8 Spatial reference frames

8.1 Introduction

A spatial reference frame is a means of specifying a spatial coordinate system for a region of an object-space. The relationship between a spatial reference frame and the corresponding spatial coordinate system is discussed in 8.2. Spatial reference frame specifications are discussed in 8.3.

Many applications need to perform operations involving multiple spatial reference frames. Relationships among spatial reference frames are commonly derived from corresponding relationships among the spatial objects of interest within the application domain. Spatial reference frame relationships are discussed in 8.4.

A spatial reference frame template provides an abstraction of spatial reference frames that share common elements. This International Standard defines a collection of spatial reference frame templates in 8.5.

This International Standard defines a collection of standardized spatial reference frames in 8.6.

Spatial reference frames may be organized into specified sets to form an atlas for a large region. This International Standard defines a collection of standardized spatial reference frame sets, as well as the members of those sets, in 8.7.

8.2 Spatial reference frame structure

A spatial reference frame uses a spatial coordinate system (see 5.4) to assign a unique coordinate n-tuple to each point in a region of object-space. A spatial coordinate system is defined as the functional composition of an abstract coordinate system generating function and a normal embedding. The abstract coordinate system generating function $\boldsymbol{G}$ associates coordinates in coordinate-space to positions in position-space. A normal embedding $\boldsymbol{E}$ maps those positions in position-space to points in object-space. Different normal embeddings produce different spatial coordinate systems. If $\boldsymbol{c}$ is a coordinate for the coordinate system, then $\boldsymbol{c}$ identifies the object-space point $\boldsymbol{p} = \boldsymbol{E} \circ \boldsymbol{G}(\boldsymbol{c})$.

A spatial reference frame uses an object reference model (see 7.4) to determine a unique normal embedding $\boldsymbol{E}$ of position-space into the object-space of the spatial object that it models. The object reference model is a set of reference datums that bind geometric primitives (points, directed curves, or oriented surfaces) in position-space to corresponding geometrics aspects of the spatial object in object-space.

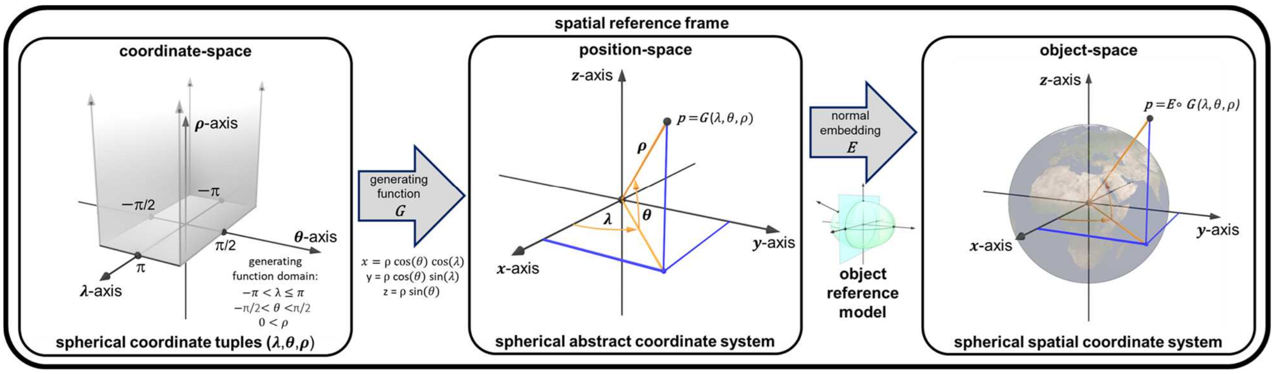

Figure 8.1 — The components of a spatial reference frame

Figure 8.1 illustrates a spatial reference frame in which a spherical spatial coordinate system is derived from a spherical abstract coordinate system and a normal embedding determined by an object reference model of the Earth. In this illustration, a coordinate (λ, θ, ρ) in coordinate-space is assigned to a position-vector [x, y, z] in position-space. That position is mapped to a location in the object-space of the Earth via the unique normal embedding that is determined by the object reference model and its associated reference datums.

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8.3 Spatial reference frame specification

8.3.1 SRF definition

A *spatial reference frame* (SRF) is a specification of a spatial coordinate system that is constructed from an ORM and a compatible abstract CS, such that coordinates uniquely specify positions with respect to the spatial object of the ORM. A specification of an SRF includes:

a) an ORM,

b) an abstract CS compatible with the ORM,

c) a binding of all parameters of the CS,

d) (optionally) k^{th} coordinate-component names,

e) (optionally) additional restrictions on the coordinate domain, and

f) (optionally) if the CS is of CS type 3D, a vertical coordinate-component identification (see 5.2.1).

An SRF specifies a spatial CS defined by the functional composition of the abstract CS generating function and the normal embedding associated with the ORM.

Spatial CS compatibility and the other elements of the specification of an SRF are defined in the following clauses.

8.3.2 SRF specification elements

8.3.2.1 ORM and CS compatibility

The compatible CS type of the CS element of an SRF depends on the dimension of the ORM. The *dimension of an ORM* is defined as the dimension of the RD components of the specification of the ORM. The compatible CS types by ORM dimension are specified in Table 8.1.

Table 8.1 — Compatible CS types

ORM dimension	Compatible CS types
1D	1D CS
2D	Curve CS 2D CS
3D	Curve CS Surface CS 3D CS

The use of surface CSs or 3D CSs that are based on an oblate ellipsoid (or sphere) are restricted to ORMs that are based on an oblate ellipsoid (or respectively, sphere) RD.

The standardized surface CSs that are based on an oblate ellipsoid (or sphere) are:

a) surface geodetic,

b) surface planetodetic, and

c) all map projections.

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The 3D CSs that are based on an oblate ellipsoid (or sphere) are:

a) geodetic 3D,

b) planetodetic 3D, and

c) all augmented map projections.

As a further restriction, some CSs are based on spheres only. CS OBLIQUE_MERCATOR_SPHERICAL has this restriction.

An SRF may be described in terms of the properties and other characteristics of the CS that is specified by the SRF. In particular, an SRF is said to be a *3D SRF*, *surface SRF*, or *2D SRF* if the CS of the SRF is of the corresponding CS type. Similarly, the CS properties of linearity, orthogonality, and handedness may be used as descriptors of an SRF corresponding to the properties of the CS that is specified by the SRF. Thus, an SRF is said to be a *linear SRF* or a *curvilinear SRF* if the CS of the SRF has the respective linearity property. Every 3D SRF in this International Standard is a right-handed SRF in consequence to the CS handedness restriction imposed in 5.2.3.

8.3.2.2 CS parameter binding

All CS parameter values must be specified. In the case of a combination of a CS and an ORM based on an oblate ellipsoid (or sphere), the major semi-axis and minor semi-axis (or equivalently, the inverse flattening) (or respectively, sphere radius) of the ORM and CS shall match.

8.3.2.3 Coordinate-component names

A CS specification (see 5.3.8) includes the coordinate-component symbols with common names (if any). A specification of an SRF may optionally assign SRF-specific names to the k^{th} coordinate-components. The name assignment shall reflect the common use in the intended application domain.

EXAMPLE For an equatorial spherical CS, the assignment of SRF-specific names to the k^{th} coordinate-components of “right ascension” for λ, “declination” for θ, and “radius” for ρ.

8.3.2.4 Applicable region

A CS specification (see 5.3.8) includes the specification of the CS domain and CS range where the generating function (or mapping equations) and its inverse(s) are defined. An SRF specification may further restrict the CS domain. An *applicable region* is a restriction of the CS domain as used in an SRF. An *extended region* is a second region that contains the applicable region as a subset. The specification of these restrictions is important for several (SRF specific) reasons:

a) If the ORM is local, the restrictions are used to model, in coordinate-space, the local region of the space of the object.

b) If the CS is a map projection or an augmented map projection, the restrictions are used to bound or otherwise limit distortions (see 5.3.7.3.3).

c) The SRF may be used in conjunction with other SRFs to form an atlas for a large region (see 8.7 SRF sets). In this case, the restrictions are used to control the pair-wise overlap of the spatial coverage of members of the SRF collection.

d) If the CS generating function (or map projection mapping equations) or the inverse function(s) have been implemented with a numerical approximation, the restrictions are used to control error bounds.

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The extended region is used primarily for overlapping regions in forming an atlas as in (c) above. Not all properties of the SRF that are true in the applicable region will necessarily be true in the extended region. In particular, a distortion error bound that holds in the applicable region may not hold in the extended region.

Applicable regions and extended regions may be described and/or specified. An *applicable region description* is a statement that describes the spatial extent of the region such as in terms of named geographic areas or political entities.

EXAMPLE 1 "The German state of Baden-Wurttemberg" and "The Baltic Sea" are applicable region descriptions.

An *applicable region specification* consists of a set of constraints that specifies the spatial extent of the region. The spatial extent of the region may always be specified in terms of coordinate-component value ranges in the coordinate system of the SRF. Such a specification is termed to be of type *coordinate-region*.

If the ORM of the SRF is based on an oblate ellipsoid (or sphere), the spatial extent of the region may alternatively be specified in terms of coordinate-component value ranges in the geodetic coordinate system of the Celestiodetic SRF for that ORM (see 8.5.4). When the coordinate-component value ranges are specified in terms of geodetic coordinates in this way, the specification is termed to be of type *geodetic-region*. To avoid loss of precision, such geodetic coordinate values may be specified in arc degrees. Applicable region specifications of type geodetic-region may be useful for local Euclidean or map projection-based SRFs.

Each coordinate-component value range may be fully bounded, with both upper and lower bounds specified, semi-bounded, with only one (either upper or lower) bound specified, or unbounded, with no bounds specified. Together, the coordinate-component value ranges specify a full or partial bounding box, in terms of either the coordinate system of the SRF (type coordinate-region), or in terms of geodetic coordinates of the Celestiodetic SRF for that ORM (type geodetic-region).

If an applicable region has been specified, an *extended region specification* of the same type (type coordinate-region or type geodetic-region) may also be specified. The ranges specified for an extended region shall contain the corresponding applicable region ranges.

A coordinate is considered to be *within the applicable region* if it is contained in the CS domain of the SRF and satisfies all constraints in the applicable region specification. In the case of an applicable region specification of type geodetic-region, the coordinate is considered to be within the applicable region if the corresponding Celestiodetic SRF coordinate satisfies all geodetic constraints in the applicable region specification.

A coordinate is considered to be *within the extended region* if it is contained in the CS domain of the SRF and satisfies the constraints in the extended region specification. In the case of an extended region specification of type geodetic-region, the coordinate is considered to be within the extended region if the corresponding Celestiodetic SRF coordinate satisfies all geodetic constraints in the extended region specification.

EXAMPLE 2 The SRF is based on a transverse Mercator map projection (see SRFT TRANSVERSE_MERCATOR).
Applicable region specification of type coordinate-region: $167\,000 \leq u \leq 833\,000$, $0 \leq v \leq 9\,500\,000$
Extended region specification of type coordinate-region: $0 < u$, $-100 < v$
Note that the extended region is partially bounded.

EXAMPLE 3 The SRF is based on a transverse Mercator map projection (see SRFT TRANSVERSE_MERCATOR).
Appliable region specification of type geodetic-region: $-78^\circ \leq \lambda < -72^\circ$, $0^\circ \leq \varphi < 84^\circ$
Extended region specification of type geodetic-region: $-78{,}5^\circ \leq \lambda < -71{,}5^\circ$

Note that the extended region is partially bounded, since no constraint on φ is specified.

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8.4 SRF relationships

8.4.1 Introduction

Many applications need to perform operations involving multiple SRFs. These SRFs can be related to one another in several different ways.

Relationships among multiple SRFs within an application often reflect corresponding relationships among the spatial objects of interest to the application domain. The SRFs can be in the same object-space or in different object-spaces corresponding to different application objects. Such application object SRF relationships are discussed in 8.4.2.

When dealing with curvilinear 3D SRFs, it is useful in some applications to reduce the dimensionality of the coordinate system of an SRF by fixing the values of one or more of its coordinate-components to induce a new SRF. Instances of such relationships include surface SRFs that are induced from corresponding 3D SRFs when one coordinate-component is fixed. This type of SRF relationship is discussed in 8.4.3.

It is also useful in some applications to create a localized SRF with its origin at a specified location on the surface of the Earth or another celestial body, its horizontal axes tangent to the surface at that point, and its vertical axis perpendicular to the surface. An orthonormal frame with these characteristics is termed a local tangent frame. Local tangent frames are discussed in 8.4.4.

Operations on directions and vector quantities require a Cartesian coordinate system. When an SRF does not provide such a coordinate system, this requirement can be met using a localized frame or local tangent frame (see 5.3.6.3) at a specified coordinate. This is discussed in 8.4.5.

8.4.2 Application object SRFs

In many applications it is useful or necessary to relate information expressed in one SRF in terms of another SRF. The SRFs may be associated with the same spatial object or may be associated with a different spatial object.

An SRF may be associated with a specified region of a spatial object of interest. The applicable region of such an SRF is a subset of the applicable region of a reference SRF associated with that same spatial object. Regional SRFs are commonly specified in terms of coordinates and parameters of the reference SRF. Regional SRFs can include:

a) An SRF for a construction site for a building or bridge (see Figure 8.2) with the SRF origin specified by a geodetic reference point (see 8.6.7), primary axis direction specified by an azimuth, and applicable region specified by a sequence of geodetic points forming a closed polygon

b) An SRF for a Mars rover operating area (see Figure 8.2) with the SRF origin specified by the Mars planetographic (see 8.6.14) coordinates of the rover's landing site, primary axis direction aligned with local east at the landing site, and applicable region specified by a maximum distance from the landing site

c) Members of SRF sets that cover adjacent regions within larger geographic areas, such as the zones of the Japan plane coordinate system (see 8.7.4 and Figure 8.2), US state plane coordinate systems (see 8.7.2 or 8.7.8), or universal transverse Mercator system (see 8.7.7)

An SRF may be associated with an object that is a component of an assembly. Such component object SRFs are commonly specified in terms of coordinates and parameters of a reference SRF associated with that assembly. It is common for component object SRFs to be linked, forming chains based on the hierarchical structure of an assembly with articulated components. Component object SRFs can include:

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a) An SRF for a radar or sensor (see Figure 8.2) specified in terms of the SRF of the vehicle to which it is attached

b) A series of SRFs for robot arm segments (see Figure 8.2) each specified in terms of the SRF of the segment to which it is attached, or the SRF of the base of the robot arm

c) A branching hierarchy of SRFs of various types (Euclidean, cylindrical, etc.) associated with a large, complex piece of agricultural or construction equipment with multiple, diverse articulated parts

An SRF may be associated with an independent object that operates within the object-space of another spatial object, which acts as a reference object. Such independent object SRFs are commonly specified in terms of coordinates and parameters of a reference SRF associated with that reference object. Applications may need to relate the positions, orientations, and other properties of two or more independent objects to one another, either by using one of them as the reference object, or by using a larger spatial object that acts as the reference for all the independent objects. Independent object SRFs can include:

a) An SRF for a vehicle (see Figure 8.2) with its origin specified by a geodetic point (see 8.6.7) corresponding to the location of the vehicle, and primary and secondary axis directions specified relative to the azimuth of the front of the vehicle

b) SRFs for two or more vehicles (see Figure 8.2) with the SRF of one chosen as the reference SRF for the others, or the geodetic SRF of the Earth (see 8.6.7) chosen as the reference SRF for all of them

c) Two celestiodetic SRFs (see 8.5.4 and Figure 8.2) for Earth and Mars, with the SRF of one chosen as the reference for the other, or the celestiocentric SRF (see 8.5.2) of the Sun chosen as the reference for both

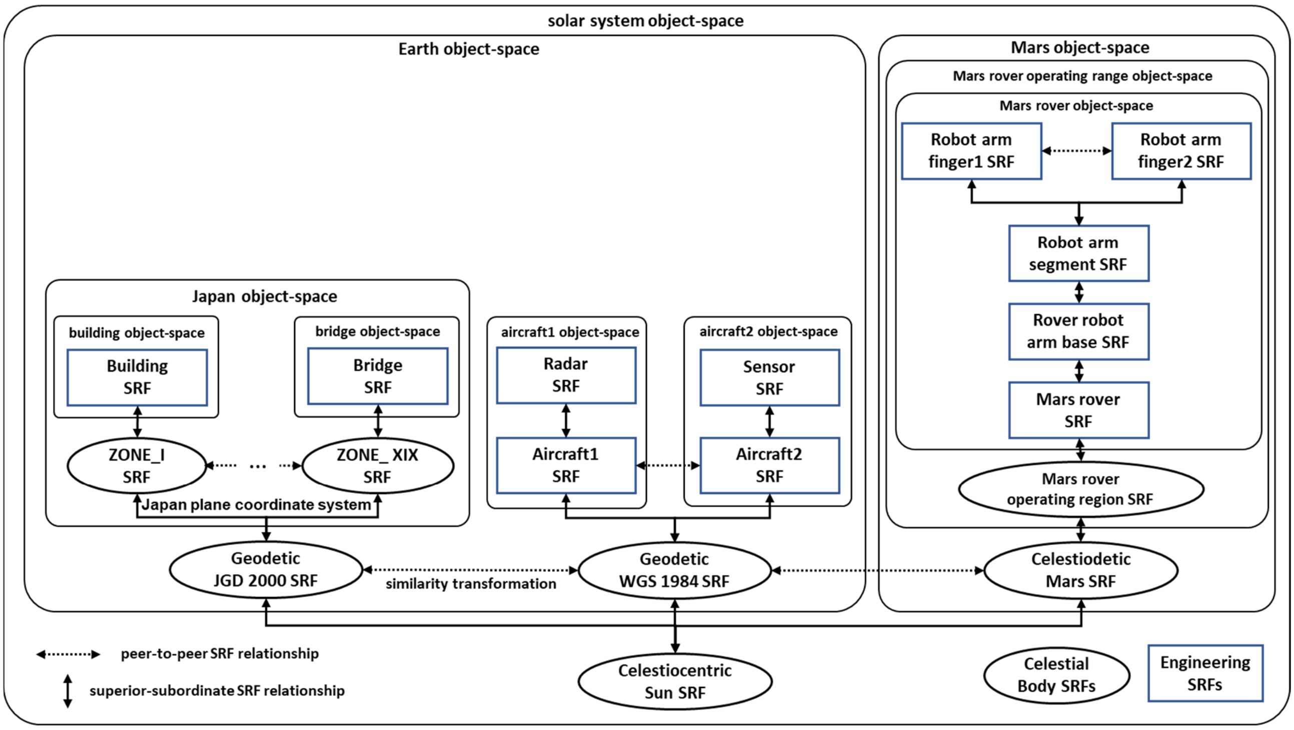

Figure 8.2 — Examples of SRF relationships

These different categories of SRF relationships can be combined in any manner that is useful to an application. Figure 8.2 illustrates several of the cases described above, including the nested object-spaces with which the various SRFs are associated. Vertical connections represent superior-to-subordinate SRF relationships, associating regional SRFs with reference SRFs for the objects of which they are subsets, or associated

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component object SRFs with the reference SRFs for the assemblies to which they are attached. Horizontal connections represent peer-to-peer SRF relationships between independent objects. These horizontal relationships can be implemented directly by choosing the SRF of one of the objects to fill the role of reference SRF, or they can be implemented indirectly by choosing a reference SRF for another object that provides the overall context.

Some SRF relationships can be specified using localization (see 5.3.6). Some regional SRFs are based on map projections, or augmented map projections (see 5.3.7). Regional, component object, or independent object SRFs can be based on spatial coordinate systems (see 5.4.2) that are translated and/or rotated with respect to a reference SRF. Local tangent space SRFs are defined in terms of a plane that is tangent to a curved surface at a specified point. Lococentric Euclidean 3D SRFs are more general, allowing arbitrary translations and/or rotations.

Such localized SRFs require an orthonormal frame. The parameters that characterize a localized orthonormal frame are the origin $\boldsymbol{q}$ and basis vectors $\boldsymbol{r}, \boldsymbol{s}$ and $\boldsymbol{t} = \boldsymbol{r} \times \boldsymbol{s}$. These vectors are specified with respect to the embedded frame in object-space generated by embedding $\boldsymbol{E}$. These parameters are used for:

1) specifying 3D Localization operator parameters in SRF templates, and
2) generating Cartesian vector spaces to specify:
    a) chained component object SRFs,
    b) local tangent frame SRFs (see 8.4.4), and
    c) directions and vector quantities (see 8.4.5).

This International Standard specifies several standardized SRF templates (see 8.5) and SRF sets (see 8.7) that use localization.

In many applications, some or all of the objects of interest, and their associated SRFs, can be moving. In all such dynamic cases, once a fixed time is specified, the object configuration (and the associated SRFs) can be treated as a static snapshot.

8.4.3 Induced surface SRFs

Coordinate-component surfaces of a 3D CS and corresponding induced surface CSs are defined in 5.3.4.2. The relationship between 3D CSs and corresponding induced surface CSs extends to SRFs, and is specified through the appropriate combination of a 3D ORM and a 3D CS. This can be an efficient way of using the specification of a 3D SRF to produce the specification of a surface SRF. This relationship also holds for SRF templates (see 8.5)

An SRF specification may optionally identify the 3rd coordinate-component as the vertical coordinate-component for the SRF. In that case, the surface CS that is induced on the zero vertical coordinate-component surface is the CS for the induced surface SRF. The 3D SRF templates celestiodetic and planetodetic can be used to instantiate surface celestiodetic and surface planetodetic SRFs, respectively. The vertical coordinate-component of these 3D SRF templates is set to zero to induce the corresponding surface SRFs.

EXAMPLE 1 For a directional sensor located at a fixed site on the Earth's surface, a local surface SRF with a polar coordinate system (measuring the angle counterclockwise from local east) is needed. Such an SRF can be created by:

1) Instantiating a local tangent space cylindrical SRF, using the geodetic coordinates of the sensor as the origin of the 3D SRF. The resulting SRF has a lococentric cylindrical 3D CS.
2) Fixing the value of the 3rd coordinate-component of the 3D SRF, h (height), at zero to induce a surface SRF with a lococentric surface polar CS.

EXAMPLE 2 For another directional sensor located at a fixed site on the Earth's surface, a local surface SRF with an azimuthal polar coordinate system (measuring the angle clockwise from local north) is needed. Such an SRF can be created by:

1) Instantiating a local tangent space azimuthal spherical SRF, using the geodetic coordinates of the sensor as the origin of the 3D SRF. The resulting SRF has a lococentric azimuthal spherical 3D CS.
2) Fixing the value of the 3rd coordinate-component of the 3D SRF, θ (depressions/elevation angle), at zero to induce a surface SRF with a lococentric surface azimuthal polar CS.

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EXAMPLE 3 For a landing site located on the surface of Mars, a local surface SRF with a Euclidean 2D coordinate system is needed. Such an SRF can be created by:

1) Instantiating a local tangent space Euclidean SRF, using the planetodetic coordinates of the centre of the landing site as the origin of the 3D SRF. The resulting SRF has a lococentric Euclidean 3D CS.
2) Fixing the value of the 3rd coordinate-component of the 3D SRF, h (height), at zero to induce a surface SRF with a lococentric surface Euclidean 2D CS.

NOTE The relationship between a surface SRF and the 3D SRF that induces it is functionally similar to, but conceptually different from, the ISO 19111 concept of compound coordinate reference system. A compound coordinate reference system synthesizes a 3D reference frame from a surface and a vertical system.

8.4.4 Local tangent frame SRFs

The local tangent frame at a coordinate $\boldsymbol{c}$ of a reference CS is defined in 5.3.6.3. The localization parameters for specifying the origin and basis vectors of the local tangent frame are defined in 5.3.6.2 and mentioned in 8.4.2. These concepts and constructs extend to SRF relationships.

Starting with a reference SRF, $\mathrm{SRF_R}$, and coordinate $\boldsymbol{c}$, a local tangent frame SRF, $\mathrm{SRF_L}$, is constructed at $\mathrm{SRF_R}$ coordinate $\boldsymbol{c}$ using the same ORM as $\mathrm{SRF_R}$ (with embedding $\boldsymbol{E}$) and any ORM compatible CS with generating function $\boldsymbol{G}_\mathrm{C}$. $\mathrm{SRF_L}$ is termed a *local tangent frame SRF* at a coordinate $\boldsymbol{c}$. $\mathrm{SRF_R}$ is termed the *reference SRF of the local tangent frame*. $\boldsymbol{G}_\mathrm{R}$ is the reference CS generating function. The localized CS with spatial generating function $\boldsymbol{E} \circ \boldsymbol{G}_\mathrm{L} = \boldsymbol{E} \circ \boldsymbol{L}_\mathrm{3D} \circ \boldsymbol{G}_\mathrm{C}$, using $\boldsymbol{L}_\mathrm{3D}$ parameters $\boldsymbol{q}, \boldsymbol{r}$, and $\boldsymbol{s}$, is used to specify $\mathrm{SRF_L}$, where $\boldsymbol{q} = \boldsymbol{G}_\mathrm{R}(\boldsymbol{c})$. The embedding function $\boldsymbol{E}$ is an isomorphism between the position-space frame and the embedded frame in object-space. Thus, the object-space vectors, $\boldsymbol{q}, \boldsymbol{r}$, and $\boldsymbol{s}$ have the same coordinate-component values as the corresponding position-space vectors and may be used as the required localization parameters.

EXAMPLE 1 If $\mathrm{SRF_R}$ is a LOCOCENTRIC_EUCLIDEAN_3D SRF with parameters $\boldsymbol{q}$, $\boldsymbol{r}$ and $\boldsymbol{s}$, and $\boldsymbol{c}$ is an $\mathrm{SRF_R}$ reference coordinate, then local tangent vectors at $\boldsymbol{c}$ are equal to the SRFT parameters $\boldsymbol{r}$ and $\boldsymbol{s}$. If $\boldsymbol{c} = (0, 0, 0)$, then $\mathrm{SRF_L}$ and $\mathrm{SRF_R}$ are identical.

EXAMPLE 2 $\mathrm{SRF_R}$ is an EQUATORIAL_INERTIAL SRF. This SRF is based on the EQUATORIAL_SPHERICAL CS. If $\boldsymbol{c} = (\lambda_0, \theta_0, \rho_0)$ is a reference coordinate, then the local tangent vectors at $\boldsymbol{c}$ are:

$\boldsymbol{r} = \boldsymbol{v}_1/\|\boldsymbol{v}_1\|$ and $\boldsymbol{s} = \boldsymbol{v}_2/\|\boldsymbol{v}_2\|$
where

$$\begin{aligned}
\boldsymbol{v}_1 &= \left|\frac{d\boldsymbol{C}_1}{d\lambda}\right|_{\lambda=\lambda_0} = \left|\frac{d}{d\lambda}[\rho_0\cos(\theta_0)\cos(\lambda),\quad \rho_0\cos(\theta_0)\sin(\lambda),\quad \rho_0\sin(\theta_0)]\right|_{\lambda=\lambda_0} \\
&= [-\rho_0\cos(\theta_0)\sin(\lambda_0),\quad \rho_0\cos(\theta_0)\cos(\lambda_0),\quad 0], \\
\boldsymbol{v}_1/\|\boldsymbol{v}_1\| &= [-\sin(\lambda_0),\quad \cos(\lambda_0),\quad 0], \\
\boldsymbol{v}_2 &= \left|\frac{d\boldsymbol{C}_2}{d\theta}\right|_{\theta=\theta_0} = \left|\frac{d}{d\theta}[\rho_0\cos(\theta)\cos(\lambda_0),\quad \rho_0\cos(\theta)\sin(\lambda_0),\quad \rho_0\sin(\theta)]\right|_{\theta=\theta_0} \\
&= [-\rho_0\sin(\theta_0)\cos(\lambda_0),\quad -\rho_0\sin(\theta_0)\sin(\lambda_0),\quad \rho_0\cos(\theta_0)], \text{ and} \\
\boldsymbol{v}_2/\|\boldsymbol{v}_2\| &= [(-\sin(\theta_0)\cos(\lambda_0),\quad -\sin(\theta_0)\sin(\lambda_0),\quad \cos(\theta_0)).]
\end{aligned}$$

EXAMPLE 3 $\mathrm{SRF_R}$ is a CELESTIODETIC SRF. This SRF is based on the GEODETIC CS. If $\boldsymbol{c} = (\lambda_0, \varphi_0, h_0)$ is a reference coordinate, then the local tangent vectors at $\boldsymbol{c}$ are:

$$\begin{aligned}
\boldsymbol{r} &= (-\sin(\lambda_0),\quad \cos(\lambda_0),\quad 0), \\
\boldsymbol{s} &= (-\sin(\varphi_0)\cos(\lambda_0),\quad -\sin(\varphi_0)\sin(\lambda_0),\quad \cos(\varphi_0)), \text{ and} \\
\boldsymbol{t} &= \boldsymbol{r} \times \boldsymbol{s} = (\cos\lambda_0\cos\varphi_0,\quad \sin\lambda_0\cos\varphi_0,\quad \sin\varphi_0).
\end{aligned}$$

In this example, $\mathrm{SRF_L}$ is equivalent to a LOCAL_TANGENT_SPACE_EUCLIDEAN SRF with template parameter values $\lambda = \lambda_0,\ \varphi = \varphi_0,\ \alpha = 0,\ x_\mathrm{F} = y_\mathrm{F} = 0$, and h_0.

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EXAMPLE 4 SRF$_R$ is based on an augmented conformal map projection CS. If $\boldsymbol{c} = (u_0, v_0, h_0)$ is a reference coordinate, and $(\lambda_0, \varphi_0, h_0)$ is the corresponding celestiodetic coordinate, then the local tangent vectors at $\boldsymbol{c}$ are:

$\boldsymbol{r} = [-\sin\lambda_0 \cos\gamma_0 + \cos\lambda_0 \sin\varphi_0 \sin\gamma_0, \quad \cos\lambda_0 \cos\gamma_0 + \sin\lambda_0 \sin\varphi_0 \sin\gamma_0, \quad -\cos\varphi \sin\gamma_0]$, and
$\boldsymbol{s} = [-\sin\lambda_0 \sin\gamma_0 - \cos\lambda_0 \sin\varphi_0 \cos\gamma_0, \quad \cos\lambda_0 \sin\gamma_0 - \sin\lambda_0 \sin\varphi_0 \cos\gamma_0, \quad \cos\varphi_0 \cos\gamma_0]$
where:
$\gamma_0 = \gamma(\lambda_0, \varphi_0)$ is the convergence of the meridian.

In this example, SRF$_L$ is equivalent to a LOCAL_TANGENT_SPACE_EUCLIDEAN SRF with template parameter values $\lambda = \lambda_0,\ \varphi = \varphi_0,\ \alpha = \gamma_0,\ x_F = y_F = 0,\ \text{and}\ h_0$.

LOCAL_TANGENT_SPACE_EUCLIDEAN, LOCAL_TANGENT_SPACE_AZIMUTHAL_SPHERICAL, and LOCAL_TANGENT_SPACE_CYLINDRICAL are local tangent frame SRF templates for use with celestiodetic SRFs. In these three SRF templates, the localization parameters $\boldsymbol{q}, \boldsymbol{r}$, and $\boldsymbol{s}$ are computed using the template parameters $\lambda_0, \varphi_0, h_0$, and α_0. The origin $\boldsymbol{q}$ is located at the reference SRF celestiodetic coordinates (λ_0, φ_0) and is displaced in the direction $\boldsymbol{t} = \boldsymbol{r} \times \boldsymbol{s}$ by h_0 units. The basis vectors $\boldsymbol{r}$ and $\boldsymbol{s}$ are rotated clockwise about axis $\boldsymbol{t}$ by azimuth angle α_0.

8.4.5 Cartesian SRFs for vector specification

Specification of vectors, including directions and vector quantities, associated with an SRF requires an underlying vector space. A direction is expressed in an SRF as a combination of a unit vector and a reference coordinate. The unit vector is expressed in the vector space of a localized frame. Vector quantities such as velocity add a magnitude to the direction unit vector.

The specifications of directions and vector quantities are defined in 5.3.6.4 in terms of a localized frame within position-space. These same definitions apply to orthonormal frames for an embedded frame within object-space. An SRF specifies an ORM for its object-space which determines a normal embedding and its corresponding embedded frame. This frame is termed the embedded frame of the SRF.

A direction in an orthogonal CS based SRF$_S$ shall be comprised of:

a) a coordinate $\boldsymbol{c}$ in the interior of the CS domain of SRF$_S$, and

b) a unit vector $\boldsymbol{n}$ in the localized frame at $\boldsymbol{c}$.

Vector quantities such as velocity and acceleration add a magnitude to this representation.

The coordinate $\boldsymbol{c}$ is termed the *reference coordinate* and its corresponding position is termed the *reference position*.

A localized frame at coordinate $\boldsymbol{c}$ can be realized by an instance of the SRFT LOCOCENTRIC_EUCLIDEAN_3D that provides a vector space for vector operations.

An SRF is either linear or curvilinear, deriving this property from its spatial coordinate system. If an SRF is linear, the structure of its spatial coordinate system provides a vector space. All lines through distinct points in a given direction $\boldsymbol{n}$ are parallel in object-space. This shows that a linear SRF supports the translation invariance of vectors. A linear SRF will not preserve angular relationships between directions unless the associated spatial coordinate system (CS) is also orthonormal. An orthonormal SRF preserves angles and distances.

If an SRF is curvilinear, the structure of its spatial coordinate system does not provide a direct vector space. To support the expression of vectors in curvilinear SRFs, an orthonormal frame at a given reference coordinate shall be established to provide a vector space. When embedded in object-space, this orthonormal frame is termed the vector reference frame (see 5.3.6.4). The SRF based on the vector reference frame is uniquely defined for each reference coordinate. Since there is neither an intrinsic SRF nor an intrinsic reference point in object-space, it is necessary to specify the coordinate of the reference point to inter-convert the representation of vectors between two SRFs.

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If an SRF is linear, the vector's direction is translation invariant. Thus, a localized frame is not necessary. However, for consistency, the use of a vector reference frame at a reference coordinate to provide a vector space is applied uniformly to both linear and curvilinear SRFs.

The coordinate system of an augmented map projection SRF (a map projection augmented with ellipsoidal height as a third dimension) appears to inherit the vector-space structure of $\mathbb{R}^3$. However, the vector properties of the (easting, northing, height)-coordinates do not carry over to object-space. This is illustrated in part by the "up pointing" vector $\boldsymbol{n} = (0, 0, 1)$ that points in different spatial directions in object-space depending on the map coordinate location at which $\boldsymbol{n}$ is placed.

In Figure 8.3, distinct position points $\boldsymbol{p}$ and $\boldsymbol{q}$ on an ellipsoid surface are projected to augmented map coordinates $(s, t, 0)$ and $(u, v, 0)$. Starting at these map coordinates, the coordinates one unit away in the "up direction" are $(s, t, 1)$ and $(u, v, 1)$, respectively. In an augmented map projection, these coordinates correspond to the position-space points $\boldsymbol{p}'$ and $\boldsymbol{q}'$. However, the direction from $\boldsymbol{p}$ to $\boldsymbol{p}'$ is not the same as the direction from $\boldsymbol{q}$ to $\boldsymbol{q}'$. This shows that, in object-space, the "up direction" is relative to a reference point.

The local tangent frame associated with a given reference point has its origin at the reference point and its axes given by the normalized vectors tangent to the coordinate curves passing through the reference point, as described in 5.3.6.3. All linear and curvilinear CSs in this International Standard are orthogonal CSs, thus the local tangent frame is an orthonormal linear SRF.

Figure 8.3 shows two local tangent frames at points $\boldsymbol{p}$ and $\boldsymbol{q}$ in object-space. The local "up" directions may be specified as a direction in either local tangent frame. Since directions are translation invariant in linear SRFs, conceptually the two local tangent frames may be translated to a common origin.

This method of associating local tangent frames with reference coordinates reduces the general problem of inter-converting vector between two SRFs to that of inter-converting between two orthonormal frames.

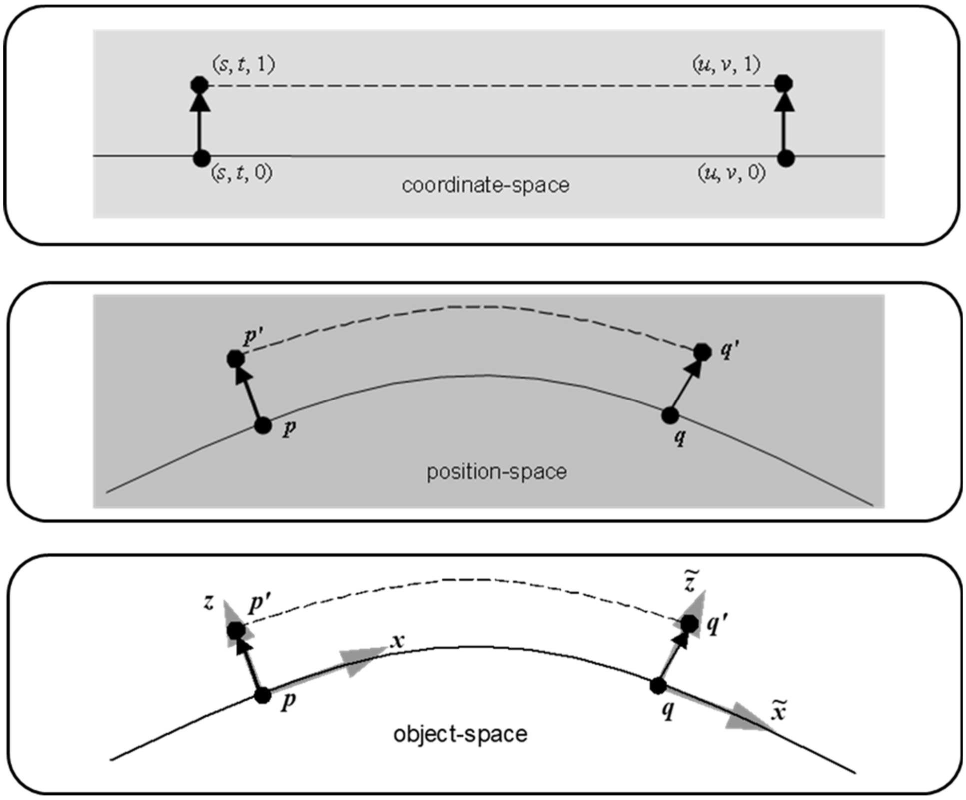

Figure 8.3 — Coordinate-space, position-space, and object-space directions compared

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8.5 SRF templates

8.5.1 Introduction

A *spatial reference frame template* (SRFT) is a standardized mechanism for specifying an SRF. An SRFT consists of an abstract CS, coordinate component names, CS parameter binding rules, and ORM constraints. SRFTs provide a convenient way to specify SRFs that share these common elements.

The coordinate system parameter binding rules may depend on both the characteristics of the reference datums in the object reference model and the way the reference datums are bound in the object-space. Therefore, a spatial reference frame template specification includes the type of spatial object and constraints on the set of object reference models for the spatial object.

EXAMPLE 1 The celestiodetic spatial reference frame template (see 8.5.4) consists of the following specifications:

a) the object type is a physical object,

b) the object reference model is a realization of the oblate ellipsoid object reference model template,

c) the abstract coordinate system is either the geodetic coordinate system (see Table 5.14) or the surface geodetic coordinate system (see Table 5.24), and

d) the major and minor semi-axis coordinate system parameter values, a and b, are equal to the major and minor semi-axis values of the oblate ellipsoid reference datum of the ellipsoid object reference model.

EXAMPLE 2 The Geodetic WGS 1984 spatial reference frame may be derived from the template in Example 1 by specifying the Earth as the spatial object and WGS_1984 as the object reference model.

EXAMPLE 3 A different geodetic spatial reference frame may be derived from the template in Example 1 by specifying the Earth as the spatial object and EUROPE_1950 as the object reference model. This spatial reference frame and the spatial reference frame in Example 2 both use the geodetic coordinate system, but they are distinct spatial reference frames. In general, they assign different coordinates to each point in the object-space of the Earth.

A spatial reference frame for an object is said to be derived from a given spatial reference frame template if it is compliant with that spatial reference frame template specification.

It is not necessary that an appropriate SRFT be defined in order to define a new SRF; however, in this International Standard all SRFs are derived from SRFTs. The specification elements for SRFTs are defined in Table 8.2.

Table 8.2 — SRFT specification elements

Element	Definition
SRFT label	The label of the SRF template (see 13.2.2).
SRFT code	The code of the SRF template (see 13.2.3). Code 0 (UNSPECIFIED) is reserved.
Short name and description	A short name for the SRF template as published or as commonly known and an optional description.
Object or object type	One or more of: abstract, physical, Earth, planet, satellite, and Sun; and, optionally, additional restrictions.
ORM constraint	Criteria for applicable ORMs.
CS label	The label of a CS of compatible type.

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Element	Definition
CS coordinate-component names and/or symbols	SRF-specific names and/or symbols for the k^{th} coordinate-component names and/or symbols. If all coordinate-component names and symbols are the same as the CS, the phrase “The same as the CS.” shall be used. In addition, if the CS is 3D, the third coordinate-component may optionally be identified as the “vertical coordinate-component”.
Template parameters	CS and RD parameters, if any, and/or SRF parameters that are not specified by a CS parameter binding rule.
CS parameter binding rules	A set of rules for binding for CS parameters and ORM component RD parameters, if any, and/or SRF parameters.
Applicable region	Optional restriction of the domain of the CS to an applicable region description and/or an applicable region specification. If an applicable region specification is included, an extended region specification may also be included. If no applicable region is specified, the phrase "No additional restrictions." shall be used.
Notes	Optional, non-normative information such as a description of the SRF structure, modelled region, intended use, and/or application domain.
References	The references (see 13.2.5).

An ORM is *applicable* to an SRFT if the object associated with the ORM satisfies the object or object type specification of the SRFT, and the ORM satisfies the ORM constraint specification of the SRFT.

Coordinates in a given SRF may be represented in a variety of formats or encodings if the coordinate-component values are sufficiently identified in the representation scheme. A representation scheme for coordinates of an SRF:

a) shall identify the coordinate-components by name and/or symbol, or
b) shall identify coordinate-components of an encoding scheme in terms of the coordinate-components specified in the SRF, or
c) shall define the ordering of a coordinate-component-tuple representation in terms of the coordinate-components specified in the SRF.

The API (see Clause 11) provides coordinate value encoding schemes in the form of data records with field names that correspond to coordinate-component names. Where coordinate-component-tuples appear in the API, the ordering is the order specified in the corresponding CS specification table.

This International Standard specifies a collection of SRFTs as identified in Table 8.3. Additional SRFTs may be specified by registration in accordance with Clause 13. Registered SRFs shall be derived only from standardized or registered SRFTs.

Several of the SRFTs listed in Table 8.3 can be used to specify SRFs based on either a 3D CS or the corresponding surface CS. These SRFTs appear in both the 3D and Surface sections of Table 8.3, with different short names. When these SRFTs are used to specify SRFs based on the surface CS, their 3rd (vertical) coordinate-component is fixed at zero and is not explicitly used.

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Table 8.3 — SRFT directory

CS type	Short name	SRFT label
3D	Celestiocentric	CELESTIOCENTRIC
	Local space rectangular 3D	LOCAL_SPACE_RECTANGULAR_3D
	Celestiodetic	CELESTIODETIC
	Planetodetic	PLANETODETIC
	Local tangent space Euclidean	LOCAL_TANGENT_SPACE_EUCLIDEAN
	Local tangent space azimuthal spherical	LOCAL_TANGENT_SPACE_AZIMUTHAL_SPHERICAL
	Local tangent space cylindrical	LOCAL_TANGENT_SPACE_CYLINDRICAL
	Lococentric Euclidean 3D	LOCOCENTRIC_EUCLIDEAN_3D
	Celestiomagnetic	CELESTIOMAGNETIC
	Equatorial inertial	EQUATORIAL_INERTIAL
	Solar ecliptic	SOLAR_ECLIPTIC
	Solar equatorial	SOLAR_EQUATORIAL
	Solar magnetic ecliptic	SOLAR_MAGNETIC_ECLIPTIC
	Solar magnetic	SOLAR_MAGNETIC_DIPOLE
	Heliospheric Aries ecliptic	HELIOSPHERIC_ARIES_ECLIPTIC
	Heliospheric Earth ecliptic	HELIOSPHERIC_EARTH_ECLIPTIC
	Heliospheric Earth equatorial	HELIOSPHERIC_EARTH_EQUATORIAL
Surface (map projection) and 3D (augmented map projection)	Mercator	MERCATOR
	Oblique Mercator spherical	OBLIQUE_MERCATOR_SPHERICAL
	Transverse Mercator	TRANSVERSE_MERCATOR
	Lambert conformal conic	LAMBERT_CONFORMAL_CONIC
	Polar stereographic	POLAR_STEREOGRAPHIC
	Equidistant cylindrical	EQUIDISTANT_CYLINDRICAL
Surface	Surface celestiodetic	CELESTIODETIC
	Surface planetodetic	PLANETODETIC
	Local tangent plane Euclidean	LOCAL_TANGENT_SPACE_EUCLIDEAN
	Local tangent plane azimuthal	LOCAL_TANGENT_SPACE_AZIMUTHAL_SPHERICAL
	Local tangent plane polar	LOCAL_TANGENT_SPACE_CYLINDRICAL
2D	Local space rectangular 2D	LOCAL_SPACE_RECTANGULAR_2D
	Local space azimuthal	LOCAL_SPACE_AZIMUTHAL_2D
	Local space polar	LOCAL_SPACE_POLAR_2D

8.5.2 Celestiocentric SRFT

Celestiocentric SRFs shall be derived from the SRFT specified in Table 8.4.

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Table 8.4 — Celestiocentric SRFT

Element	Specification
SRFT label	CELESTIOCENTRIC
SRFT code	1
Short name and description	Celestiocentric SRFT The generalization of geocentric spatial reference frames to include non-Earth objects.
Object type	physical
ORM constraint	Shall be derived from any 3D ORM.
CS label	EUCLIDEAN_3D
CS coordinate-component names and/or symbols	The same as the CS.
Template parameters	none
CS parameter binding rules	None (no CS parameters).
Applicable region	No additional restrictions.
Notes	When the object is Earth, this SRFT is referred to as a *geocentric SRFT*.
References	[EDM]

8.5.3 Local space rectangular 3D SRFT

Local space rectangular 3D SRFs shall be derived from the SRFT specified in Table 8.5.

Table 8.5 — Local space rectangular 3D SRFT

Element	Specification
SRFT label	LOCAL_SPACE_RECTANGULAR_3D
SRFT code	2
Short name and description	Local space rectangular 3D SRFT A 3D Euclidean spatial reference frame for an abstract 3D space.
Object type	3D abstract object
ORM constraint	Shall be an ORM for a 3D abstract object.
CS label	LOCOCENTRIC_EUCLIDEAN_3D
CS coordinate-component names and/or symbols	The same as the CS.
Template parameters	$\boldsymbol{r}$ = vector direction of forward (forward axis). $\boldsymbol{s}$ = vector direction of up (up axis).

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Element	Specification
CS parameter binding rules	$q = 0$, r and s select from: $+e_1$ positive primary axis, $+e_2$ positive secondary axis, $+e_3$ positive tertiary axis, $-e_1$ negative primary axis, $-e_2$ negative secondary axis, $-e_3$ negative tertiary axis, subject to: $s \neq \pm r$, where: $\boldsymbol{e}_1 = \begin{bmatrix}1\\0\\0\end{bmatrix}, \boldsymbol{e}_2 = \begin{bmatrix}0\\1\\0\end{bmatrix}, \text{and } \boldsymbol{e}_3 = \begin{bmatrix}0\\0\\1\end{bmatrix}.$
Applicable region	No additional restrictions.
Notes	CAD/CAM and other engineering applications.
References	[EDM]

8.5.4 Celestiodetic SRFT

Celestiodetic and surface celestiodetic SRFs shall be derived from the SRFT specified in Table 8.6.

Table 8.6 — Celestiodetic SRFT

Element	Specification
SRFT label	CELESTIODETIC
SRFT code	3
Short name and description	Celestiodetic or surface celestiodetic SRFT The generalization of geodetic SRFs to include other planets and ellipsoidal bodies. The surface celestiodetic SRFT is not specified separately (see Note 2).
Object type	Physical
ORM constraint	Shall be derived from: ORMT OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN, SPHERE, or SPHERE_ORIGIN.
CS label	GEODETIC (for celestiodetic SRFT) SURFACE_GEODETIC (for surface celestiodetic SRFT)
CS coordinate-component names and/or symbols	The same as the CS. The vertical coordinate-component is ellipsoidal height (h).
Template parameters	ORMT RD parameters: For OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN: a = major semi-axis f = flattening For SPHERE, SPHERE_ORIGIN: r = radius.

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Element	Specification
CS parameter binding rules	CS parameters match RD values. Oblate ellipsoid RD case with major semi-axis a and inverse flattening f^{-1}: $a = a$ $b = a(1 - f)$ Sphere RD case with radius r: $a = b = r$.
Applicable region	No additional restrictions.
Notes	1) This SRFT can be used to specify either 3D SRFs based on the GEODETIC CS or surface SRFs based on the or SURFACE_GEODETIC CS. When this SRFT is used to specify a surface SRF, the 3rd (vertical) coordinate-component (h) is fixed at zero and is not explicitly used. 2) The surface celestiodetic SRFT is not specified explicitly. Surface celestiodetic SRFs are induced on the oblate ellipsoid (or sphere) RD surface, which is the zero 3rd coordinate-component surface (h=0) of celestiodetic SRFs. 3) When the object is Earth, this SRFT is referred to as a *geodetic SRFT*.
References	[HEIK]

8.5.5 Planetodetic SRFT

Planetodetic and surface planetodetic SRFs shall be derived from the SRFT specified in Table 8.7.

Table 8.7 — Planetodetic SRFT

Element	Specification
SRFT label	PLANETODETIC
SRFT code	4
Short name and description	Planetodetic or surface planetodetic SRFT Similar to celestiodetic SRFT with reversed direction for longitude. The surface planetodetic SRFT is not specified separately (see Note 3).
Object type	planet
ORM constraint	Shall be derived from: ORMT OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN, SPHERE, or SPHERE_ORIGIN.
CS label	PLANETODETIC (for planetodetic SRFT) SURFACE_PLANETODETIC (for surface planetodetic SRFT)
CS coordinate component names and/or symbols	The same as the CS. The vertical coordinate-component is ellipsoidal height (h).
Template parameters	ORMT RD parameters: For OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN: a = major semi-axis f = flattening For SPHERE, SPHERE_ORIGIN: r = radius.

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Element	Specification
CS parameter binding rules	CS parameters match RD values: Oblate ellipsoid RD case with major semi-axis a and inverse flattening f^{1}: $a = a$ $b = a(1 - f)$ Sphere RD case with radius r: $a = b = r.$
Applicable region	No additional restrictions.
Notes	1) Planetary science applications. 2) This SRFT can be used to specify either 3D SRFs based on the PLANETODETIC CS or surface SRFs based on the SURFACE_PLANETODETIC CS. When this SRFT is used to specify a surface SRF, the 3rd (vertical) coordinate-component (h) is fixed at zero and is not explicitly used. 3) The surface planetodetic SRFT is not specified explicitly. Surface planetodetic SRFs are induced on the oblate ellipsoid (or sphere) RD surface, which is the zero 3rd coordinate-component surface (h=0) of planetodetic SRFs.
References	[RIIC15]

8.5.6 Local tangent space Euclidean SRFT

Local tangent space Euclidean and local tangent plane Euclidean SRFs shall be derived from the SRFT specified in Table 8.8. The case with template parameters $h_0 > 0$ and $\alpha_0 = 15°$ is illustrated in Figure 8.4.

Table 8.8 — Local tangent space Euclidean SRFT

Element	Specification
SRFT label	LOCAL_TANGENT_SPACE_EUCLIDEAN
SRFT code	5
Short name and description	Local tangent space Euclidean or local tangent plane Euclidean SRFT The generalization of Euclidean SRFs with the zero 3rd coordinate-component ($h = 0$) plane surface parallel to the plane that is tangent to the oblate ellipsoid RD at the point with surface geodetic coordinate (λ_0, φ_0). The CS origin is vertically offset from the tangent point by the height h_0. The local tangent plane Euclidean SRFT is not specified separately (see Note 7).
Object type	physical
ORM constraint	Shall be derived from: ORMT OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN, SPHERE, or SPHERE_ORIGIN.
CS label	LOCOCENTRIC_EUCLIDEAN_3D (for local tangent space Euclidean SRFT) LOCOCENTRIC_SURFACE_EUCLIDEAN (for local tangent plane Euclidean SRFT)

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<table>
<tr><th>Element</th><th>Specification</th></tr>
<tr><td>CS coordinate-component names and/or symbols</td><td>u: x (x)
v: y (y)
w: height (h) is the vertical coordinate-component.</td></tr>
<tr><td>Template parameters</td><td>(λ_0,φ_0) = surface geodetic coordinate of the tangent point, $\varphi_0 \neq \pm\frac{\pi}{2}$
h_0 = offset height
α_0 = azimuth (the $\boldsymbol{s}$-axis azimuth from local north)
x_F = x-axis origin shift
y_F = y-axis origin shift

ORMT RD parameters:
For OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN:
    a = major semi-axis
    f = flattening
For SPHERE, SPHERE_ORIGIN:
    r = radius.</td></tr>
<tr><td>CS parameter binding rules</td><td>$\boldsymbol{r} = \boldsymbol{R}\boldsymbol{r}_0,\quad \boldsymbol{s} = \boldsymbol{R}\boldsymbol{s}_0,$ and $\boldsymbol{q} = \boldsymbol{q}_0 + h_0\boldsymbol{t} - x_F\boldsymbol{r} - y_F\boldsymbol{s}$
where:
$$\boldsymbol{r}_0 = \begin{bmatrix} -\sin\lambda_0 \\ \cos\lambda_0 \\ 0 \end{bmatrix},\quad \boldsymbol{s}_0 = \begin{bmatrix} -\cos\lambda_0\sin\varphi_0 \\ -\sin\lambda_0\sin\varphi_0 \\ \cos\varphi_0 \end{bmatrix},\quad \boldsymbol{t} = \boldsymbol{r}_0 \times \boldsymbol{s}_0,$$
$$\boldsymbol{R} = \begin{bmatrix} \cos\alpha_0 & \sin\alpha_0 & 0 \\ -\sin\alpha_0 & \cos\alpha_0 & 0 \\ 0 & 0 & 1 \end{bmatrix},$$ and
$$\boldsymbol{q}_0 = \boldsymbol{G}_{\text{Surf GD}}\big((\lambda_0,\varphi_0)\big) = \begin{bmatrix} \mathcal{N}(\varphi_0)\cos(\varphi_0)\cos(\lambda_0) \\ \mathcal{N}(\varphi_0)\cos(\varphi_0)\sin(\lambda_0) \\ \frac{b^2}{a^2}\mathcal{N}(\varphi_0)\sin(\varphi_0) \end{bmatrix}.$$
$\boldsymbol{G}_{\text{Surf GD}}(\,)$ is the SURFACE_GEODETIC CS generating function.
For oblate ellipsoid RD case with major semi-axis a and flattening f:
    $a = a$ (CS and RD values are identical)
    $b = a(1-f)$
For sphere RD case with radius r:
    $a = b = r.$</td></tr>
<tr><td>Applicable region</td><td>No additional restrictions.</td></tr>
</table>

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Element	Specification
Notes	1) This SRFT can be used to specify either 3D SRFs based on the LOCOCENTRIC_EUCLIDEAN_3D CS or surface SRFs based on the or LOCOCENTRIC_SURFACE_EUCLIDEAN CS. When this SRFT is used to specify a surface SRF, the 3rd (vertical) coordinate-component (w or h) is fixed at zero and is not explicitly used. 2) The object-space vectors $\boldsymbol{q}, \boldsymbol{r}, \boldsymbol{s}$ are required localization parameters for the LOCOCENTRIC_EUCLIDEAN_3D or LOCOCENTRIC_SURFACE_EUCLIDEAN CS. 3) h_0 is the ellipsoidal height of the CS origin. 4) α_0 is the geodetic azimuth of the secondary axis (v or y) direction relative to local north (see Figure 8.4). $\boldsymbol{R}$ is the matrix for the clockwise rotation by azimuth angle α_0 about the axis $\boldsymbol{t} = \boldsymbol{r}_0 \times \boldsymbol{s}_0$. 5) The vectors $\boldsymbol{q}_0, \boldsymbol{r}_0, \boldsymbol{s}_0$ form a local tangent frame at the tangent point $\boldsymbol{q}_0$, with the SURFACE_GEODETIC CS as the reference CS. The $h = -h_0$ coordinate-component plane[21] is tangent to the oblate ellipsoid RD at the point $\boldsymbol{q}_0$ with surface celestiodetic coordinate (λ_0, φ_0). This frame is translated vertically by offset height h_0, and rotated by $\boldsymbol{R}$ according to template parameter α_0. The frame is optionally further translated horizontally according to origin shift template parameters x_F and y_F. The combination of these operations form the $\boldsymbol{q}, \boldsymbol{r}, \boldsymbol{s}, \boldsymbol{t}$ orthonormal frame (see Figure 8.4). 6) The local tangent space Euclidean u, v, w axes align with the frame vectors $\boldsymbol{r}, \boldsymbol{s}, \boldsymbol{t}$ respectively at local origin $\boldsymbol{q}$. 7) The local tangent plane Euclidean SRFT is not specified explicitly. Local tangent plane Euclidean SRFs are induced on the plane surface spanned by vectors $\boldsymbol{r}$ and $\boldsymbol{s}$ at local origin $\boldsymbol{q}$. This plane surface is the zero 3rd coordinate-component surface (h=0) of local tangent space Euclidean SRFs.
References	[EDM]

[21] In ISO 19111 terminology, the tangent plane is an engineering datum.

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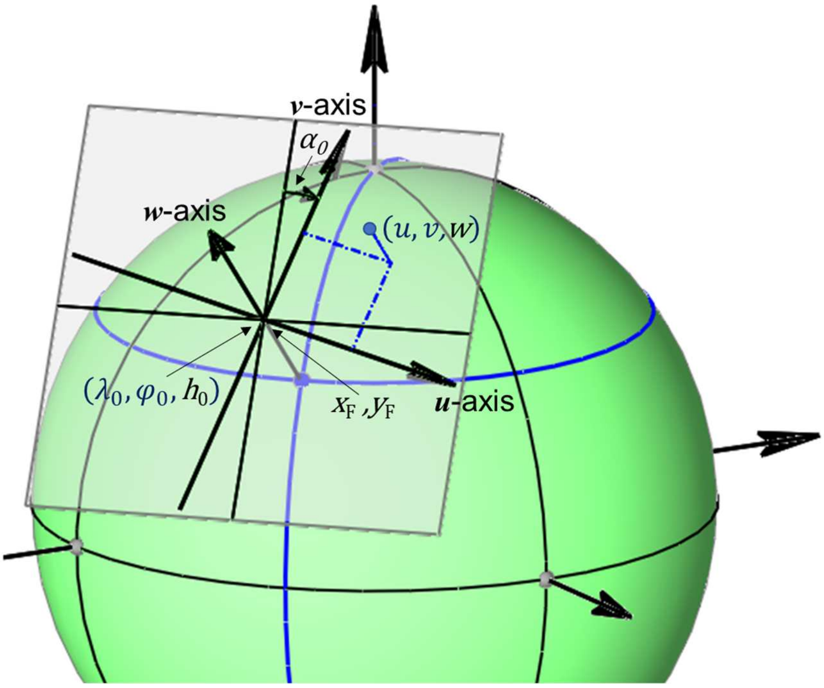

Figure 8.4 — Local tangent space Euclidean SRFT

8.5.7 Local tangent space azimuthal spherical SRFT

Local tangent space azimuthal spherical and local tangent plane azimuthal SRFs shall be derived from the SRFT specified in Table 8.9. The case with template parameters $h_0 = 0$ and $\alpha_0 = 15°$ is illustrated in Figure 8.5.

Table 8.9 — Local tangent space azimuthal spherical SRFT

Element	Specification
SRFT label	LOCAL_TANGENT_SPACE_AZIMUTHAL_SPHERICAL
SRFT code	6
Short name and description	Local tangent space azimuthal spherical or local tangent plane azimuthal SRFT The generalization of azimuthal spherical SRFs with the zero 3rd coordinate-component ($\theta = 0$) plane surface parallel to the plane that is tangent to the oblate ellipsoid RD at the point with surface geodetic coordinate (λ_0, φ_0). The CS origin is vertically offset from the tangent point by the height h_0. The local tangent plane azimuthal SRFT is not specified separately (see Note 7).
Object type	physical
ORM constraint	Shall be derived from: ORMT OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN, SPHERE, or SPHERE_ORIGIN.

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<table>
<tr><th>Element</th><th>Specification</th></tr>
<tr><td>CS label</td><td>LOCOCENTRIC_AZIMUTHAL_SPHERICAL (for local tangent space azimuthal spherical SRFT)
LOCOCENTRIC_SURFACE_AZIMUTHAL (for local tangent plane azimuthal SRFT</td></tr>
<tr><td>CS coordinate-component names and/or symbols</td><td>α: azimuth
ρ: radius
θ: depression/elevation angle, the vertical coordinate-component</td></tr>
<tr><td>Template parameters</td><td>(λ_0, φ_0) = surface geodetic coordinate of the tangent point, $\varphi_0 \neq \pm\frac{\pi}{2}$
h_0 = offset height
α_0 = azimuth (the secondary axis azimuth relative to local north)
ORMT RD parameters:
For OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN:
a = major semi-axis
f = flattening
For SPHERE, SPHERE_ORIGIN:
r = radius.</td></tr>
<tr><td>CS parameter binding rules</td><td>$\boldsymbol{r} = \boldsymbol{R}\boldsymbol{r}_0, \quad \boldsymbol{s} = \boldsymbol{R}\boldsymbol{s}_0,$ and $\boldsymbol{q} = \boldsymbol{q}_0 + h_0\boldsymbol{t}$
where:
$$\boldsymbol{r}_0 = \begin{bmatrix} -\sin\lambda_0 \\ \cos\lambda_0 \\ 0 \end{bmatrix}, \quad \boldsymbol{s}_0 = \begin{bmatrix} -\cos\lambda_0 \sin\varphi_0 \\ -\sin\lambda_0 \sin\varphi_0 \\ \cos\varphi_0 \end{bmatrix}, \quad \boldsymbol{t} = \boldsymbol{r}_0 \times \boldsymbol{s}_0,$$
$$\boldsymbol{R} = \begin{bmatrix} \cos\alpha_0 & \sin\alpha_0 & 0 \\ -\sin\alpha_0 & \cos\alpha_0 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \text{ and}$$
$$\boldsymbol{q}_0 = \boldsymbol{G}_{\text{Surf GD}}\big((\lambda_0, \varphi_0)\big) = \begin{bmatrix} \mathcal{N}(\varphi_0)\cos(\varphi_0)\cos(\lambda_0) \\ \mathcal{N}(\varphi_0)\cos(\varphi_0)\sin(\lambda_0) \\ \frac{b^2}{a^2}\mathcal{N}(\varphi_0)\sin(\varphi_0) \end{bmatrix}.$$
$\boldsymbol{G}_{\text{Surf GD}}(\,)$ is the SURFACE_GEODETIC CS generating function.
For oblate ellipsoid RD case with major semi-axis a and flattening f:
$a = a$ (CS and RD values are identical)
$b = a(1-f)$
For sphere RD case with radius r:
$a = b = r$.</td></tr>
<tr><td>Applicable region</td><td>No additional restrictions.</td></tr>
</table>

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Element	Specification
Notes	1) Used in radar localization. 2) This SRFT can be used to specify either 3D SRFs based on the LOCOCENTRIC_AZIMUTHAL_SPHERICAL CS or surface SRFs based on the LOCOCENTRIC_SURFACE_AZIMUTHAL CS. When this SRFT is used to specify a surface SRF, the 3rd (vertical) coordinate-component (θ) is fixed at zero and is not explicitly used. 3) The object-space vectors $\boldsymbol{q}, \boldsymbol{r}, \boldsymbol{s}$ are required localization parameters for the LOCOCENTRIC_AZIMUTHAL_SPHERICAL or LOCOCENTRIC_SURFACE_AZIMUTHAL CS. 4) h_0 is the ellipsoidal height of the CS origin. 5) α_0 is the geodetic azimuth of the secondary axis (v) direction relative to local north (see Figure 8.5). $\boldsymbol{R}$ is the matrix for the clockwise rotation by azimuth angle α_0 about the axis $\boldsymbol{t} = \boldsymbol{r}_0 \times \boldsymbol{s}_0$. 6) The vectors $\boldsymbol{q}_0, \boldsymbol{r}_0, \boldsymbol{s}_0, \boldsymbol{t}$ form a local tangent frame at the tangent point $\boldsymbol{q}_0$, with the SURFACE_GEODETIC CS as the reference CS. The $h = -h_0$ coordinate-component plane[22] is tangent to the oblate ellipsoid RD at the point $\boldsymbol{q}_0$ with surface celestiodetic coordinate (λ_0, φ_0). This frame is translated vertically by offset height h_0, and rotated by $\boldsymbol{R}$ according to template parameter α_0. The combination of these operations forms the $\boldsymbol{q}, \boldsymbol{r}, \boldsymbol{s}, \boldsymbol{t}$ orthonormal frame (see Figure 8.5). 7) The local tangent plane azimuthal SRFT is not specified explicitly. Local tangent plane azimuthal SRFs are induced on the plane surface spanned by vectors $\boldsymbol{r}$ and $\boldsymbol{s}$ at local origin $\boldsymbol{q}$. This plane surface is the zero 3rd coordinate-component surface (θ=0) of local tangent space azimuthal spherical SRFs.
References	[EDM]

[22] In ISO 19111 terminology, the tangent plane is an engineering datum.

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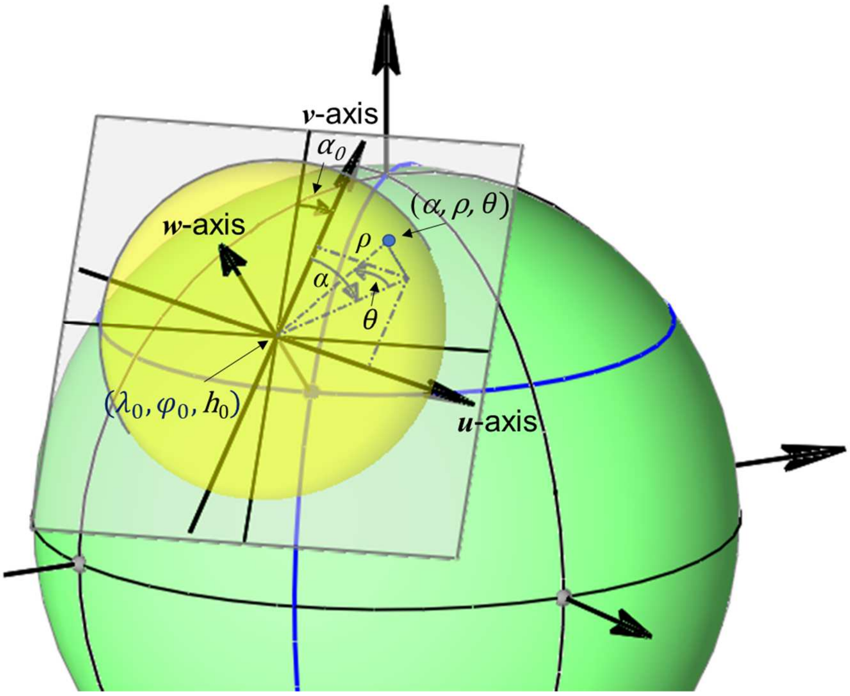

Figure 8.5 — Local tangent space azimuthal spherical SRFT

8.5.8 Local tangent space cylindrical SRFT

Local tangent space cylindrical and local tangent plane polar SRFs shall be derived from the SRFT specified in Table 8.10. The case with template parameters h_0 = 0 and α_0 = 15° is illustrated in Figure 8.6.

Table 8.10 — Local tangent space cylindrical SRFT

Element	Specification
SRFT label	LOCAL_TANGENT_SPACE_CYLINDRICAL
SRFT code	7
Short name and description	Local tangent space cylindrical or local tangent plane polar SRFT The generalization of cylindrical SRFs with the zero 3rd coordinate-component ($h = 0$) plane surface parallel to the plane that is tangent to the oblate ellipsoid RD at the point with surface geodetic coordinate (λ_0, φ_0). The CS origin is vertically offset from the tangent point by the height h_0. The local tangent plane polar SRFT is not specified separately (see Note 6).
Object type	physical
ORM constraint	Shall be derived from: ORMT OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN, SPHERE, or SPHERE_ORIGIN.
CS label	LOCOCENTRIC_CYLINDRICAL (for local tangent space cylindrical SRFT) LOCOCENTRIC_SURFACE_POLAR (for local tangent plane polar SRFT)

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Element	Specification
CS coordinate-component names and/or symbols	The same as the CS. The same as the CS. ζ: height (h) is the vertical coordinate
Template parameters	(λ_0, φ_0) = surface geodetic coordinate of the tangent point, $\varphi_0 \neq \pm\frac{\pi}{2}$ h_0 = offset height α_0 = azimuth (the secondary axis azimuth relative to local north) ORMT RD parameters: For OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN: a = major semi-axis f = flattening For SPHERE, SPHERE_ORIGIN: r = radius.
CS parameter binding rules	$\boldsymbol{r} = \boldsymbol{R}\boldsymbol{r}_0, \quad \boldsymbol{s} = \boldsymbol{R}\boldsymbol{s}_0,$ and $\boldsymbol{q} = \boldsymbol{q}_0 + h_0\boldsymbol{t}$ where: $\boldsymbol{r}_0 = \begin{bmatrix} -\sin\lambda_0 \\ \cos\lambda_0 \\ 0 \end{bmatrix}, \quad \boldsymbol{s}_0 = \begin{bmatrix} -\cos\lambda_0 \sin\varphi_0 \\ -\sin\lambda_0 \sin\varphi_0 \\ \cos\varphi_0 \end{bmatrix}, \quad \boldsymbol{t} = \boldsymbol{r}_0 \times \boldsymbol{s}_0,$ $\boldsymbol{R} = \begin{bmatrix} \cos\alpha_0 & \sin\alpha_0 & 0 \\ -\sin\alpha_0 & \cos\alpha_0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$, and $\boldsymbol{q}_0 = \boldsymbol{G}_{\text{Surf GD}}\big((\lambda_0, \varphi_0)\big) = \begin{bmatrix} \mathcal{N}(\varphi_0)\cos(\varphi_0)\cos(\lambda_0) \\ \mathcal{N}(\varphi_0)\cos(\varphi_0)\sin(\lambda_0) \\ \frac{b^2}{a^2}\mathcal{N}(\varphi_0)\sin(\varphi_0) \end{bmatrix}.$ $\boldsymbol{G}_{\text{Surf GD}}(\,)$ is the SURFACE_GEODETIC CS generating function. For oblate ellipsoid RD case with major semi-axis a and flattening f: $a = a$ (CS and RD values are identical) $b = a(1 - f)$ For sphere RD case with radius r: $a = b = r$.
Applicable region	No additional restrictions.

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Element	Specification
Notes	1) This SRFT can be used to specify either 3D SRFs based on the LOCOCENTRIC_CYLINDRICAL CS or surface SRFs based on the LOCOCENTRIC_SURFACE_POLAR CS. When this SRFT is used to specify a surface SRF, the 3rd (vertical) coordinate-component (w or h) is fixed at zero and is not explicitly used. 2) The object-space vectors $\boldsymbol{q}, \boldsymbol{r}, \boldsymbol{s}$ are required localization parameters for the LOCOCENTRIC_CYLINDRICAL or LOCOCENTRIC_SURFACE_POLAR CS. 3) h_0 is the ellipsoidal height of the CS origin. 4) α_0 is the geodetic azimuth of the secondary axis (v) direction relative to local north (see Figure 8.6). $\boldsymbol{R}$ is the matrix for the clockwise rotation by azimuth angle α_0 about the axis $\boldsymbol{t} = \boldsymbol{r}_0 \times \boldsymbol{s}_0$. 5) The vectors $\boldsymbol{q}_0, \boldsymbol{r}_0, \boldsymbol{s}_0, \boldsymbol{t}$ form a local tangent frame at the tangent point $\boldsymbol{q}_0$ with the SURFACE_GEODETIC CS as the reference CS. The $h = -h_0$ coordinate-component plane[23] is tangent to the oblate ellipsoid RD at the point $\boldsymbol{q}_0$ with surface celestiodetic coordinate (λ_0, φ_0). This frame is translated vertically by offset height h_0, and rotated by $\boldsymbol{R}$ according to template parameter α_0. The combination of these operations forms the $\boldsymbol{q}, \boldsymbol{r}, \boldsymbol{s}, \boldsymbol{t}$ orthonormal frame (see Figure 8.6). 6) The local tangent plane polar SRFT is not specified explicitly. Local tangent plane polar SRFs are induced on the plane surface spanned by vectors $\boldsymbol{r}$ and $\boldsymbol{s}$ at local origin $\boldsymbol{q}$. This plane surface is the zero 3rd coordinate-component surface ($h = 0$) of local tangent space cylindrical SRFs.
References	[EDM]

[23] In ISO 19111 terminology, the tangent plane is an engineering datum.

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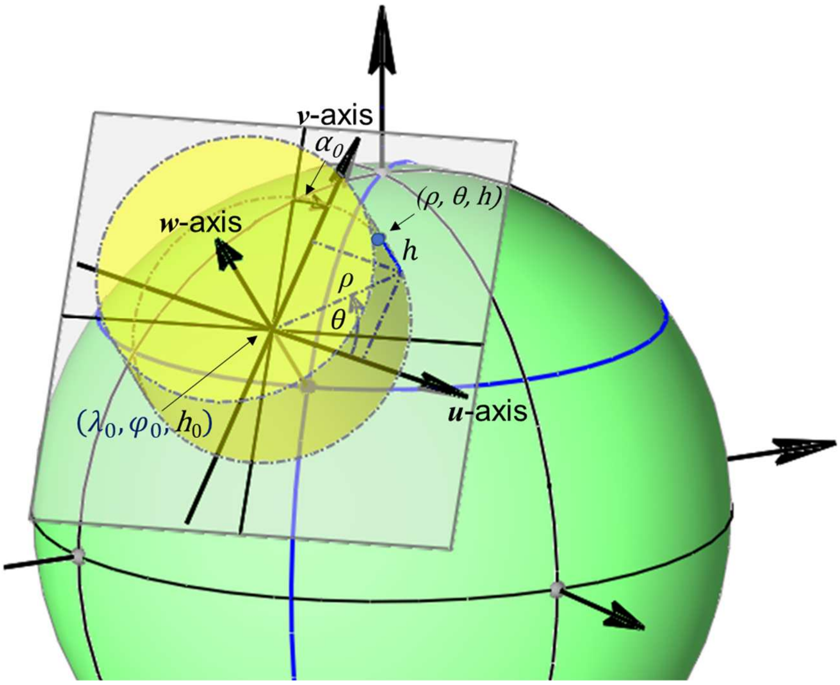

Figure 8.6 — Local tangent space cylindrical SRFT

8.5.9 Lococentric Euclidean 3D SRFT

Lococentric Euclidean 3D SRFs shall be derived from the SRFT specified in Table 8.11.

Table 8.11 — Lococentric Euclidean 3D SRFT

Element	Specification
SRFT label	LOCOCENTRIC _EUCLIDEAN_3D
SRFT code	8
Short name and description	Lococentric Euclidean 3D SRFT Euclidean 3D spatial CS with a localised origin and axes orientations.
Object type	any 3D object
ORM constraint	Shall be derived from any 3D ORM.
CS label	LOCOCENTRIC_EUCLIDEAN_3D
CS coordinate-component names and/or symbols	The same as the CS.
Template parameters	Localization parameters: $\boldsymbol{q}$: the lococentric origin, $\boldsymbol{r}$: primary axis direction, and $\boldsymbol{s}$: secondary axis direction. Constraints: $\boldsymbol{r}$ and $\boldsymbol{s}$ are orthonormal vectors.
CS parameter binding rules	The template parameters are the CS parameters.

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Element	Specification
Applicable region	No additional restrictions.
Notes	1) A CELESTIOCENTRIC SRFT is special case of an instance of this SRFT with $\boldsymbol{q} = [0 \quad 0 \quad 0]^{\mathrm{T}}$, $\boldsymbol{r} = [1 \quad 0 \quad 0]^{\mathrm{T}}$, $\boldsymbol{s} = [0 \quad 1 \quad 0]^{\mathrm{T}}$, and a physical object. 2) A LOCAL_SPACE_RECTANGULAR_3D SRFT is special case of an instance of this SRFT with $\boldsymbol{q} = [0 \quad 0 \quad 0]^{\mathrm{T}}$, and an abstract object. 3) A LOCAL_TANGENT_SPACE_EUCLIDEAN SRFT is special case of an instance of this SRFT with $\boldsymbol{q}$, $\boldsymbol{r}$, $\boldsymbol{s}$, satisfying the SRFT LOCAL_TANGENT_SPACE_EUCLIDEAN CS parameter binding rules and ORM constraint. 4) This SRFT is required for the SRM treatment of directions (see 10.5).
References	[EDM]

8.5.10 Celestiomagnetic SRFT

Celestiomagnetic SRFs shall be derived from the SRFT specified in Table 8.12.

Table 8.12 — Celestiomagnetic SRFT

Element	Specification
SRFT label	CELESTIOMAGNETIC
SRFT code	9
Short name and description	Celestiomagnetic SRFT An equatorial spherical CS based SRFT aligned with the magnetic dipole of a celestial object.
Object type	A planet or rotating satellite in a solar system with a magnetic dipole axis distinct from its rotational axis.
ORM constraint	Based on ORMT BI_AXIS_ORIGIN_3D and OBRS CELESTIOMAGNETIC.
CS label	EQUATORIAL_SPHERICAL
CS coordinate-component names and/or symbols	The same as the CS.
Template parameters	none
CS parameter binding rules	none
Applicable region	No additional restrictions.
Notes	1) See 7.5.8. 2) When the object is Earth, this SRFT is referred to as a *geomagnetic SRFT*. 3) These SRFs are typically used at radii where the magnetic field is approximated by a dipole.
References	[CRUS]

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8.5.11 Equatorial inertial SRFT

Equatorial inertial SRFs shall be derived from the SRFT specified in Table 8.13.

Table 8.13 — Equatorial inertial SRFT

Element	Specification
SRFT label	EQUATORIAL_INERTIAL
SRFT code	10
Short name and description	Equatorial inertial SRFT An equatorial spherical CS based SRF aligned with the equator of a planet and the direction to the Sun at the vernal equinox (at a specified epoch).
Object type	A planet in the solar system for which the ecliptic plane is distinct from the equatorial plane.
ORM constraint	Based on ORMT BI_AXIS_ORIGIN_3D and OBRS EQUATORIAL_INERTIAL.
CS label	EQUATORIAL_SPHERICAL
CS coordinate-component names and/or symbols	λ: right ascension (*ra*) θ: declination (*dec*) ρ: radius or range(r)
Template parameters	none
CS parameter binding rules	none
Applicable region	No additional restrictions.
Notes	1) See 7.5.2. 2) Star catalogues use right ascension and declination to specify directions.
References	[SEID]

8.5.12 Solar ecliptic SRFT

Solar ecliptic SRFs shall be derived from the SRFT specified in Table 8.14.

Table 8.14 — Solar ecliptic SRFT

Element	Specification
SRFT label	SOLAR_ECLIPTIC
SRFT code	11
Short name and description	Solar ecliptic SRFT An equatorial spherical CS based SRF aligned with the ecliptic plane of a planet and the direction of the Sun.
Object type	A planet in the solar system.
ORM constraint	Based on ORMT BI_AXIS_ORIGIN_3D and OBRS SOLAR_ECLIPTIC.
CS label	EQUATORIAL_SPHERICAL

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Element	Specification
CS coordinate-component names and/or symbols	The same as the CS.
Template parameters	none
CS parameter binding rules	none
Applicable region	No additional restrictions.
Notes	See 7.5.3.
References	[HAPG]

8.5.13 Solar equatorial SRFT

Solar equatorial SRFs shall be derived from the SRFT specified in Table 8.15.

Table 8.15 — Solar equatorial SRFT

Element	Specification
SRFT label	SOLAR_EQUATORIAL
SRFT code	12
Short name and description	Solar equatorial SRFT An equatorial spherical CS based planet centred SRF aligned with the ecliptic plane and the rotational axis of the Sun.
Object type	A planet in the solar system for which the ecliptic plane is distinct from the equatorial plane.
ORM constraint	Based on ORMT BI_AXIS_ORIGIN_3D and OBRS SOLAR_EQUATORIAL.
CS label	EQUATORIAL_SPHERICAL
CS coordinate-component names and/or symbols	The same as the CS.
Template parameters	none
CS parameter binding rules	none
Applicable region	No additional restrictions.
Notes	See 7.5.4.
References	[CRUS]

8.5.14 Solar magnetic ecliptic SRFT

Solar magnetic ecliptic SRFs shall be derived from the SRFT specified in Table 8.16.

Table 8.16 — Solar magnetic ecliptic SRFT

Element	Specification
SRFT label	SOLAR_MAGNETIC_ECLIPTIC
SRFT code	13

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Element	Specification
Short name and description	Solar magnetic ecliptic SRFT A Euclidean 3D CS based planet centred SRF aligned with the direction to the Sun and the plane determined by that direction and the magnetic dipole of the planet.
Object type	A planet in the solar system with a magnetic dipole.
ORM constraint	Based on ORMT BI_AXIS_ORIGIN_3D and OBRS SOLAR_MAGNETIC_ECLIPTIC.
CS label	EUCLIDEAN_3D
CS coordinate-component names and/or symbols	The same as the CS.
Template parameters	none
CS parameter binding rules	none
Applicable region	No additional restrictions.
Notes	1) See 7.5.9. 2) In the case of planet Earth, this SRFT is also known as a *geocentric solar magnetospheric SRFT*.
References	[CRUS]

8.5.15 Solar magnetic dipole SRFT

Solar magnetic dipole SRFs shall be derived from the SRFT specified in Table 8.17.

Table 8.17 — Solar magnetic dipole SRFT

Element	Specification
SRFT label	SOLAR_MAGNETIC_DIPOLE
SRFT code	14
Short name and description	Solar magnetic dipole SRFT A Euclidean 3D CS based planet centred SRF with the z-axis aligned with the magnetic dipole and the xz-plane containing the Sun.
Object type	A planet in the solar system with a magnetic dipole axis distinct from its rotational axis.
ORM constraint	Based on ORMT BI_AXIS_ORIGIN_3D and OBRS SOLAR_MAGNETIC_DIPOLE.
CS label	EUCLIDEAN_3D
CS coordinate-component names and/or symbols	The same as the CS.
Template parameters	none
CS parameter binding rules	none
Applicable region	No additional restrictions.
Notes	See 7.5.10.
References	[CRUS], [BHAV]

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8.5.16 Heliospheric Aries ecliptic SRFT

Heliospheric Aries ecliptic SRFs shall be derived from the SRFT specified in Table 8.18.

Table 8.18 — Heliospheric Aries ecliptic SRFT

Element	Specification
SRFT label	HELIOSPHERIC_ARIES_ECLIPTIC
SRFT code	15
Short name and description	Heliospheric Aries ecliptic SRFT An equatorial spherical CS based Sun centred SRF with the zero spherical latitude aligned with the ecliptic plane and the zero longitude aligned to the first point of Aries.
Object type	Sun
ORM constraint	Based on ORMT BI_AXIS_ORIGIN_3D and OBRS HELIOCENTRIC_ARIES_ECLIPTIC.
CS label	EQUATORIAL_SPHERICAL
CS coordinate-component names and/or symbols	The same as the CS.
Template parameters	none
CS parameter binding rules	none
Applicable region	No additional restrictions.
Notes	See 7.5.5.
References	[HAPG]

8.5.17 Heliospheric Earth ecliptic SRFT

Heliospheric Earth ecliptic SRFs shall be derived from the SRFT specified in Table 8.19.

Table 8.19 — Heliospheric Earth ecliptic SRFT

Element	Specification
SRFT label	HELIOSPHERIC_EARTH_ECLIPTIC
SRFT code	16
Short name and description	Heliospheric Earth ecliptic SRFT An equatorial spherical CS based Sun centred SRF with zero spherical latitude aligned with the ecliptic plane and the zero longitude aligned to the centre of the Earth.
Object type	Sun
ORM constraint	Based on ORMT BI_AXIS_ORIGIN_3D and OBRS HELIOCENTRIC_PLANET_ECLIPTIC.
CS label	EQUATORIAL_SPHERICAL
CS coordinate-component names and/or symbols	The same as the CS.

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Element	Specification
Template parameters	none
CS parameter binding rules	none
Applicable region	No additional restrictions.
Notes	See 7.5.6.
References	[HAPG]

8.5.18 Heliospheric Earth equatorial SRFT

Heliospheric Earth equatorial SRFs shall be derived from the SRFT specified in Table 8.20.

Table 8.20 — Heliospheric Earth equatorial SRFT

Element	Specification
SRFT label	HELIOSPHERIC_EARTH_EQUATORIAL
SRFT code	17
Short name and description	Heliospheric Earth equatorial SRFT An equatorial spherical CS based Sun centred SRF with the zero spherical latitude aligned with the equator of the Sun and the zero longitude aligned to the centre of the Earth.
Object type	Sun
ORM constraint	Based on ORMT BI_AXIS_ORIGIN_3D and OBRS HELIOCENTRIC_PLANET_EQUATORIAL with respect to Earth.
CS label	EQUATORIAL_SPHERICAL
CS coordinate-component names and/or symbols	The same as the CS.
Template parameters	none
CS parameter binding rules	none
Applicable region	No additional restrictions.
Notes	See 7.5.7.
References	[HAPG]

8.5.19 Mercator SRFT

Mercator SRFs shall be derived from the SRFT specified in Table 8.21.

Table 8.21 — Mercator SRFT

Element	Specification
SRFT label	MERCATOR
SRFT code	18
Short name and description	Mercator SRFT A Mercator and augmented Mercator map projection of the oblate or sphere RD component of the ORM.

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Element	Specification
Object type	physical
ORM constraint	Shall be derived from: ORMT OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN, SPHERE, or SPHERE_ORIGIN.
CS label	MERCATOR
CS coordinate-component names and/or symbols	The same as the CS. h: ellipsoidal height is the vertical coordinate-component.
Template parameters	λ_{origin} : longitude of origin $(-\pi < \lambda_{origin} \leq \pi)$ k_0: central scale $(0 < k_0 \leq 1)$ u_F: false easting v_F: false northing ORMT RD parameters: For OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN: a = major semi-axis f = flattening For SPHERE, SPHERE_ORIGIN: r = radius.
CS parameter binding rules	CS parameters match RD values: For oblate ellipsoid RD case with major semi-axis a and flattening f: $a = a$ (CS and RD values are identical) $b = a(1-f)$ $\varepsilon = \sqrt{(1 - b^2/a^2)}$ For sphere RD case with radius r: $a = b = r$ $\varepsilon = 0$.
Applicable region	No additional restrictions.
Notes	1. The augmented Mercator CS induces the Mercator CS on the zero vertical coordinate-component surface (which coincides with the RD surface). 2. True scale (point distortion $= 1$) may be specified at a given latitude φ_1 by setting: $k_0 = (1/a)\mathcal{N}(\varphi_1)\cos(\varphi_1)$.
References	[SNYD]

8.5.20 Oblique Mercator spherical SRFT

Oblique Mercator spherical SRFs shall be derived from the SRFT specified in Table 8.22.

Table 8.22 — Oblique Mercator spherical SRFT

Element	Specification
SRFT label	OBLIQUE_MERCATOR_SPHERICAL
SRFT code	19
Short name and description	Oblique Mercator SRFT for a sphere ORM An oblique Mercator and augmented oblique Mercator map projection of the sphere RD component of the ORM.
Object type	physical

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Element	Specification
ORM constraint	Shall be derived from ORMT SPHERE or SPHERE_ORIGIN.
CS label	OBLIQUE_MERCATOR_SPHERICAL
CS coordinate-component names and/or symbols	The same as the CS. h: ellipsoidal height is the vertical coordinate-component.
Template parameters	(λ_1,φ_1): first point on the central line (λ_2,φ_2): second point on the central line k_0: central scale $(0 < k_0 \leq 1)$ u_F: false easting v_F: false northing (λ_1,φ_1) and (λ_2,φ_2) are two distinct points on the shortest great circle arc on the sphere representing the desired central line, k_0 is the point distortion on the central line, and $-\pi/2 < \varphi_1 < \pi/2,\ -\pi/2 < \varphi_2 < \pi/2,\ \lvert\varphi_1\rvert + \lvert\varphi_2\rvert > 0,$ $-\pi < \lambda_1 \leq \pi,\ -\pi < \lambda_2 \leq \pi,\ \ \lambda_1 \neq \lambda_2,\ \text{and}\ \ \lvert\lambda_1 - \lambda_2\rvert \neq \pi.$ ORMT RD parameter: r = radius.
CS parameter binding rules	The CS parameter R matches the RD value: Radius $R = r$. The values of λ_1, φ_1, λ_2, φ_2, k_0, u_F and v_F match the corresponding template parameters.
Applicable region	No additional restrictions.
Notes	The augmented oblique Mercator CS induces the oblique Mercator CS on the zero vertical coordinate-component surface (which coincides with the RD surface).
References	[SNYD]

8.5.21 Transverse Mercator SRFT

Transverse Mercator SRFs shall be derived from the SRFT specified in Table 8.23.

Table 8.23 — Transverse Mercator SRFT

Element	Specification
SRFT label	TRANSVERSE_MERCATOR
SRFT code	20
Short name and description	Transverse Mercator SRFT A transverse Mercator and augmented transverse Mercator map projection of the oblate or sphere RD component of the ORM.
Object type	physical
ORM constraint	Shall be derived from: ORMT OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN, SPHERE, or SPHERE_ORIGIN.
CS label	TRANSVERSE_MERCATOR

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Element	Specification
CS coordinate-component names and/or symbols	The same as the CS. h: ellipsoidal height is the vertical coordinate-component.
Template parameters	λ_{origin}: longitude of origin $(-\pi < \lambda_{\text{origin}} \leq \pi)$ φ_{origin}: latitude of origin $(-\pi/2 < \varphi_{\text{origin}} \leq \pi/2)$ k_0: central scale $(0 < k_0 \leq 1)$ u_F: false easting v_F: false northing ORMT RD parameters: For OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN: a = major semi-axis f = flattening For SPHERE, SPHERE_ORIGIN: r = radius.
CS parameter binding rules	CS parameters match RD values: For oblate ellipsoid RD case with major semi-axis a and flattening f: $a = a$ (CS and RD values are identical) $b = a(1 - f)$ $\varepsilon = \sqrt{(1 - b^2/a^2)}$ For sphere RD case with radius r: $a = b = r$ $\varepsilon = 0$.
Applicable region	No additional restrictions.
Notes	The augmented transverse Mercator CS induces the transverse Mercator CS on the zero vertical coordinate-component surface (which coincides with the RD surface).
References	[SNYD]

8.5.22 Lambert conformal conic SRFT

Lambert conformal conic SRFs shall be derived from the SRFT specified in Table 8.24.

Table 8.24 — Lambert conformal conic SRFT

Element	Specification
SRFT label	LAMBERT_CONFORMAL_CONIC
SRFT code	21
Short name and description	Lambert conformal conic SRFT A Lambert conformal conic and augmented Lambert conformal conic map projection of the oblate or sphere RD component of the ORM.
Object type	physical
ORM constraint	Shall be derived from: ORMT OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN, SPHERE, or SPHERE_ORIGIN.
CS label	LAMBERT_CONFORMAL_CONIC
CS coordinate-component names and/or symbols	The same as the CS. h: ellipsoidal height is the vertical coordinate-component.

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Element	Specification
Template parameters	λ_{origin}: longitude of origin $(-\pi < \lambda_{\text{origin}} \leq \pi)$ φ_{origin}: latitude of origin $(-\pi/2 < \varphi_{\text{origin}} \leq \pi/2)$ φ_1,φ_2: standard latitudes $(-\pi/2 < \varphi_1 \leq \pi/2, -\pi/2 < \varphi_2 \leq \pi/2,\ \varphi_1 \neq -\varphi_2)$ u_F: false easting v_F: false northing ORMT RD parameters: For OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN: a = major semi-axis f = flattening For SPHERE, SPHERE_ORIGIN: r = radius.
CS parameter binding rules	CS parameters match RD values: For oblate ellipsoid RD case with major semi-axis a and flattening f: $a = a$ (CS and RD values are identical) $b = a(1 - f)$ $\varepsilon = \sqrt{(1 - b^2/a^2)}$ For sphere RD case with radius r: $a = b = r$ $\varepsilon = 0$.
Applicable region	No additional restrictions.
Notes	The augmented Lambert conformal conic CS induces the Lambert conformal conic CS on the zero vertical coordinate-component surface (which coincides with the RD surface).
References	[SNYD]

8.5.23 Polar stereographic SRFT

Polar stereographic SRFs shall be derived from the SRFT specified in Table 8.25.

Table 8.25 — Polar stereographic SRFT

Element	Specification
SRFT label	POLAR_STEREOGRAPHIC
SRFT code	22
Short name and description	Polar stereographic SRFT A polar stereographic and augmented polar stereographic map projection of the oblate or sphere RD component of the ORM.
Object type	physical
ORM constraint	Shall be derived from: ORMT OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN, SPHERE, or SPHERE_ORIGIN.
CS label	POLAR_STEREOGRAPHIC
CS coordinate-component names and/or symbols	The same as the CS. h: ellipsoidal height is the vertical coordinate-component.

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Element	Specification
Template parameters	polar aspect: north or south λ_{origin}: longitude of origin $(-\pi < \lambda_{origin} \leq \pi)$ k_0: central scale $(1/2 < k_0 \leq 1)$ u_F: false easting v_F: false northing ORMT RD parameters: For OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN: a = major semi-axis f = flattening For SPHERE, SPHERE_ORIGIN: r = radius.
CS parameter binding rules	CS parameters match RD values: For oblate ellipsoid RD case with major semi-axis a and flattening f: $a = a$ (CS and RD values are identical) $b = a(1-f)$ $\varepsilon = \sqrt{(1 - b^2/a^2)}$ For sphere RD case with radius r: $a = b = r$ $\varepsilon = 0.$ $\varphi_{origin} = +\pi/2$ if north aspect $\varphi_{origin} = -\pi/2$ if south aspect
Applicable region	No additional restrictions.
Notes	1. The augmented polar stereographic CS induces the polar stereographic CS on the zero vertical coordinate-component surface (which coincides with the RD surface). 2. True scale (point distortion $= 1$) may be specified at a given latitude φ_1 by setting: $k_0 = \mathcal{N}(\varphi_1)\cos(\varphi_1)/2aE\tau(\varphi_1)$.
References	[SNYD]

8.5.24 Equidistant cylindrical SRFT

Equidistant cylindrical SRFs shall be derived from the SRFT specified in Table 8.26.

Table 8.26 — Equidistant cylindrical SRFT

Element	Specification
SRFT label	EQUIDISTANT_CYLINDRICAL
SRFT code	23
Short name and description	Equidistant cylindrical SRFT A equidistant cylindrical and augmented equidistant cylindrical map projection of the sphere RD component of the ORM.
Object type	physical
ORM constraint	Shall be derived from: ORMT OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN, SPHERE, or SPHERE_ORIGIN.
CS label	EQUIDISTANT_CYLINDRICAL

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Element	Specification
CS coordinate-component names and/or symbols	The same as the CS. h: ellipsoidal height is the vertical coordinate-component.
Template parameters	λ_{origin}: longitude of origin $(-\pi < \lambda_{origin} \leq \pi)$ k_0: central scale $(0 < k_0 \leq 1)$ u_F: false easting v_F: false northing ORMT RD parameters: For OBLATE_ELLIPSOID, OBLATE_ELLIPSOID_ORIGIN: a = major semi-axis f = flattening For SPHERE, SPHERE_ORIGIN: r = radius.
CS parameter binding rules	CS parameters match RD values: For oblate ellipsoid RD case with major semi-axis a and flattening f: $a = a$ (CS and RD values are identical) $b = a(1-f)$ $\varepsilon = \sqrt{(1 - b^2/a^2)}$ For sphere RD case with radius r: $a = b = r$ $\varepsilon = 0$.
Applicable region	No additional restrictions.
Notes	1. The augmented equidistant cylindrical CS induces the equidistant cylindrical CS on the zero vertical coordinate-component surface (which coincides with the RD surface). 2. Longitudinal point distortion may be set to one at a given latitude φ_1 by setting: $k_0 = (1/a)R_N(\varphi_1)\cos(\varphi_1)$.
References	[SNYD]

8.5.25 Local space rectangular 2D SRFT

Local space rectangular 2D SRFs shall be derived from the SRFT specified in Table 8.27.

Table 8.27 — Local space rectangular 2D SRFT

Element	Specification
SRFT label	LOCAL_SPACE_RECTANGULAR_2D
SRFT code	24
Short name and description	Local space rectangular 2D SRFT A 2D Euclidean spatial reference frame for an abstract 2D space.
Object type	2D abstract object
ORM constraint	Shall be an ORM for a 2D abstract object.
CS label	LOCOCENTRIC_EUCLIDEAN_2D
CS coordinate-component names and/or symbols	The same as the CS.
Template parameters	$\mathbf{r}$ = vector direction of forward (forward axis).

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Element	Specification
CS parameter binding rules	$\mathbf{e}_1 = \begin{bmatrix}1\\0\end{bmatrix}$, and $\boldsymbol{e}_2 = \begin{bmatrix}0\\1\end{bmatrix}$. $\boldsymbol{E}(axis) = \begin{cases} +\boldsymbol{e}_1 \text{ positive primary axis} \\ +\boldsymbol{e}_2 \text{ positive secondary axis} \\ -\boldsymbol{e}_1 \text{ negative primary axis} \\ -\boldsymbol{e}_2 \text{ negative secondary axis} \end{cases}$ $\boldsymbol{r} = \boldsymbol{E}(\text{forward axis})$ $\boldsymbol{s} = \begin{bmatrix}0 & -1\\1 & 0\end{bmatrix}\boldsymbol{r}$ $\boldsymbol{q} = 0$
Applicable region	No additional restrictions.
Notes	CAD/CAM and 2D graphic applications.
References	[EDM]

8.5.26 Local space azimuthal 2D SRFT

Azimuthal 2D SRFs shall be derived from the SRFT specified in Table 8.28.

Table 8.28 — Local space azimuthal 2D SRFT

Element	Specification
SRFT label	LOCAL_SPACE_AZIMUTHAL_2D
SRFT code	25
Short name and description	Local space azimuthal 2D SRFT An azimuthal CS based SRF for 2D abstract space.
Object type	2D abstract object
ORM constraint	Shall be an ORM for a 2D abstract object.
CS label	AZIMUTHAL_2D
CS coordinate-component names and/or symbols	The same as the CS.
Template parameters	none
CS parameter binding rules	none
Applicable region	No additional restrictions.
Notes	none
References	[EDM]

8.5.27 Local space polar 2D SRFT

Polar 2D SRFs shall be derived from the SRFT specified in Table 8.29.

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Table 8.29 — Local space polar 2D SRFT

Element	Specification
SRFT label	LOCAL_SPACE_POLAR_2D
SRFT code	26
Short name and description	Local space polar 2D SRFT A polar CS based SRF for 2D abstract space.
Object type	2D abstract object
ORM constraint	Shall be an ORM for a 2D abstract object.
CS label	POLAR_2D
CS coordinate-component names and/or symbols	The same as the CS.
Template parameters	none
CS parameter binding rules	none
Applicable region	No additional restrictions.
Notes	none
References	[EDM]

8.6 Standardized SRFs

8.6.1 Introduction

This International Standard specifies a collection of standardized SRFs. These SRFs are derived from SRFTs. The specification elements for these standardized SRFs are defined in Table 8.30. Table 8.31 is a directory of these specifications, which appear in Table 8.32 through Table 8.45. Additional SRFs derived from SRFTs may be specified by registration in accordance with Clause 13

Table 8.30 — Standardized SRF specification elements

Element	Definition
SRF label	The label of the SRF (see 13.2.2).
SRF code	The code of the SRF (see 13.2.3). Code 0 (UNSPECIFIED) is reserved.
Short name	A short name as published or as commonly known and an optional description.
SRF template	The label of the applicable SRF template.
ORM label	The label of the applicable ORM.
Applicable region	Optional restriction of the domain of the CS to an applicable region description and/or an applicable region specification. If an applicable region specification is included, an extended region specification may also be included. If no applicable region is specified, the phrase “No additional restrictions.” shall be used.

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Element	Definition
Parameter values	The SRF template parameter values specified by value or by reference. If by reference, this specification element shall contain a citation(s) for the SRF template parameters values. Terms appearing in the references that are cited for a value shall be enclosed in brackets ({ }). Any parameter value that is not specified in the citation(s) shall be specified by value.
Notes	Optional, additional, non-normative information concerning the SRF, such as a description of its structure, modelled region, intended use, and/or application domain.
References	The references (see 13.2.5).

Table 8.31 — Directory of standardized SRFs

Short name	SRF label
British national grid	BRITISH_NATIONAL_GRID_AIRY
UK ordnance survey GRS80 grid.	BRITISH_OSGRS80_GRID
Delaware (US) state plane coordinate system	DELAWARE_SPCS_1993
Geocentric WGS 1984	GEOCENTRIC_WGS_1984
Geodetic Australia 1984	GEODETIC_AUSTRALIA_1984
Geodetic WGS 1984	GEODETIC_WGS_1984
Geodetic north American 1983	GEODETIC_N_AMERICAN_1983
Irish grid	IRISH_GRID_1965
Irish transverse Mercator	IRISH_TRANSVERSE_MERCATOR_1989
Lambert-93	LAMBERT_93
Lambert II étendu (Lambert II wide)	LAMBERT_II_WIDE
Mars planetocentric	MARS_PLANETOCENTRIC_2000
Mars planetodetic	MARS_PLANETOGRAPHIC_2000
Maryland (US) state plane coordinate system	MARYLAND_SPCS_1983

8.6.2 British national grid

Table 8.32 — British national grid SRF

Element	Specification	Element	Specification
SRF label	**BRITISH_NATIONAL_GRID_AIRY**	**SRF code**	**1**
Short name	British national grid. A transverse Mercator projection using the AIRY_1830 ellipsoid.		
SRF template	TRANSVERSE_MERCATOR	**ORM label**	OSGB_1936
Applicable region	Applicable region description: Great Britain.		
Parameter values	longitude of origin: λ_{origin} = -2° latitude of origin: φ_{origin} = 49° central scale: k_0 = 0,999 601 271 7 false easting: u_F = 400 000 m false northing: v_F = -100 000 m		

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Notes	Also known as the UK national projection.
References	[OSTM, Section 7, "National projection"]

8.6.3 UK ordnance survey GRS80 grid

Table 8.33 — UK ordnance survey GRS80 grid SRF

Element	Specification	Element	Specification
SRF label	**BRITISH_OSGRS80_GRID**	**SRF code**	**2**
Short name	UK ordnance survey GRS80 grid. A transverse Mercator projection using the GRS_1980 ellipsoid.		
SRF template	TRANSVERSE_MERCATOR	**ORM label**	ETRF
Applicable region	Applicable region description: Great Britain.		
Parameter values	longitude of origin: λ_{origin} = -2° latitude of origin: φ_{origin} = 49° central scale: k_0 = 0,999 601 271 7 false easting: u_F = 400 000 m false northing: v_F = -100 000 m		
Notes	Also known as the OSGRS80 grid.		
References	[OSTM, Section 7, " OSGRS80"]		

8.6.4 Delaware (US) state plane coordinate system

Table 8.34 — Delaware (US) state plane coordinate system SRF

Element	Specification	Element	Specification
SRF label	**DELAWARE_SPCS_1983**	**SRF code**	**3**
Short name	Delaware (US) state plane coordinate system		
SRF template	TRANSVERSE_MERCATOR	**ORM label**	N_AM_1983
Applicable region	Applicable region description: State of Delaware (US).		
Parameter values	longitude of origin: λ_{origin} = -75°25′ latitude of origin: φ_{origin} = 38° central scale: k_0 = 1 - 1/200 000 false easting: u_F = 200 000 m false northing: v_F = 0 m		
Notes	The conventional coordinate unit is US survey feet. To convert a coordinate in metres to a grid coordinate in US survey feet, use 1m = (39,37 / 12) US survey feet.		
References	[SNYD, Table 8 and Appendix C, "Delaware"]		

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8.6.5 Geocentric WGS 1984

Table 8.35 — Geocentric WGS 1984 SRF

Element	Specification	Element	Specification
SRF label	**GEOCENTRIC_WGS_1984**	**SRF code**	**4**
Short name	Geocentric WGS 1984		
SRF template	CELESTIOCENTRIC	**ORM label**	WGS_1984
Applicable region	Applicable region description: Earth, global.		
Parameter values	none		
Notes	Mass centred.		
References	[NGA36, Chapter 2.1]		

8.6.6 Geodetic Australia 1984

Table 8.36 — Geodetic Australia 1984 SRF

Element	Specification	Element	Specification
SRF label	**GEODETIC_AUSTRALIA_1984**	**SRF code**	**5**
Short name	Geodetic Australia 1984		
SRF template	CELESTIODETIC	**ORM label**	AUSTRALIAN_GEOD_1984
Applicable region	Applicable region description: Australia and Tasmania.		
Parameter values	none		
Notes	none		
References	[CECT]		

8.6.7 Geodetic WGS 1984

Table 8.37 — Geodetic WGS 1984 SRF

Element	Specification	Element	Specification
SRF label	**GEODETIC_WGS_1984**	**SRF code**	**6**
Short name	Geodetic WGS 1984		
SRF template	CELESTIODETIC	**ORM label**	WGS_1984
Applicable region	Applicable region description: Earth, global.		
Parameter values	none		
Notes	none		

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Element	Specification	Element	Specification
References	[NGA36, Chapter 3]		

8.6.8 Geodetic North American 1983

Table 8.38 — Geodetic North American 1983 SRF

Element	Specification	Element	Specification
SRF label	**GEODETIC_N_AMERICAN_1983**	**SRF code**	**7**
Short name	Geodetic North American 1983		
SRF template	CELESTIODETIC	**ORM label**	N_AM_1983
Applicable region	Applicable region description: Continental United States		
Parameter values	none		
Notes	none		
References	[SNYD]		

8.6.9 Irish Grid

Table 8.39 — Irish Grid SRF

Element	Specification	Element	Specification
SRF label	**IRISH_GRID_1965**	**SRF code**	**8**
Short name	Irish Grid		
SRF template	TRANSVERSE_MERCATOR	**ORM label**	IRELAND_1965
Applicable region	Applicable region description: Ireland.		
Parameter values	longitude of origin: $\lambda_{\mathrm{origin}}$ = -8° latitude of origin: $\varphi_{\mathrm{origin}}$ = 53°30′ central scale: k_0 = 1,000 035 false easting: u_{F} = 200 000 m false northing: v_{F} = 250 000 m		
Notes	The Irish Grid has been developed over more than two hundred years and is the coordinate reference system used in Ireland.		
References	[IGRID, "The Transverse Mercator Map Projection"]		

8.6.10 Irish transverse Mercator

Table 8.40 — Irish transverse Mercator SRF

Element	Specification	Element	Specification
SRF label	**IRISH_TRANSVERSE_MERCATOR_1989**	**SRF code**	**9**
Short name	Irish transverse Mercator		

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Element	Specification	Element	Specification
SRF template	TRANSVERSE_MERCATOR	**ORM label**	ETRF
Applicable region	Applicable region description: Ireland.		
Parameter values	longitude of origin: λ_{origin} = -8° latitude of origin: φ_{origin} = 53°30′ central scale: k_0 = 0,999 820 false easting: u_F = 600 000 m false northing: v_F = 750 000 m		
Notes	A newly derived projection designed for GPS compatibility. The longitude and latitude of origin defined in the Irish Grid are maintained.		
References	[NMPI, Table 1, "ITM"]		

8.6.11 Lambert-93

Table 8.41 — Lambert-93 SRF

Element	Specification	Element	Specification
SRF label	**LAMBERT_93**	**SRF code**	**10**
Short name	Lambert-93		
SRF template	LAMBERT_CONFORMAL_CONIC	**ORM label**	RGF_1993
Applicable region	Applicable region description: France.		
Parameter values	first parallel: φ_1 = 44° second parallel: φ_2 = 49° longitude of origin: λ_{origin} = 3° latitude of origin: φ_{origin} = 46°30′ false easting: u_F = 700 000 m false northing: v_F = 6 600 000 m		
Notes	Originally specified in September 1996.		
References	[PASG, "Caractéristiques de la projection conique conforme (projection dite de Lambert)"]		

8.6.12 Lambert II étendu (Lambert II wide)

Table 8.42 — Lambert II étendu (Lambert II wide) SRF

Element	Specification	Element	Specification
SRF label	**LAMBERT_II_WIDE**	**SRF code**	**11**
Short name	Lambert II étendu (Lambert II wide)		
SRF template	LAMBERT_CONFORMAL_CONIC	**ORM label**	NTF_1896_PM_PARIS
Applicable region	Applicable region description: France.		

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Element	Specification	Element	Specification
Parameter values	first parallel: φ_1 = 45°53′56,108″ second parallel: φ_2 = 47°41′45,652″ longitude of origin: λ_{origin} = 0° latitude of origin: φ_{origin} = 46°48′ false easting: u_F = 600 000 m false northing: v_F = 2 200 000 m		
Notes	An extension of Lambert Zone II to cover all of France. The prime meridian of the ORM is Paris (not Greenwich).		
References	[LIIE, "Valeurs pour le calcul des coordonnes en projection Lambert de l'ellipsoïde de Clarke 1880 IGN.", "Zone lambert: II étendu"]		

8.6.13 Mars planetocentric

Table 8.43 — Mars planetocentric SRF

Element	Specification	Element	Specification
SRF label	**MARS_PLANETOCENTRIC_2000**	**SRF code**	**12**
Short name	Mars planetocentric		
SRF template	CELESTIODETIC	**ORM label**	MARS_SPHERE_2000
Applicable region	Applicable region description: Mars, global.		
Parameter values	none		
Notes	1) Also referred to as "east/'ocentric"; adopted as the basis for current map production by the United States Geological Survey (USGS), National Aeronautics and Space Administration (NASA, US), and the European Space Agency (ESA). 2) Spherical latitude coincides with geodetic latitude.		
References	[DUXB]		

8.6.14 Mars planetographic

Table 8.44 — Mars planetographic SRF

Element	Specification	Element	Specification
SRF label	**MARS_PLANETOGRAPHIC_2000**	**SRF code**	**13**
Short name	Mars planetodetic		
SRF template	PLANETODETIC	**ORM label**	MARS_2000
Applicable region	Applicable region description: Mars, global.		
Parameter values	none		
Notes	1) Also referred to as "west/'ographic"; used historically for map production. 2) Planetodetic longitude is positive westwards.		

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Element	Specification	Element	Specification
References	[DUXB]		

8.6.15 Maryland (US) state plane coordinate system

Table 8.45 — Maryland (US) state plane coordinate system SRF

Element	Specification	Element	Specification
SRF label	**MARYLAND_SPCS_1983**	**SRF code**	**14**
Short name	Maryland (US) state plane coordinate system		
SRF template	LAMBERT_CONFORMAL_CONIC	**ORM label**	N_AM_1983
Applicable region	Applicable region description: State of Maryland (US).		
Parameter values	first parallel: φ_1 = 38°18′ second parallel: φ_2 = 39°27′ longitude of origin: λ_{origin} = -77° latitude of origin: φ_{origin} = 37°40′ false easting: u_F = 400 000 m false northing: v_F = 0 m		
Notes	The conventional coordinate unit is US survey feet. To convert a coordinate in metres to a grid coordinate in US survey feet, use 1m = (39,37 / 12) US survey feet.		
References	[SNYD, Table 8 and Appendix C, "Maryland"]		

8.7 Standardized SRF sets

8.7.1 Introduction

An *SRF set* for an ORM is a finite parameterized set of two or more spatial reference frames that:

a) are derived from the same SRF template using the given ORM, and

b) the applicable regions of the set members have non-overlapping interiors.

An SRF set specification may further restrict the ORM constraints of the SRFT. The specification elements for SRF sets are defined in Table 8.46. Specification elements for SRF set members are defined in Table 8.47. Each SRF set member shall have a code. The members of an SRF set member may be labelled. If any member of an SRF set has been assigned a label, all members of the set shall be assigned unique labels. An SRF set may contain a large number of members. In particular, the SRF set GTRS_GLOBAL_COORDINATE_SYSTEM, has more than 49 000 members. In such cases, assigning a label to each set member may provide no additional information beyond that which can be obtained from the corresponding code. For such cases, labels may be omitted. In cases where legacy SRF sets have commonly known and widely used member identifiers, such identifiers may be retained as the label for each set member. In particular, the members of the SRF set UNIVERSAL_TRANSVERSE_MERCATOR are labelled.

SRF set member specifications may be either explicit, with a complete specification given for each individual set member, or implicit, with specifications given in terms of general rules that can be instantiated for each individual member. The SRF sets GTRS_GLOBAL_COORDINATE_SYSTEM and UNIVERSAL_TRANSVERSE_MERCATOR illustrate the implicit specification concept.

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This International Standard specifies a collection of SRF sets. These specifications appear in Table 8.49 through Table 8.62. Table 8.48 is a directory of standardized SRF sets. The specified collection is not intended to be exhaustive. It includes national and regional grid systems as exemplars of the SRF set concept. Additional SRF sets and their members may be specified by registration in accordance with Clause 13.

Table 8.46 — SRF set specification elements

Element	Definition
SRF set label	The label of the SRF set (see 13.2.2).
SRF set code	The code of the SRF set (see 13.2.3). Code 0 is reserved.
Short name	A short name as published or as commonly known, and an optional description.
SRF template	The label of the applicable SRF template.
ORM constraints	Criteria for applicable ORMs. Specifying a single ORM indicates that only that ORM shall be used.
Coverage description	Optional description of the region corresponding to the union of the applicable regions of all of the set members.
SRF set membership	A specification of the parameterization of the set members by listing or parameter algorithm, and applicable region descriptions or specifications. If applicable region specifications are included, extended region specifications may also be included. References to other specification tables may be used for this purpose (see Table 8.47).
Notes	An optional description of the structure, modelled region, intended use, and/or application domain of the SRF set.
References	Optional references (see 13.2.5).

The specification elements for an *SRF set member* (SSM) is defined in Table 8.47.

Table 8.47 — SRF set member specification elements

Element	Definition
SSM label	The optional label of the SRF set member (see 13.2.2), or "n/a" (see 8.7.1).
SSM code	The code of the SRF set member (see 13.2.3); the set member parameter. Code 0 is reserved.
Short name	A short name as published or as commonly known and an optional description.
Applicable region	An applicable region description or applicable region specification. If an applicable region specification is included, an extended region specification may also be included.
Parameter values	The SRF template parameter values specified by value or by reference. If by reference, this specification element shall contain a citation(s) for the SRF template parameters values. Terms appearing in the references that are cited for a value shall be enclosed in brackets ({ }). Any parameter value that is not specified in the citation(s) shall be specified by value case.

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Element	Definition
Notes	Optional, additional, non-normative information concerning the SRF set member.

Table 8.48 — Directory of SRF sets

Short name	SRF set label
Alabama (US) state plane coordinate system.	ALABAMA_SPCS
GTRS global coordinate system (GCS) (Earth).	GTRS_GLOBAL_COORDINATE_SYSTEM
Japan plane coordinate system	JAPAN_RECTANGULAR_PLANE_CS
Lambert NTF	LAMBERT_NTF
Universal polar stereographic (Earth)	UNIVERSAL_POLAR_STEREOGRAPHIC
Universal transverse Mercator (Earth)	UNIVERSAL_TRANSVERSE_MERCATOR
Wisconsin (US) state plane coordinate system	WISCONSIN_SPCS

8.7.2 Alabama (US) state plane coordinate system

Table 8.49 — Alabama (US) state plane coordinate system SRF set

Element	Specification	Element	Specification
SRF set label	**ALABAMA_SPCS**	**SRF set code**	**1**
Short name	Alabama (US) state plane coordinate system		
SRF template	TRANSVERSE_MERCATOR	**ORM constraints**	ORM N_AM_1983
Coverage description	Applicable region description: State of Alabama (US).		
SRF set membership	Specified in Table 8.50.		
Notes	1) A set of two adjacent SRFs where only one SRF is used for each county in the state and no overlap is allowed. 2) The conventional coordinate unit is US survey feet. To convert a coordinate in metres to a grid coordinate in US survey feet, use 1m = (39,37 / 12) US survey feet.		
References	[SNYD, Table 8 and Appendix C, "Alabama" (East and West)], [ALSP]		

Table 8.50 — SRF set membership Alabama (US) state plane coordinate system

Element	Specification	Element	Specification
SSM label	WEST_ZONE	**SSM code**	**1**
Short name	West zone		
Applicable region	Applicable region description: Counties: Autauga, Baldwin, Bibb, Blount, Butler, Chilton, Choctaw, Clarke, Colbert, Conecuh, Cullman, Dallas, Escambia, Fayette, Franklin, Greene, Hale, Jefferson, Lamar, Lauderdale, Lawrence, Limestone, Lowndes, Marengo, Marion, Mobile, Monroe, Morgan, Perry, Pickens, Shelby, Sumter, Tuscaloosa, Walker, Washington, Wilcox and Winston.		

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Element	Specification	Element	Specification
Parameter values	longitude of origin: λ_{origin} = -87°30′ latitude of origin: φ_{origin} = 30° central scale: k_0 = 1 - 1/15 000 false easting: u_F = 600 000 m false northing: v_F =0 m		
Notes	none		
SSM label	EAST_ZONE	**SSM code**	**2**
Short name	East zone		
Applicable region	Applicable region description: Counties: Barbour, Bullock, Calhoun, Chambers, Cherokee, Clay, Cleburne, Coffee, Coosa, Covington, Crenshaw, Dale, DeKalb, Elmore, Etowah, Geneva, Henry, Houston, Jackson, Lee, Macon, Madison, Marshall, Montgomery, Pike, Randolph, Russell, Saint Clair, Talladega and Tallapoosa.		
Parameter values	longitude of origin: λ_{origin} = -85°50′ latitude of origin: φ_{origin} = 30°30′ central scale: k_0 = 1 - 1/25 000 false easting: u_F = 200 000 m false northing: v_F = 0 m		
Notes	none		

8.7.3 GTRS global coordinate system (GCS)

Table 8.51 — GTRS global coordinate system (GCS) SRF set

Element	Specification	Element	Specification
SRF set label	**GTRS_GLOBAL_COORDINATE_SYSTEM**	**SRF set code**	**2**
Short name	GTRS global coordinate system (GCS) (Earth)		
SRF template	LOCAL_TANGENT_SPACE_EUCLIDEAN	**ORM constraints**	A global model ERM such as ORM WGS_1984.
Coverage description	Applicable region description: Earth (complete).		
SRF set membership	Specified in Table 8.52.		
Notes	A set of 49 896 SRFs, each approximately 100 kilometres square, that are identified according to the geotile reference system indexing scheme. The members of this SRF set are known as cells. For much of the RD surface, each cell valid-region covers one arc degree of geodetic latitude by one arc degree of geodetic longitude. However, near the poles, many arc degrees of longitude are grouped together into a single GCS cell since an arc degree of geodetic longitude becomes arbitrarily small near the poles. GCS cells are always one arc degree of geodetic latitude in extent. Within each GCS cell, a false origin offset is provided. The point of tangency is at the centre of the rectangular GCS cell, even if more than one arc degree of geodetic longitude falls within the GCS SRF cell. The SRFT LOCAL_TANGENT_SPACE_EUCLIDEAN azimuth parameter (α) is zero.		
References	ISO/IEC 18025, Table 6.11, GTRS_GEOTILE, [BIRK]		

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Table 8.52 — SRF set membership GTRS global coordinate system (GCS)

Element	Specification	Element	Specification
SSM label	n/a	**SSM code**	1…49 896: As specified in Table 8.53.
Short name	Tile <code>		
Applicable region	Applicable region specification: As specified in Table 8.53 as type geodetic-region.		
Parameter values	surface geodetic coordinate of the tangent point as specified in Table 8.53 azimuth: $\alpha = 0$ offset height: $h_0 = 0$ m false easting: x_F = 50 000 m false northing: y_F = 50 000 m		
Notes	none		

Table 8.53 — GTRS natural origin and applicable region by code index

Latitude band (Tile size)	Tile code	Surface geodetic coordinate of the tangent point (λ_{origin}, φ_{origin})	Applicable region specification
88º-90ºS (1º x 30º)	1 + 12•m + n (m=0,1; n=0,..,11)	(-165º + n•30º, -89,5º + m•1º)	-15º ≤ $\lambda - \lambda_{origin}$ ≤+15º -0,5º ≤ $\varphi - \varphi_{origin}$ ≤+0,5º
86º-88ºS (1º x 15º)	25 + 24•m + n (m=0,1; n=0,..,23)	(-172,5º + n•15º, -87,5º + m•1º)	-7,5º ≤ $\lambda - \lambda_{origin}$ ≤+7,5º -0,5º ≤ $\varphi - \varphi_{origin}$ ≤+0,5º
84º-86ºS (1º x 10º)	73 + 36• m + n (m=0,1; n=0,..,35)	(-175º + n•10º, -85,5º + m•1º)	-5º ≤ $\lambda - \lambda_{origin}$ ≤+5º -0,5º ≤ $\varphi - \varphi_{origin}$ ≤+0,5º
80º-84ºS (1º x 6º)	145 + 60• m + n (m=0,..,3; n=0,..,59)	(-177º + n•6º, -83,5º + m•1º)	-3º ≤ $\lambda - \lambda_{origin}$ ≤+3º -0,5º ≤ $\varphi - \varphi_{origin}$ ≤+0,5º
78º-80ºS (1º x 5º)	385 + 72• m + n (m=0,1; n=0,..,71)	(-177,5º + n•5º, -79,5º + m•1º)	-2,5º ≤ $\lambda - \lambda_{origin}$ ≤+2,5º -0,5º ≤ $\varphi - \varphi_{origin}$ ≤+0,5º
71º-78ºS (1º x 3º)	529 + 120• m + n (m=0,..,6; n=0,..,119)	(-178.5º + n•3º, -77,5º + m•1º)	-1,5º ≤ $\lambda - \lambda_{origin}$ ≤+1,5º -0,5º ≤ $\varphi - \varphi_{origin}$ ≤+0,5º
60º-71ºS (1º x 2º)	1 369 + 180• m + n (m=0,..,10; n=0,..,179)	(-179º + n•2º, -70,5º + m•1º)	-1º ≤ $\lambda - \lambda_{origin}$ ≤+1º -0,5º ≤ $\varphi - \varphi_{origin}$ ≤+0,5º
60ºS - 60ºN (1º x 1º)	3 349 + 360• m + n (m=0,..,119; n=0,..,359)	(-179,5º + n•1º, -59,5º + m•1º)	-0,5º ≤ $\lambda - \lambda_{origin}$ ≤+0,5º -0,5º ≤ $\varphi - \varphi_{origin}$ ≤+0,5º
71º-60ºN (1º x 2º)	46 549 + 180• m + n (m=0,..,10; n=0,..,179)	(-179º + n•2º, 60,5º + m•1º)	-1º ≤ $\lambda - \lambda_{origin}$ ≤+1º -0,5º ≤ $\varphi - \varphi_{origin}$ ≤+0,5º
78º-71ºN (1º x 3º)	48 529 + 120• m + n (m=0,..,6; n=0,..,119)	(-178.5º + n•3º, 71,5º + m•1º)	-1,5º ≤ $\lambda - \lambda_{origin}$ ≤+1,5º -0,5º ≤ $\varphi - \varphi_{origin}$ ≤+0,5º
80º-78ºN (1º x 5º)	49 369 + 72• m + n (m=0,1; n=0,..,71)	(-177,5º + n•5º, 78,5º + m•1º)	-2,5º ≤ $\lambda - \lambda_{origin}$ ≤+2,5º -0,5º ≤ $\varphi - \varphi_{origin}$ ≤+0,5º
84º-80ºN (1º x 6º)	49 513 + 60• m + n (m=0,..,3; n=0,..,59)	(-177º + n•6º, 80,5º + m•1º)	-3º ≤ $\lambda - \lambda_{origin}$ ≤+3º -0,5º ≤ $\varphi - \varphi_{origin}$ ≤+0,5º

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Latitude band (Tile size)	Tile code	Surface geodetic coordinate of the tangent point (λ_{origin}, φ_{origin})	Applicable region specification
86º-84ºN (1º x 10º)	49 752 + 36• m + n (m=0,1; n=0,..,35)	(-175º + n•10º, 84,5º + m•1º)	-5º ≤ λ - λ_{origin} ≤+5º -0,5º ≤ φ - φ_{origin} ≤+0,5º
88º-86ºN (1º x 15º)	49 825 + 24• m + n (m=0,1; n=0,..,23)	(-172,5º + n•15º, 86,5º + m•1º)	-7,5º ≤ λ - λ_{origin} ≤+7,5º -0,5º ≤ φ - φ_{origin} ≤+0,5º
90º-88ºN (1º x 30º)	49 873 + 12• m + n (m=0,1; n=0,..,11)	(-165º + n•30º, 88,5º + m•1º)	-15º ≤ λ - λ_{origin} ≤+15º -0,5º ≤ φ - φ_{origin} ≤+0,5º

8.7.4 Japan plane coordinate system

Table 8.54 — Japan plane coordinate system SRF set

Element	Specification	Element	Specification
SRF set label	**JAPAN_RECTANGULAR_PLANE_CS**	**SRF set code**	**3**
Short name	Japan plane coordinate system		
SRF template	TRANSVERSE_MERCATOR	**ORM constraints**	ORM JGD_2000
Coverage description	Applicable region description: Japan excluding northern territories.		
SRF set membership	Specified in Table 8.55.		
Notes	1) The official representation scheme for the Japan plane coordinate system is (v:northing, u:easting) and the coordinate values are commonly encoded in the form NE, where N denotes digits of northing in metres and E denotes the same number of digits of easting in metres. 2) A set of nineteen SRFs, each limited to 130 km eastward and westward from the central meridian. Applicable regions are described by political regions (cities, prefectures, counties, and/or partitions thereof).		
References	[JMLIT], [EPSG, Code 2443 - 2461]		

Table 8.55 — SRF set membership Japan plane coordinate system

Element	Specification	Element	Specification
SSM label	ZONE_I	**SSM code**	1
Short name	Zone I		
Applicable region	Applicable region description: Prefectures: Nagasaki, Kagosima (all islands, atolls, and reefs bounded by 128º18′ ≤ λ ≤ 130º (130º13′ for Amami Islands); 27º ≤ φ ≤ 32º)		
Parameter values	longitude of origin: λ_{origin} = +129º30′ latitude of origin: φ_{origin} = +33º central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		

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Element	Specification	Element	Specification
SSM label	ZONE_II	**SSM code**	2
Short name	Zone II		
Applicable region	Applicable region description: Prefectures: Hukuoka, Saga, Kumamoto, Oita, Miyazaki, Kagosima (excluding the range in Zone_I)		
Parameter values	longitude of origin: λ_{origin} = +131° latitude of origin: φ_{origin} = +33° central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_III	**SSM code**	3
Short name	Zone III		
Applicable region	Applicable region description: Prefectures: Yamaguti, Simane, Hirosima		
Parameter values	longitude of origin: λ_{origin} = +132°10′ latitude of origin: φ_{origin} = +36° central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_IV	**SSM code**	4
Short name	Zone IV		
Applicable region	Applicable region description: Prefectures: Kagawa, Ehime, Tokusima, Koti		
Parameter values	longitude of origin: λ_{origin} = +133°30′ latitude of origin: φ_{origin} = +33° central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_V	**SSM code**	5
Short name	Zone V		
Applicable region	Applicable region description: Prefectures: Hyogo, Tottori, Okayama		
Parameter values	longitude of origin: λ_{origin} = +134°20′ latitude of origin: φ_{origin} = +36° central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_VI	**SSM code**	6

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Element	Specification	Element	Specification
Short name	Zone VI		
Applicable region	Applicable region description: Prefectures: Kyoto, Osaka, Hukui, Siga, Mie, Nara, Wakayama		
Parameter values	longitude of origin: λ_{origin} = +136º00′ latitude of origin: φ_{origin} = +36º central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_VII	**SSM code**	7
Short name	Zone VII		
Applicable region	Applicable region description: Prefectures: Isikawa, Toyama, Gihu, Aiti		
Parameter values	longitude of origin: λ_{origin} = +137º10′ latitude of origin: φ_{origin} = +36º central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_VIII	**SSM code**	8
Short name	Zone VIII		
Applicable region	Applicable region description: Prefectures: Niigata, Nagano, Yamanasi, Sizuoka		
Parameter values	longitude of origin: λ_{origin} = +138º30′ latitude of origin: φ_{origin} = +36º central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_IX	**SSM code**	9
Short name	Zone IX		
Applicable region	Applicable region description: Prefectures: Tokyo (excluding the ranges in Zone_XIV, Zone_XVIII, and Zone_XIX), Hukusima, Totigi, Ibaraki, Saitama, Tiba, Gunma, Kanagawa		
Parameter values	longitude of origin: λ_{origin} = +139º50′ latitude of origin: φ_{origin} = +36º central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_X	**SSM code**	10
Short name	Zone X		

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Element	Specification	Element	Specification
Applicable region	Applicable region description: Prefectures: Aomori, Akita, Yamagata, Iwate, Miyagi		
Parameter values	longitude of origin: λ_{origin} = +140º50′ latitude of origin: φ_{origin} = +40º central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_XI	**SSM code**	11
Short name	Zone XI		
Applicable region	Applicable region description: Cities: Otaru, Hakodate, Date Branch offices: Iburi (only the towns of Toyoura, Sobetsu, and Toyako), Hiyama, Siribesi, Osima		
Parameter values	longitude of origin: λ_{origin} = +140º15′ latitude of origin: φ_{origin} = +44º central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_XII	**SSM code**	12
Short name	Zone XII		
Applicable region	Applicable region description: Hokkaido (excluding areas specified in Zone_XI and Zone_XIII)		
Parameter values	longitude of origin: λ_{origin} = +142º15′ latitude of origin: φ_{origin} = +44º central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_XIII	**SSM code**	13
Short name	Zone XIII		
Applicable region	Applicable region description: Cities: Kitami, Obihiro, Kusiro, Abasiri, Nemuro Branch offices: Nemuro, Kusiro, Okhotsk (the towns of Bihoro, Tsubetsu, Shari, Kiyosato, Koshimizu, Kunneppu, Oketo, Saroma, and Ozora), Tokati		
Parameter values	longitude of origin: λ_{origin} = +144º15′ latitude of origin: φ_{origin} = +44º central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_XIV	**SSM code**	14
Short name	Zone XIV		

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Element	Specification	Element	Specification
Applicable region	Applicable region description: Tokyo (140º30′ < λ < 143º00′, φ < 28º)		
Parameter values	longitude of origin: λ_{origin} = +142º00′ latitude of origin: φ_{origin} = +26º central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_XV	**SSM code**	15
Short name	Zone XV		
Applicable region	Applicable region description: Okinawa Prefecture (126º < λ < 130º)		
Parameter values	longitude of origin: λ_{origin} = +127º30′ latitude of origin: φ_{origin} = +26º central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_XVI	**SSM code**	16
Short name	Zone XVI		
Applicable region	Applicable region description: Okinawa Prefecture (λ < 126º)		
Parameter values	longitude of origin: λ_{origin} = +124º00′ latitude of origin: φ_{origin} = +26º central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_XVII	**SSM code**	17
Short name	Zone XVII		
Applicable region	Applicable region description: Okinawa Prefecture (130º < λ)		
Parameter values	longitude of origin: λ_{origin} = +131º00′ latitude of origin: φ_{origin} = +26º central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_XVIII	**SSM code**	18
Short name	Zone XVIII		
Applicable region	Applicable region description: Tokyo (λ < 140º30′, φ < 28º)		

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Element	Specification	Element	Specification
Parameter values	longitude of origin: λ_{origin} = +136°00′ latitude of origin: φ_{origin} = +20° central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		
SSM label	ZONE_XIX	**SSM code**	19
Short name	Zone XIX		
Applicable region	Applicable region description: Tokyo (143° < λ, φ < 28°)		
Parameter values	longitude of origin: λ_{origin} = +154°00′ latitude of origin: φ_{origin} = +26° central scale: k_0 = 0,999 9 false easting: u_F = 0 m false northing: v_F = 0 m		
Notes	none		

8.7.5 Lambert NTF

Table 8.56 — Lambert NTF SRF set

Element	Specification	Element	Specification
SRF set label	**LAMBERT_NTF**	**SRF set code**	**4**
Short name	Lambert NTF The Lambert projection-based mapping system for France associated with the NTF.		
SRF template	LAMBERT_CONFORMAL_CONIC	**ORM constraints**	ORM NTF_1896_PM_PARIS
Coverage description	Applicable region description: France.		
SRF set membership	Specified in Table 8.57.		
Notes	A set of four adjacent SRFs where only one SRF is used for each portion of France and no overlap is allowed. The prime meridian for each is Paris, France.		
References	[LIIE, "Valeurs pour le calcul des coordonnes en projection Lambert de l'ellipsoïde de Clarke 1880 IGN.", "Zone lambert" (I, II, III, and IV)]		

Table 8.57 — SRF set membership Lambert NTF

Element	Specification	Element	Specification
SSM label	ZONE_I	**SSM code**	1
Short name	Zone I		
Applicable region	Applicable region specification of type geodetic-region: -5° ≤ λ ≤ 10° 48,15° ≤ φ < 51,3° (53,5gr ≤ φ < 57gr)		

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Element	Specification	Element	Specification
Parameter values	first parallel: φ_1 = 48º35′54,682″ second parallel: φ_2 = 50º23′45,282″ longitude of origin: λ_{origin} = 0º latitude of origin: φ_{origin} = 49,5º false easting: u_F = 600 000 m false northing: v_F =200 000 m		
Notes	The prime meridian is Paris, France. In the reference, the applicable region latitude boundary values are specified in grads (gr).		
SSM label	ZONE_II	**SSM code**	2
Short name	Zone II		
Applicable region	Applicable region specification of type geodetic-region: -5º ≤ λ ≤ 10º 45,45º ≤ φ < 48,15º (50,5gr ≤ φ < 53,5gr)		
Parameter values	first parallel: φ_1 = 45º53′56,108″ second parallel: φ_2 = 47º41′45,652″ longitude of origin: λ_{origin} = 0º latitude of origin: φ_{origin} = 46,8º false easting: u_F = 600 000 m false northing: v_F =200 000 m		
Notes	The prime meridian is Paris, France. In the reference, the applicable region latitude boundary values are defined in grads (gr).		
SSM label	ZONE_III	**SSM code**	3
Short name	Zone III		
Applicable region	Applicable region specification of type geodetic-region: -5º ≤ λ ≤ 10º 42,3º ≤ φ < 45,45º (47gr ≤ φ < 50,5gr)		
Parameter values	first parallel: φ_1 = 43º11′57,449″ second parallel: φ_2 = 44º59′45,938″ longitude of origin: λ_{origin} = 0º latitude of origin: φ_{origin} = 44,1º false easting: u_F = 600 000 m false northing: v_F =200 000 m		
Notes	The prime meridian is Paris, France. In the reference, the applicable region latitude boundary values are defined in grads (gr).		
SSM label	ZONE_IV	**SSM code**	4
Short name	Zone IV		
Applicable region	Applicable region description: The island of Corsica.		
Parameter values	first parallel: φ_1 = 41º33′37,396″ second parallel: φ_2 = 42º46′3,588″ longitude of origin: λ_{origin} = 0º latitude of origin: φ_{origin} = 42º9′54″ false easting: u_F = 234 358 m false northing: v_F = 185 861,369 m		
Notes	The prime meridian is Paris, France.		

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8.7.6 Universal polar stereographic

Table 8.58 — Universal polar stereographic (UPS) SRF set

Element	Specification	Element	Specification
SRF set label	**UNIVERSAL_POLAR_STEREOGRAPHIC**	**SRF set code**	**5**
Short name	Universal polar stereographic (UPS) (Earth)		
SRF template	POLAR_STEREOGRAPHIC	**ORM constraints**	A global model ERM such as ORM WGS_1984.
Coverage description	Applicable region specification of type geodetic-region: $\varphi \leq -80°$ or $84° \leq \varphi$ Extended region specification: $\varphi \leq -79{,}5°$ or $83{,}5° \leq \varphi$		
SRF set membership	Specified in Table 8.59.		
Notes	A set of two SRFs addressing the north and south polar regions of the Earth. Shares a common boundary with SRF set UNIVERSAL_TRANSVERSE_MERCATOR.		
References	[83582, "3-2.4 Specifications of the UPS"]		

Table 8.59 — SRF set membership Universal polar stereographic (UPS)

Element	Specification	Element	Specification
SSM label	NORTHERN_POLE.	**SSM code**	1
Short name	UPS, northern pole		
Applicable region	Applicable region specification of type geodetic-region: $\varphi \geq 84°$ Extended region specification: $\varphi \geq 83{,}5°$		
Parameter values	longitude of origin: λ_{origin} = 0° latitude of true scale: φ_1 = +90° scale at φ_1: k_1 = 0,994 false easting: u_F = 2 000 000 m false northing: v_F = 2 000 000 m		
Notes	none		
SSM label	SOUTHERN_POLE	**SSM code**	2
Short name	UPS, southern pole		
Applicable region	Applicable region specification of type geodetic-region: $\varphi \leq -80°$ Extended region specification: $\varphi \leq -79{,}5°$		
Parameter values	longitude of origin: λ_{origin} = 0° latitude of true scale: φ_1 = -90° scale at φ_1: k_1 = 0,994 false easting: u_F = 2 000 000 m false northing: v_F = 2 000 000 m		
Notes	none		

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8.7.7 Universal transverse Mercator

Table 8.60 — Universal transverse Mercator (UTM) SRF set

Element	Specification	Element	Specification
SSM label	**UNIVERSAL_TRANSVERSE_MERCATOR**	**SRF set code**	**6**
Short name	Universal transverse Mercator (UTM) (Earth)		
SRF template	TRANSVERSE_MERCATOR	**ORM constraints**	A global model ERM such as ORM WGS_1984.
Coverage description	Applicable region specification of type geodetic-region: -80° ≤ φ ≤ 84° Extended region specification: -80,5° ≤ φ ≤ 84,5°		
SRF set membership	Specified in Table 8.61.		
Notes	A set of 120 SRFs, where limited overlap is modelled by extended regions in the member SRFs. Shares a common boundary with SRF set UNIVERSAL_POLAR_STEREOGRAPHIC.		
References	[83582, "2-3 Specifications of the UTM"]		

Table 8.61 — SRF set membership Universal transverse Mercator (UTM)

Element	Specification	Element	Specification
SSM label	"ZONE_" + <code> + "_NORTHERN_HEMISPHERE", where the "+" symbol shall denote concatenation of character strings	**SSM code**	1…60
Short name	UTM Zone <code>, Northern hemisphere		
Applicable region	Applicable region specification of type geodetic-region: (-186° + (<code>)•6°) ≤ λ ≤ (-180° + (<code>)•6°) 0° ≤ φ ≤ 84° Extended region specification: (-186,5° + (<code>)•6°) ≤ λ ≤ (-179,5° + (<code>)•6°) -0,5° ≤ φ ≤ 84,5°		
Parameter values	longitude of origin: λ_{origin} = (-183° + (<code>)•6°) latitude of origin: φ_{origin} = 0° central scale: k_0 = 0,999 6 false easting: u_F = 500 000 m false northing: v_F = 0 m		
Notes	none		
SSM label	"ZONE_" + (<code> - 60) + "_SOUTHERN_HEMISPHERE", where the "+" symbol shall denote concatenation of character strings	**SSM code**	61…120
Short Name	UTM Zone <code>, Southern hemisphere		

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Element	Specification	Element	Specification
Applicable region	Applicable region specification of type geodetic-region: $(-186° + (\text{<code>} - 60)\cdot 6°) \le \lambda \le (-180° + (\text{<code>} - 60)\cdot 6°)$ $-80° \le \varphi \le 0°$ Extended region specification: $(-186{,}5° + (\text{<code>} - 60)\cdot 6°) \le \lambda \le (-179{,}5° + (\text{<code>} - 60)\cdot 6°)$ $-80{,}5° \le \varphi \le 0{,}5°$		
Parameter values	longitude of origin: $\lambda_{origin} = (-183° + (\text{<code>} - 60)\cdot 6°)$ latitude of origin: $\varphi_{origin} = 0°$ central scale: k_0 = 0,999 6 false easting: u_F = 500 000 m false northing: v_F = 10 000 000 m		
Notes	none		

8.7.8 Wisconsin (US) state plane coordinate system

Table 8.62 — Wisconsin (US) state plane coordinate system SRF set

Element	Specification	Element	Specification
SRF set label	**WISCONSIN_SPCS**	**SRF set code**	**7**
Short name	Wisconsin (US) state plane coordinate system		
SRF template	LAMBERT_CONFORMAL_CONIC	**ORM constraints**	ORM N_AM_1983
Coverage description	Applicable region description: State of Wisconsin (US).		
SRF set membership	Specified in Table 8.63.		
Notes	1) A set of three adjacent SRFs where only one SRF is used for each county in the state and no overlap is allowed. 2) The conventional coordinate unit is US survey feet. To convert a coordinate in metres to a grid coordinate in US survey feet, use 1m = (39,37 / 12) US survey feet.		
References	[WSCO, "SPC 83" (South, Central, and North)]		

Table 8.63 — SRF set membership Wisconsin (US) state plane coordinate

Element	Specification	Element	Specification
SSM label	SOUTH_ZONE	**SSM code**	1
Short name	South zone		
Applicable region	Applicable region description: Counties: Adams, Calumet, Columbia, Crawford, Dane, Dodge, Fond Du Lac, Grant, Green Lake, Green, Iowa, Jefferson, Juneau, Kenosha, La Crosse, Lafayette, Manitowoc, Marquette, Milwaukee, Monroe, Ozaukee, Racine, Richland, Rock, Sauk, Sheboygan, Vernon, Walworth, Washington, Waukesha, Waushara, Winnebago		

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Element	Specification	Element	Specification
Parameter values	first parallel: φ_1 = 42°44′ second parallel: φ_2 = 44°04′ longitude of origin: λ_{origin} = -90° latitude of origin: φ_{origin} = 42° false easting: u_F = 600 000 m false northing: v_F = 0 m		
Notes	none		
SSM label	CENTRAL_ZONE	**SSM code**	2
Short name	Central zone		
Applicable region	Applicable region description: Counties: Barron, Brown, Buffalo, Chippewa, Clark, Door, Dunn, Eau Claire, Jackson, Kewaunee, Langlade, Lincoln, Marathon, Marinette, Menominee, Oconto, Outagamie, Pepin, Pierce, Polk, Portage, Rusk, Shawano, St. Croix, Taylor, Trempealeau, Waupaca, Wood		
Parameter values	first parallel: φ_1 = 44°15′ second parallel: φ_2 = 45°30′ longitude of origin: λ_{origin} = -90° latitude of origin: φ_{origin} = 43°50′ false easting: u_F = 600 000 m false northing: v_F = 0 m		
Notes	none		
SSM label	NORTH_ZONE	**SSM code**	3
Short name	North zone		
Applicable region	Applicable region description: Counties: Ashland, Bayfield, Burnett, Douglas, Florence, Forest, Iron, Oneida, Price, Sawyer, Vilas, Washburn		
Parameter values	first parallel: φ_1 = 45°34′ second parallel: φ_2 = 46°46′ longitude of origin: λ_{origin} = -90° latitude of origin: φ_{origin} = 45°10′ false easting: u_F = 600 000 m false northing: v_F = 0 m		
Notes	none		

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