Engineering and Scientific
Subroutine Library Products

IBM

General Information

GC23-0529-06

Engineering and Scientific
Subroutine Library Products

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Notes!

Special Notices are included in “Special Notices” on page v.

Seventh Edition (October 1999)

This major revision replaces GC23-0529-05 and renders it obsolete. This edition applies to the following:

- IBM* Parallel Engineering and Scientific Subroutine Library (Parallel ESSL) for Advanced Interactive Executive (AIX*), program number 5765-C41
- IBM Engineering and Scientific Subroutine Library for AIX (ESSL), program number 5765-C42
- IBM Engineering and Scientific Subroutine Library: Vector and Scalar/370 (ESSL/370), program number 5688-226

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Acknowledgement: The Parallel Basic Linear Algebra Subprograms (BLAS), Linear Algebra Equations, and Eigensystem Analysis and Singular Value Analysis routines in Parallel ESSL are based on the Scalable Linear Algebra Package (ScaLAPACK) public domain offering. ScaLAPACK is a scalable linear algebra

library for distributed memory concurrent computers. The library was jointly developed by the University of Tennessee, Knoxville, Oak Ridge National Laboratory, and the University of California, Berkeley, and is available from Professor Dongarra, Computer Science Department, the University of Tennessee.

Abbreviated Names: The abbreviated names used in this book are defined below.

Short Name	Full Name
AIX	Advanced Interactive Executive
BLACS	Basic Linear Algebra Communication Subprograms
BLAS	Basic Linear Algebra Subprograms
CBIPO	MVS Custom-Built Installation Process Offering
CMS	Conversational monitor system
ESSL	Engineering and Scientific Subroutine Library for AIX
ESSL/370	Engineering and Scientific Subroutine Library: Vector and Scalar/370
FDDI	Fiber Distributed Data Interface
HPF	High Performance Fortran
HTML	Hypertext Markup Language
ICA	Intercompilation analysis
IP	Internet Protocol
IVP	Installation Verification Programs
LAPACK	Linear Algebra Package
LAPI	Low-level Application Programming Interface
MPI	Message Passing Interface
MPL	Message Passing Library
PE	Parallel Environment
PBLAS	Parallel Basic Linear Algebra Subprograms
POWER, PowerPC, POWER2, and POWER3 processors	RS/6000 processors
PSSP	Parallel System Support Programs
ScaLAPACK	Scalable Linear Algebra Package
SDO	System delivery offering
SFS	Shared file systems
SMP	Symmetric Multi-Processing
SPMD	Single Program Multiple Data
SMP/E	System Modification Program Extended
TLB	Translation Lookaside Buffer
US	User Space
VM	Virtual Machine
VMSES/E	Virtual Machine Serviceability Enhancements Staged/Extended

Short Name	Full Name
VSE	Virtual Storage Extended

About This Book: This *Engineering and Scientific Subroutine Library Products General Information* manual is intended to help the customer evaluate IBM Parallel Engineering and Scientific Subroutine Library (Parallel ESSL) for AIX, IBM Engineering and Scientific Subroutine Library for AIX, and IBM Engineering and Scientific Subroutine Library: Vector and Scalar/370. It contains high-level information about these products, which is helpful in making your purchasing decision.

In this document: ***Parallel ESSL*** refers to IBM Parallel Engineering and Scientific Subroutine Library for AIX. ***ESSL*** refers to IBM Engineering and Scientific Subroutine Library for AIX. ***ESSL/370*** refers to IBM Engineering and Scientific Subroutine Library: Vector and Scalar/370.

MPI refers to the Message Passing Interface provided by Parallel Environment (PE).

Engineering and Scientific Subroutine Library (ESSL)—Designed to Meet Your Application Needs

The family of ESSL products consists of:

- Parallel Engineering and Scientific Subroutine Library (Parallel ESSL) for Advanced Interactive Executive (AIX), program number 5765-C41
- Engineering and Scientific Subroutine Library (ESSL) for AIX, program number 5765-C42
- Engineering and Scientific Subroutine Library: Vector and Scalar/370 (ESSL/370), program number 5688-226

These products are state-of-the-art collections of mathematical subroutines that provide a wide range of mathematical functions for many different scientific and engineering applications.

Parallel ESSL offers mathematical subroutines in six computational areas (listed on page 6) that run on the following platforms:

- IBM RS/6000 SP*
- Clusters of IBM RS/6000* workstations

ESSL offers mathematical subroutines in nine computational areas (listed on page 7) that run on the following platforms:

- IBM RS/6000 POWER, POWER3, PowerPC, Symmetric Multi-Processing (SMP) PowerPC, and POWER2 Processors.
- IBM RS/6000 SP (serial mode only)

ESSL/370 offers mathematical subroutines in nine computational areas (listed on page 7) that run on the following platforms:

- IBM Enterprise System/3090* (ES/3090*) Vector Facility.
- IBM Enterprise System/9000* (ES/9000*) Vector Facility.
- IBM System/370* and System/390* Scalar Processors.

ESSL/370 also offers a group of subroutines that run in a parallel processing environment on the mainframes.

You can use these subroutine libraries to develop and enable many different types of scientific and engineering applications. New applications can be designed and developed to take full advantage of all the capabilities of ESSL. Existing applications can be enabled by replacing comparable subroutines and in-line code with calls to ESSL subroutines. Some of the types of applications that can take advantage of the ESSL capabilities are:

Structural Analysis	Time Series Analysis
Computational Chemistry	Computational Techniques
Fluid Dynamics Analysis	Mathematical Analysis
Seismic Analysis	Dynamic Systems Simulation
Reservoir Modeling	Nuclear Engineering

Quantitative Analysis	Electronic Circuit Design

The Parallel ESSL subroutines can be called from application programs written in Fortran, High Performance Fortran (HPF), C, and C++. Parallel ESSL runs under the AIX operating system. On the RS/6000 SP, Parallel System Support Programs (PSSP) is also required.

The ESSL subroutines can be called from application programs written in Fortran, C, C++, and PL/I. ESSL runs under the AIX operating system.

The ESSL/370 subroutines can be called from application programs written in Fortran, C, PL/I, APL2, and System/370 assembler language. ESSL/370 runs under the Multiple Virtual Storage (MVS*) and the Virtual Machine/Enterprise Systems Architecture* (VM/ESA*) operating systems.

Your Choice of Libraries

This section describes the subroutine libraries available to you.

IBM Parallel Engineering and Scientific Subroutine Library for AIX—Program Number 5765-C41

Parallel ESSL is a scalable mathematical subroutine library that supports parallel processing applications on the IBM RS/6000 SP Systems and clusters of IBM RS/6000 workstations. Parallel ESSL supports the Single Program Multiple Data (SPMD) programming model using either the Message Passing Interface (MPI) signal handling library or the MPI threaded library. Parallel ESSL provides these run-time libraries:

- The **Parallel ESSL SMP Library** is provided for use with the Parallel ESSL message passing subroutines and the PE MPI threaded library. You may run single or multithreaded applications on all types of nodes; however, you cannot simultaneously call Parallel ESSL from multiple threads. Use this Parallel ESSL library if you are using both PE MPI and the Communications Low-level Application Programming Interface (LAPI). The SMP library is for use on RS/6000 POWER and PowerPC (for example, POWER3 SMP Thin, Wide, or High Nodes) processors.
- The **Parallel ESSL Thread-Tolerant POWER2 Library** is provided for use with the Parallel ESSL message passing subroutines and the MPI threaded library. You may run single or multithreaded applications on POWER2 nodes; however, you cannot simultaneously call Parallel ESSL from multiple threads. Use this library if you are using both MPI and the Communications Low-level Application Programming Interface (LAPI). The Thread-Tolerant POWER2 library is tuned for the RS/6000 POWER2 processors.
- The **Parallel ESSL POWER Library** are provided for use with the Parallel ESSL message-passing and HPF subroutines, and the MPI signal handling library. The POWER libraries are tuned for the RS/6000 POWER and PowerPC processors.
- The **Parallel ESSL POWER2 Library** are provided for use with the Parallel ESSL message-passing and HPF subroutines, and the MPI signal handling library. The POWER2 libraries are tuned for the RS/6000 POWER2 processors.

It provides subroutines in six major areas of mathematical computation using high-performance algorithms.

Parallel ESSL provides distinct libraries for AIX 4.2.1 and AIX 4.3.2:

- The AIX 4.2.1 **Parallel ESSL Thread-Tolerant POWER2 Library** and the **Parallel ESSL SMP Library** were built using the pthreads draft 7 library supplied on AIX 4.2.1.
- The AIX 4.3.2 **Parallel ESSL Thread-Tolerant POWER2 Library** and the **Parallel ESSL SMP Library** were built using the pthreads library that conforms to the IEEE POSIX 1003.1-1996 specification supplied on AIX 4.3.

IBM Engineering and Scientific Subroutine Library for AIX— Program Number 5765-C42

ESSL performs computations using high-performance algorithms. ESSL provides these run-time libraries:

- The **ESSL SMP Library** provides thread-safe versions of the ESSL subroutines for use on the RS/6000 SMP (for example, 604e or 630) processors. In addition, a subset of these subroutines are multithreaded versions; that is, they support the shared memory parallel processing programming model. You do not have to change your existing application programs that call ESSL to take advantage of the increased performance of the SMP processors. You can simply re-link your existing programs. For a list of the multithreaded subroutines in the ESSL SMP Library, see the *ESSL Version 3 Guide and Reference*.
- The **ESSL Thread-Safe Library** provides thread-safe versions of the ESSL subroutines for use on all RS/6000 processors. You may use this library to develop your own multithreaded applications.
- The **ESSL Thread-Safe POWER2 Library** provides thread-safe versions of the ESSL subroutines and is tuned for the POWER2 uniprocessors. You may use this library to develop your own multithreaded applications.
- The **ESSL POWER Library** is tuned for the RS/6000 POWER, POWER3, and PowerPC processors.
- The **ESSL POWER2 Library** is tuned for the RS/6000 POWER2 processors.

All libraries are designed to provide high levels of performance for numerically intensive computing jobs on these respective processors. All versions provide mathematically equivalent results. Most of the subroutine calls are compatible with those of the ESSL/370 product.

The **ESSL POWER Library**, the **ESSL Thread-Safe Library**, and the **ESSL SMP Library** support both 32-bit environment and 64-bit environment applications.

ESSL for AIX provides distinct libraries for AIX 4.2.1 and AIX 4.3.2:

- The AIX 4.2.1 **ESSL Thread-Safe Library**, the **ESSL Thread-Safe POWER2 Library**, and the **ESSL SMP Library** were built using the pthreads draft 7 library supplied on AIX 4.2.1.
- The AIX 4.3.2 **ESSL Thread-Safe Library**, the **ESSL Thread-Safe POWER2 Library**, and the **ESSL SMP Library** were built using the pthreads library that conforms to the IEEE POSIX 1003.1-1996 specification supplied on AIX 4.3.

IBM Engineering and Scientific Subroutine Library: Vector and Scalar/370—Program Number 5688-226

ESSL/370 provides both vector and scalar versions of all the subroutines in the Vector Library and the Scalar Library, respectively. The two versions provide mathematically equivalent results.

- The **ESSL/370 Vector Library** is designed to provide high levels of performance for numerically intensive computing jobs on the Vector Facilities, running under the MVS and VM/ESA operating systems. ESSL subroutines perform computations using high-performance algorithms that are generally coded in System/370 assembler language and are tuned to specific operating characteristics of the processors with Vector Facilities.

  The Vector Library provides eight parallel processing subroutines designed to further reduce job turnaround time by splitting up the computations of a subroutine call and performing them in parallel on multiprocessors.

- The **ESSL/370 Scalar Library** is designed to support numerically intensive computing jobs on the scalar processors, running under the MVS and VM/ESA operating systems. In addition, by providing subroutine calls completely compatible with those of the Vector Library, applications developed in a scalar environment can be run in a production vector environment without recompilation. (Relinkage is required, however.)

  The parallel processing subroutines are also provided in the Scalar Library.

Easy to Use

The ESSL products have been designed for ease of use. For example,

- All products have an easy-to-use call interface and informative error-handling capabilities.
- The ESSL products are compatible with public domain subroutine libraries such as Basic Linear Algebra Subprograms (BLAS), Scalable Linear Algebra Package (ScaLAPACK), and Parallel Basic Linear Algebra Subprograms (PBLAS), making it easy to migrate from these libraries to an ESSL product.
- Parallel ESSL supports XL High Performance Fortran (HPF). XL HPF provides a way to easily develop parallel software with the SPMD programming model on your RS/6000 SP or cluster configuration. The XL HPF compiler, guided by HPF directives in your source code, handles the distribution of data and communication between programs on multiple processes.
- ESSL for AIX enables you to obtain high performance on the PowerPC SMP processors without requiring extensive knowledge of parallelization techniques.
- The **ESSL POWER Library**, the **ESSL Thread-Safe Library**, and the **ESSL SMP Library** support a 64-bit environment. For complete details, see the *ESSL Version 3 Guide and Reference*.
- The printed and softcopy documentation allows for quick retrieval of information.

  For Parallel ESSL and ESSL for AIX, online documentation available on the product media can be displayed using a common Hypertext Markup Language (HTML) document browser (such as Netscape Navigator).

PostScript files of the *ESSL Version 3 Guide and Reference* and the *Parallel ESSL Version 2 Guide and Reference* are also provided on the product media for your convenience.

For ESSL/370, online documentation can be displayed using BookManager*.

- ESSL/370 enables you to obtain high performance on the mainframe processors with Vector Facilities without requiring extensive knowledge of the Vector Facility or of vectorization and parallelization techniques.
- A VS FORTRAN intercompilation analysis (ICA) file is provided.

  This enables you to diagnose inconsistencies in your ESSL/370 call statements in your VS FORTRAN program at compile time. Using the ICA compiler option may save you time in debugging large, complex VS FORTRAN programs.

ESSL Internet Resources

This section describes how you can use the ESSL resources available over the Internet.

Obtaining Documentation

The product documentation is available in Portable Document Format (PDF) and HTML format at the IBM RS/6000 Web site at:

http://www.rs6000.ibm.com/resource/aix_resource/sp_books

Accessing ESSL's Home Pages

The following home pages contain information on Parallel ESSL and ESSL:

- For Parallel ESSL, use:

  http://www.rs6000.ibm.com/software/sp_products/esslpara.html
- For ESSL for AIX, use:

  http://www.rs6000.ibm.com/software/Apps/essl.html

Getting on the ESSL Mailing List

Information concerning ESSL's home pages and other home pages available for the RS/6000 family of products, plus late breaking information about ESSL, can be obtained by being placed on the ESSL mailing list. In addition, users on the mailing list will receive information about new ESSL function and may receive customer satisfaction surveys and requirements surveys to provide feedback to ESSL Development on the product and user requirements.

You can be placed on the mailing list by sending a request to either of the following, asking to be placed on the ESSL mailing list:

International Business Machines Corporation
ESSL Development
Department LQJA / MS P963
522 South Rd.
Poughkeepsie, N.Y. 12601-5400

e-mail: essl@us.ibm.com

Note: You should send us e-mail if you would like to be withdrawn from the ESSL mailing list.

When requesting to be placed on the mailing list or asking any questions, please provide the following information:

- Your name
- The name of your company
- Your mailing address
- Your Internet address
- Your phone number

Wide Range of Mathematical Functions

The ESSL libraries provide a variety of complex mathematical functions for many different scientific and engineering applications.

Parallel ESSL Subroutines (Message Passing and HPF)

The Parallel ESSL mathematical subroutines cover the following areas:

- Level 2 PBLAS
- Level 3 PBLAS
- Linear Algebraic Equations
- Eigensystem Analysis and Singular Value Analysis
- Fourier Transforms
- Random Number Generation
- Utilities

Parallel ESSL subroutines are available in long-precision versions. The Fourier transform subroutines also include short-precision versions.

Level 2 PBLAS include a subset of the standard set of distributed memory parallel versions of the Level 2 BLAS.

Level 3 PBLAS include a subset of the standard set of distributed memory parallel versions of the Level 3 BLAS.

Linear Algebraic Equations Subroutines consist of dense, banded, and sparse subroutines, and include a subset of the ScaLAPACK subroutines.

- *Dense Linear Algebraic Equations Subroutines* provide solutions to linear systems of equations for real and complex general matrices and their transposes, and for positive definite real symmetric and complex Hermitian matrices.
- *Banded Linear Algebraic Equations Subroutines* provide solutions to linear systems of equations for real positive definite symmetric band matrices, real general tridiagonal matrices, diagonally-dominant real general tridiagonal matrices, and real positive definite tridiagonal matrices.

- *Sparse Linear Algebraic Equations Subroutines* and their utility subroutines provide iterative solutions to linear systems of equations for real general sparse matrices.

Eigensystem Analysis and Singular Value Analysis Subroutines provide solutions to the algebraic eigensystem analysis problem for real symmetric matrices and the ability to reduce real symmetric and real general matrices to condensed form. These subroutines include a subset of the ScaLAPACK subroutines.

Fourier Transform Subroutines perform mixed-radix transforms in two and three dimensions.

Random Number Generation Subroutine generates uniformly distributed random numbers.

Utility Subroutines perform general service functions, rather than mathematical computations.

ESSL for AIX and ESSL/370 Subroutines

The ESSL for AIX and ESSL/370 mathematical subroutines cover the following areas:

- Linear Algebra Subprograms
- Matrix Operations
- Linear Algebraic Equations
- Eigensystem Analysis
- Fourier Transforms, Convolutions and Correlations, and Related Computations
- Sorting and Searching
- Interpolation
- Numerical Quadrature
- Random Number Generation
- ESSL/370 Parallel Processing
- Utilities

Several versions of most subroutines are provided, depending on the type of data you are processing. These may include a short- and long-precision real version, a short- and long-precision complex version, and an integer version.

Linear Algebra Subprograms consist of vector-scalar, sparse vector-scalar, matrix-vector, and sparse matrix-vector linear algebra subprograms.

- *Vector-Scalar Linear Algebra Subprograms* include a subset of the standard set of Level 1 BLAS and subroutines for other commonly used computations. Both real and complex versions of the subprograms are provided.
- *Sparse Vector-Scalar Linear Algebra Subprograms* operate on sparse vectors; only the nonzero elements of the vectors need to be stored. These subprograms provide functions similar to those of the vector-scalar subprograms and represent a subset of the sparse extensions to the Level 1 BLAS. Both real and complex versions of the subprograms are provided.

- *Matrix-Vector Linear Algebra Subprograms* operate on a higher-level data structure, matrix-vector rather than vector-scalar, using optimized algorithms to improve performance. These subprograms represent a subset of the Level 2 BLAS. Both real and complex versions of the subprograms are provided.
- *Sparse Matrix-Vector Linear Algebra Subprograms* operate on sparse matrices; only the nonzero elements of the matrix need to be stored. These subprograms provide functions similar to those of the matrix-vector subprograms.

Matrix Operations Subroutines include Level 3 BLAS, as well as the commonly used matrix operations: addition, subtraction, multiplication, and transposition.

Linear Algebraic Equations Subroutines consist of dense, banded, sparse, and linear least squares subroutines.

- *Dense Linear Algebraic Equations Subroutines* provide solutions to linear systems of equations for real and complex general matrices and their transposes, positive definite real symmetric and complex Hermitian matrices, and triangular matrices. Some of these subroutines correspond to the Level 2 and Level 3 BLAS.
- *Banded Linear Algebraic Equations Subroutines* provide solutions to linear systems of equations for real general band matrices, real positive definite symmetric band matrices, real or complex general tridiagonal matrices, real positive definite symmetric tridiagonal matrices, and real or complex triangular band matrices.
- *Sparse Linear Algebraic Equations Subroutines* provide direct and iterative solutions to linear systems of equations, both for general sparse matrices and their transposes and for sparse symmetric matrices.
- *Linear Least Squares Subroutines* provide least squares solutions to linear systems of equations for real general matrices. Two methods are provided: one that uses a singular value decomposition and another that uses a QR decomposition with column pivoting.

Eigensystem Analysis Subroutines provide solutions to the algebraic eigensystem analysis problem $\boldsymbol{A}\boldsymbol{z} = w\boldsymbol{z}$ and the generalized eigensystem analysis problem $\boldsymbol{A}\boldsymbol{z} = w\boldsymbol{B}\boldsymbol{z}$. These subroutines give you several options for computing eigenvalues or eigenvalues and eigenvectors.

Fourier Transform, Convolution and Correlation, and Related Computation Subroutines are as follows:

- *Fourier Transform Subroutines* perform mixed-radix transforms in one, two, and three dimensions.
- *Convolution and Correlation Subroutines* offer a choice between Fourier methods or direct methods. The Fourier-method subroutines contain a high-performance mixed-radix capability. Also, several direct-method subroutines provide decimated output.
- *Related Computation Subroutines* can be used in general signal processing applications. They are similar to those provided on the IBM 3838 Array Processor; however, the ESSL subroutines generally solve a wider range of problems.

Sorting and Searching Subroutines operate on three types of data: integer, short-precision real, and long-precision real. The sorting subroutines perform a sort with or without index designations. The searching subroutines perform either a binary or a sequential search.

Interpolation Subroutines provide capabilities for polynomial interpolation, local polynomial interpolation, and both one- and two-dimensional cubic spline interpolation.

Numerical Quadrature Subroutines provide one-dimensional methods for integrating a tabulated function and a user-supplied function over a finite, semi-infinite, or infinite region of integration by Gaussian quadrature methods. They also provide a two-dimensional quadrature capability within a rectangular boundary.

Random Number Generation Subroutines generate uniformly or normally distributed random numbers.

ESSL/370 Parallel Processing Subroutines enable you to run your application programs in a mainframe parallel processing environment. If you have multiple mainframe processors available, these subroutines may significantly improve your turnaround time.

Utility Subroutines perform general service functions, rather than mathematical computations.

Parallel ESSL

The following sections describe key aspects of Parallel ESSL, as well as how to order it.

Highlights of Parallel ESSL

- Parallel ESSL provides these run-time libraries:
  - The **Parallel ESSL SMP Library** is provided for use with the Parallel ESSL message passing subroutines and the MPI threaded library. You may run single or multithreaded applications on all types of nodes; however, you cannot simultaneously call Parallel ESSL from multiple threads. Use this Parallel ESSL library if you are using both MPI and the Communications Low-level Application Programming Interface (LAPI). The SMP library is for use on RS/6000 POWER and PowerPC (for example, POWER3 SMP Thin, Wide, or High Nodes) processors.
  - The **Parallel ESSL Thread-Tolerant POWER2 Library** is provided for use with the Parallel ESSL message passing subroutines and the MPI threaded library. You may run single or multithreaded applications on POWER2 nodes; however, you cannot simultaneously call Parallel ESSL from multiple threads. Use this library if you are using both MPI and the Communications Low-level Application Programming Interface (LAPI). The Thread-Tolerant POWER2 library is tuned for the RS/6000 POWER2 processors.
  - The **Parallel ESSL POWER Libraries** are provided for use with the Parallel ESSL message passing and HPF subroutines, and the MPI signal handling library. The POWER libraries are tuned for the RS/6000 POWER and PowerPC processors.
  - The **Parallel ESSL POWER2 Libraries** are provided for use with the Parallel ESSL message-passing and HPF subroutines, and the MPI signal handling library. The POWER2 libraries are tuned for the RS/6000 POWER2 processors.
- Parallel processing subroutines (distributed memory versions) provided in key math areas:
  - Subset of Level 2 and Level 3 Parallel BLAS (PBLAS)
  - Linear Algebraic Equations
    - Subset of ScaLAPACK (dense and banded)
    - Sparse subroutines and their utilities
  - Subset of ScaLAPACK Eigensystem Analysis and Singular Value Analysis
  - Fourier transforms
  - Uniform random number generation

  For a list of subroutines, refer to “Parallel ESSL Subroutines (Message Passing and HPF)” on page 31.
- Supports the IBM RS/6000 SP and clusters of IBM RS/6000 workstations

- Includes the Basic Linear Algebra Communication Subprograms (BLACS) which provides ease of use for message passing.
- Supports the SPMD programming model:
  - Uses the ESSL subroutines for computations on each processor node
  - Uses the Parallel Environment (PE) MPI signal handling or threaded libraries for communication:
    - US—High Performance Switch, SP Switch
    - IP—Ethernet, Token Ring, Fiber Distributed Data Interface (FDDI), High Performance Switch, SP Switch
- Callable from application programs written in Fortran, C, C ++, and HPF.
- Provides an environment variable, PESSL_ERROR_SYNC, which allows you to disable error handling synchronization. This may allow you to improve the performance of production-level code.

High Performance of Parallel ESSL

Performance has been the primary objective in the design of the Parallel ESSL subroutines. To achieve this performance goal, the Parallel ESSL subroutines use state-of-the-art algorithms tailored to specific operational characteristics of the hardware. In addition, Parallel ESSL leverages the high performance provided by ESSL, for processor computations.

Choosing a Parallel ESSL Library

The Parallel ESSL library you may use depends on:

1. Your choice of MPI library.
2. The type of nodes you are running on.

The MPI library you choose, is dependent upon the following:

- If you are using the Parallel ESSL message-passing subroutines, you may use either the MPI signal handling library or the MPI threaded library.
- If you are an HPF user, you may only use the MPI signal handling library.
- If you are using LAPI, you may only use the MPI threaded library.

XL HPF and Parallel ESSL

XL HPF allows you to easily develop parallel software using the SPMD programming model. The XL HPF compiler, guided by HPF directives in your source code, handles the distribution of data and communication between programs on multiple processes. The HPF directives make developing an HPF program that calls Parallel ESSL easier than developing a message passing program that calls Parallel ESSL. However, the performance obtained when using a Parallel ESSL HPF subroutine is less than that obtained when using a Parallel ESSL message passing subroutine because there is a certain amount of overhead involved in supporting the extrinsic hpf_local interface.

Because the XL HPF compiler only supports CYCLIC(N) in the interface blocks for extrinsic hpf_local subroutines, a redistribution of data occurs whenever a Level 3

PBLAS, Dense Linear Algebraic Equations, Eigensystem Analysis or Singular Value Analysis subroutine is called. Also, data may be copied locally because the extrinsic hpf_local subroutines require the use of assumed-shape arrays while the Parallel ESSL message passing subroutines use assumed-size arrays.

Parallel ESSL Techniques

The following techniques are used by most subroutines to optimize performance:

- Minimizing the impact of communications by exchanging larger blocks of data
- Blocking data to match the processor cache size

The design of Parallel ESSL gives you the ability to directly influence performance through the selection of process grid size and block sizes for the distribution of data. While developing and tuning your applications you can select the optimum parameters to suit your problem size. Guidelines for optimum performance and tuning tips are described below:

- Number and types of processors (such as, POWER Thin, POWER2 Thin, POWER3 Wide, POWER Wide)

  Choosing the number of processors depends primarily on the problem size. It is reasonable to increase the number of processors, if the global problem size increases sufficiently to keep the amount of local data per process at a reasonable size. If, however, using more processes, such as 17 rather than 16, causes you to use a one-dimensional grid rather than a two-dimensional grid, performance may be degraded. See the next item.

- Shape of process grid

  For most subroutines, using a two dimensional (square or as close to square as possible) grid is suggested. For example, if sixteen processors were used, define a 4 by 4 process grid. For exceptions to this rule, see the subroutine descriptions in the reference section of the *Parallel ESSL Version 2 Guide and Reference*.

- Block size(s) in the Message Passing subroutines

  The optimal block size in your message passing program depends on the underlying node computations, load balancing, communications, system buffering requirements, problem size, and dimension and shape of the process grid.

- PESSL_HPF module for the HPF subroutines

  For all HPF subroutines, except GEBRD, data directives are included in the interface module PESSL_HPF; therefore, you can specify any data distribution for your vectors, matrices, and sequences, because the XL HPF compiler will, if necessary, redistribute the data prior to calling the HPF Parallel ESSL subroutine. Data directives for GEBRD cannot be included in the PESSL_HPF module, because the alignment requirements for some of the vectors depend on the size of the matrix.

  When using cyclic distribution in your HPF program, you can only specify CYCLIC(1) data distributions. However, the performance of the Level 3 PBLAS, Dense Linear Algebraic Equations, and Eigensystems Analysis and Singular Value Analysis subroutines is improved if a CYCLIC(N) data distribution is used. To accomplish this, PESSL_HPF contains CYCLIC(N) data directives for a two-dimensional process grid in the interface for these subroutines.

There are CYCLIC(1) directives for a two-dimensional process grid in the interfaces in PESSL_HPF for the Level 2 PBLAS.

There are BLOCK data directives for a one-dimensional process grid in the interfaces in PESSL_HPF for the Banded Linear Algebraic Equations, Fourier transform and Random Number Generation subroutines.

For more information about the Parallel ESSL HPF module, see the *Parallel ESSL Version 2 Guide and Reference*.

- If you are using the MPI threaded library for a single message-passing thread, specify MP_SINGLE_THREAD=yes to minimize thread overhead.
- You should be able to improve performance of production-level code by using the PESSL_ERROR_SYNC environment variable to disable error synchronization.

The choices made from the above list generally depend on the specific parallel routine being called. For specific performance information, see the Parallel ESSL home page at:

http://www.rs6000.ibm.com/software/sp_products/esslpara.html.

Informative Error Handling in Parallel ESSL

Parallel ESSL features informative and flexible error handling. Exception handling is tailored to the type of error. The Parallel ESSL input-argument checking strategy exceeds the standards defined by existing subroutine library packages. Parallel ESSL checks the validity of the input arguments, and if any of these arguments are invalid, issues an appropriate error message. In addition, Parallel ESSL also provides increased useability by providing a single, comprehensive message when all processors detect the same input argument error.

Migration Considerations

This section summarizes the impact of migrating to Parallel ESSL.

Migrating From Parallel ESSL Version 2.1.1 to Parallel ESSL 2.1.2: The format of the output from PDDTTRF and DTTRF has changed. Therefore, the factorization and solve must be performed using Parallel ESSL Version 2 Release 1.2.

Banded Linear Algebraic Equation subroutines PDPBSV, PDGTSV, PDDTSV and PDPTSV have been modified for the case where N is greater than zero and NRHS is zero so that the matrix is factored. Previously, this was a quick return condition and the matrix was not factored. For all other subroutines, no changes to your application programs are required if you are migrating from Parallel ESSL Version 2 Release 1.1 to Parallel ESSL Version 2 Release 1.2.

Migrating From Parallel ESSL Version 2 to Parallel ESSL 2.1.1: The calling sequences for the subroutines in Parallel ESSL Version 2 Release 1 and Parallel ESSL Version 2 Release 1.1 products are identical.

Parallel ESSL provides distinct libraries for AIX 4.2.1 and AIX 4.3.2:

- For AIX 4.2.1, the **Parallel ESSL Thread-Tolerant POWER2 Library** and the **Parallel ESSL SMP Library** were built using the pthreads draft 7 supplied on AIX 4.2.1. This is the same as Parallel ESSL 2.1.

- For AIX 4.3.2, the **Parallel ESSL Thread-Tolerant POWER2 Library** and the **Parallel ESSL SMP Library** were built using the pthreads library that conforms to the IEEE POSIX 1003.1-1996 specification supplied on AIX 4.3.

Applications built using Parallel ESSL 2.1 will continue to run with Parallel ESSL 2.1.1.

Migrating From Parallel ESSL Version 1 to Parallel ESSL Version 2: All application programs previously migrated to accommodate the new array descriptor, can run unchanged with Parallel ESSL Version 2 Release 1. However, if you were dependent upon the `PESSL_DESC_TYPE` environment variable, you must change the array descriptors as defined in the *Parallel ESSL Version 2 Guide and Reference*.

Subroutines with the option of dynamic allocation have been updated to be consistent with ScaLAPACK 1.5. You do not need to update your application programs unless you choose to exploit the new capability. For more information, see the *Parallel ESSL Version 2 Guide and Reference*.

The message-passing and HPF tridiagonal subroutines have been updated to be consistent with ScaLAPACK 1.5. If Parallel ESSL detects a computational error, the value returned in *info* is the process number where the error occurred. Previously, the index of the pivot where the matrix failed was returned in info. For the message-passing tridiagonal subroutines, the scope of *info* is now global. You do not have to make any modifications to your existing programs that call these subroutines. For more information, see the appropriate subroutine descriptions in the *Parallel ESSL Version 2 Guide and Reference*.

Migrating from ScaLAPACK 1.5 to Parallel ESSL Version 2.1.2: If you are currently using the ScaLAPACK 1.5 offerings from the Oak Ridge National Laboratory, Parallel ESSL Version 2.1.2 uses compatible calling sequences with this version of ScaLAPACK. For details, see the *Parallel ESSL Version 2 Guide and Reference*.

Migrating from a Commercial Parallel Library to Parallel ESSL: Migrating from a commercial parallel library, such as CMSSL, requires at least a partial, if not substantial, redesign of the application.

Where to find Details on Migration: Complete details on migration are given in the "Migrating Your Programs" chapter in the *Parallel ESSL Guide and Reference*.

Product Requirements

This section describes the hardware, operating systems, and software products you need when using Parallel ESSL.

Hardware for Parallel ESSL

Parallel ESSL runs on IBM RS/6000 SP and clusters of RS/6000 workstations supported by the operating systems listed under “Operating Systems for Parallel ESSL” on page 16.

Operating Systems for Parallel ESSL

Parallel ESSL for AIX is supported in the following operating system environments:

- AIX Version 4.2.1 or later modification levels of AIX Version 4.2 (program number 5765-655 or 5765-C34)

  On the SP, you also need the following along with AIX:

  – Parallel System Support Programs (PSSP) for AIX, Version 2.3 or later modification levels (program number 5765-529)

  – Any additional AIX 4.2.1 PTFs required for running on the SP

- AIX Version 4.3.2 or later modification levels of AIX Version 4.3 (program number 5765-C34)

  On the SP, you also need the following along with AIX:

  – PSSP for AIX, Version 3.1 or later modification levels (program number 5765-D51)

  – Any additional AIX 4.3.2 PTFs required for running on the SP

Software Products Required for Parallel ESSL

Parallel ESSL runs with the software products shown in Table 1.

ESSL for AIX must be ordered separately.

Table 1 (Page 1 of 2). Software Products Required for Use with Parallel ESSL

For Compiling	For Linking, Loading, or Running
XL Fortran for AIX, Version 5.1.1 or later (program number 5808-AAR part number 04L2110) *–or–* IBM C, C++ compilers Version 3.6.4[1] *–or–* C for AIX, Version 4.4 or later (program number 5765-C64 with part number 31L0497 with feature 0002)	XL Fortran Run-time Environment for AIX, Version 5.1.1 or later (program number 5808-AAR part number 04L2123) *–or–* XL High Performance Fortran Run-time Environment for AIX, Version 1.3.1 or later (program number 5765-612) **–and–** Parallel Environment for AIX, Version 2.4 or later (program number 5765-543) on AIX 4.3.2 *–or–* Parallel Environment for AIX, Version 2.3 (program number 5765-543 and APAR IX72055) on AIX 4.2.1 **–and–** ESSL for AIX, Version 3.1.2 (program number 5765-C42) **–and–** C libraries[2]
XL High Performance Fortran for AIX, Version 1.3.1 or later (program number 5765-613)[3,4]	XL High Performance Fortran Run-Time Environment for AIX, Version 1.3.1 or later (program number 5765-612)[1] **–and–** Parallel Environment for AIX, Version 2.4 or later (program number 5765-543) on AIX 4.3.2 *–or–* Parallel Environment for AIX, Version 2.3 (program number 5765-543 and APAR IX72055) on AIX 4.2.1 **–and–** ESSL for AIX, Version 3.1.2 (program number 5765-C42) **–and–** C libraries[2]

Table 1 (Page 2 of 2). Software Products Required for Use with Parallel ESSL	
For Compiling	**For Linking, Loading, or Running**
[1] Available as a component of the VisualAge C ++ Professional for AIX, Version 4, product. If using Parallel Environment 2.3 commands to compile with C++ Version 3.6, PE requires APAR IX76163.	
[2] AIX includes the C libraries and math libraries in the Application Development Toolkit.	
[3] XL HPF for AIX is only needed when you call Parallel ESSL HPF subroutines.	
[4] If using Parallel Environment 2.3 commands to compile non-HPF programs with XL HPF, PE requires APAR IX80634.	

Thread Safety

Parallel ESSL is not thread safe; however, Parallel ESSL is thread-tolerant and can therefore be called from a single thread of a multithreaded application. Multiple simultaneous calls to Parallel ESSL from different threads of a single process causes unpredictable results.

For more information on thread programming concepts, see the *IBM AIX Version 4 General Programming Concepts: Writing and Debugging Programs*.

Installation and Customization Requirements

Parallel ESSL is distributed on an 4-millimeter cartridge or a 8-millimeter cartridge. The *Parallel ESSL Version 2 Installation Memo*, GI10-0607 provides the detailed information you need to install Parallel ESSL on AIX.

The Parallel ESSL product is packaged in accordance with the AIX guidelines. The product can be installed using the **smit** command, as described in the *IBM Parallel System Support Programs for AIX: Administration Guide*. The product can be installed on multiple nodes using the **dsh** command, as described in the *IBM Parallel System Support Programs for AIX: Administration Guide* and the **installp** command, as described in the *IBM AIX Version 4 Commands Reference*.

Online Documentation Requirements

The *Parallel ESSL Version 2 Guide and Reference* is available in PostScript and HTML on the product media.

To view the online publications shipped on the product media, you need the following:

- Access to a common HTML document browser (such as Netscape Navigator).
- The location of the HTML index file provided with the file sets. Contact your system administrator or installer for this location.

The *Parallel ESSL Guide and Reference Version 2* is available in PDF and HTML format at the IBM RS/6000 Web site at:

http://www.rs6000.ibm.com/resource/aix_resource/sp_books.

To view the Parallel ESSL PDF publication, you need to access the Adobe Acrobat Reader 3.0.1. The Acrobat Reader is shipped with the AIX Version 4.3 Bonus Pack and is also freely available for downloading from th Adobe Web site at:

http://www.adobe.com

Ordering Parallel ESSL

You can order Parallel ESSL from your IBM Marketing Representative, or by:

- calling 1-800-IBM-CALL (1-800-426-2255)
- using the IBM Web site at:

  http://www.ibm.com/shop/

Ask for:

- IBM Parallel Engineering and Scientific Subroutine Library for AIX (program number 5765-C41)

Parallel ESSL Product Package

The Parallel ESSL package provides:

- Parallel ESSL libraries
- Parallel ESSL header file for C and C++
- Parallel ESSL modules
- Installation Verification Programs
- Parallel ESSL Documentation
  - Softcopy:
    - *Parallel ESSL Version 2 Guide and Reference*, HTML files.
  - Print-on-Demand:
    - *Parallel ESSL Version 2 Guide and Reference*, PostScript file.
  - Printed:
    - *Parallel ESSL Version 2 Licensed Information*, GA22-7303
    - Parallel ESSL Proof of Entitlement
    - *Parallel ESSL Version 2 Installation Memo*, GI10-0607
    - *Parallel ESSL Memo to New Users*, GI10-0606

The printed publication of the *Parallel ESSL Version 2 Guide and Reference*, SA22-7273, is not automatically shipped with your product order. To order this publication:

- Use feature number 7008 to obtain a free initial copy.
- Use feature number 8025 to obtain additional copies for a fee.

ESSL for AIX

The following sections describe key aspects of the ESSL for AIX product, as well as how to order it.

Highlights of ESSL for AIX

- ESSL provides these run-time libraries:
  - The **ESSL SMP Library** provides thread-safe versions of the ESSL subroutines for use on the RS/6000 SMP (for example, 604e or 630) processors. In addition, a subset of these subroutines are multithreaded versions; that is, they support the shared memory parallel processing programming model. You do not have to change your existing application programs that call ESSL to take advantage of the increased performance of the SMP processors. You can simply re-link your existing application programs. For a list of the multithreaded subroutines in the ESSL SMP Library, see the *ESSL Version 3 Guide and Reference*.
  - The **ESSL Thread-Safe Library** provides thread-safe versions of the ESSL subroutines for use on all RS/6000 processors. You may use this library to develop your own multithreaded applications.
  - The **ESSL Thread-Safe POWER2 Library** provides thread-safe versions of the ESSL subroutines tuned for the RS/6000 POWER2 uniprocessors. You may use this library to develop your own multithreaded applications.
  - The **ESSL POWER Library** is tuned for the RS/6000 POWER, POWER3, and PowerPC uniprocessors.
  - The **ESSL POWER2 Library** is tuned for the RS/6000 POWER2 uniprocessors.

  All libraries are designed to provide high levels of performance for numerically intensive computing jobs on these respective processors. All versions provide mathematically equivalent results.

  The **ESSL POWER Library**, the **ESSL Thread-Safe Library**, and the **ESSL SMP Library** support both 32-bit environment and 64-bit environment applications. For complete details, see the *ESSL Guide and Reference Version 3 Release 1.1*, available on the RS/6000 Web site.
- Callable from Fortran, C, C++, and PL/I programs.
- For a list of ESSL subroutines see “ESSL for AIX Subroutines” on page 37.

High Performance of ESSL for AIX

Algorithms: The ESSL subroutines have been designed to provide high performance. To achieve this performance, the subroutines use state-of-the-art algorithms tailored to specific operational characteristics of the hardware, such as cache size, Translation Lookaside Buffer (TLB) size, and page size.

Most subroutines use the following techniques to optimize performance:

- Managing the cache and TLB efficiently so the hit ratios are maximized; that is, data is blocked so it stays in the cache or TLB for its computation.
- Accessing data stored contiguously—that is, using stride-1 computations.
- Exploiting the large number of available floating-point registers.
- Using algorithms that minimize paging.
- On the PowerPC SMP processor:
  - The ESSL SMP Library is designed to exploit the processing power and shared memory of the SMP processor. In addition, a subset of the ESSL SMP subroutines have been coded to take advantage of increased performance from multithreaded (parallel) programming techniques. For a list of the multithreaded subroutines in the ESSL SMP Library, see the *ESSL Version 3 Guide and Reference*. Many of the other ESSL SMP subroutines make one or more calls to multithreaded subroutines, and also benefit from increased performance.
  - Choosing the number of threads depends on the problem size, the specific subroutine being called, and the number of physical processors you are running on. To achieve optimal performance, experimentation is necessary; however, picking the number of threads equal to the number of online processors generally provides good performance in most cases. In a some cases, performance may increase if you choose the number of threads to be less than the number of online processors.

    You should use the the XL Fortran XLSMPOPTS environment variable to specify the number of threads you want to create.
- On the POWER processor:
  - Using algorithms that balance floating-point operations with loads in the innermost loop.
  - Using algorithms that minimize stores in the innermost loops.
  - Structuring the ESSL subroutines so, where applicable, the compiled code uses the Multiply-Add instructions. Neglecting overhead, these instructions perform two floating-point operations per cycle.
- On the POWER3 processor:
  - Structuring the ESSL subroutines so, where applicable, the compiled code fully utilizes the dual floating-point execution units. Because two Multiply-Add instructions can be executed each cycle, neglecting overhead, this allows four floating-point operations per cycle to be performed.
  - Structuring the ESSL subroutines so, where applicable, the compiled code takes full advantage of the hardware data prefetching.
- On the POWER2 processor:
  - Structuring the ESSL subroutines so, where applicable, the compiled code fully utilizes the dual fixed-point and floating-point execution units. Because two Multiply-Add instructions can be executed each cycle, neglecting overhead, this allows four floating-point operations per cycle to be performed.
  - Structuring the ESSL subroutines so, where applicable, the compiled code uses the POWER2 Load and Store Floating Point Quad instructions. For example, in one cycle, two Load Floating Point Quad instructions can be

executed. Neglecting overhead, this allows four doublewords to be loaded per cycle.

Mathematical Techniques: All areas of ESSL use state-of-the-art mathematical techniques to achieve high performance. For example, the matrix-vector linear algebra subprograms operate on a higher-level data structure, matrix-vector rather than vector-scalar. As a result, they optimize performance directly for your program and indirectly through those ESSL subroutines using them.

For specific performance information, see the ESSL home page at:

http://www.rs6000.ibm.com/software/Apps/essl.html.

Migration Considerations

This section summarizes the impact of migrating to ESSL.

Migrating From ESSL Version 3 Release 1.1 to ESSL Version 3 Release 1.2: The calling sequences for the subroutines in the ESSL Version 3 Release 1.1 and the ESSL Version 3 Release 1.2 product are identical. No changes to your application programs are required if you are migrating from ESSL Version 3 Release 1.1 to Essl Version 3 Release 1.2.

Migrating From ESSL Version 3 to ESSL Version 3 Release 1.1: The calling sequences for the subroutines in the ESSL Version 3 Release 1 and the ESSL Version 3 Release 1.1 product are identical.

Distinct Libraries are provided provided for AIX 4.2.1 and AIX 4.3.2:

- For AIX 4.2.1, the **ESSL Thread-Safe Library**, the **ESSL Thread-Safe POWER2 Library**, and the **ESSL SMP Library** were built using the pthreads draft 7 supplied on AIX 4.2.1. This is the same as ESSL 3.1.
- For AIX 4.3.1, the **ESSL Thread-Safe Library**, the **ESSL Thread-Safe POWER2 Library**, and the **ESSL SMP Library** were built using the pthreads library that conforms to the IEEE POSIX 1003.1-1996 specification supplied on AIX 4.3.

Applications built using ESSL 3.1 will continue to run with ESSL 3.1.1.

If you are migrating to a 64-bit environment you may need to make changes to your calls to **ERRSET**.

Migrating From ESSL Version 2 to ESSL Version 3: The calling sequences for the subroutines in the ESSL Version 2 and ESSL Version 3 product are identical. This includes the new ESSL SMP and Thread-Safe Libraries that are included in the ESSL Version 3 product. You do not have to change your existing application programs that call ESSL when migrating to the ESSL Version 3 product. You must, however, re-link your application program.

ESSL messages have been reformatted and are now in a message catalog. Some input-argument and computational error message numbers were changed to attention message numbers. The old message numbers can still be used when calling ERRSET, however, you should migrate to the new message numbers. For details, see the *ESSL Version 3 Guide and Reference*. For the _GEF and _GEFCD subroutines, the first column of the matrix ***L*** with the corresponding $\boldsymbol{U}_{ii} = 0$ diagonal element is identified in a computational error message. Previously, the last column was identified. You do not have to make any modifications to your existing application programs that call these subroutines.

Migrating from LAPACK: ESSL contains a few subroutines that conform to the LAPACK interface, see Appendix B in the *ESSL Version 3 Guide and Reference*. If you are using these subroutines, no coding changes are needed to migrate to ESSL.

Additionally, you may be interested in using the Call Conversion Interface (CCI) that is available with LAPACK. The CCI substitutes a call to an ESSL subroutine in place of an LAPACK subroutine whenever an ESSL subroutine provides either functional or near-functional equivalence. Using the CCI allows LAPACK users to obtain the optimized performance of ESSL for an additional subset of LAPACK subroutines. For details, see *Call Conversion Interface (CCI) for LAPACK/ESSL*, LAPACK Working Note 82, Department of Computer Science University of Tennessee, Knoxville, Tennessee. (You can download this document from: **http://www.netlib.org/lapack/lawns/lawn82.ps**.)

Migrating Between ESSL/370 and ESSL Version 3: The ESSL calling sequences are predominantly compatible with the ESSL/370 calling sequences; therefore, most ESSL mainframe application programs can be easily ported to and from the IBM RS/6000 system.

Where to Find Details on Migration: Complete details on migration are given in the "Migrating Your Programs" chapter of the *ESSL Version 3 Guide and Reference* manual.

Product Requirements

This section describes the hardware and and software products you need when using ESSL.

Hardware for ESSL

ESSL runs on the IBM RS/6000 processors supported by the AIX operating systems listed under “Operating Systems for ESSL.”

64-bit applications require 64-bit hardware.

Operating Systems for ESSL

ESSL is supported in the following operating system environments:

- AIX Version 4.2.1 or later modification levels of AIX Version 4.2 (product number 5765-655 or 5765-C34)
- AIX Version 4.3.2 or later modification levels (product number 5765-C34)

Software Products Required for ESSL

ESSL runs with the software products shown below.

Table 2. Software Products Required for Use with ESSL

For Compiling	For Linking, Loading, or Running
XL Fortran for AIX, Version 5.1.1 or later (program number 5808-AAR part number 04L2110) *–or–* XL High Performance Fortran for AIX, Version 1.3.1 or later (program number 5765-613) *–or–* IBM C, C++ compilers Version 3.6.4[1] *–or–* C for AIX, Version 4.4 or later (program number 5765-C64 part number 31L0497 with feature number 0002) *–or–* PL/I Set for AIX, Version 1.1 or later (program number 5765-549)	XL Fortran Run-Time Environment for AIX, Version 5.1.1 or later (program number 5808-AAR part number 04L2123) *–or–* XL High Performance Fortran Run-Time Environment for AIX, Version 1.3.1 or later (program number 5765-612) **–and–** C libraries[2]

[1] Available as a component of the VisualAge C ++ Professional for AIX, Version 4, product.

[2] The AIX Version 4 product includes the C libraries and math libraries in the Application Development Toolkit.

Thread Safety

ESSL provides thread-safe versions of the ESSL subroutines for use on all RS/6000 processors. For more information, see the *ESSL Version 3 Guide and Reference*.

For more information on thread programming concepts, see the *IBM AIX Version 4 General Programming Concepts: Writing and Debugging Programs*.

Installation and Customization Requirements

ESSL: The ESSL licensed program is distributed on a 4-millimeter or an 8-millimeter cartridge. The *ESSL Version 3 Installation Memo*, GI10-0604, provides the detailed information you need to install ESSL on AIX.

The ESSL product is packaged in accordance to the AIX guidelines, as described in the *IBM AIX Version 4 General Programming Concepts: Writing and Debugging Programs*. The product can be installed using the **smit** command, as described in the *IBM AIX Version 4 System Management Guide: Operating System and Devices*,.

Online Documentation Requirements

The *ESSL Version 3 Guide and Reference* is available in PostScript and HTML on the product media.

To view the online publications shipped on the product media, you need the following:

- Access to a common HTML document browser (such as Netscape Navigator).

- The location of the HTML index file provided with the file sets. Contact your system administrator or installer for this location.

The *ESSL Guide and Reference Version 3* is available in PDF and HTML format at the IBM RS/6000 Web site at:

http://www.rs6000.ibm.com/resource/aix_resource/sp_books.

To view the ESSL PDF publication, you need to access the Adobe Acrobat Reader 3.0.1. The Acrobat Reader is shipped with the AIX Version 4.3 Bonus Pack and is also freely available for downloading from th Adobe Web site at:

http://www.adobe.com

Ordering ESSL for AIX

You can order ESSL from your IBM Marketing Representative, or by:

- calling 1-800-IBM-CALL (1-800-426-2255)
- using the IBM Web site at:

  http://www.ibm.com/shop/

Ask for the ESSL product:

- IBM Engineering and Scientific Subroutine Library for AIX (program number 5765-C42)

ESSL Product Package

Each ESSL product package provides:

- ESSL libraries
- ESSL header file for C and C++
- ESSL modules
- Installation Verification Programs
- ESSL for AIX Documentation
  - Softcopy:
    - *ESSL Version 3 Guide and Reference*, HTML files.
  - Print-on-Demand:
    - *ESSL Version 3 Guide and Reference*, SA22-7272, PostScript file.
  - Printed:
    - *ESSL Version 3 Licensed Information*, GA22-7302
    - ESSL Proof of Entitlement
    - *ESSL Version 3 Installation Memo*, GI10-0604
    - *ESSL Memo to New User's*, GI10-0603

The printed publication of the *ESSL Version 3 Guide and Reference* is not automatically shipped with your product order. To order this publication:

- Use feature number 7013 to obtain a free initial copy.
- Use feature number 8032 to obtain additional copies for a fee.

ESSL/370

The following sections describe key aspects of the ESSL/370 product, as well as how to order it.

Highlights for ESSL/370

- Provides both vector and scalar versions of all subroutines, including eight parallel processing subroutines:
  - ESSL/370 Vector Library provides high levels of performance for numerically intensive computing jobs on the IBM ES/3090 and ES/9000 Vector Facilities
  - ESSL/370 Scalar Library supports numerically intensive computing jobs running on System/370 and System/390 scalar processors
- ESSL/370 runs under the MVS and VM/ESA operating systems.
- ESSL/370 subroutines can be called from applications written in Fortran, C, PL/I, APL2, and System/370 assembler language.
- The online version of the *ESSL Version 2 Guide Reference* contains most of the information in the *ESSL Version 2 Guide Reference*, SC23-0526 manual. For ESSL/370, the online book is provided as a BookManager book, available on the IBM Online Library Omnibus Editions for MVS, Virtual Machine (VM), and OS/390.
- For a list of subroutines, refer to "ESSL for AIX Subroutines" on page 37.

High Performance of ESSL/370

Algorithms: The ESSL/370 vector subroutines have been designed to provide high performance. To achieve this performance, the vector subroutines use state-of-the-art algorithms tailored to specific operational characteristics of the hardware, such as cache size, vector section size, number of vector registers available, page size, and Translation Lookaside Buffer (TLB) size.

Most subroutines use the following techniques to optimize performance:

- Managing (multilevel) cache and TLB efficiently so the hit ratios are maximized; that is, data is blocked so it stays in the cache or TLB for its computation.
- Accessing data stored contiguously—that is, using stride-1 computations for both real and complex arithmetic.
- Performing operations using vector registers, minimizing loads and stores.
- Sectioning array data into blocks of optimal size for the vector section size.
- Performing fewer load and store operations for short-precision data by using long-precision instructions.
- Using algorithms that minimize paging.

The ESSL/370 parallel processing subroutines have also been designed to provide faster processing, making the best possible use of the number of processors available. To achieve this performance, the parallel processing subroutines use algorithms tailored to each parallel processing environment.

Machine Instructions: Most of the key ESSL/370 subroutines are implemented in System/370 assembler language, using the most efficient machine instructions. These instructions allow the algorithms to be fine tuned to achieve very high performance on the Vector Facility. For example, wherever possible, ESSL/370 chooses those machine instructions that double the floating-point operation rate. These instructions, neglecting overhead, perform two floating-point operations per cycle.

Mathematical Techniques: All areas of ESSL/370 use state-of-the-art mathematical techniques to achieve high performance. For example, the matrix-vector linear algebra subprograms operate on a higher-level data structure, matrix-vector rather than vector-scalar. As a result, they optimize performance directly for your program and indirectly through those ESSL/370 subroutines using them.

Migration Considerations

This section summarizes the impact of migrating from the previous release of ESSL to the new release. It also tells where to find detailed information.

From ESSL Version 2 Release 1 to ESSL Version 2 Release 2: Most application programs that run using ESSL Version 2 Release 1 can be run unchanged with ESSL Version 2 Release 2.

Where to Find Details on Migration: Complete details on migration are given in the following sections in the *ESSL Version 2 Guide Reference* manual, SC23-0526, which is provided with the ESSL product package:

- New and changed items for the new release are listed in the “What's New for This Release” section.
- Details on updates to your application programs for the new release are described in the “Migrating Your Program” chapter.
- Migration information from all previous editions of the *ESSL Version 2 Guide Reference* manual, SC23-0526, is accumulated in “Appendix C.”

Product Requirements

This section describes the hardware, operating systems, and software products you need when using ESSL/370.

Hardware for ESSL/370

ESSL/370 runs on the mainframe processors supported by the operating systems listed under "Operating Systems for ESSL/370." The ESSL/370 Vector Library subroutines require that the Vector Facility be installed. The ESSL/370 Scalar Library subroutines run on any IBM System/370 or System/390 processor.

Operating Systems for ESSL/370

The **ESSL/370 Vector Library** is supported in the following operating system environments:

- MVS/ESA*: MVS/SP Version 5.1.0 or later (JES2: program number 5655-068)
- MVS/ESA MVS/SP Version 4.1.0 or later (JES3: program number 5695-048 or JES2: program number 5695-047)
- MVS/ESA: MVS/SP Version 3.1.0 or later (JES3: program number 5685-002 or JES2: program number 5685-001)
- MVS/XA*: MVS/SP Version 2.2.1 or later (JES3: program number 5665-291) or Version 2.2.0 or later (JES2: program number 5740-XC6)
- VM/ESA (program number 5684-112) Version 1.1.1 or later, plus applicable PTFs for VM/ESA, listed in the *Engineering and Scientific Subroutine Library Version 2 Program Directory* for use with VM.

The **ESSL/370 Scalar Library** is supported in the same environments as the ESSL/370 Vector Library, listed above, in addition to:

- VM/ESA (program number 5684-112) Version 1.1.5 370 Feature, plus applicable PTFs for VM/ESA, listed in the *Engineering and Scientific Subroutine Library Version 2 Program Directory* for use with VM.

Software Products Required for ESSL/370

The ESSL/370 Vector Library and Scalar Library subroutines run with the software products shown below.

Table 3 (Page 1 of 2). Software Products Required for Use with ESSL/370

For Compiling, Assembling, or Interpreting	For Linking, Loading, or Running
MVS and VM Operating Systems	
VS FORTRAN Version 2.1 or later (program number 5668-806 or 5688-087) **–or–** VS FORTRAN Version 1.3 or later (program number 5748-F03) **–or–** IBM High Level Assembler/MVS & VM & Virtual Storage Extended (VSE) Release 1 or later (program number 5696-234)	VS FORTRAN Version 2.5 Library or later (program number 5668-805, 5668-806, or 5688-087)[1]
AD/Cycle* C/370 Compiler Version 1.2 (program number 5688-216)	IBM C/370 Version 2.2 Library (program number 5688-188) **–and–** VS FORTRAN Version 2.5 Library or later (program number 5668-805, 5668-806, or 5688-087)[3]

Table 3 (Page 2 of 2). Software Products Required for Use with ESSL/370	
For Compiling, Assembling, or Interpreting	**For Linking, Loading, or Running**
OS PL/I Compiler Version 2.2 or later (program number 5668-909 or 5668-910)	OS PL/I Version 2.2 Library or later (program number 5668-909, 5668-910, or 5668-911) **–and–** VS FORTRAN Version 2.5 Library or later (program number 5668-805, 5668-806, or 5688-087)[3]
APL2 Version 1.3 (program number 5668-899)[2] **–or–** APL2 Version 2.1 (program number 5688-228)[2]	VS FORTRAN Version 2.5 Library or later (program number 5668-805, 5668-806, or 5688-087)

[1] In this environment, the ESSL parallel subroutines use the VS FORTRAN Multitasking Facility (MTF) or the VS FORTRAN Parallel Feature (PF).

[2] The Numerical Quadrature subroutines (_GLNQ, _GLNQ2, _GLGQ, _GHMQ, and _GRAQ), the Parallel Processing subroutines, and the Utility Subroutine (EINFO) cannot be called from APL2 programs.

[3] In this environment, the ESSL parallel subroutines use the VS FORTRAN Multitasking Facility (MTF) on MVS and run in uniprocessing mode on VM.

Installation and Customization Requirements

The ESSL/370 licensed program is distributed on a 9-track magnetic tape (6250) or a 3480 cartridge. The *Engineering and Scientific Subroutine Library Version 2 Program Directory* for each operating system provides the detailed information you need to install ESSL/370.

The ESSL/370 MVS product is packaged in System Modification Program Extended (SMP/E) format and can be installed using SMP/E. The product is also available through the MVS Custom-Built Installation Process Offering (CBIPO).

The ESSL/370 VM product is installable using Virtual Machine Serviceability Enhancements Staged/Extended (VMSES/E). The product is also available through the VM/ESA system delivery offering (SDO). The product is installable on conversational monitor system (CMS) minidisks or CMS shared file systems (SFS).

For customization of ESSL/370 in the MVS and VM environments, an assembler is required.

Online Documentation Requirements

If you have the following software product, along with the hardware to support it, you can view the online version of the *ESSL Version 2 Guide Reference* on your display:

- BookManager 2.1 READ product, installed on any of the operating systems supported by BookManager

For ESSL/370, the files for the BookManager book are available on the IBM Online Library Omnibus Editions listed in the next section. You must order at least one of the libraries, which you or your system support group installs. (See "Ordering ESSL/370" on page 29).

Ordering ESSL/370

You can order ESSL/370, as well as an IBM Online Library Omnibus Edition, from your IBM Marketing Representative, or by:

- calling 1-800-IBM-CALL (1-800-426-2255)
- using the IBM Web site at:

  http://www.ibm.com/shop/

Ask for the ESSL/370 product:

- IBM Engineering and Scientific Subroutine Library: Vector and Scalar/370 (program number 5688-226)

ESSL/370 Product Package

Each ESSL/370 product package provides:

- ESSL libraries
- NAMES file for APL2
- ESSL header file for C
- ICA file
- IVPs
- ESSL/370 Documentation
  - Softcopy:

    For ESSL/370, the online version of the *ESSL Version 2 Guide Reference* is available as a BookManager book on the IBM Online Library Omnibus Editions listed below. The online version contains most of the information that is in the manual. Ask for the appropriate library:

    - MVS: SK2T-0710 (CD-ROM)
    - VM: SK2T-2067 (CD-ROM)
    - OS/390: SK2T-6700 (CD-ROM)
  - Printed:
    - *ESSL Version 2 Licensed Program Specifications*, GC23-0528
    - *ESSL Version 2 Guide Reference*, SC23-0526
    - *Engineering and Scientific Subroutine Library Version 2 Program Directory*

Additional copies of the printed manuals can be ordered separately.

Parallel ESSL Subroutines (Message Passing and HPF)

This chapter includes a complete list of the subroutines offered in Parallel ESSL.

The subroutines are grouped by mathematical area, where:

Φ A capital phi indicates the subroutines that are new for Parallel ESSL Version 2 Release 1.2.

The message passing subroutine names are distinguished by a prefix based on the following letters:

P for Parallel ESSL message passing subroutines (first letter)
S for short-precision real
D for long-precision real
Z for long-precision complex

Notes:

1. The message passing Level 2 PBLAS, Level 3 PBLAS, Dense and Banded Linear Algebraic Equations, and Eigensystem Analysis and Singular Value Analysis subroutines were designed in accordance with the proposed ScaLAPACK standard. If these subroutines do not comply with the standard as approved, IBM will consider updating them to do so. If IBM updates these subroutines, the update could require modifications of the calling application program.
2. The HPF PBLAS, Dense and Banded Linear Algebraic Equations, and Eigensystem Analysis and Singular Value Analysis subroutines were designed to be consistent with the proposals for the Fortran 90 BLAS and the Fortran 90 Linear Algebra Package (LAPACK). If these subroutines do not comply with any eventual proposal for HPF interfaces to the PBLAS and ScaLAPACK, IBM will consider updating them to do so. If IBM updates these subroutines, the update could require modifications of the calling application program.

Following is a complete list of the subroutines offered in Parallel ESSL.

Level 2 PBLAS

Matrix-Vector Product for a General Matrix or Its Transpose	PDGEMV PZGEMVΦ GEMM*
Matrix-Vector Product for a Real Symmetric or a Complex Hermitian Matrix	PDSYMV PZHEMVΦ SYMM*
Rank-One Update of a General Matrix	PDGER PZGERUΦ PZGERCΦ GEMM*
Rank-One Update of a Real Symmetric or a Complex Hermitian Matrix	PDSYR PZHERΦ SYRK*

Rank-Two Update of a Real Symmetric or a Complex Hermitian Matrix	PDSYR2 PZHER2Φ SYR2K*
Matrix-Vector Product for a Triangular Matrix or Its Transpose	PDTRMV PZTRMVΦ TRMM*
Solution of Triangular System of Equations with a Single Right-hand Side	PDTRSV PZTRSVΦ TRSM*

* Only long-precision real data types are supported.

Level 3 PBLAS

Matrix-Matrix Product for a General Matrix or Its Transpose or Its Conjugate Transpose	PDGEMM PZGEMM GEMM
Matrix-Matrix Product Where One Matrix is Real Symmetric or Complex Hermitian	PDSYMM PZSYMMΦ PZHEMMΦ SYMM*
Triangular Matrix-Matrix Product	PDTRMM PZTRMMΦ TRMM*
Solution of Triangular System of Equations with Multiple Right-hand Sides	PDTRSM PZTRSMΦ TRSM*
Rank-K Update of a Real Symmetric or a Complex Hermitian Matrix	PDSYRK PZSYRKΦ PZHERKΦ SYRK*
Rank-2K Update of a Real Symmetric or a Complex Hermitian Matrix	PDSYR2K PZSYR2KΦ PZHER2KΦ SYR2K*
Matrix Transpose for a General Matrix	PDTRAN PZTRANUΦ PZTRANCΦ TRAN*

* Only long-precision real data types are supported.

Linear Algebraic Equations

Dense Linear Algebraic Equations

General Matrix Factorization and Solve	PDGESVΦ PZGESVΦ
General Matrix Factorization	PDGETRF PZGETRF GETRF

General Matrix Solve	PDGETRS PZGETRS GETRS
Positive Definite Real Symmetric or Complex Hermitian Matrix Factorization and Solve	PDPOSV$^{\Phi}$ PZPOSV$^{\Phi}$
Positive Definite Real Symmetric or Complex Hermitian Matrix Factorization	PDPOTRF PZPOTRF POTRF
Positive Definite Real Symmetric or Complex Hermitian Matrix Solve	PDPOTRS PZPOTRS POTRS

Banded Linear Algebraic Equations

Positive Definite Symmetric Band Matrix Factorization and Solve	PDPBSV PBSV
Positive Definite Symmetric Band Matrix Factorization	PDPBTRF PBTRF
Positive Definite Symmetric Band Matrix Solve	PDPBTRS PBTRS
General Tridiagonal Matrix Factorization and Solve	PDGTSV GTSV
General Tridiagonal Matrix Factorization	PDGTTRF GTTRF
General Tridiagonal Matrix Solve	PDGTTRS GTTRS
Diagonally-Dominant General Tridiagonal Matrix Factorization and Solve	PDDTSV DTSV
Diagonally-Dominant General Tridiagonal Matrix Factorization	PDDTTRF DTTRF
Diagonally-Dominant General Tridiagonal Matrix Solve	PDDTTRS DTTRS
Positive Definite Symmetric Tridiagonal Matrix Factorization and Solve	PDPTSV PTSV
Positive Definite Symmetric Tridiagonal Matrix Factorization	PDPTTRF PTTRF
Positive Definite Symmetric Tridiagonal Matrix Solve	PDPTTRS PTTRS

Fortran 90 Sparse Linear Algebraic Equations and Utilities

Allocates Space for an Array Descriptor for a General Sparse Matrix	PADALL
Allocates Space for a General Sparse Matrix	PSPALL
Allocates Space for a Dense Vector	PGEALL
Inserts Local Data into a General Sparse Matrix	PSPINS
Inserts Local Data into a Dense Vector	PGEINS
Assembles a General Sparse Matrix	PSPASB
Assembles a Dense Vector	PGEASB

Preconditioner for a General Sparse Matrix	PSPGPR
Iterative Linear System Solver for a General Sparse Matrix	PSPGIS
Deallocates Space for a Dense Vector	PGEFREE
Deallocates Space for a General Sparse Matrix	PSPFREE
Deallocates Space for an Array Descriptor for a General Sparse Matrix	PADFREE

Fortran 77 Sparse Linear Algebraic Equations and Utilities

Initializes an Array Descriptor for a General Sparse Matrix	PADINIT
Initializes a General Sparse Matrix	PDSPINIT
Inserts Local Data into a General Sparse Matrix	PDSPINS
Inserts Local Data into a Dense Vector	PDGEINS
Assembles a General Sparse Matrix	PDSPASB
Assembles a Dense Vector	PDGEASB
Preconditioner for a General Sparse Matrix	PDSPGPR
Iterative Linear System Solver for a General Sparse Matrix	PDSPGIS

Eigensystem Analysis and Singular Value Analysis

Selected Eigenvalues and, Optionally, the Eigenvectors of a Real Symmetric Matrix	PDSYEVX SYEVX
Reduce a Real Symmetric Matrix to Tridiagonal Form	PDSYTRD SYTRD
Reduce a General Matrix to Upper Hessenberg Form	PDGEHRD GEHRD
Reduce a General Matrix to Bidiagonal Form	PDGEBRD GEBRD

Fourier Transforms

Complex Fourier Transform in Two Dimensions	PSCFT2	PDCFT2	FFT
Real-to-Complex Fourier Transform in Two Dimensions	PSRCFT2	PDRCFT2	FFT
Complex-to-Real Fourier Transform in Two Dimensions	PSCRFT2	PDCRFT2	FFT
Complex Fourier Transform in Three Dimensions	PSCFT3	PDCFT3	FFT
Real-to-Complex Fourier Transform in Three Dimensions	PSRCFT3	PDRCFT3	FFT
Complex-to-Real Fourier Transform in Three Dimensions	PSCRFT3	PDCRFT3	FFT

Random Number Generation

Uniform Random Number Generator	PDURNG URNG

Utilities

Determine the Level of Parallel ESSL Installed on Your System	IPESSL
Compute the Number of Rows or Columns of a Block-Cyclically Distributed Matrix Contained in a Process	NUMROC

ESSL for AIX Subroutines

This chapter includes a complete list of the subroutines offered in ESSL Version 3 Release 1.

The subroutines are grouped by mathematical area, where:

- ■ A box indicates the subroutines that correspond to Level 1 BLAS.
- ♦ A diamond indicates the subroutines that correspond to Level 2 BLAS.
- ◂ A left arrowhead indicates the subroutines that correspond to Level 3 BLAS.
- ‡ A double dagger indicates the subroutines that correspond to LAPACK.
- § A section indicates the subroutines that are provided for migration from earlier releases of ESSL and are not intended for use in new programs.

Both short- and long-precision real versions of the subroutines are provided in most areas of ESSL. In some areas, short- and long-precision complex versions are also provided, and, occasionally, an integer version is provided. The subroutine names are distinguished by a one-, two-, or three-letter prefix based on the following letters:

S for short-precision real

D for long-precision real

C for short-precision complex

Z for long-precision complex

I for integer

Some of the linear algebra subprograms, matrix operations subroutines, and linear algebraic equation subroutines were designed in accordance with the Level 1, Level 2, and Level 3 BLAS, and LAPACK de facto standard. If these subprograms do not comply with the standard as approved, IBM will consider updating them to do so. If IBM updates these subprograms, the updates could require modifications of the calling application program.

Linear Algebra Subprograms

Vector-Scalar Linear Algebra Subprograms

Position of the First or Last Occurrence of the Vector Element Having the Largest Magnitude	ISAMAX■ ICAMAX■	IDAMAX■ IZAMAX■
Position of the First or Last Occurrence of the Vector Element Having Minimum Absolute Value	ISAMIN	IDAMIN
Position of the First or Last Occurrence of the Vector Element Having Maximum Value	ISMAX	IDMAX
Position of the First or Last Occurrence of the Vector Element Having Minimum Value	ISMIN	IDMIN
Sum of the Magnitudes of the Elements in a Vector	SASUM■ SCASUM■	DASUM■ DZASUM■

Multiply a Vector X by a Scalar, Add to a Vector Y, and Store in the Vector Y	SAXPY■ CAXPY■	DAXPY■ ZAXPY■
Copy a Vector	SCOPY■ CCOPY■	DCOPY■ ZCOPY■
Dot Product of Two Vectors	SDOT■ CDOTU■ CDOTC■	DDOT■ ZDOTU■ ZDOTC■
Compute SAXPY or DAXPY N Times	SNAXPY	DNAXPY
Compute Special Dot Products N Times	SNDOT	DNDOT
Euclidean Length of a Vector with Scaling of Input to Avoid Destructive Underflow and Overflow	SNRM2■ SCNRM2■	DNRM2■ DZNRM2■
Euclidean Length of a Vector with No Scaling of Input	SNORM2 CNORM2	DNORM2 ZNORM2
Construct a Givens Plane Rotation	SROTG■ CROTG■	DROTG■ ZROTG■
Apply a Plane Rotation	SROT■ CROT■ CSROT■	DROT■ ZROT■ ZDROT■
Multiply a Vector X by a Scalar and Store in the Vector X	SSCAL■ CSCAL■ CSSCAL■	DSCAL■ ZSCAL■ ZDSCAL■
Interchange the Elements of Two Vectors	SSWAP■ CSWAP■	DSWAP■ ZSWAP■
Add a Vector X to a Vector Y and Store in a Vector Z	SVEA CVEA	DVEA ZVEA
Subtract a Vector Y from a Vector X and Store in a Vector Z	SVES CVES	DVES ZVES
Multiply a Vector X by a Vector Y and Store in a Vector Z	SVEM CVEM	DVEM ZVEM
Multiply a Vector X by a Scalar and Store in a Vector Y	SYAX CYAX CSYAX	DYAX ZYAX ZDYAX
Multiply a Vector X by a Scalar, Add to a Vector Y, and Store in a Vector Z	SZAXPY CZAXPY	DZAXPY ZZAXPY

Sparse Vector-Scalar Linear Algebra Subprograms

Scatter the Elements of a Sparse Vector X in Compressed-Vector Storage Mode into Specified Elements of a Sparse Vector Y in Full-Vector Storage Mode	SSCTR CSCTR	DSCTR ZSCTR
Gather Specified Elements of a Sparse Vector Y in Full-Vector Storage Mode into a Sparse Vector X in Compressed-Vector Storage Mode	SGTHR CGTHR	DGTHR ZGTHR
Gather Specified Elements of Sparse Vector Y in Full-Vector Mode into Sparse Vector X in Compressed-Vector Mode, and Zero the Same Specified Elements of Y	SGTHRZ CGTHRZ	DGTHRZ ZGTHRZ
Multiply a Sparse Vector X in Compressed-Vector Storage Mode by a Scalar, Add to a Sparse Vector Y in Full-Vector Storage Mode, and Store in the Vector Y	SAXPYI CAXPYI	DAXPYI ZAXPYI

Dot Product of a Sparse Vector X in Compressed-Vector Storage Mode and a Sparse Vector Y in Full-Vector Storage Mode	SDOTI CDOTCI CDOTUI	DDOTI ZDOTCI ZDOTUI

Matrix-Vector Linear Algebra Subprograms

Matrix-Vector Product for a General Matrix, Its Transpose, or Its Conjugate Transpose	SGEMV♦ CGEMV♦ SGEMX§ SGEMTX§	DGEMV♦ ZGEMV♦ DGEMX§ DGEMTX§
Rank-One Update of a General Matrix	SGER♦ CGERU♦ CGERC♦	DGER♦ ZGERU♦ ZGERC♦
Matrix-Vector Product for a Real Symmetric or Complex Hermitian Matrix	SSPMV♦ CHPMV♦ SSYMV♦ CHEMV♦ SSLMX§	DSPMV♦ ZHPMV♦ DSYMV♦ ZHEMV♦ DSLMX§
Rank-One Update of a Real Symmetric or Complex Hermitian Matrix	SSPR♦ CHPR♦ SSYR♦ CHER♦ SSLR1§	DSPR♦ ZHPR♦ DSYR♦ ZHER♦ DSLR1§
Rank-Two Update of a Real Symmetric or Complex Hermitian Matrix	SSPR2♦ CHPR2♦ SSYR2♦ CHER2♦ SSLR2§	DSPR2♦ ZHPR2♦ DSYR2♦ ZHER2♦ DSLR2§
Matrix-Vector Product for a General Band Matrix, Its Transpose, or Its Conjugate Transpose	SGBMV♦ CGBMV♦	DGBMV♦ ZGBMV♦
Matrix-Vector Product for a Real Symmetric or Complex Hermitian Band Matrix	SSBMV♦ CHBMV♦	DSBMV♦ ZHBMV♦
Matrix-Vector Product for a Triangular Matrix, Its Transpose, or Its Conjugate Transpose	STRMV♦ CTRMV♦ STPMV♦ CTPMV♦	DTRMV♦ ZTRMV♦ DTPMV♦ ZTPMV♦
Matrix-Vector Product for a Triangular Band Matrix, Its Transpose, or Its Conjugate Transpose	STBMV♦ CTBMV♦	DTBMV♦ ZTBMV♦

Sparse Matrix-Vector Linear Algebra Subprograms

Matrix-Vector Product for a Sparse Matrix in Compressed-Matrix Storage Mode	DSMMX
Transpose a Sparse Matrix in Compressed-Matrix Storage Mode	DSMTM
Matrix-Vector Product for a Sparse Matrix or Its Transpose in Compressed-Diagonal Storage Mode	DSDMX

Matrix Operations

Matrix Addition for General Matrices or Their Transposes	SGEADD CGEADD	DGEADD ZGEADD
Matrix Subtraction for General Matrices or Their Transposes	SGESUB CGESUB	DGESUB ZGESUB
Matrix Multiplication for General Matrices, Their Transposes, or Conjugate Transposes	SGEMUL CGEMUL	DGEMUL ZGEMUL DGEMLP§
Matrix Multiplication for General Matrices, Their Transposes, or Conjugate Transposes Using Winograd's Variation of Strassen's Algorithm	SGEMMS CGEMMS	DGEMMS ZGEMMS
Combined Matrix Multiplication and Addition for General Matrices, Their Transposes, or Conjugate Transposes	SGEMM◂ CGEMM◂	DGEMM◂ ZGEMM◂
Matrix-Matrix Product Where One Matrix is Real or Complex Symmetric or Complex Hermitian	SSYMM◂ CSYMM◂ CHEMM◂	DSYMM◂ ZSYMM◂ ZHEMM◂
Triangular Matrix-Matrix Product	STRMM◂ CTRMM◂	DTRMM◂ ZTRMM◂
Rank-K Update of a Real or Complex Symmetric or a Complex Hermitian Matrix	SSYRK◂ CSYRK◂ CHERK◂	DSYRK◂ ZSYRK◂ ZHERK◂
Rank-2K Update of a Real or Complex Symmetric or a Complex Hermitian Matrix	SSYR2K◂ CSYR2K◂ CHER2K◂	DSYR2K◂ ZSYR2K◂ ZHER2K◂
General Matrix Transpose (In-Place)	SGETMI CGETMI	DGETMI ZGETMI
General Matrix Transpose (Out-of-Place)	SGETMO CGETMO	DGETMO ZGETMO

Linear Algebraic Equations

Dense Linear Algebraic Equations

General Matrix Factorization	SGEF CGEF SGETRF‡ CGETRF‡	DGEF ZGEF DGETRF‡ ZGETRF‡ DGEFP§
General Matrix, Its Transpose, or Its Conjugate Transpose Solve	SGES CGES	DGES ZGES
General Matrix, Its Transpose, or Its Conjugate Transpose Multiple Right-Hand Side Solve	SGESM CGESM SGETRS‡ CGETRS‡	DGESM ZGESM DGETRS‡ ZGETRS‡
General Matrix Factorization, Condition Number Reciprocal, and Determinant	SGEFCD	DGEFCD

Positive Definite Real Symmetric or Complex Hermitian Matrix Factorization	SPPF SPOF CPOF	DPPF DPOF ZPOF DPPFP§
Positive Definite Real Symmetric Matrix Solve	SPPS	DPPS
Positive Definite Real Symmetric or Complex Hermitian Matrix Multiple Right-Hand Side Solve	SPOSM CPOSM	DPOSM ZPOSM
Positive Definite Real Symmetric Matrix Factorization, Condition Number Reciprocal, and Determinant	SPPFCD SPOFCD	DPPFCD DPOFCD
General Matrix Inverse, Condition Number Reciprocal, and Determinant	SGEICD	DGEICD
Positive Definite Real Symmetric Matrix Inverse, Condition Number Reciprocal, and Determinant	SPPICD SPOICD	DPPICD DPOICD
Solution of a Triangular System of Equations with a Single Right-Hand Side	STRSV♦ CTRSV♦ STPSV♦ CTPSV♦	DTRSV♦ ZTRSV♦ DTPSV♦ ZTPSV♦
Solution of Triangular Systems of Equations with Multiple Right-Hand Sides	STRSM◂ CTRSM◂	DTRSM◂ ZTRSM◂
Triangular Matrix Inverse	STRI STPI	DTRI DTPI

Banded Linear Algebraic Equations

General Band Matrix Factorization	SGBF	DGBF
General Band Matrix Solve	SGBS	DGBS
Positive Definite Symmetric Band Matrix Factorization	SPBF SPBCHF	DPBF DPBCHF
Positive Definite Symmetric Band Matrix Solve	SPBS SPBCHS	DPBS DPBCHS
General Tridiagonal Matrix Factorization	SGTF	DGTF
General Tridiagonal Matrix Solve	SGTS	DGTS
General Tridiagonal Matrix Combined Factorization and Solve with No Pivoting	SGTNP CGTNP	DGTNP ZGTNP
General Tridiagonal Matrix Factorization with No Pivoting	SGTNPF CGTNPF	DGTNPF ZGTNPF
General Tridiagonal Matrix Solve with No Pivoting	SGTNPS CGTNPS	DGTNPS ZGTNPS
Positive Definite Symmetric Tridiagonal Matrix Factorization	SPTF	DPTF
Positive Definite Symmetric Tridiagonal Matrix Solve	SPTS	DPTS
Triangular Band Equation Solve	STBSV♦ CTBSV♦	DTBSV♦ ZTBSV♦

Sparse Linear Algebraic Equations

General Sparse Matrix Factorization Using Storage by Indices, Rows, or Columns	DGSF	
General Sparse Matrix or Its Transpose Solve Using Storage by Indices, Rows, or Columns	DGSS	
General Sparse Matrix or Its Transpose Factorization, Determinant, and Solve Using Skyline Storage Mode	DGKFS DGKFSP§	
Symmetric Sparse Matrix Factorization, Determinant, and Solve Using Skyline Storage Mode	DSKFS DSKFSP§	
Iterative Linear System Solver for a General or Symmetric Sparse Matrix Stored by Rows	DSRIS	
Sparse Positive Definite or Negative Definite Symmetric Matrix Iterative Solve Using Compressed-Matrix Storage Mode	DSMCG§	
Sparse Positive Definite or Negative Definite Symmetric Matrix Iterative Solve Using Compressed-Diagonal Storage Mode	DSDCG	
General Sparse Matrix Iterative Solve Using Compressed-Matrix Storage Mode	DSMGCG§	
General Sparse Matrix Iterative Solve Using Compressed-Diagonal Storage Mode	DSDGCG	

Linear Least Squares

Singular Value Decomposition for a General Matrix	SGESVF	DGESVF
Linear Least Squares Solutions for a General Matrix Using the Singular Value Decomposition	SGESVS	DGESVS
Linear Least Squares Solution for a General Matrix Using a QR Decomposition with Column Pivoting	SGELLS	DGELLS

Eigensystems Analysis

Eigenvalues and, Optionally, All or Selected Eigenvectors of a General Matrix	SGEEV CGEEV	DGEEV ZGEEV
Eigenvalues and, Optionally, the Eigenvectors of a Real Symmetric Matrix or a Complex Hermitian Matrix	SSPEV CHPEV	DSPEV ZHPEV
Extreme Eigenvalues and, Optionally, the Eigenvectors of a Real Symmetric Matrix or a Complex Hermitian Matrix	SSPSV CHPSV	DSPSV ZHPSV
Eigenvalues and, Optionally, the Eigenvectors of a Generalized Real Eigensystem, Az = wBz, where A and B Are Real General Matrices	SGEGV	DGEGV
Eigenvalues and, Optionally, the Eigenvectors of a Generalized Real Symmetric Eigensystem, Az = wBz, where A Is Real Symmetric and B Is Real Symmetric Positive Definite	SSYGV	DSYGV

Fourier Transforms, Convolutions and Correlations, and Related Computations

Fourier Transforms

Complex Fourier Transform	SCFT SCFTP§	DCFT
Real-to-Complex Fourier Transform	SRCFT	DRCFT
Complex-to-Real Fourier Transform	SCRFT	DCRFT
Cosine Transform	SCOSF SCOSFT§	DCOSF
Sine Transform	SSINF	DSINF
Complex Fourier Transform in Two Dimensions	SCFT2	DCFT2
Real-to-Complex Fourier Transform in Two Dimensions	SRCFT2	DRCFT2
Complex-to-Real Fourier Transform in Two Dimensions	SCRFT2	DCRFT2
Complex Fourier Transform in Three Dimensions	SCFT3 SCFT3P§	DCFT3
Real-to-Complex Fourier Transform in Three Dimensions	SRCFT3	DRCFT3
Complex-to-Real Fourier Transform in Three Dimensions	SCRFT3	DCRFT3

Convolutions and Correlations

Convolution or Correlation of One Sequence with One or More Sequences	SCON§ SCOR§	
Convolution or Correlation of One Sequence with Another Sequence Using a Direct Method	SCOND SCORD	
Convolution or Correlation of One Sequence with One or More Sequences Using the Mixed-Radix Fourier Method	SCONF SCORF	
Convolution or Correlation with Decimated Output Using a Direct Method	SDCON SDCOR	DDCON DDCOR
Autocorrelation of One or More Sequences	SACOR§	
Autocorrelation of One or More Sequences Using the Mixed-Radix Fourier Method	SACORF	

Related Computations

Polynomial Evaluation	SPOLY	DPOLY
I-th Zero Crossing	SIZC	DIZC
Time-Varying Recursive Filter	STREC	DTREC
Quadratic Interpolation	SQINT	DQINT
Wiener-Levinson Filter Coefficients	SWLEV CWLEV	DWLEV ZWLEV

Sorting and Searching

Sort the Elements of a Sequence	SSORT ISORT	DSORT
Sort the Elements of a Sequence and Note the Original Element Positions	SSORTX ISORTX	DSORTX
Sort the Element of a Sequence Using a Stable Sort and Note the Original Element Positions	SSORTS ISORTS	DSORTS
Binary Search for Elements of a Sequence X in a Sorted Sequence Y	SBSRCH IBSRCH	DBSRCH
Sequential Search for Elements of a Sequence X in the Sequence Y	SSSRCH ISSRCH	DSSRCH

Interpolation

Polynomial Interpolation	SPINT	DPINT
Local Polynomial Interpolation	STPINT	DTPINT
Cubic Spline Interpolation	SCSINT	DCSINT
Two-Dimensional Cubic Spline Interpolation	SCSIN2	DCSIN2

Numerical Quadrature

Numerical Quadrature Performed on a Set of Points	SPTNQ	DPTNQ
Numerical Quadrature Performed on a Function Using Gauss-Legendre Quadrature	SGLNQ	DGLNQ
Numerical Quadrature Performed on a Function Over a Rectangle Using Two-Dimensional Gauss-Legendre Quadrature	SGLNQ2	DGLNQ2
Numerical Quadrature Performed on a Function Using Gauss-Laguerre Quadrature	SGLGQ	DGLGQ
Numerical Quadrature Performed on a Function Using Gauss-Rational Quadrature	SGRAQ	DGRAQ
Numerical Quadrature Performed on a Function Using Gauss-Hermite Quadrature	SGHMQ	DGHMQ

Random Number Generation

Generate a Vector of Uniformly Distributed Random Numbers	SURAND	DURAND
Generate a Vector of Normally Distributed Random Numbers	SNRAND	DNRAND
Generate a Vector of Long Period Uniformly Distributed Random Numbers	SURXOR	DURXOR

Utilities

ESSL Error Information-Handler Routine	EINFO
ESSL ERRSAV Subroutine for the Workstations	ERRSAV
ESSL ERRSET Subroutine for the Workstations	ERRSET
ESSL ERRSTR Subroutine for the Workstations	ERRSTR
Set the Vector Section Size (VSS) for the ESSL/370 Scalar Library	IVSSET§
Set the Extended Vector Operations Indicator for the ESSL/370 Scalar Library	IEVOPS§
Determine the Level of ESSL Installed	IESSL
Determine the Stride Value for Optimal Performance in Specified Fourier Transform Subroutines	STRIDE
Convert a Sparse Matrix from Storage-by-Rows to Compressed-Matrix Storage Mode	DSRSM
For a General Sparse Matrix, Convert Between Diagonal-Out and Profile-In Skyline Storage Mode	DGKTRN
For a Symmetric Sparse Matrix, Convert Between Diagonal-Out and Profile-In Skyline Storage Mode	DSKTRN

ESSL/370 Subroutines

This chapter includes a complete list of the subroutines offered in ESSL Version 2 Release 2.

The subroutines are grouped by mathematical area, where:

- Φ A capital phi indicates the subroutines that are new for ESSL Version 2 Release 2.
- ▪ A box indicates the subroutines that correspond to Level 1 BLAS.
- ♦ A diamond indicates the subroutines that correspond to Level 2 BLAS.
- ◂ A left arrowhead indicates the subroutines that correspond to Level 3 BLAS.

Both short- and long-precision real versions of the subroutines are provided in most areas of ESSL. In some areas, short- and long-precision complex versions are also provided, and, occasionally, an integer version is provided. The subroutine names are distinguished by a one-, two-, or three-letter prefix based on the following letters:

S for short-precision real

D for long-precision real

C for short-precision complex

Z for long-precision complex

I for integer

Linear Algebra Subprograms

Vector-Scalar Linear Algebra Subprograms

Position of the First or Last Occurrence of the Vector Element Having the Largest Magnitude	ISAMAX▪ ICAMAX▪	IDAMAX▪ IZAMAX▪
Position of the First or Last Occurrence of the Vector Element Having Minimum Absolute Value	ISAMIN	IDAMIN
Position of the First or Last Occurrence of the Vector Element Having Maximum Value	ISMAX	IDMAX
Position of the First or Last Occurrence of the Vector Element Having Minimum Value	ISMIN	IDMIN
Sum of the Magnitudes of the Elements in a Vector	SASUM▪ SCASUM▪	DASUM▪ DZASUM▪
Multiply a Vector X by a Scalar, Add to a Vector Y, and Store in the Vector Y	SAXPY▪ CAXPY▪	DAXPY▪ ZAXPY▪
Copy a Vector	SCOPY▪ CCOPY▪	DCOPY▪ ZCOPY▪
Dot Product of Two Vectors	SDOT▪ CDOTU▪ CDOTC▪	DDOT▪ ZDOTU▪ ZDOTC▪
Compute SAXPY or DAXPY N Times	SNAXPY	DNAXPY

Compute Special Dot Products N Times	SNDOT	DNDOT
Euclidean Length of a Vector with Scaling of Input to Avoid Destructive Underflow and Overflow	SNRM2▪ SCNRM2▪	DNRM2▪ DZNRM2▪
Euclidean Length of a Vector with No Scaling of Input	SNORM2 CNORM2	DNORM2 ZNORM2
Construct a Givens Plane Rotation	SROTG▪ CROTG▪	DROTG▪ ZROTG▪
Apply a Plane Rotation	SROT▪ CROT▪ CSROT▪	DROT▪ ZROT▪ ZDROT▪
Multiply a Vector X by a Scalar and Store in the Vector X	SSCAL▪ CSCAL▪ CSSCAL▪	DSCAL▪ ZSCAL▪ ZDSCAL▪
Interchange the Elements of Two Vectors	SSWAP▪ CSWAP▪	DSWAP▪ ZSWAP▪
Add a Vector X to a Vector Y and Store in a Vector Z	SVEA CVEA	DVEA ZVEA
Subtract a Vector Y from a Vector X and Store in a Vector Z	SVES CVES	DVES ZVES
Multiply a Vector X by a Vector Y and Store in a Vector Z	SVEM CVEM	DVEM ZVEM
Multiply a Vector X by a Scalar and Store in a Vector Y	SYAX CYAX CSYAX	DYAX ZYAX ZDYAX
Multiply a Vector X by a Scalar, Add to a Vector Y, and Store in a Vector Z	SZAXPY CZAXPY	DZAXPY ZZAXPY

Sparse Vector-Scalar Linear Algebra Subprograms

Scatter the Elements of a Sparse Vector X in Compressed-Vector Storage Mode into Specified Elements of a Sparse Vector Y in Full-Vector Storage Mode	SSCTR CSCTR	DSCTR ZSCTR
Gather Specified Elements of a Sparse Vector Y in Full-Vector Storage Mode into a Sparse Vector X in Compressed-Vector Storage Mode	SGTHR CGTHR	DGTHR ZGTHR
Gather Specified Elements of Sparse Vector Y in Full-Vector Mode into Sparse Vector X in Compressed-Vector Mode, and Zero the Same Specified Elements of Y	SGTHRZ CGTHRZ	DGTHRZ ZGTHRZ
Multiply a Sparse Vector X in Compressed-Vector Storage Mode by a Scalar, Add to a Sparse Vector Y in Full-Vector Storage Mode, and Store in the Vector Y	SAXPYI CAXPYI	DAXPYI ZAXPYI
Dot Product of a Sparse Vector X in Compressed-Vector Storage Mode and a Sparse Vector Y in Full-Vector Storage Mode	SDOTI CDOTCI CDOTUI	DDOTI ZDOTCI ZDOTUI

Matrix-Vector Linear Algebra Subprograms

Matrix-Vector Product for a General Matrix, Its Transpose, or Its Conjugate Transpose	SGEMV♦ CGEMV♦ SGEMX SGEMTX	DGEMV♦ ZGEMV♦ DGEMX DGEMTX
Rank-One Update of a General Matrix	SGER♦ CGERU♦ CGERC♦	DGER♦ ZGERU♦ ZGERC♦
Matrix-Vector Product for a Real Symmetric or Complex Hermitian Matrix	SSPMV♦ CHPMV♦ SSYMV♦ CHEMV♦ SSLMX	DSPMV♦ ZHPMV♦ DSYMV♦ ZHEMV♦ DSLMX
Rank-One Update of a Real Symmetric or Complex Hermitian Matrix	SSPR♦ CHPR♦ SSYR♦ CHER♦ SSLR1	DSPR♦ ZHPR♦ DSYR♦ ZHER♦ DSLR1
Rank-Two Update of a Real Symmetric or Complex Hermitian Matrix	SSPR2♦ CHPR2♦ SSYR2♦ CHER2♦ SSLR2	DSPR2♦ ZHPR2♦ DSYR2♦ ZHER2♦ DSLR2
Matrix-Vector Product for a General Band Matrix, Its Transpose, or Its Conjugate Transpose	SGBMV♦ CGBMV♦	DGBMV♦ ZGBMV♦
Matrix-Vector Product for a Real Symmetric or Complex Hermitian Band Matrix	SSBMV♦ CHBMV♦	DSBMV♦ ZHBMV♦
Matrix-Vector Product for a Triangular Matrix, Its Transpose, or Its Conjugate Transpose	STRMV♦ CTRMV♦ STPMV♦ CTPMV♦	DTRMV♦ ZTRMV♦ DTPMV♦ ZTPMV♦
Matrix-Vector Product for a Triangular Band Matrix, Its Transpose, or Its Conjugate Transpose	STBMV♦ CTBMV♦	DTBMV♦ ZTBMV♦

Sparse Matrix-Vector Linear Algebra Subprograms

Matrix-Vector Product for a Sparse Matrix in Compressed-Matrix Storage Mode	DSMMX
Transpose a Sparse Matrix in Compressed-Matrix Storage Mode	DSMTM
Matrix-Vector Product for a Sparse Matrix or Its Transpose in Compressed-Diagonal Storage Mode	DSDMX

Matrix Operations

Matrix Addition for General Matrices or Their Transposes	SGEADD CGEADD	DGEADD ZGEADD
Matrix Subtraction for General Matrices or Their Transposes	SGESUB CGESUB	DGESUB ZGESUB
Matrix Multiplication for General Matrices, Their Transposes, or Conjugate Transposes	SGEMUL CGEMUL	DGEMUL ZGEMUL

Matrix Multiplication for General Matrices, Their Transposes, or Conjugate Transposes Using Winograd's Variation of Strassen's Algorithm	SGEMMS CGEMMS	DGEMMS ZGEMMS
Combined Matrix Multiplication and Addition for General Matrices, Their Transposes, or Conjugate Transposes	SGEMM◂ CGEMM◂	DGEMM◂ ZGEMM◂
Matrix-Matrix Product Where One Matrix is Real or Complex Symmetric or Complex Hermitian	SSYMM◂ CSYMM◂ CHEMM◂	DSYMM◂ ZSYMM◂ ZHEMM◂
Triangular Matrix-Matrix Product	STRMM◂ CTRMM◂	DTRMM◂ ZTRMM◂
Rank-K Update of a Real or Complex Symmetric or a Complex Hermitian Matrix	SSYRK◂ CSYRK◂ CHERK◂	DSYRK◂ ZSYRK◂ ZHERK◂
Rank-2K Update of a Real or Complex Symmetric or a Complex Hermitian Matrix	SSYR2K◂ CSYR2K◂ CHER2K◂	DSYR2K◂ ZSYR2K◂ ZHER2K◂
General Matrix Transpose (In-Place)	SGETMI CGETMI	DGETMI ZGETMI
General Matrix Transpose (Out-of-Place)	SGETMO CGETMO	DGETMO ZGETMO

Linear Algebraic Equations

Dense Linear Algebraic Equations

General Matrix Factorization	SGEF CGEF	DGEF ZGEF
General Matrix or Its Transpose Solve	SGES CGES	DGES ZGES
General Matrix, Its Transpose, or Its Conjugate Transpose Multiple Right-Hand Side Solve	SGESM CGESM	DGESM ZGESM
General Matrix Factorization, Condition Number Reciprocal, and Determinant	SGEFCD	DGEFCD
Positive Definite Real Symmetric or Complex Hermitian Matrix Factorization	SPPF SPOF CPOF	DPPF DPOF ZPOF
Positive Definite Real Symmetric Matrix Solve	SPPS	DPPS
Positive Definite Real Symmetric or Complex Hermitian Matrix Multiple Right-Hand Side Solve	SPOSM CPOSM	DPOSM ZPOSM
Positive Definite Real Symmetric Matrix Factorization, Condition Number Reciprocal, and Determinant	SPPFCD SPOFCD	DPPFCD DPOFCD
General Matrix Inverse, Condition Number Reciprocal, and Determinant	SGEICD	DGEICD
Positive Definite Real Symmetric Matrix Inverse, Condition Number Reciprocal, and Determinant	SPPICD SPOICD	DPPICD DPOICD
Solution of a Triangular System of Equations with a Single Right-Hand Side	STRSV♦ CTRSV♦ STPSV♦ CTPSV♦	DTRSV♦ ZTRSV♦ DTPSV♦ ZTPSV♦

Solution of Triangular Systems of Equations with Multiple Right-Hand Sides	STRSM◂ CTRSM◂	DTRSM◂ ZTRSM◂
Triangular Matrix Inverse	STRI STPIΦ	DTRI DTPIΦ

Banded Linear Algebraic Equations

General Band Matrix Factorization	SGBF	DGBF
General Band Matrix Solve	SGBS	DGBS
Positive Definite Symmetric Band Matrix Factorization	SPBF SPBCHFΦ	DPBF DPBCHFΦ
Positive Definite Symmetric Band Matrix Solve	SPBS SPBCHSΦ	DPBS DPBCHSΦ
General Tridiagonal Matrix Factorization	SGTF	DGTF
General Tridiagonal Matrix Solve	SGTS	DGTS
General Tridiagonal Matrix Combined Factorization and Solve with No Pivoting	SGTNPΦ CGTNPΦ	DGTNPΦ ZGTNPΦ
General Tridiagonal Matrix Factorization with No Pivoting	SGTNPF CGTNPF	DGTNPF ZGTNPF
General Tridiagonal Matrix Solve with No Pivoting	SGTNPS CGTNPS	DGTNPS ZGTNPS
Positive Definite Symmetric Tridiagonal Matrix Factorization	SPTF	DPTF
Positive Definite Symmetric Tridiagonal Matrix Solve	SPTS	DPTS
Triangular Band Equation Solve	STBSV♦ CTBSVΦ ♦	DTBSV♦ ZTBSVΦ ♦

Sparse Linear Algebraic Equations

General Sparse Matrix Factorization Using Storage by Indices, Rows, or Columns	DGSF
General Sparse Matrix or Its Transpose Solve Using Storage by Indices, Rows, or Columns	DGSS
General Sparse Matrix or Its Transpose Factorization, Determinant, and Solve Using Skyline Storage Mode	DGKFS
Symmetric Sparse Matrix Factorization, Determinant, and Solve Using Skyline Storage Mode	DSKFS
Iterative Linear System Solver for a General or Symmetric Sparse Matrix Stored by Rows	DSRIS
Sparse Positive Definite or Negative Definite Symmetric Matrix Iterative Solve Using Compressed-Matrix Storage Mode	DSMCG
Sparse Positive Definite or Negative Definite Symmetric Matrix Iterative Solve Using Compressed-Diagonal Storage Mode	DSDCG
General Sparse Matrix Iterative Solve Using Compressed-Matrix Storage Mode	DSMGCG
General Sparse Matrix Iterative Solve Using Compressed-Diagonal Storage Mode	DSDGCG

Linear Least Squares

Singular Value Decomposition for a General Matrix	SGESVF	DGESVF
Linear Least Squares Solutions for a General Matrix Using the Singular Value Decomposition	SGESVS	DGESVS
Linear Least Squares Solution for a General Matrix Using a QR Decomposition with Column Pivoting	SGELLS	DGELLS

Eigensystems Analysis

Eigenvalues and, Optionally, All or Selected Eigenvectors of a General Matrix	SGEEV CGEEV	DGEEV ZGEEV
Eigenvalues and, Optionally, the Eigenvectors of a Real Symmetric Matrix or a Complex Hermitian Matrix	SSPEV CHPEV	DSPEV ZHPEV
Extreme Eigenvalues and, Optionally, the Eigenvectors of a Real Symmetric Matrix or a Complex Hermitian Matrix	SSPSV CHPSV	DSPSV ZHPSV
Eigenvalues and, Optionally, the Eigenvectors of a Generalized Real Eigensystem, Az = wBz, where A and B Are Real General Matrices	SGEGV	DGEGV
Eigenvalues and, Optionally, the Eigenvectors of a Generalized Real Symmetric Eigensystem, Az = wBz, where A Is Real Symmetric and B Is Real Symmetric Positive Definite	SSYGV	DSYGV

Fourier Transforms, Convolutions and Correlations, and Related Computations

Fourier Transforms

Complex Fourier Transform	SCFT	DCFT
Real-to-Complex Fourier Transform	SRCFT	DRCFT
Complex-to-Real Fourier Transform	SCRFT	DCRFT
Cosine Transform	SCOSFΦ SCOSFT	DCOSFΦ
Sine Transform	SSINFΦ	DSINFΦ
Complex Fourier Transform in Two Dimensions	SCFT2	DCFT2
Real-to-Complex Fourier Transform in Two Dimensions	SRCFT2	DRCFT2
Complex-to-Real Fourier Transform in Two Dimensions	SCRFT2	DCRFT2
Complex Fourier Transform in Three Dimensions	SCFT3	DCFT3
Real-to-Complex Fourier Transform in Three Dimensions	SRCFT3	DRCFT3
Complex-to-Real Fourier Transform in Three Dimensions	SCRFT3	DCRFT3

Convolutions and Correlations

Convolution or Correlation of One Sequence with One or More Sequences	SCON SCOR	
Convolution or Correlation of One Sequence with Another Sequence Using a Direct Method	SCOND SCORD	
Convolution or Correlation of One Sequence with One or More Sequences Using the Mixed-Radix Fourier Method	SCONF SCORF	
Convolution or Correlation with Decimated Output Using a Direct Method	SDCON SDCOR	DDCON DDCOR
Autocorrelation of One or More Sequences	SACOR	
Autocorrelation of One or More Sequences Using the Mixed-Radix Fourier Method	SACORF	

Related Computations

Polynomial Evaluation	SPOLY	DPOLY
I-th Zero Crossing	SIZC	DIZC
Time-Varying Recursive Filter	STREC	DTREC
Quadratic Interpolation	SQINT	DQINT
Wiener-Levinson Filter Coefficients	SWLEV	DWLEV

Sorting and Searching

Sort the Elements of a Sequence	SSORT ISORT	DSORT
Sort the Elements of a Sequence and Note the Original Element Positions	SSORTX ISORTX	DSORTX
Sort the Element of a Sequence Using a Stable Sort and Note the Original Element Positions	SSORTS ISORTS	DSORTS
Binary Search for Elements of a Sequence X in a Sorted Sequence Y	SBSRCH IBSRCH	DBSRCH
Sequential Search for Elements of a Sequence X in the Sequence Y	SSSRCH ISSRCH	DSSRCH

Interpolation

Polynomial Interpolation	SPINT	DPINT
Local Polynomial Interpolation	STPINT	DTPINT
Cubic Spline Interpolation	SCSINT	DCSINT
Two-Dimensional Cubic Spline Interpolation	SCSIN2	DCSIN2

Numerical Quadrature

Numerical Quadrature Performed on a Set of Points	SPTNQ	DPTNQ
Numerical Quadrature Performed on a Function Using Gauss-Legendre Quadrature	SGLNQ	DGLNQ
Numerical Quadrature Performed on a Function Over a Rectangle Using Two-Dimensional Gauss-Legendre Quadrature	SGLNQ2	DGLNQ2
Numerical Quadrature Performed on a Function Using Gauss-Laguerre Quadrature	SGLGQ	DGLGQ
Numerical Quadrature Performed on a Function Using Gauss-Rational Quadrature	SGRAQ	DGRAQ
Numerical Quadrature Performed on a Function Using Gauss-Hermite Quadrature	SGHMQ	DGHMQ

Random Number Generation

Generate a Vector of Uniformly Distributed Random Numbers	SURAND	DURAND
Generate a Vector of Normally Distributed Random Numbers	SNRAND	DNRAND
Generate a Vector of Long Period Uniformly Distributed Random Numbers	SURXOR	DURXOR

Parallel Processing Subroutines

Matrix Multiplication for General Matrices or Their Transposes	DGEMLP
General Matrix Factorization	DGEFP
Positive Definite Symmetric Matrix Factorization	DPPFP
General Sparse Matrix or Its Transpose Factorization, Determinant, and Solve Using Skyline Storage Mode	DGKFSP
Symmetric Sparse Matrix Factorization, Determinant, and Solve Using Skyline Storage Mode	DSKFSP
Complex Fourier Transform	SCFTP
Complex Fourier Transform in Two Dimensions	SCFT2P
Complex Fourier Transform in Three Dimensions	SCFT3P

Utilities

ESSL Error Information-Handler Routine	EINFO
ESSL ERRSAV Subroutine for the Workstations	ERRSAV
ESSL ERRSET Subroutine for the Workstations	ERRSET
ESSL ERRSTR Subroutine for the Workstations	ERRSTR
Set the Vector Section Size (VSS) for the ESSL/370 Scalar Library	IVSSET

Set the Extended Vector Operations Indicator for the ESSL/370 Scalar Library	IEVOPS
Determine the Level of ESSL Installed on Your System	IESSLΦ
Determine the Stride Value for Optimal Performance in Specified Fourier Transform Subroutines	STRIDE
Convert a Sparse Matrix from Storage-by-Rows to Compressed-Matrix Storage Mode	DSRSM
For a General Sparse Matrix, Convert Between Diagonal-Out and Profile-In Skyline Storage Mode	DGKTRN
For a Symmetric Sparse Matrix, Convert Between Diagonal-Out and Profile-In Skyline Storage Mode	DSKTRN

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