \qquad (1)$$

Where a mask is used as a feature detector (as in the current project), it is normal to apply the zero-sum constraint

$$\sum_{m=-N}^{N} \sum_{n=-N}^{N} k(m, n) = 0, \qquad (2)$$

to prevent response to a uniformly gray image.

Figure and table

APPENDIXES

Appendixes (if used) follow the main body of text and contain supplemental information. Although they stand alone, they must be mentioned in the text. They are set up in the same manner as the first page of text with two exceptions:

- The headers for left- and right-hand pages continue, except on the first page of each appendix.
- There is no "Manuscript approved [date]" footer.

Margins—1st Page

	Inches
Top	2
Bottom	0.75
Left	1
Right	1

Margins—Following Pages

	Inches
Top	1
Bottom	0.75
Left	1
Right	1

Title

The word "Appendix" on the first page starts 2 in. from the top. There is a blank line between the Appendix designation and the title. Both are set in 12-point bold Times Roman in full caps.

Text

There are two blank lines between the last line of the title and the first line of the text. Text on the succeeding pages begins at the top of the page.

No header on this page

2 in.

12 pt bold centered

Appendix A

FORMAL METHODS TECHNIQUES

Text: 11 pt

2 blank lines

SOFTWARE COST REDUCTION (SCR)

1 blank line

The description presented here is based on our understanding of the work performed at Ontario Hydro (on the Darlington shutdown system). This work includes evolutionary enhancements to (Henry 1978) by Parnas, his colleagues, and others.

← 1 in. →

← 1 in. →

How the Method Works

Representations Used

Tabular representations of software requirements (described in a blackbox manner) and of program functions. In the latter case, the tables are called "program function tables" and, essentially, are "strongest post condition" descriptions of a procedure. The strongest post condition explicitly states how a variable is modified by a procedure. Also included are "linkage tables."

The tabular approach to describing software requirements is derived from the work performed at NRL. For this reason, we call the approach "SCR-style." The derivation of program function tables and the use of proofs (described below) were not part of the initial work on the SCR.

Steps Performed

The Darlington project was generally a reverse engineering exercise. The code already existed when they developed the specifications and other tables. Proofs were required to demonstrate that a routine specification was equivalent to the program function description. Proofs were performed by hand, though it could be mechanized.

Code linkage tables identify how the outputs of a program function table may be used as inputs to other program function tables. It is through code linkage tables that all the physical inputs and program variables that have an effect on a physical output are identified. Similar linkage tables exist for the specification. Hence, linkage tables help to modularize the descriptions of the specification and code.

Interaction between asynchronous processes was viewed as interprocess I/O occurring via shared data objects. Each process had its own specifications and program function tables. Processes were analyzed separately and the process interaction was handled separately from program function table analysis.

Tools Applied

No specific tools exist to support the SCR-style of documentation. Tools are expected to be developed. The strongest post condition explicitly states how a variable is modified by a procedure.

31

0.75 in.

0.5 in.

CLASSIFICATION MARKINGS

Covers and SF 298

Prepared by the STIO.

Every Page

The overall classification of the report is typed at the top and bottom of each page, as shown, centered in 14-point bold Helvetica (or Arial or Univers) full caps. This requires modification of the headers and footers.

Headers

The headers are modified by adding two lines at the top of the header. The first line is for the page classification; the second line is a blank spacing line. The top margin is set at 0.5 in. for all pages.

Footers

The bottom margin is changed to 0.5 in. for all pages. A footer is set up to insert the report classification centered at the bottom margin of each page. The "Manuscript approved [date]" footer must be modified by adding two lines to the bottom. The bottom line is for the page classification; the next line up is a blank line.

Contents

A security classification is indicated in parentheses immediately following each heading and title.

Text

Enter a classification marking following the title and preceding every heading and paragraph.

The paragraph classification carrryover statement, e.g., "((*U*) *paragraph continues*)" is no longer required.

Footnotes

Enter a classification marking following the title and preceding every heading and paragraph.

Example: *(U) This is a footnote.

Each footnote receives a classification marking.

Figures

The classification of each figure is typed centered, full caps, in 9-point Helvetica (or Arial or Univers), 0.25 in. below the figure. The figure caption is placed 0.065 in. below the classification. The figure is marked even if it is unclassified.

Caption

The classification of the figure caption is placed after the em-dash following the figure number and before the first word of the caption (e.g., Fig. 10—(U) The caption).

Tables

The classification of each table is typed centered, full caps, 9-point Helvetica (or Arial or Univers), 0.25 in. below the table.

Title

The classification of the table title is placed after the table number and before the first word of the title, (e.g., Table 2—(U) The Title).

Appendixes

All elements of an appendix are handled the same as text pages.

Unclassified Appendix in a Classified Report

Although an unclassified appendix does not require headings or paragraph markings, it must carry the following statement in 12-point bold, initial caps, centered above the title and appendix designation on the first page of the appendix.

(This appendix is unclassified)

A sample is shown on page 33.

Blank Pages

Blank pages have the following statement centered on the page, "This page intentionally left blank." These pages are numbered.

CLASSIFICATION

Naval Research Laboratory
Washington, DC 20375-5320

NRL/FR/6840--97-9845

CHRISTINE: A Multifrequency Parametric Simulation Code for Traveling Wave Tube Amplifiers (U)

THOMAS M. ANTONSEN, JR.

Science Applications International Corporation
McLean, VA

BARUCH LEVUSH

Vacuum Electronics Branch
Electronics Science and Technology Division

May 5, 1997

Exempt from Distribution to Defense Technical Information Center in accordance with DoD Instruction 5100.38.

Derived From: Multiple Sources Declassify On: X1, X4

Further dissemination only as directed by Commanding Officer, Naval Research Laboratory,Washington, DC 20375-5320; July 1993; or higher DoD authority.

CLASSIFICATION

Classified cover

CLASSIFICATION

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.			
1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE May 31, 1993	3. REPORT TYPE AND DATES COVERED Interim Report	
4. TITLE AND SUBTITLE Electron Beam Quality Limitations and Beam Conditioning in Free Electron Lasers (U)			5. FUNDING NUMBERS PE - 9987N45J PR - 128NJ90M1 WU - DN879-00
6. AUTHOR(S) Philip Sprangle, B. Hafizi,* Glen Joyce, and Philip Serafim†			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Research Laboratory Washington, DC 20375-5320			8. PERFORMING ORGANIZATION REPORT NUMBER NRL/MR/6183--93-7166
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Naval Research Arlington, VA 22217-5660			10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES *Icarus Research, Bethesda, MD 20814 †Northeastern University, Boston, MA 02115			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Further dissemination only as directed by Commanding Officer, Naval Research Laboratory, Washington, DC 20375-5320; July 1993; or higher DoD authority. [Select appropriate distribution statement from the back of the Publication Approval Form, HQ-NRL 5219/1 (REV. 12-93.)]			12b. DISTRIBUTION CODE
13. ABSTRACT *(Maximum 200 words)* (U) The operation of free electron lasers can be severely limited by the axial velocity of the beam electrons. In this report we propose methods for reducing the axial velocity spread in electron beams by redistributing the electron energy via interaction with an axially symmetric, slow, TM waveguide mode. In the first method, the energy redistribution is correlated with the electrons' betatron amplitude, while in the second method it is correlated with the electrons' synchrotron amplitude. Reductions of more than a factor of 40 in the rms axial velocity spread have been obtained in simulations.			
14. SUBJECT TERMS Free electron laser (U) Axial velocity spread (U) Emittance (U) Beam conditioning (U)			15. NUMBER OF PAGES 14 16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT CLASSIFICATION	18. SECURITY CLASSIFICATION OF THIS PAGE CLASSIFICATION	19. SECURITY CLASSIFICATION OF ABSTRACT CLASSIFICATION	20. LIMITATION OF ABSTRACT SAR

NSN 7540-01-280-5500

i

Standard Form 298 (Rev 2-89)
Prescribe by ANSI Std 239-18
298-102

CLASSIFICATION

Classified Report Documentation Page, SF 298

0.5 in.

CLASSIFICATION

CONTENTS (U)

1 hard return

iii

CLASSIFICATION

0.5 in.

Classified contents

CLASSIFICATION

EXECUTIVE SUMMARY (U)

(U) INTRODUCTION

(U) Formal methods are mathematically based techniques, often supported by reasoning tools that can offer a rigorous and effective way to model, design and analyze computer systems. This report summarizes the results of an independent study of 12 cases in which formal methods were applied to the construction of industrial systems. A major conclusion of the study is that formal methods, while still immature in certain important respects, are beginning to be used seriously and successfully by industry to design and develop computer systems.

(U) Canada's Atomic Energy Control Board (AECB), the U.S. National Institute of Science and Technology (NIST), and the U.S. Naval Research Laboratory (NRL) commissioned this study to determine the industrial track record of formal methods to date and to assess the efficacy of formal methods for meeting their needs. The study had three main objectives:

1. (U) To better inform deliberations within industry and government on standards and regulations;
2. (U) To provide an authoritative record on the practical experience of formal methods to date; and
3. (U) To suggest areas where further research and technology development are needed.

(U) These objectives have been accomplished through the publication of this report. The report consists of two volumes and this Executive Summary. The first volume is the analysis of the supporting data contained in the second volume. Volume One includes a discussion on formal methods and a brief characterization of the formal and related methods used in the cases, a summary of the 12 cases, a description of the methodology used in the survey, a cluster-by-cluster analysis of the data, a discussion on the key events and timing associated with each case, and an analysis of our formal methods R&D summary; it concludes with the findings, observations, and conclusions. The appendixes to Volume One contain brief biographies of the authors, brief characterizations of 11 formal methods used in the cases, the initial questionnaire, the questionnaire used in our structured interviews, and acknowledgements. Volume Two contains detailed supporting data on the 12 cases.

(U) Through these means, the sponsors have been provided with an organized body of systematic information, assessments, evaluations and observations that interpret and extrapolate useful data on cases of significant industrial scale and applicability to real-world products.

(U) This Executive Summary presents the following:

1. (U) A summary of the major findings of the study.
2. (U) Recommendations for continuing R&D in formal methods.

(U) FINDINGS AND RECOMMENDATIONS

(U) The following conclusions are the result of applying the expertise of the authors in analyzing the cases.

E-1

CLASSIFICATION

Classified Executive Summary

CLASSIFICATION

AN INTERNATIONAL SURVEY OF INDUSTRIAL APPLICATIONS OF FORMAL METHODS (U)

VOLUME 1

PURPOSE, APPROACH, ANALYSIS AND CONCLUSIONS (U)

(U) INTRODUCTION

(U) Formal methods are mathematically based techniques, often supported by reasoning tools that can offer a rigorous and effective way to model, design and analyze computer systems. The purpose of this study is to evaluate international industrial experience in using formal methods. The cases selected are, we believe, representative of industrial-grade projects and span a variety of application domains. The study had three main objectives:

- (U) To better inform deliberations within industry and government on standards and regulations;
- (U) To provide an authoritative record on the practical experience of formal methods to date; and
- (U) To suggest areas where future research and technology development are needed.

(U) This study was undertaken by three experts in formal methods and software engineering: Dan Craigen of ORA Canada, Susan Gerhart of Applied Formal Methods, and Ted Ralston of Ralston Research Associates. Robin Bloomfield of Adelard was involved with the Darlington Nuclear Generating Station Shutdown System case. Brief biographies of the authors are included in Appendix A.

(U) Support for this study was provided by organizations in Canada and the United States. The Atomic Energy Control Board of Canada (AECB) provided support for Dan Craigen and for the technical editing provided by Karen Summerskill. The Naval Research Laboratory (NRL), Washington, DC, provided support for all three authors. The U.S. National Institute of Standards and Technology (NIST) provided support for Ted Ralston.

(U) This final report consists of two volumes. This first volume describes the study, formal methods, the cases that were studied, our approach to performing the study, and our analysis, findings, and conclusions.

(U) The second volume of the final report provides the details on the case studies. For each of the case studies, we present a case description, summarize the information obtained (from interviews and the literature), provide an evaluation of the case, highlight R&D issues pertaining to formal methods, and provide some conclusions. Earlier drafts of the case studies were reviewed by the relevant participants.

(U) From the authors' analysis of the 12 cases and the stated R&D needs from those we interviewed, other areas are suggested for future R&D. These areas are drawn from the particular set of cases that we studied.

Manuscript approved March 31, 1993.

1

CLASSIFICATION

Classified first page of text

(U) FORMAL METHODS

(U) Before proceeding, we provide an historical perspective, explain the term "formal methods" and introduce the broad spectrum of formal methods techniques that are represented in the survey.

(U) Historical Perspective

(U) For over two decades, researchers have explored topics in the mathematics of program synthesis and analysis. The article "Assigning Meaning to Programs" [Floyd 1968] stated the goal of both (1) semantics of programming languages, and (2) specification and reasoning about individual programs. This goal evolved into the key idea of inductive assertions then defining both language semantics and program meaning by relationships among preconditions, program statements, and postconditions. The intriguing possibility of mechanical proof of programs, or alternatively, heuristic generation of programs, yielded many exploratory systems and theoretical insights. Two barriers to practical application arose: (1) it was difficult to capture the full semantic content of programming languages and operating environments, and (2) it was a constant challenge to express the functional and nonfunctional intent for a program in its context of use.

(U) Important Concepts

(U) Research led to many important concepts: formal definitions of complex language features and identification of pitfalls of unnecessary and overly complex features; specification languages for abstract data types, concurrent processes, and abstract machines; a theory of abstraction behind hierarchical system structures; mechanizable logics that permitted computational reasoning about program properties; and theories of domains such as security, synchronous clocks, microprocessors, and compiling. Practical applications were found in these domains and small-to-medium scale examples were worked out. Industrialization began in the U.S. about a decade ago through the government mandate of certification of security properties.

(U) Practice went a different route. Verification was achieved (and defined) through case-based reasoning (i.e., testing) with numerous criteria and strategies for good testing practice (primarily functional and structural coverage). Reviews provided the primary means of intellectual control: mental checking of desirable properties of systems under development and the concomitant communication among stakeholders (such as managers, designers, testers, and documenters). Heuristic methodologies for structured requirements analysis and design offered additional guidance toward systems that captured the conventional wisdom of good structure and provided a common means of communication.

(U) Verification

(U) Researchers developed a theoretical base for testing and the results, although mostly negative, suggested various heuristics for testing that more closely approximated an ideal where each test case meant something with some chance of revealing errors or demonstrating new evidence of correctness. The following paragraphs elaborate on this information.

(U) *Heuristic Methodologies*—Heuristic methodologies from practice never gained much research attention although abstract data types gave rise to object-oriented languages and methods to add even more structure and support to heuristic system development. Effort in this area is somewhat limited and should be expanded for additional analysis. A number of important concepts and their interrelationships need to be explored.

Classified left-hand text page

CLASSIFICATION

(U) Theoretical results—Theoretical results have also played a role in system development (e.g., data compression, error correction, and encryption algorithms for disk and network storage and data structures permit representation and searching of data bases and processing of visual images).

(U) Other complexities—Especially demanding are theories and strategies for managing distributed computation and data on both physically distributed resources and multiprocessor computing systems.

(U) No matter what technical approach is applied in software development, common information processing needs arise: maintaining consistency among, and intelligibility of, an interwoven mass of documents expressing the points of view of many stakeholders, with constant change in content and often change in structure of that mass, while the set of stakeholders also changes over what may be many years of a system's life. Programming environments have evolved to address this need: structured editors, configuration management, database representations, graphical interfaces, and ways of coordinating work flow among, as well as work products of groups of system stakeholders. Particularly important are those assets that are viewed as worthy of use beyond their project context (e.g., software components, document templates, review guidebooks, error and productivity data). More research will be done in this area in the future.

(U) Thread in Practice

(U) Yet another thread in practice has been the greater attention forced onto the process aspects of system development: how an organization manages and improves its infrastructure and specific procedures. While the logic-based form of mathematical approaches to system description was maturing, so was another form: statistical reasoning about errors and growth of reliability over time, with the objective of introducing industrial quality control and assurance practices.

(U) Thus we have the setting for this study and the present report: mathematical techniques have been maturing for 25 years while non-mathematical techniques and general concerns for process have driven the practice. In the past five years, sparse anecdotal evidence indicated that formal methods were beginning to be used in industrial practice, leading to sponsorship of the present study to determine systematically and factually where these applications were occurring, why, and how the methods were being used.

(U) What Are Formal Methods?

(U) Definitions of formal methods abound. In the FM89 report (Craigen and Summerskill 1989), formal methods were defined as:

> "Methods that add mathematical rigor to the development, analysis, and operation of computer systems and to applications based thereupon."

> "...are nothing but the application of applied mathematics–in this case, formal logic–to the design and analysis of software-intensive systems."

(U) In more concrete terms, there has been a tendency, on the part of the formal methods community, to define formal methods in terms of a Hilbert-style axiomatization.

CLASSIFICATION

Classified right-hand text page

CLASSIFICATION

(U) PATTERN RECOGNITION ALGORITHM

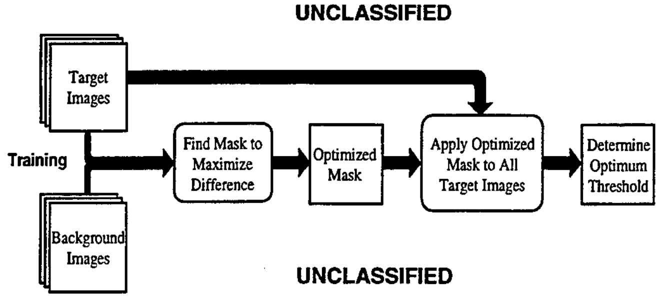
(U) Suppose we have a digitized $I \times J$ image g and that this is convolved with a mask or kernel k of size $(2N+1) \times (2N+1)$ to form an unscaled image h. The variables involved are defined by Table 1. The process of optimization, as shown in Fig. 1, comprises a search for the mask k_{opt} in a domain, or set of acceptable masks, K for which $f(G, k)$ is maximum.

Table 1 — (U) Definitions of Variables

Object	Format	Class*	Domain†
Original Image	$g = g(i, j)$	$g, i, j \in$ Z	$0 \leq g \leq G$ $1 \leq i \leq I$ $1 \leq j \leq J$
Convolution Mask	$k = k(m, n)$	k $\in$ R $m, n \in$ Z	$-K \leq k \leq K$ $-N \leq m \leq N$

*Z represents the set of all integers and R the set of all real numbers
†G is the maximum grey level in g, and K is the maximum absolute value for an element of k.

UNCLASSIFIED



UNCLASSIFIED

Fig. 1 – (U) Schematic diagram of autonomous target-detection system

(U) The convolution operation $h = g + k$ is commonly defined by

$$h(i,j) = \sum_{m=-N}^{N} \sum_{n=-N}^{N} g(i+m, j+n). \quad (1)$$

Where a mask is used as a feature detector (as in the current project), it is normal to apply the zero-sum constraint

$$\sum_{m=-N}^{N} \sum_{n=-N}^{N} k(m, n) = 0. \quad (2)$$

CLASSIFICATION

Classified figure and table

CLASSIFICATION

Appendix A

FORMAL METHODS TECHNIQUES (U)

(U) SOFTWARE COST REDUCTION (SCR)

(U) The description presented here is based on our understanding of the work performed at Ontario Hydro (on the Darlington shutdown system). This work includes evolutionary enhancements to (Henry 1978) by Parnas, his colleagues, and others.

(U) How the Method Works

(U) Representations Used

(U) Tabular representations of software requirements (described in a blackbox manner) and of program functions. In the latter case, the tables are called "program function tables" and, essentially, are "strongest post condition" descriptions of a procedure. The strongest post condition explicitly states how a variable is modified by a procedure. Also included are "linkage tables."

(U) The tabular approach to describing software requirements is derived from the work performed at NRL. For this reason, we call the approach "SCR-style." The derivation of program function tables and the use of proofs (described below) were not part of the initial work on the SCR.

(U) Steps Performed

(U) The Darlington project was generally a reverse engineering exercise. The code already existed when they developed the specifications and other tables. Proofs were required to demonstrate that a routine specification was equivalent to the program function description. Proofs were performed by hand, though it could be mechanized.

(U) Code linkage tables identify how the outputs of a program function table may be used as inputs to other program function tables. It is through code linkage tables that all the physical inputs and program variables that have an effect on a physical output are identified. Similar linkage tables exist for the specification. Hence, linkage tables help to modularize the descriptions of the specification and code.

(U) Interaction between asynchronous processes was viewed as interprocess I/O occurring via shared data objects. Each process had its own specifications and program function tables. Processes were analyzed separately and the process interaction was handled separately from program function table analysis.

(U) Tools Applied

(U) No specific tools exist to support the SCR-style of documentation. Tools are expected to be developed.

CLASSIFICATION

Classified appendix

CLASSIFICATION

This page
intentionally
left blank.

34

CLASSIFICATION

Blank page in a classified report

CLASSIFICATION

(This appendix is unclassified)

Appendix A

FORMAL METHODS TECHNIQUES

Unclassified appendixes to classified documents may be printed as separate documents if desired; page and item classification markings are omitted in this case. However, almost all appendixes are bound in the document and, having been bound together, remain together. Thus, an unclassified appendix in a classified document must bear page security markings reflecting the highest security classification used in the document. If the appendixes contain no classified material (such as headings, text, tables, and figures), they must begin on a right-hand page.

CLASSIFICATION

Unclassified appendix in a classified report–title page

Appendix

ADDITIONAL TYPOGRAPHICAL COMMENTS

PAPER SIZE 8.5 x 11 in.

FONTS

Use a Roman typeface such as Times Roman, New Times Roman, or CG Times. The use of bold and italic fonts of these typefaces is required to match the specified format.

Title	**TIMES ROMAN BOLD 12-POINT FULL CAPS**
Text	Times Roman 11 point
Heading Level 1	**TIMES Roman BOLD 11-POINT FULL CAPS**
Heading Level 2	**Times Roman Bold 11-point Initial Caps**
Heading Level 3	*Times Roman 11-point Italic*
Heading Level 4	**Times Roman Bold 11-point Initial Caps Indented**
Heading Level 5	Times Roman 11-point Indented Initial Caps—run in with paragraph.
Heading Level 6	Times Roman 11-point Indented Initial Cap of 1st word—run in with paragraph.
Header A—Author's name(s)	Times Roman10-point italic
Header B—Brief title	Times Roman 10-point italic
Figure captions	Times Roman 9 point
Table titles	Times Roman 11 point
Footer A—Manuscript approved	Times Roman 9 point

TABS AND INDENTS

Although tabs and indents may be adjusted to fit the requirements of the document, the following are recommended basic spacings for tabs and indents:

	Inches
1st	0.273
2nd	0.438
3rd	0.921
4th	1.175
5th	2.0
6th	2.75

JUSTIFICATION Full

SPACES

At end of sentence	Single space	
After a sequential number (e.g., 1., 2., 3., etc.)	Em-space	An em-space is equal to the type size in points. An em-space for 11-point type is

11 points wide, with no space before or after. (A double space is acceptable.)

DASHES

Hyphenation	Use a regular hyphen or dash	
After a figure number in a caption	Em-dash	An em-dash is equal to the type size in points. An em-dash for 11-point type is 11 points wide. Put a space before and after the em-dash.
To show a range	En-dash	An en-dash is half of an em dash.
Double dashes (--)	Use an em-dash (—).	

PAGE NUMBERING

Front matter	Lowercase Roman numerals centered at bottom of page 0.5 in. from bottom edge set in 11-point Times Roman.
Page 1 of text	Arabic "1" centered at bottom of page, 0.5 in. from bottom edge set in 11-point Times Roman.
All other text pages	Arabic numbers part of headers A and B set in 10 point Times Roman at outer margins: odd pages (header A) are flush right, even pages (header B) are flush left.
EXECUTIVE SUMMARY	Arabic numbers starting with E-1 centered at bottom of page 0.5 in. from bottom edge set in 11-point Times Roman.

MULTILINE FIGURE CAPTIONS

If a figure caption is two lines long, the second line is centered under the first caption line, *including the figure number*. If the figure caption is three or more lines long, the lines are typed full-figure width, same as the first line of the caption, *including the figure number*.

MULTILINE TABLE TITLES

If a table title is more than one line long, subsequent lines are centered under the complete first line of the title, *including the table number*.

PARAGRAPH NUMBERING

Paragraphs generally are not numbered. However, if paragraph numbering is required for reference purposes, then use the numeric decimal system as follows with an em-space between the number and the heading or text.