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Publications Branch
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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.

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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.**

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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 accurate 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.

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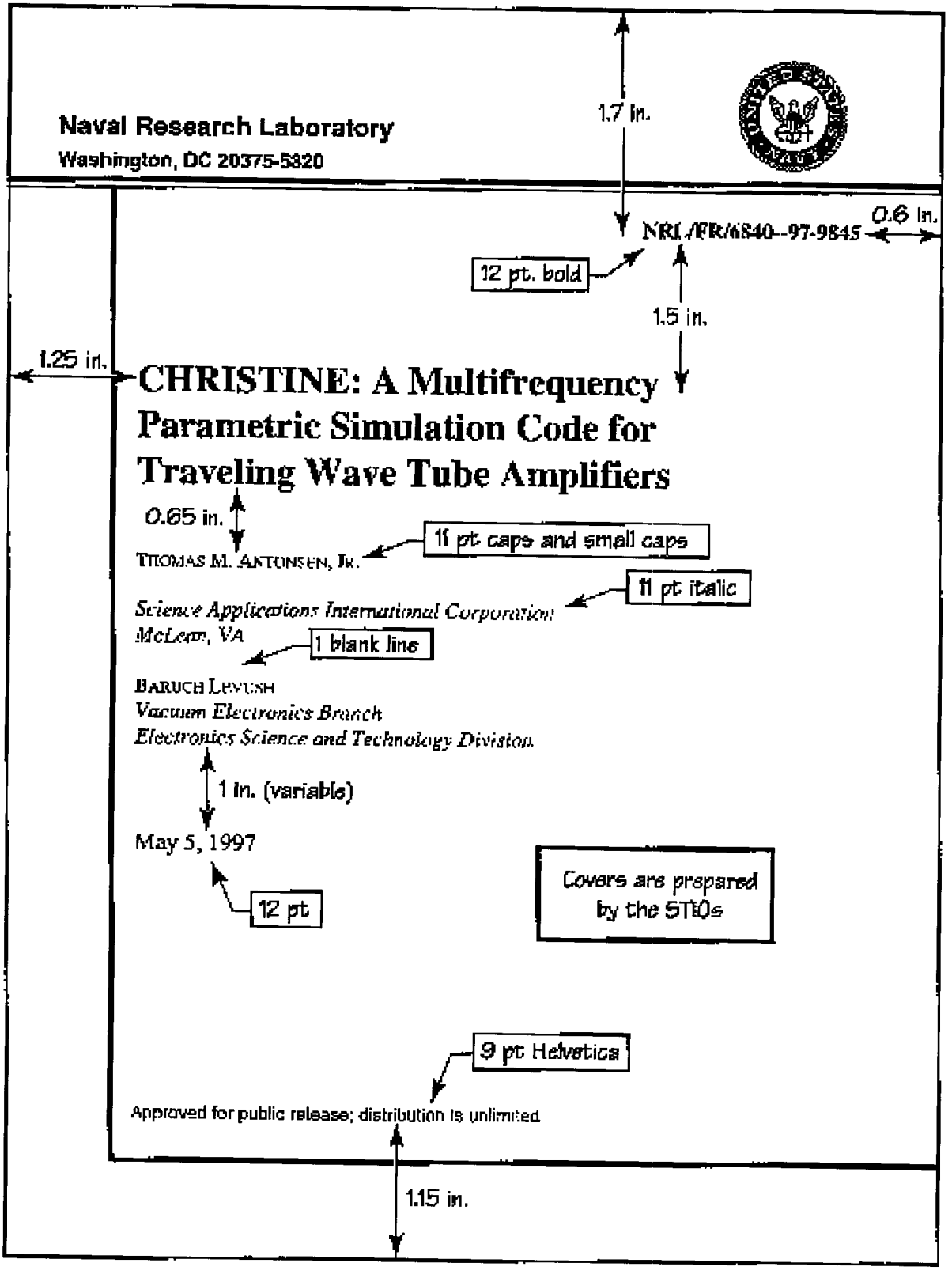
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13. ABSTRACT (Maximum 200 words)

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.

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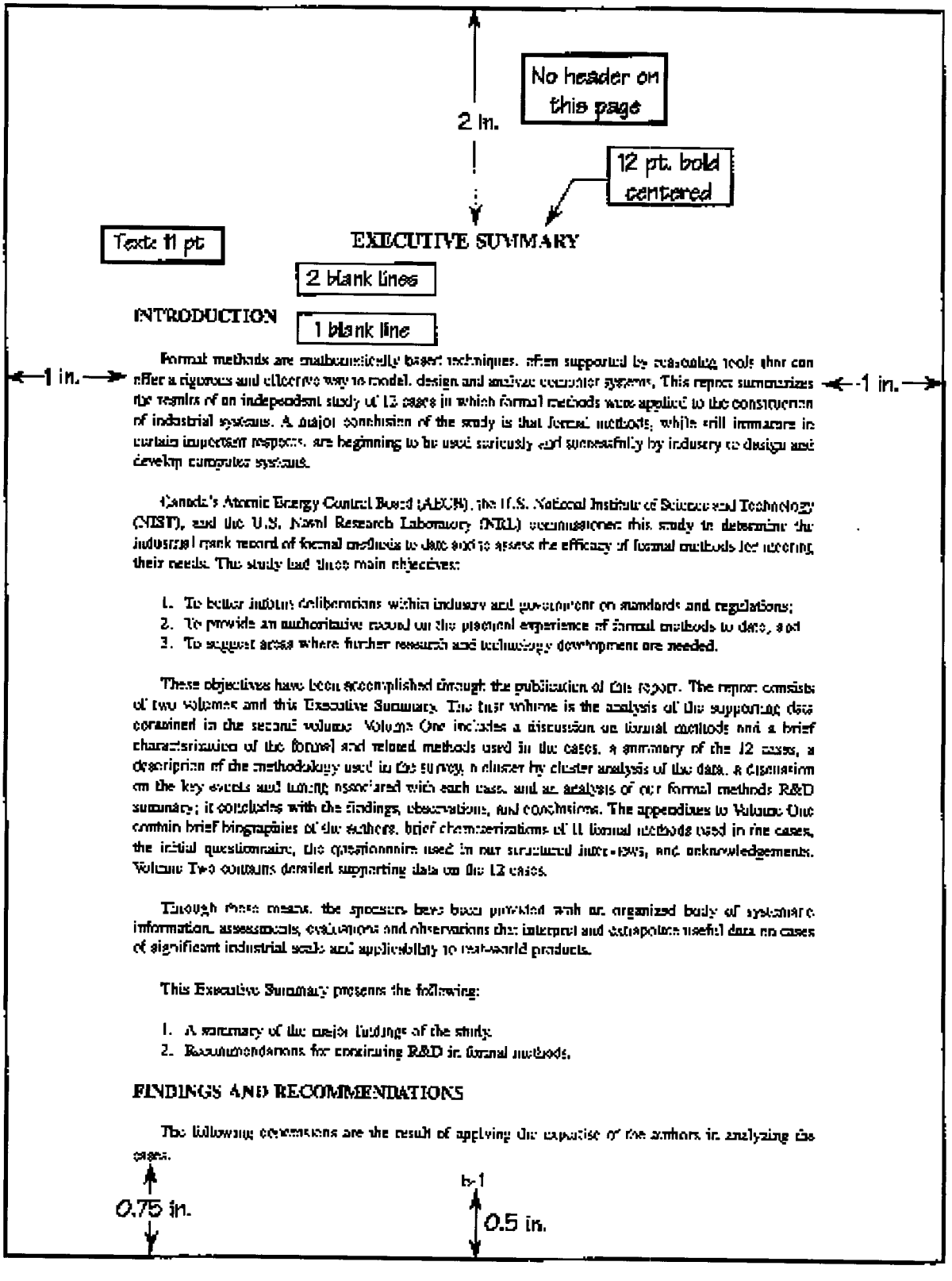

EXECUTIVE SUMMARY

INTRODUCTION

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 factors associated with each case, and an analysis of our formal methods R&D summary; it concludes with the findings, observations, and conclusions. The appendices 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.

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AN INTERNATIONAL SURVEY OF INDUSTRIAL APPLICATIONS OF FORMAL METHODS

VOLUME I
PURPOSE, APPROACH, ANALYSIS AND CONCLUSIONS

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INTRODUCTION

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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:

- 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. Rubin 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.

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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 stood: (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; manageable 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 (usually 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 have 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 developers. 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.

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1.3 in.

International Survey of Industrial Applications—Vol. 1 3

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). 1 in.

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 to 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 gradual attention focused 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: rigorous 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 formally 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:

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Right-hand text page

FIGURES

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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).

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

Table 1 — Definitions of Variables

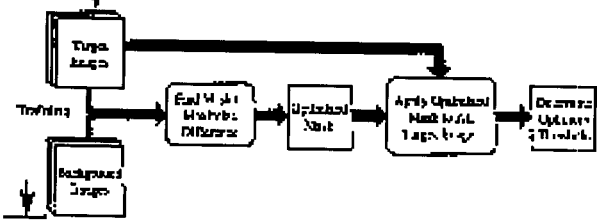
0.25 in.

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

*Compression set of all integers and R the set of all real numbers

†G is the maximum gray level in g, and K is the maximum absolute value on an element in k.

0.5 in.



0.25 in.

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

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0.5 in.

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

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

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

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

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:

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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.

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2 in.

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Appendix A

FORMAL METHODS TECHNIQUES

Text 11 pt

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SOFTWARE COST REDUCTION (SCR)

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The descriptions 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.

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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 LEVISH

Vacuum Electronics Branch
Electronics Science and Technology Division

May 5, 1997

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(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)
Emittance (U)
Axial velocity spread (U)
Beam conditioning (U)

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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 a rationale based 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 appendices 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 problems.

(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

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.

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(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] started 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 inferred 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

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International Survey of Industrial Applications Vol. I 3

(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 formally 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.

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(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.

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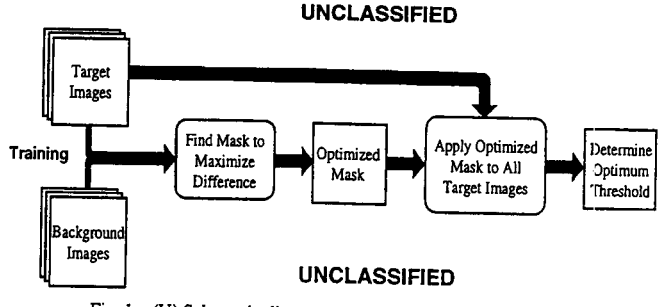

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Fig. 1 – (U) Schematic diagram of autonomous target-detection system

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

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

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

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

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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

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(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.

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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.

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Appendix

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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

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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.
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Double dashes (--)	Use an em-dash (—).	

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