

# axiom™



## The 30 Year Horizon

<i>Manuel Bronstein</i>	<i>William Burge</i>	<i>Timothy Daly</i>
<i>James Davenport</i>	<i>Michael Dewar</i>	<i>Martin Dunstan</i>
<i>Albrecht Fortenbacher</i>	<i>Patrizia Gianni</i>	<i>Johannes Grabmeier</i>
<i>Jocelyn Guidry</i>	<i>Richard Jenks</i>	<i>Larry Lambe</i>
<i>Michael Monagan</i>	<i>Scott Morrison</i>	<i>William Sit</i>
<i>Jonathan Steinbach</i>	<i>Robert Sutor</i>	<i>Barry Trager</i>
<i>Stephen Watt</i>	<i>Jim Wen</i>	<i>Clifton Williamson</i>

Volume 2: Axiom Users Guide

Portions Copyright (c) 2005 Timothy Daly

The Blue Bayou image Copyright (c) 2004 Jocelyn Guidry

Portions Copyright (c) 2004 Martin Dunstan

Portions Copyright (c) 1991-2002,  
The Numerical ALgorithms Group Ltd.  
All rights reserved.

This book and the Axiom software is licensed as follows:

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

- Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
- Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
- Neither the name of The Numerical Algorithms Group Ltd. nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT OWNER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

Inclusion of names in the list of credits is based on historical information and is as accurate as possible. Inclusion of names does not in any way imply an endorsement but represents historical influence on Axiom development.

Cyril Alberga	Roy Adler	Richard Anderson
George Andrews	Henry Baker	Stephen Balzac
Yurij Baransky	David R. Barton	Gerald Baumgartner
Gilbert Baumslag	Fred Blair	Vladimir Bondarenko
Mark Botch	Alexandre Bouyer	Peter A. Broadbery
Martin Brock	Manuel Bronstein	Florian Bundschuh
William Burge	Quentin Carpent	Bob Caviness
Bruce Char	Cheekai Chin	David V. Chudnovsky
Gregory V. Chudnovsky	Josh Cohen	Christophe Conil
Don Coppersmith	George Corliss	Robert Corless
Gary Cornell	Meino Cramer	Claire Di Crescenzo
Timothy Daly Sr.	Timothy Daly Jr.	James H. Davenport
Jean Della Dora	Gabriel Dos Reis	Michael Dewar
Claire DiCrescendo	Sam Dooley	Lionel Ducos
Martin Dunstan	Brian Dupee	Dominique Duval
Robert Edwards	Heow Eide-Goodman	Lars Erickson
Richard Fateman	Bertfried Fauser	Stuart Feldman
Brian Ford	Albrecht Fortenbacher	George Frances
Constantine Frangos	Timothy Freeman	Korrinn Fu
Marc Gaetano	Rudiger Gebauer	Kathy Gerber
Patricia Gianni	Holger Gollan	Teresa Gomez-Diaz
Laureano Gonzalez-Vega	Stephen Gortler	Johannes Grabmeier
Matt Grayson	James Griesmer	Vladimir Grinberg
Oswald Gschnitzer	Jocelyn Guidry	Steve Hague
Vilya Harvey	Satoshi Hamaguchi	Martin Hassner
Ralf Hemmecke	Henderson	Antoine Hersen
Pietro Iglio	Richard Jenks	Kai Kaminski
Grant Keady	Tony Kennedy	Paul Kosinski
Klaus Kusche	Bernhard Kutzler	Larry Lambe
Frederic Lehotobey	Michel Levaud	Howard Levy
Rudiger Loos	Michael Lucks	Richard Luczak
Camm Maguire	Bob McElrath	Michael McGettrick
Ian Meikle	David Mentre	Victor S. Miller
Gerard Milmeister	Mohammed Mobarak	H. Michael Moeller
Michael Monagan	Marc Moreno-Maza	Scott Morrison
Mark Murray	William Naylor	C. Andrew Neff
John Nelder	Godfrey Nolan	Arthur Norman
Jinzhong Niu	Michael O'Connor	Kostas Oikonomou
Julian A. Padget	Bill Page	Jaap Weel
Susan Pelzel	Michel Petitot	Didier Pinchon
Claude Quitte	Norman Ramsey	Michael Richardson
Renaud Rioboo	Jean Rivlin	Nicolas Robidoux
Simon Robinson	Michael Rothstein	Martin Rubey
Philip Santas	Alfred Scheerhorn	William Schelter
Gerhard Schneider	Martin Schoenert	Marshall Schor
Fritz Schwarz	Nick Simicich	William Sit
Elena Smirnova	Jonathan Steinbach	Christine Sundaresan
Robert Sutor	Moss E. Sweedler	Eugene Surowitz
James Thatcher	Baldir Thomas	Mike Thomas
Dylan Thurston	Barry Trager	Themos T. Tsikas
Gregory Vanuxem	Bernhard Wall	Stephen Watt
Juergen Weiss	M. Weller	Mark Wegman
James Wen	Thorsten Werther	Michael Wester
John M. Wiley	Berhard Will	Clifton J. Williamson
Stephen Wilson	Shmuel Winograd	Robert Wisbauer
Sandra Wityak	Waldemar Wiwianka	Knut Wolf
Clifford Yapp	David Yun	Richard Zippel
Evelyn Zoernack	Bruno Zuercher	Dan Zwillinger



# Contents

0.1 Makefile . . . . .	1
------------------------	---

## New Foreword

On October 1, 2001 Axiom was withdrawn from the market and ended life as a commercial product. On September 3, 2002 Axiom was released under the Modified BSD license, including this document. On August 27, 2003 Axiom was released as free and open source software available for download from the Free Software Foundation's website, Savannah.

Work on Axiom has had the generous support of the Center for Algorithms and Interactive Scientific Computation (CAISS) at City College of New York. Special thanks go to Dr. Gilbert Baumslag for his support of the long term goal.

The online version of this documentation is roughly 1000 pages. In order to make printed versions we've broken it up into three volumes. The first volume is tutorial in nature. The second volume is for programmers. The third volume is reference material. We've also added a fourth volume for developers. All of these changes represent an experiment in print-on-demand delivery of documentation. Time will tell whether the experiment succeeded.

Axiom has been in existence for over thirty years. It is estimated to contain about three hundred man-years of research and has, as of September 3, 2003, 143 people listed in the credits. All of these people have contributed directly or indirectly to making Axiom available. Axiom is being passed to the next generation. I'm looking forward to future milestones.

With that in mind I've introduced the theme of the "30 year horizon". We must invent the tools that support the Computational Mathematician working 30 years from now. How will research be done when every bit of mathematical knowledge is online and instantly available? What happens when we scale Axiom by a factor of 100, giving us 1.1 million domains? How can we integrate theory with code? How will we integrate theorems and proofs of the mathematics with space-time complexity proofs and running code? What visualization tools are needed? How do we support the conceptual structures and semantics of mathematics in effective ways? How do we support results from the sciences? How do we teach the next generation to be effective Computational Mathematicians?

The "30 year horizon" is much nearer than it appears.

Tim Daly  
CAISS, City College of New York  
November 10, 2003 ((iHy))

## 0.1 Makefile

This book is actually a literate program[2] and can contain executable source code. In particular, the Makefile for this book is part of the source of the book and is included below. Axiom uses the “noweb” literate programming system by Norman Ramsey[6].

```
<*)≡
PROJECT=bookvol2
TANGLE=/usr/local/bin/NOTANGLE
WEAVE=/usr/local/bin/NOWEAVE
LATEX=/usr/bin/latex
MAKEINDEX=/usr/bin/makeindex

all:
    ${WEAVE} -t8 -delay ${PROJECT}.pamphlet >${PROJECT}.tex
    ${LATEX} ${PROJECT}.tex 2>/dev/null 1>/dev/null
    ${MAKEINDEX} ${PROJECT}.idx
    ${LATEX} ${PROJECT}.tex 2>/dev/null 1>/dev/null
```



# Bibliography

- [1] Jenks, R.J. and Sutor, R.S. “Axiom – The Scientific Computation System” Springer-Verlag New York (1992) ISBN 0-387-97855-0
- [2] Knuth, Donald E., “Literate Programming” Center for the Study of Language and Information ISBN 0-937073-81-4 Stanford CA (1992)
- [3] Daly, Timothy, “The Axiom Wiki Website”  
<http://axiom.axiom-developer.org>
- [4] Watt, Stephen, “Aldor”,  
<http://www.aldor.org>
- [5] Lamport, Leslie, “Latex – A Document Preparation System”, Addison-Wesley, New York ISBN 0-201-52983-1
- [6] Ramsey, Norman “Noweb – A Simple, Extensible Tool for Literate Programming”  
<http://www.eecs.harvard.edu/~nr/noweb>
- [7] Daly, Timothy, ”The Axiom Literate Documentation”  
<http://axiom.axiom-developer.org/axiom-website/documentation.html>