REUSE MANUAL

TRANSVERSE MERCATOR

10xxxxxx.1

Implementation

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SECTION 1. INTRODUCTION

1.1 PURPOSE OF THE REUSE MANUAL

This document describes the characteristics of the TRANSVERSE MERCATOR reusable software component and provides instructions on its installation and operation. The manual is a self-contained reference for the software engineer intending to incorporate the component in another software system. This manual was written with the assumption that the user has a basic working knowledge of C and is familiar with fundamental C concepts and terminology.

1.2 PURPOSE OF THE REUSABLE SOFTWARE COMPONENT

The purpose of TRANSVERSE MERCATOR is to provide a reusable component which supports the following coordinate conversions:

- Geodetic coordinates (latitude and longitude in radians) to Transverse Mercator projection coordinates (easting and northing in meters),
- Transverse Mercator projection coordinates (easting and northing in meters) to Geodetic coordinates (latitude and longitude in radians).

A particular ellipsoid is specified in terms of the following parameters:

- Semi-Major Axis (a): Radius (in meters) at the equator, and
- Semi-Minor Axis (b): Radius (in meters) at a pole.

A particular variation of the Transverse Mercator projection is specified in terms of the following parameters:

- Central Meridian – Longitude (in radians) at the origin of the projection,
- Origin Latitude – Latitude (in radians) at the origin of the projection,
- False Easting – A coordinate value (in meters) assigned to the central meridian of the projection to avoid the inconvenience of using negative coordinates,
- False Northing – A coordinate value (in meters) assigned to the origin latitude of the projection to avoid the inconvenience of using negative coordinates, and
- Scale Factor – a multiplier for reducing a distance in projected coordinates to the actual distance along the central meridian.

1.3 GENERAL INFORMATION

1.3.1 POINT OF CONTACT

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1.3.2 CERTIFICATION LEVEL

This RSC has been certified at level 4. A level 4 component satisfies the criteria for reliability, testing, and documentation for the Army Reuse Center (ARC). The component comes with test materials and a Reuse Manual that aids in integrating the component into a software system.

1.3.3 LEGAL RESTRICTIONS

SECTION 2. INSTALLATION

The following is a list of the compilation files for the TRANSVERSE MERCATOR component:

Source Code Files:

```
tranmerc.c
```

Header Files :

```
tranmerc.h
```

Data Files :

```
none
```

The compilation instructions for the TRANSVERSE MERCATOR component are as follows:

DOS Makefile (Uses Microsoft C):

```
cl /nologo /W3 /FR /G2 /DNDEBUG /Gs /Ox /AM /D_DOS /c tranmerc.c
```

UNIX Makefile (Uses gcc compiler):

```
cc -g -O -ansi -Wall -c tranmerc.c
```

The compilation order of the TRANSVERSE MERCATOR component relative to other components is unconstrained.

2.1 PARTIAL REUSE

The TRANSVERSE MERCATOR component does not allow for partial reuse.

2.2 MODIFICATIONS

The TRANSVERSE MERCATOR component does not permit modifications.

SECTION 3. ENVIRONMENT

This section provides details on the environment under which TRANSVERSE MERCATOR was developed, tested, and executed.

3.1 HARDWARE

3.1.1 DEVELOPMENT

The following is a list of hardware configurations under which TRANSVERSE MERCATOR was developed and tested.

- SUN SparcStation 20
- IBM compatible Pentium PC

3.1.2 TARGET

The following is a list of hardware configurations under which TRANSVERSE MERCATOR was executed.

- SUN SparcStation 20
- IBM compatible Pentium PC

3.2 SOFTWARE

3.2.1 OPERATING SYSTEM

The following is a list of operating systems under which TRANSVERSE MERCATOR was executed and tested.

- Solaris 2.5
- Windows 95

3.2.2 COMPILERS

The following is a list of compilers on which TRANSVERSE MERCATOR was compiled successfully.

- GCC version 2.8.1
- Microsoft Visual C++ version 6

3.3 ASSUMPTIONS AND PERFORMANCE LIMITATIONS

There are no hardware or environment constraints. There are no limitations.

This RSC is written in ANSI C.

SECTION 4. GLOBAL RSC ENVIRONMENT

4.1 TYPES

Not applicable.

4.2 CONSTANTS

The following is a list of significant visible constants declared globally in TRANSVERSE MERCATOR with their descriptions.

```
TRANMERC_NO_ERROR               : No errors occurred in function
TRANMERC_LAT_ERROR              : Latitude outside of valid range
                                   (-90 to 90 degrees)
TRANMERC_LON_ERROR              : Longitude outside of valid range
                                   (-180 to 360 degrees, and within
                                    +/- 90 of Central Meridian)
TRANMERC_EASTING_ERROR          : Easting outside of valid range
                                   (depending on ellipsoid and
                                    projection parameters)
TRANMERC_NORTHING_ERROR         : Northing outside of valid range
                                   (depending on ellipsoid and
                                    projection parameters)
TRANMERC_ORIGIN_LAT_ERROR       : Origin latitude outside of valid range
                                   (-90 to 90 degrees)
TRANMERC_CENT_MER_ERROR         : Central meridian outside of valid range
                                   (-180 to 360 degrees)
TRANMERC_A_ERROR                : Semi-major axis less than or equal to zero
TRANMERC_B_ERROR                : Semi-minor axis less than or equal to zero
TRANMERC_A_LESS_B_ERROR         : Semi-major axis less than semi-minor axis
TRANMERC_SCALE_FACTOR_ERROR     : Scale factor outside of valid range
                                   (0.3 to 3.0)
TRANMERC_LON_WARNING            : Distortion will result if longitude is more
                                   than 9 degrees from the Central Meridian
```

4.3 VARIABLES

The following is a list of significant global variables declared in TRANSVERSE MERCATOR with their descriptions.

```
Ellipsoid Parameters:
static double TranMerc_a         : Semi-major axis of ellipsoid in meters
static double TranMerc_b         : Semi-minor axis of ellipsoid in meters

Projection Parameters:
static double TranMerc_Origin_Lat   : Latitude of origin in radians
static double TranMerc_Origin_Long  : Longitude of origin in radians
static double TranMerc_False_Easting  : False easting in meters
static double TranMerc_False_Northing : False northing in meters
static double TranMerc_Scale_Factor   : Scale factor

Isometric to geodetic latitude parameters:
static double TranMerc_ap
```

```
static double TranMerc_bp
static double TranMerc_cp
static double TranMerc_dp
static double TranMerc_ep

Maximum variance for easting and northing values:
static double TranMerc_Delta_Easting
static double TranMerc_Delta_Northing
```

4.4 INCLUDE FILES

```
math.h                          : Standard C math library
tranmerc.h                      : Error codes and prototype error checking
```

4.5 DEPENDENCIES

None, other than the standard ANSI C math library.

SECTION 5. FUNCTIONS

5.1 SET_TRANSVERSE_MERCATOR_PARAMETERS

5.1.1 DESCRIPTION

This function sets the ellipsoid and Transverse Mercator projection parameters to the specified values.

5.1.2 INTERFACES AND EXAMPLES

The following is a list of the formal arguments required to use this function.

```
long Set_Transverse_Mercator_Parameters (double a,
             double b,
             double Origin_Latitude,
             double Central_Meridian,
             double False_Easting,
             double False_Northing,
             double Scale_Factor);
```

a	Semi-major axis of ellipsoid in meters (input),
b	Semi-minor axis of ellipsoid in meters (input),
Origin_Latitude	Latitude in radians at the origin of the projection (input),
Central_Meridian	Longitude in radians at the origin of the projection (input),
False_Easting	Coordinate value in meters assigned to the central meridian (input),
False_Northing	Coordinate value in meters assigned to the origin latitude (input),
Scale_Factor	Multiplier which reduces the distances in the projection to the actual distances on the ellipsoid, along the central meridian (input).

Example:

```
status = Set_Transverse_Mercator_Parameters (a, b, Origin_Latitude,
            Central_Meridian, False_Easting, False_Northing, Scale_Factor)
```

Inputs:

a	6378137.0
b	6356752.3142

Origin_Latitude 0.0

Central_Meridian 0.0

False_Easting 0.0

False_Northing 0.0

Scale_Factor 1.0

Outputs:

None.

5.1.3 DECLARATIONS

5.1.3.1 TYPES

Not applicable.

5.1.3.2 CONSTANTS

Not applicable.

5.1.3.3 VARIABLES

Not applicable.

5.1.4 DEPENDENCIES

None.

5.1.5 ERROR HANDLING

This function returns the following status codes:

```
TRANMERC_NO_ERROR               : No errors occurred in function
TRANMERC_ORIGIN_LAT_ERROR       : Origin latitude outside of valid range
                                    (-90 to 90 degrees)
TRANMERC_CENT_MER_ERROR         : Central meridian outside of valid range
                                    (-180 to 360 degrees)
TRANMERC_A_ERROR                : Semi-major axis less than or equal to zero
TRANMERC_B_ERROR                : Semi-minor axis less than or equal to zero
TRANMERC_A_LESS_B_ERROR         : Semi-major axis less than semi-minor axis
```

```
TRANMERC_SCALE_FACTOR_ERROR      : Scale factor outside of valid range
                                     (0.3 to 3.0)
```

5.2 GET_TRANSVERSE_MERCATOR_PARAMETERS

5.2.1 DESCRIPTION

This function returns the current values of the ellipsoid parameters and Transverse Mercator projection parameters.

5.2.2 INTERFACES AND EXAMPLES

The following is a list of the formal arguments required to use this function.

```
void Get_Transverse_Mercator_Parameters (double *a,
             double *b,
             double *Origin_Latitude,
             double *Central_Meridian,
             double *False_Easting,
             double *False_Northing,
             double *Scale_Factor);
```

a	Semi-major axis of ellipsoid in meters (output),
b	Semi-minor axis of ellipsoid in meters (output),
Origin_Latitude	Latitude in radians at the origin of the projection (output),
Central_Meridian	Longitude in radians at the origin of the projection (output),
False_Easting	Coordinate value in meters assigned to the central meridian (output),
False_Northing	Coordinate value in meters assigned to the origin latitude (output),
Scale_Factor	Multiplier which reduces the distances in the projection to the actual distances on the ellipsoid, along the central meridian (output).

5.2.3 DECLARATIONS

5.2.3.1 TYPES

Not applicable.

5.2.3.2 CONSTANTS

Not applicable.

5.2.3.3 VARIABLES

Not applicable.

5.2.4 DEPENDENCIES

None.

5.2.5 ERROR HANDLING

No errors are reported by this function.

5.3 CONVERT_GEODETIC_TO_TRANSVERSE_MERCATOR

5.3.1 DESCRIPTION

This function converts Geodetic coordinates (latitude and longitude in radians) to Transverse Mercator projection coordinates (easting and northing in meters), using the current ellipsoid and Transverse Mercator projection parameters.

5.3.2 INTERFACES AND EXAMPLES

The following is a list of the formal arguments required to use this function.

```
long Convert_Geodetic_To_Transverse_Mercator (double Latitude,
             double Longitude,
             double *Easting,
             double *Northing);
```

Latitude	Latitude in radians (input),
Longitude	Longitude in radians (input),
Easting	Easting (X) in meters (output),
Northing	Northing (Y) in meters (output).

Example:

```
status = Convert_Geodetic_To_Transverse_Mercator (Latitude, Longitude,
            Easting, Northing)
```

Inputs:

Latitude:	35.0
Longitude:	-2.0

Outputs:

Easting:	-182187
Northing:	3876416

5.3.3 DECLARATIONS

5.3.3.1 TYPES

Not applicable.

5.3.3.2 CONSTANTS

Not applicable.

5.3.3.3 VARIABLES

Not applicable.

5.3.4 DEPENDENCIES

None.

5.3.5 ERROR HANDLING

This function returns the following status codes:

```
TRANMERC_NO_ERROR               : No errors occurred in function
TRANMERC_LAT_ERROR              : Latitude outside of valid range
                                    (-90 to 90 degrees)
TRANMERC_LON_ERROR              : Longitude outside of valid range
```

```
                                    (-180 to 360 degrees, and within
                                     +/- 90 of Central Meridian)
TRANMERC_LON_WARNING              : Distortion will result if longitude is more
                                    than 9 degrees from the Central Meridian
```

5.4 CONVERT_TRANSVERSE_MERCATOR_TO_GEODETIC

5.4.1 DESCRIPTION

This function converts Transverse Mercator projection coordinates (easting and northing in meters) to Geodetic coordinates (latitude and longitude in radians), using the current ellipsoid and Transverse Mercator projection parameters.

5.4.2 INTERFACES AND EXAMPLES

The following is a list of the formal arguments required to use this function.

```
long Convert_Transverse_Mercator_To_Geodetic (double Easting,
             double Northing,
             double *Latitude,
             double *Longitude)
```

Easting	Easting (X) in meters (input),
Northing	Northing (Y) in meters (input),
Latitude	Latitude in radians (output),
Longitude	Longitude in radians (output).

Example:

```
status = Convert_Transverse_Mercator_To_Geodetic (Easting, Northing, Latitude,
            Longitude)
```

Inputs:

Easting:	-182187
Northing:	3876416

Outputs:

Latitude:	35.0
Longitude:	-2.0

5.4.3 DECLARATIONS

5.4.3.1 TYPES

Not applicable.

5.4.3.2 CONSTANTS

Not applicable.

5.4.3.3 VARIABLES

Not applicable.

5.4.4 DEPENDENCIES

None.

5.4.5 ERROR HANDLING

This function returns the following status codes:

```
TRANMERC_NO_ERROR               : No errors occurred in function
TRANMERC_EASTING_ERROR          : Easting outside of valid range
                                    (depending on ellipsoid and
                                     projection parameters)
TRANMERC_NORTHING_ERROR         : Northing outside of valid range
                                    (depending on ellipsoid and
                                     projection parameters)
TRANMERC_LON_WARNING            : Distortion will result if longitude is more
                                    than 9 degrees from the Central Meridian
```

APPENDIX A STRUCTURE/DEPENDENCY DIAGRAMS

This component consists of a single compilation unit and depends only on the ANSI C standard math library.

APPENDIX B DEFINITIONS/GLOSSARY

Central Meridian – Longitude at the horizontal center of a projection; Origin Longitude.

Coordinate – Linear or angular quantities that designate the position that a point occupies in a given reference frame or system. Also used as a general term to designate the particular kind of reference frame or system, such as Cartesian or spherical coordinates.

Ellipsoid – The surface generated by an ellipse rotating about one of its axes.

False Easting – A coordinate value (in meters) assigned to the central meridian of the projection to avoid the inconvenience of using negative coordinates.

False Northing – A coordinate value (in meters) assigned to the origin latitude of the projection to avoid the inconvenience of using negative coordinates.

Geodetic Coordinates – The quantities of latitude and longitude that define the position of a point on the surface of the earth with respect to the reference ellipsoid. Also, imprecisely called geographic coordinates.

Geodetic Latitude – The angle between the plane of the equator and the normal to the ellipsoid through the computation point. Geodetic latitude is positive north of the equator and negative south of the equator.

Geodetic Longitude – The angle between the plane of a meridian and the plane of the prime meridian. A longitude can be measured from the angle formed between the local and prime meridians at the pole of rotation of the reference ellipsoid, or by the arc along the equator intercepted by these meridians.

Map Projection – A function relating coordinates of points on a curved surface (usually an ellipsoid or sphere) to coordinates of points on a plane. A map projection may be established by analytical computation or, less commonly, may be constructed geometrically.

Map Scale – The ratio between a distance on a map and the corresponding actual distance on the earth's surface.

Meridian – A north-south reference line, particularly a great circle through the geo–graphical poles of the earth, from which longitudes and azimuths are determined; or the intersection of a plane forming a great circle that contains both geographic poles of the earth, and the ellipsoid.

Origin Latitude – Latitude of the origin of the projected coordinate system.

Parallel – A line on the earth, or a representation thereof, that represents the same latitude at every point.

Scale Factor (Projection) – A multplier for reducing a distance in a map projection to the actual distance on the chosen reference ellipsoid.

Transverse Mercator Projection – A conformal projection for which the scale factor is one along the central meridian. The line Y = 0 is the projection of the equator, and the line X=0 is the projection of the central meridian.

APPENDIX C REFERENCES

(1) Topographic Engineering Center, TEC-SR-7, **Handbook for transformation of DATUMS, PROJECTIONS, GRIDS, AND COMMON COORDINATE SYSTEMS**, January 1996.