



Charter Document

Important Information

Notice

The Numerical Mathematics Consortium Charter Document is authored by the Numerical Mathematics Consortium member companies. For a membership roster list, please visit the consortium's web site at www.nmconsortium.org.

The Numerical Mathematics Consortium wants to receive your comments on this specification. You can contact the foundation via e-mail at info@nmconsortium.org, via the web site at www.nmconsortium.org or you can write to the Numerical Mathematics Consortium, Mail Stop : 8S.E09, 11500 N. Mopac Expressway, Austin, Texas, 78759-3504.

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Numerical Mathematics Consortium Charter Document

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Numerical Mathematics Consortium Charter Revision History

This section is an overview of the revision history of the Numerical Mathematics Consortium Charter Document.

Executive Summary

Algorithms – The Backbone of Technical Professionals

Numerical algorithms form the backbone of many technical pursuits. From advanced research projects to industrial applications, algorithms provide the brains to problem-solving engines. Many engineers, scientists, and researchers spend months, years, even entire careers developing and honing algorithms in efforts to provide breakthrough innovation or create a better world around us.

It is this huge investment in intellectual property that the Numerical Mathematics Consortium (NMC) seeks to preserve by standardizing on a core set of mathematical functions applicable to numerical algorithms. With so much value placed in numerical algorithms, it is critical to allow the work of these technical professionals to be maintained across platforms, tools, and environments, without spending a significant amount of valuable time in “porting” or re-developing them.

Standards – A Must for Portability and Compatibility

Scientists and engineers have a plethora of tools at their disposal to help streamline the process of creating, optimizing, visualizing, translating, or targeting key algorithms needed for their work. Whether analyzing how different materials dissipate heat, or controlling an automobile’s engine performance with code running on an ECU, much of this work can leverage a basic set of numerical functions and libraries. However, each of the current numerical tools and platforms have created their own set, even for the most common and core functions, which makes it very difficult for users to move their algorithms from one tool or platform to another. With rapidly converging technologies in the products we use today, while combining electronics, mechanical, physical, and multi-physics elements, designers must be able to freely use tools that specialize in these different domains during the process of bringing their product to market. Without standard function definitions, engineers are trapped in their current tool or platform with no hope of leveraging the best aspects of each tool without long and arduous rewriting of their algorithms.

The Numerical Mathematics Consortium is a group of vendors, professors, and users committed to eliminating this unnecessary reworking of algorithms. By standardizing the semantics of functions, inputs and outputs will have the same meaning and order in any compliant application. While the syntax may change among compliant applications, a developer well versed in the syntax of multiple products will no longer have to concern himself with the details of parameter ordering and behavior. Developers will have an easier time moving algorithms across platforms during a development cycle. This will empower users to choose the best tool for a particular problem and mix and match tools without worrying about all the difficulties of learning a new product. Vendors can retain their intellectual property without having to conform to a specific implementation, as well as keep the advantages their individual environments provide for specific application domains.

How Did We Get Here?

Algorithm design tools have not always been so fragmented. In fact, when FORTRAN was invented and released commercially as the first high-level programming language in 1957, scientists and engineers had a jumpstart on everyone else. FORTRAN, or Formula Translation,

was specifically designed to allow easy translation of mathematical formulas into code. Several years after its release, FORTRAN had developed many different variations, making it very difficult to transfer programs. These problems led the American Standards Association, or ASA (now known as the American National Standards Institute, or ANSI) to release its first “Standard for a Programming Language” in 1966. This first standardized version came to be known as FORTRAN ‘66 (also FORTRAN IV). Despite this standardization, a few years later, various new versions began to surface again, requiring the ASA to review the language again. This version was known as FORTRAN ‘77. One of the major reasons for the large-scale adoption and success of FORTRAN was attributed to its standardization.

As modern numerical programming languages have replaced FORTRAN as the language of choice, and as new interactive design and development tools were introduced over the years, the standardized representation of common functions began to disperse again. The problem is as simple as looking at the Fast Fourier Transform (FFT) function:

```
MathCAD
t := 0..127
x := sin(2·p·.01·t)
w :=fft(x)
```

```
MATLAB
t = 0:127
x = sin(2*pi*.01*t)
w = fft(x)
```

Size of w:
MathCAD = 65
MATLAB = 128

As in this case, even if the syntax is identical, the calculations yield different results!

By definition, the FFT function produces a result where the second half of the data is the complex conjugate of the first half. MathCAD uses this and only returns the first half of the data (i.e. $N/2 + 1$). MATLAB returns all of the data (N). Both are valid interpretations.

The Numerical Mathematics Consortium is proposing a semantic standard for core numerical functions so as to help solve issues such as this.

There have been some attempts in the past to solve this problem, and some real progress has been made in specific areas. Linear Algebra PACKage (LAPACK) and Basic Linear Algebra Subroutines (BLAS) have become de facto standards for linear algebra routines.

The Numerical Mathematics Consortium’s objective is to replicate the past standardization success of FORTRAN and scale the more recent success of LAPACK & BLAS onto a broader set of numerical mathematics functional areas that will make the portability and reuse of numerical algorithms easy.

MATLAB® is a registered trademark of The MathWorks, Inc.

Introduction

During 2004 and early 2005, a number of customers and math vendors expressed an interest in standardizing on numerical mathematics to enable portability of algorithms. An initial working group put together a draft technical scope and charter document which received good reactions from both the vendor and user communities. This group has evolved into a formal working group, the Numerical Mathematics Consortium (NMC), with the purpose of promoting standardization of core numerical mathematics. NMC membership is open to users and vendors interested in these issues. Those interested in joining the consortium can contact any member companies or the consortium itself.

What is the Numerical Mathematics Consortium?

The Numerical Mathematics Consortium is an organization whose members share a common commitment to numerical algorithm development through open mathematical semantics standardization. The Numerical Mathematics Consortium will focus on the areas of core mathematical definitions, algorithm interchangeability, and function semantics. The Numerical Mathematics Consortium will not focus on standardizing syntax for a particular mathematical language.

Common Mathematical Functionality

Many mathematical functions exist for use in numerical algorithms. The Numerical Mathematics Consortium will identify function classes based on the most common functionality and usage available today. Initial classes have been selected based on importance and popularity in common mathematical applications. In the future, additional classes will be identified and defined. A number of functions are limited to very specialized disciplines. Such functions are not included in the core mathematical functionality.

The current list of core function classes within the scope of the NMC are:

APPROXIMATION	<u>Approximation, Integration and Interpolation</u> perform estimation calculations.
BITWISE	<u>Bit-oriented Functions</u> manipulate the bits of given bit-patterns.
BOOLEAN	<u>Boolean Functions</u> manipulate the Boolean content of variables.
COMPARISON	<u>Relational Operators</u> compare numbers and matrices.
CONSTANTS	<u>Constants</u> reference known data type states useful in manipulating and evaluating expressions.
ELEMENTARY	<u>Elementary Functions</u> consist of exponential, trigonometric and other basic functions.
LINALGEBRA	<u>Linear Algebra</u> encapsulates the manipulation of real and complex matrices.
MATRIXGEN	<u>Matrix Generation</u> reference special matrix structures and content.

MATRIXOPS	<u>Matrix Operators</u> generate new matrices using unitary and binary matrix functions.
MEMBERSHIP	<u>Membership Functions</u> determine if elements belong to a given class of objects.
POLYNOMIALS	<u>Polynomial Functions</u> generate or manipulate polynomials and polynomial roots.
PROGRAMMING	<u>Programming Constructs</u> build complex scripts.
SETOPS	<u>Set Operators</u> manipulate groups of numeric data.
SPECIAL	<u>Special Functions</u> compute Airy, Bessel, beta, elliptic, and other functions.
STATISTICS	<u>Statistic Functions</u> facilitate statistical analysis.
STRING	<u>String Functions</u> manipulate, generate, search for, and convert strings.
SUPPORT	<u>Support Functions</u> manage folders and convert, display, and manage variables.
TIME	<u>Date and Time Functions</u> generate or return information about dates and times.
TIMING	<u>Timing Functions</u> analyze the duration of operations.
VECTOR ANALYSIS	<u>Vector Analysis</u> produce vectors from vectors or matrices.

Standardize Semantics, Not Syntax

The Numerical Mathematics Consortium will standardize the semantics of common mathematical functions. Function behavior will be defined, as will the number, order, and meaning of the parameters. Data types will be defined only to the degree that each function requires. Other data type details will be left to each particular implementation. A particular syntax will not be specified or even required. Semantics will be specified wherever possible without suggesting any particular implementation. However, a recommended implementation may be provided in some cases.

Interchangeability of Algorithms

The goal of the Numerical Mathematics Consortium is to reduce the overall cost of numerical algorithm development in different disciplines. By standardizing the function semantics, inputs and outputs will have the same meaning in any compliant application. While the syntax may change among compliant applications, a developer well versed in the syntax of multiple products will no longer have to concern himself with the minutia of parameter ordering and behavior. A colleague reading an algorithm in a particular syntax with which he is unfamiliar will have a much greater chance of understanding the objective at a mathematical level. Developers will have an easier time moving algorithms across platforms (for example, from desktop to embedded) during a development cycle. However, it is not a goal to provide binary compatibility among the compliant applications. Even the simple action of recompiling source code with a different compiler may result in the application producing different results. LAPACK and BLAS which are successful standards also do not require binary compatibility.

Charter

The charter of the Numerical Mathematics Consortium is to define standard specifications for mathematical functions. The focus of the consortium is to define a common set of mathematical functions applicable for most disciplines and on algorithm exchange facilitated by well-known function semantics in different applications. When multiple choices exist for a function definition, the consortium will avoid function ambiguities by choosing the one most consistent with other functions of a particular class. The semantics of functions will be consistent with their data types.

Through this charter, the Numerical Mathematics Consortium will build on the standards presented to develop a mathematical community where ideas and information exchange are supported by a common vocabulary. This will allow users to choose the best tool for a particular problem without worrying about all the difficulties of learning a new product. Vendors will be able to retain IP without having to conform to a specific implementation, and maintain the advantages that their individual environments provide for specific application domains.

Benefits

1. Portability, consistency, and usability

The Numerical Mathematics Consortium will offer a set of function classes and functions, including parameter definitions and algorithm specifics (when appropriate). The cost to maintain algorithms across educational, research, development, prototype, and deployment disciplines will be reduced significantly. The sharing of algorithms among a community of users, disciplines, and platforms will also increase.

2. Standard core math functionality focus

The Numerical Mathematics Consortium will focus almost entirely on core functionality. The consortium will identify function classes and functions based on the most common functionality and usage available today. That will allow many vendors to comply with specifications published by the consortium. Classes of functions that are limited to a very specialized audience will not be included in the core.

3. Universal numerical math functionality through well-specified semantics

By focusing on the semantics of math functions, the consortium will be able to propose a universal numerical math environment. Abstracting away the syntax will be beneficial to all members of the consortium and to users as well. All consortium members will still have all degrees of freedom to implement a specific instance of a function. Moreover, focusing on semantics, including definitions and references to algorithms, will reduce the overall cost of numerical algorithm development. Users will have to learn the meaning of specific functions and the parameter definition only once.

4. Platform independence

Numerical algorithms are very important for a growing number of applications. They are found in mathematical packages running on standard operating systems, as part of engineering software solutions, even in office packages (spreadsheets, for example) and a growing number of embedded systems that rely heavily on numerical algorithms. All of these applications will benefit from a platform-independent definition of numerical mathematics. That is true for both horizontal compatibility (for example, among math packages) and vertical compatibility (for example, math packages mapped onto embedded platforms). The latter would allow developers of embedded systems to use standard math packages very early in the design cycle without experiencing a paradigm shift when the transition from pure software solutions to hardware centric implementations happens.

5. Synchronization with existing/de facto standards

Many core functions are related to existing IEEE standards or de facto standards such as LAPACK. Typically, existing math packages refer to and use these standards. The consortium will seek to protect these investments by making the integration of existing packages easy. For example, the semantics of linear algebra functions will be defined in such a way that the mapping onto LAPACK is straightforward and easy.

Guiding Principles

The Numerical Mathematics Consortium has identified 10 guiding principles to drive the activities of the group. These guiding principles represent the commitment of the member companies to each other and to end users. The guiding principles are:

1. Maximize software reuse through interchangeable function definitions.

The goal of the Numerical Mathematics Consortium is to reduce the overall cost of numerical algorithm development in different disciplines.

2. Identify and support core functionality.

The Numerical Mathematics Consortium will focus on core functionality only. The term “core functionality” means that functions or algorithms recommended by the consortium are likely to be found in typical applications that require numerical mathematics. Excluded are very advanced special functions, functions that are related to symbolic computations, and functions that are used exclusively in very specialized fields, to name a few. The boundaries are not static here and the set of core functions will almost certainly grow over time.

3. Focus on the semantics of math functionality.

The Numerical Mathematics Consortium will focus on the semantics of the common mathematical functions. Function behavior will be defined, as will as the number, order, and meaning of the parameters. A particular syntax will not be specified or even required. Semantics will be specified wherever possible without suggesting any particular implementation.

4. Maintain long-term compatibility with installed base.

By standardizing the semantics of functions, inputs and outputs will have the same meaning and order in any compliant application. The Numerical Mathematics Consortium will make sure to define core function semantics in such a way that changes over time will not be necessary.

5. Synchronize with existing/de facto standards.

The Numerical Mathematics Consortium will embrace and support well-established standards and/or de facto standards. As an example, functionality that addresses linear algebra or special matrices is tightly connected to LAPACK functionality. The consortium will not refer to LAPACK directly, but will instead provide semantics that allow for straightforward mapping onto LAPACK. Existing math packages follow a similar approach already.

6. Let algorithm and function requirements drive the core features.

The definition of core features will not be based on abstract mathematical concepts. The Numerical Mathematics Consortium will identify function classes and functions based on the most common functionality and usage available today. Sources for that identification process are:

- existing numerical math packages and other software that requires numerical math
- requirements defined by the industry or educational sectors
- textbooks and other publications
- established/de facto standards such as LAPACK

7. Avoid defining yet another scripting language to be executed.

The Numerical Mathematics Consortium will intentionally avoid defining yet another scripting language. The emphasis will be on the semantics of core functionality. The core functionality will not have to be implemented in a textual language; graphical programming languages and other paradigms are equally valid. Any semantics will be specified wherever possible without suggesting any particular implementation.

8. Discuss emerging technologies and check their importance for the consortium.

The Numerical Mathematics Consortium will maintain a catalog of emerging technologies that are relevant to numerical math functionality. The broad spectrum of these topics ranges from advanced, processor-specific issues to high-level problems such as the potential use of MathML and OpenMath for numerical math. It is the goal of the consortium to identify such topics early enough to participate in the process. Other examples are LAPACK and sparse LAPACK.

9. Define data types and syntax only to the degree that each function requires.

Data types will not be defined in a strong theoretical sense. Data type details will be left to each particular implementation. The range of recommended data types might grow over time, and the need might arise to add more sophisticated data types (for examples, sparse matrices in conjunction with sparse matrix functions, rational polynomials, matrices of rational polynomials, or more sophisticated structures based on standard data types).

10. Leave enough room for vendor IP and UIs.

It is not the goal of the Numerical Mathematics Consortium to be too restrictive regarding specific implementations. On the contrary, by focusing on semantics alone, the consortium seeks to make it easier for vendors to generate NMC-compliant implementations. Vendor IP of any kind will remain untouched (for example, highly optimized implementations for special functions), and there will be virtually no requirements regarding the user interface. For instance, the consortium will not recommend specific plot functionality or any textual output formats. Given the fact that the consortium seeks to address a very broad range of applications – among them embedded ones – it would not make sense to exclude vendors who want to focus on such platforms by insisting on plot functions.

Liaisons to Standards Groups

Numerical Mathematics Consortium members recognize ongoing efforts by other standards groups regarding mathematics. The consortium will identify key personnel to act as liaisons to these standards bodies to encourage cooperation and compatibility where possible by providing technical information and feedback. The key organizations identified at this time include:

- MathML
- OpenMath

Future Directions

Numerical Mathematics Consortium members will meet actively to review core numerical mathematics specifications and maintain progress on new specifications and other associated utility and quality assurance mechanisms.

At appropriate times, focused working groups will be formed to address specific technical issues, such as:

- Identifying the complete list of functions and function categories
- Developing specifications for semantics of the core functions
- Defining compliance and validation procedures
- Establishing mechanisms for reporting compliance issues
- Developing specifications for adjacent areas to the core
- Facilitating portability of NMC-compliant algorithms between applications
- Investigating error propagation

Membership

The founding members are companies that understand the need for numerical mathematics standardization and have already invested significant time and effort into solving these issues on their own. Each of these members has extensive experience in numerical mathematics as a business for external customers or for internal needs.

NMC membership is open to other interested parties who wish to take an active role in standardizing numerical mathematics. The consortium will openly promote vendors, developers, and users who support the standards and are compliant with the specifications.

There are three types of membership. The Full Membership with voting rights are for those companies who want to actively participate in the consortium and typically targets the vendor community (\$2,500 annual fee). The Associate Membership with no voting rights will have full access to the consortium's output and be engaged in some of the consortium's activities and is typically for the user community, both academia and industry (\$200 annual fee). The Advisory Membership is for those who want to support and endorse the consortium without actively participating in its activities (no fee). This membership is by invitation only. To apply for membership, simply fax or mail a completed application form to the group.

Much of the business planning, preparation and dissemination of information will be conducted through electronic channels (e-mail and the web). The Web site (www.nmconsortium.org) will also be updated regularly with the latest NMC information.

Membership Responsibilities

Numerical Mathematics Consortium members will be expected to take an active role in defining, reviewing, and testing numerical mathematics specifications, as appropriate to their membership type. Specific activities include:

- Sending representatives to quarterly general meetings and periodic working group meetings
- Reviewing specifications
- Developing and/or beta testing implementations based on the specification for general usage and distribution
- Providing feedback on real-world usage to continuously improve the specifications
- Acting as a liaison to other industry groups involved in similar or related efforts

History and Rationale

One of the most prominent specifications impacting numeric algorithms in the last few decades is the IEEE Standard for Binary Floating-Point Arithmetic (IEEE 754), which blended a collection of requirements and definitions that transcended software and hardware. To solve existing problems, the authors abandoned prior art in favor of a clear, consistent, and manageable approach to the fundamental issues in numeric programming.

The original goal of the LAPACK project was to make the widely used EISPACK and LINPACK libraries run efficiently on shared-memory vector and parallel processors. It has since become a de facto standard for numerical math applications. Several vendors have created hardware-optimized libraries for LAPACK to use for optimal performance on a particular platform. Due to this well-adopted presence, the goal of the Numerical Mathematics Consortium is to leverage LAPACK as much as possible. (For more information on LAPACK, visit www.netlib.org/lapack.)

When providing guidance on mathematical application development – and more specifically, numeric algorithm development based on well-defined mathematical principles – the goals defining the scope of those recommendations are similar in most respects. Several attempts to specify math functionality over the last 15 years have either faded or lacked universal backing, but the efforts in this direction allude to their necessity and utility. In some sense, industry has already confirmed this, with consumers relying on a relatively small set of math development environments to generate math-intensive numeric algorithms.

As with IEEE 754, the Numerical Mathematics Consortium will favor breadth over depth to facilitate the diverse classes of applications that depend on a core fundamental set of math functionality. It is important to get alignment on a core set that will be used widely across disciplines. Targeting a particular discipline specifically improperly weights non-universal math functionality. Focusing on a specific audience often skews the definition of common functionality on basic data types, and may even exclude others which have broader applicability. Additionally, in this specification, details define the behavior of the math-based algorithms rather than stipulate individual implementations.

To allow for portability, some components in this document require definitions not based purely on mathematics. For example, the order of input parameters to a function is not always defined by the math being instituted. For these cases, consistency is the highest priority so that usability is maximized. When uniformity is not an issue, existing specifications and industry-based math packages will be leveraged to maximize the universality.

Development of numerical algorithms is time consuming and requires special knowledge of a problem and its underlying mathematics. For this reason, this document incorporates standard approaches to solving numerical problems. In fact, it embraces many of the practices that have been used in industry for more than a decade. Since these practices were not enforced at a higher level, some evolved for vertical markets, thus diminishing their applicability to broader domains. Whenever possible, the NMC specification will reverse those trends in order to serve the larger community.

At the heart of efficient algorithm development is the existence of building blocks encapsulating tedious but fundamental operations. In math-based numerical algorithms, this constitutes a collection of math functions used across multiple application fields. To properly specify these functions, definitions are provided for:

- the interface to standard functions encapsulating fundamental math algorithms
- the syntactic and semantic infrastructures for packaging and integrating the common math-based functionality
- the fundamental data types necessary to propagate results

While an incredible amount of detail is possible in defining particular math syntax, semantics, or data types, the scope of the Numerical Mathematics Consortium is limited to the needs of the function interface definitions. This enables portability of both functions and data without sacrificing implementation flexibility.

Numerical Mathematics Consortium

Full Membership Application



Note: *Please note that this applies to a company/institution only. Please attach to this application a brief (one page or less) description why your company /institution wants to join the Numerical Mathematics Consortium.*

Dear Numerical Mathematics Consortium Members,

My company is interested in numerical mathematics standardization. We build products or systems leveraging numerical mathematics and have experience in or the need for leveraging the numerical math specification. We have read the NMC Charter Document and agree with the scope, benefits, and purpose outlined. By submitting this application, my company is officially applying for a voting membership in the Numerical Mathematics Consortium. We intend to send representatives to NMC workshops, review all numerical math specifications, build products leveraging the NMC specification, support NMC concepts in industry standardizations, and publicly endorse the NMC specifications. We understand that there is a \$2,500 annual membership fee and that administrative costs of the consortium that exceed the annual membership fees and that are approved by the General Membership Meeting will be divided equally and paid for by the Full Membership. We also understand we will have one vote.

Company Name: _____

Company Address: _____

Company Web Page: _____

Name: _____ **Signature:** _____

Phone: _____ **Fax:** _____ **Date:** _____

Title: _____

Official Company Contacts:

Voting Contact – Name: _____ Phone: _____

Title: _____ Fax: _____

Address: _____ E-mail: _____

Marketing – Name: _____ Phone: _____

Title: _____ Fax: _____

Address: _____ E-mail: _____

Technical – Name: _____ Phone: _____

Title: _____ Fax: _____

Address: _____ E-mail: _____

Mail or fax this application (with attached company information) to:

Numerical Mathematics Consortium

Mail Stop: 8S.E09

11500 N. Mopac Expwy.

Austin, Texas 78759

Fax: 512-683-5500

Official Use Only—Approval Date: _____

Numerical Mathematics Consortium Associate Membership Application



Note: *Please note that this applies to an individual or a company/ institution. Please attach to this application a brief (one page or less) description of yourself or your company/ institution and why you want to join the Numerical Mathematics Consortium.*

Dear Numerical Mathematics Consortium Members,

I and/or my company or institution am/are interested in numerical mathematics standardization. We implement systems for internal or external use and have experience or a need for leveraging the numerical math specification. I have read the NMC Charter Document and agree with the scope, benefits, and purpose outlined. By submitting this application, I and/or my company or institution officially apply for an associate membership in the Numerical Mathematics Consortium. I intend to attend NMC workshops, review all numerical math specifications, build products leveraging the NMC specification, support NMC concepts in industry standardizations, and publicly endorse the NMC specifications. I understand that there is a \$200 annual membership. I also understand that this membership does not have any voting rights.

Individual Name: _____

Company/Institution Name: _____

Address: _____

Web site: _____

Signature: _____ **Date:** _____

Phone: _____ **Fax:** _____

Title: _____

Official Contacts (if different than above):

Marketing – Name: _____ Phone: _____

Title: _____ Fax: _____

Address: _____ E-mail: _____

Technical – Name: _____ Phone: _____

Title: _____ Fax: _____

Address: _____ E-mail: _____

Mail or fax this application (with attached company information) to:

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Official Use Only—Approval Date: _____

