

<b>Contents</b>	<b>Page</b>
Foreword .....	<a href="#">xxiii</a>
0 Introduction .....	<a href="#">xxv</a>
0.1 Purpose .....	<a href="#">xxv</a>
0.2 Design criteria .....	<a href="#">xxv</a>
1 Scope .....	<a href="#">1</a>
2 Normative references .....	<a href="#">3</a>
3 Terms, definitions, symbols, and abbreviated terms .....	<a href="#">5</a>
3.1 Terms and definitions .....	<a href="#">5</a>
3.2 Notation, symbols, and abbreviated terms .....	<a href="#">6</a>
4 Concepts .....	<a href="#">13</a>
4.1 Overview .....	<a href="#">13</a>
4.2 Coordinate-space, position-space, and object-space .....	<a href="#">15</a>
4.2.1 Coordinate-space .....	<a href="#">15</a>
4.2.2 Position-space and orthonormal frames .....	<a href="#">15</a>
4.2.3 Object-space and normal embeddings .....	<a href="#">16</a>
4.3 Coordinate systems .....	<a href="#">17</a>
4.3.1 Abstract coordinate systems .....	<a href="#">17</a>
4.3.2 Spatial coordinate systems .....	<a href="#">19</a>
4.3.3 Temporal coordinate systems .....	<a href="#">19</a>
4.4 Orientation .....	<a href="#">20</a>
4.5 Reference datums .....	<a href="#">20</a>
4.6 Object reference models .....	<a href="#">23</a>
4.7 Spatial reference frames .....	<a href="#">25</a>
4.8 Designated spatial surfaces and vertical offset surfaces .....	<a href="#">26</a>
4.9 Spatial operations .....	<a href="#">27</a>
4.10 Application program interface .....	<a href="#">28</a>
4.11 Profiles .....	<a href="#">28</a>
4.12 Registration .....	<a href="#">28</a>
4.13 Conformance .....	<a href="#">29</a>
5 Coordinate systems .....	<a href="#">31</a>
5.1 Overview .....	<a href="#">31</a>
5.2 Coordinate-space, position-space, and object-space .....	<a href="#">31</a>
5.2.1 Coordinate-space .....	<a href="#">31</a>
5.2.2 Orthonormal frames .....	<a href="#">32</a>
5.2.3 Position-space .....	<a href="#">33</a>
5.2.4 Object-space .....	<a href="#">34</a>
5.2.5 Normal embeddings .....	<a href="#">35</a>
5.3 Abstract coordinate systems .....	<a href="#">37</a>
5.3.1 Overview .....	<a href="#">37</a>
5.3.2 Definition .....	<a href="#">37</a>
5.3.3 Coordinate system types .....	<a href="#">38</a>
5.3.4 Coordinate-component surfaces and curves .....	<a href="#">41</a>
5.3.4.1 Overview .....	<a href="#">41</a>
5.3.4.2 Coordinate-component surfaces and induced surface CSs .....	<a href="#">41</a>
5.3.4.3 Coordinate-component curves .....	<a href="#">42</a>
5.3.5 CS properties .....	<a href="#">43</a>
5.3.5.1 Linearity .....	<a href="#">43</a>

5.3.5.2	Orthogonality .....	<a href="#">43</a>
5.3.5.3	Linear CS properties: Cartesian, and orthogonal .....	<a href="#">43</a>
5.3.5.4	CS right-handedness and coordinate-component ordering .....	<a href="#">44</a>
5.3.6	CS localization .....	<a href="#">44</a>
5.3.6.1	Overview .....	<a href="#">44</a>
5.3.6.2	Localization operators .....	<a href="#">45</a>
5.3.6.3	Localized frame and local tangent frame at a coordinate .....	<a href="#">47</a>
5.3.6.4	Vectors, directions, and localized frames .....	<a href="#">50</a>
5.3.7	Map projection coordinate systems .....	<a href="#">51</a>
5.3.7.1	Map projections .....	<a href="#">51</a>
5.3.7.2	Map projection as a surface CS .....	<a href="#">51</a>
5.3.7.3	Map projection geometry .....	<a href="#">52</a>
5.3.7.4	Relationship to projection functions .....	<a href="#">56</a>
5.3.7.5	Map projection CS common parameters .....	<a href="#">59</a>
5.3.7.6	Augmented map projections .....	<a href="#">60</a>
5.3.8	CS specifications .....	<a href="#">61</a>
5.3.8.1	Specification table elements and common functions and parameters .....	<a href="#">61</a>
5.3.8.2	Euclidean 3D CS specification .....	<a href="#">64</a>
5.3.8.3	Lococentric Euclidean 3D CS specification .....	<a href="#">65</a>
5.3.8.4	Equatorial Spherical CS specification .....	<a href="#">67</a>
5.3.8.5	Lococentric Equatorial Spherical CS specification .....	<a href="#">68</a>
5.3.8.6	Azimuthal Spherical CS specification .....	<a href="#">70</a>
5.3.8.7	Lococentric Azimuthal Spherical CS specification .....	<a href="#">72</a>
5.3.8.8	Geodetic 3D CS specification .....	<a href="#">73</a>
5.3.8.9	Planetodetic 3D specification .....	<a href="#">76</a>
5.3.8.10	Cylindrical CS specification .....	<a href="#">77</a>
5.3.8.11	Lococentric Cylindrical CS specification .....	<a href="#">79</a>
5.3.8.12	Mercator CS specification .....	<a href="#">80</a>
5.3.8.13	Oblique Mercator Spherical CS specification .....	<a href="#">82</a>
5.3.8.14	Transverse Mercator CS specification .....	<a href="#">85</a>
5.3.8.15	Lambert Conformal Conic CS specification .....	<a href="#">89</a>
5.3.8.16	Polar Stereographic CS specification .....	<a href="#">91</a>
5.3.8.17	Equidistant Cylindrical CS specification .....	<a href="#">93</a>
5.3.8.18	Surface Geodetic CS specification .....	<a href="#">95</a>
5.3.8.19	Surface Planetodetic CS specification .....	<a href="#">96</a>
5.3.8.20	Lococentric Surface Euclidean CS specification .....	<a href="#">98</a>
5.3.8.21	Lococentric Surface Azimuthal CS specification .....	<a href="#">100</a>
5.3.8.22	Lococentric Surface Polar CS specification .....	<a href="#">101</a>
5.3.8.23	Euclidean 2D CS specification .....	<a href="#">103</a>
5.3.8.24	Lococentric Euclidean 2D CS specification .....	<a href="#">104</a>
5.3.8.25	Azimuthal CS specification .....	<a href="#">106</a>
5.3.8.26	Lococentric Azimuthal CS specification .....	<a href="#">107</a>
5.3.8.27	Polar CS specification .....	<a href="#">109</a>
5.3.8.28	Lococentric Polar CS specification .....	<a href="#">110</a>
5.3.8.29	Euclidean 1D CS specification .....	<a href="#">112</a>
5.3.8.30	Azimuthal Cylindrical CS specification .....	<a href="#">113</a>
5.3.8.31	Lococentric Azimuthal Cylindrical CS specification .....	<a href="#">114</a>
5.4	Spatial coordinate systems .....	<a href="#">116</a>
5.4.1	Overview .....	<a href="#">116</a>
5.4.2	Definition .....	<a href="#">116</a>
5.5	Temporal coordinate systems .....	<a href="#">118</a>
5.5.1	Overview .....	<a href="#">118</a>
5.5.2	Universal time .....	<a href="#">119</a>
5.5.3	International atomic time .....	<a href="#">119</a>
5.5.4	Coordinated universal time .....	<a href="#">119</a>
5.5.5	Specified temporal coordinate systems .....	<a href="#">119</a>

6	Orientation – change of basis and rotation .....	<a href="#">121</a>
6.1	Overview .....	<a href="#">121</a>
6.2	Change of basis .....	<a href="#">121</a>
6.2.1	Overview .....	<a href="#">121</a>
6.2.2	Change of basis operations .....	<a href="#">121</a>
6.2.3	Direction cosine matrix .....	<a href="#">124</a>
6.2.4	Consecutive change of basis .....	<a href="#">124</a>
6.2.5	Equivalence of change of basis and rotation operators .....	<a href="#">124</a>
6.2.6	Change of basis and orientation .....	<a href="#">125</a>
6.3	Orientation .....	<a href="#">125</a>
6.3.1	Overview .....	<a href="#">125</a>
6.3.2	Orientation defined in terms of a change of basis operator .....	<a href="#">126</a>
6.3.3	Orientation defined in terms of a rotation operator .....	<a href="#">126</a>
6.3.4	Orientation contexts .....	<a href="#">126</a>
6.4	Rotation .....	<a href="#">126</a>
6.4.1	Overview .....	<a href="#">126</a>
6.4.2	Coordinate-free rotation .....	<a href="#">127</a>
6.4.2.1	Origin-fixed rotation .....	<a href="#">127</a>
6.4.2.2	Rodrigues' rotation formula .....	<a href="#">128</a>
6.4.2.3	Rotation properties .....	<a href="#">128</a>
6.4.2.4	Consecutive rotations .....	<a href="#">129</a>
6.4.3	Frame-based rotation .....	<a href="#">133</a>
6.4.3.1	Overview .....	<a href="#">133</a>
6.4.3.2	Rotation of position-vectors .....	<a href="#">134</a>
6.4.3.3	Rotation of basis vectors and orthonormal frames .....	<a href="#">135</a>
6.4.3.4	Principal rotations .....	<a href="#">136</a>
6.4.3.5	Equivalence of rotation and change of basis operators .....	<a href="#">136</a>
6.4.4	Rotation and orientation .....	<a href="#">137</a>
6.5	Operator summary .....	<a href="#">137</a>
6.6	Representing rotations .....	<a href="#">139</a>
6.6.1	Overview .....	<a href="#">139</a>
6.6.2	Axis-angle .....	<a href="#">139</a>
6.6.3	Matrix .....	<a href="#">139</a>
6.6.4	Euler angles .....	<a href="#">140</a>
6.6.4.1	Principal rotations .....	<a href="#">140</a>
6.6.4.2	Euler angle conventions .....	<a href="#">140</a>
6.6.4.3	The Euler z-x-z convention .....	<a href="#">141</a>
6.6.4.4	Tait-Bryan angles .....	<a href="#">142</a>
6.6.4.5	Gimbal lock .....	<a href="#">143</a>
6.6.5	Quaternions .....	<a href="#">144</a>
6.6.5.1	Quaternion notations and conventions .....	<a href="#">144</a>
6.6.5.2	Quaternion algebra .....	<a href="#">145</a>
6.6.5.3	Quaternion operators on 3D Euclidean space .....	<a href="#">145</a>
6.6.6	Representation summary .....	<a href="#">146</a>
6.7	Rotation representation conversions .....	<a href="#">147</a>
6.7.1	Overview .....	<a href="#">147</a>
6.7.2	From axis-angle to matrix .....	<a href="#">147</a>
6.7.3	From matrix to axis-angle .....	<a href="#">147</a>
6.7.4	From Euler angle z-x-z convention to matrix .....	<a href="#">147</a>
6.7.5	From matrix to Euler angle z-x-z convention .....	<a href="#">148</a>
6.7.6	From Tait-Bryan angle x-y-z convention to matrix .....	<a href="#">149</a>
6.7.7	From matrix to Tait-Bryan angle x-y-z convention .....	<a href="#">149</a>
6.7.8	From Tait-Bryan angle z-y-x convention to matrix .....	<a href="#">150</a>
6.7.9	From matrix to Tait-Bryan angle z-y-x convention .....	<a href="#">150</a>
6.7.10	From axis-angle to quaternion .....	<a href="#">151</a>
6.7.11	From quaternion to axis-angle .....	<a href="#">151</a>
6.7.12	From quaternion to matrix .....	<a href="#">152</a>
6.7.13	From matrix to quaternion .....	<a href="#">152</a>

6.7.14	From Euler angle z-x-z convention to quaternion .....	<a href="#">152</a>
6.7.15	From quaternion to Euler angle z-x-z convention .....	<a href="#">153</a>
6.7.16	From Tait-Bryan angle x-y-z convention to quaternion .....	<a href="#">153</a>
6.7.17	From quaternion to Tait-Bryan angle x-y-z convention .....	<a href="#">153</a>
6.7.18	From Tait-Bryan angle z-y-x convention to quaternion .....	<a href="#">154</a>
6.7.19	From quaternion to Tait-Bryan angle z-y-x convention .....	<a href="#">154</a>
7	Reference datums, embeddings, and object reference models .....	<a href="#">155</a>
7.1	Overview .....	<a href="#">155</a>
7.2	Reference datums .....	<a href="#">155</a>
7.2.1	Overview .....	<a href="#">155</a>
7.2.2	Reference datum categories .....	<a href="#">155</a>
7.2.3	Ellipsoidal RDs .....	<a href="#">157</a>
7.2.4	RDs associated with physical objects .....	<a href="#">159</a>
7.2.5	RD binding .....	<a href="#">160</a>
7.3	Normal embeddings and similarity transformations .....	<a href="#">162</a>
7.3.1	Normal embeddings .....	<a href="#">162</a>
7.3.2	Similarity transformations .....	<a href="#">162</a>
7.3.3	Similarity transformation templates .....	<a href="#">165</a>
7.3.3.1	Identity transformation 3D .....	<a href="#">167</a>
7.3.3.2	Identity transformation 2D .....	<a href="#">167</a>
7.3.3.3	Translation transformation 3D .....	<a href="#">168</a>
7.3.3.4	Translation transformation 2D .....	<a href="#">168</a>
7.3.3.5	Simplified Helmert transformation (PVR convention) .....	<a href="#">169</a>
7.3.3.6	Simplified Helmert transformation (CFR convention) .....	<a href="#">170</a>
7.3.3.7	Molodensky-Badekas transformation (CFR convention) .....	<a href="#">171</a>
7.3.3.8	General rotate-scale-translate transformation 3D .....	<a href="#">172</a>
7.3.3.9	General rotate-scale-translate transformation 2D .....	<a href="#">173</a>
7.3.3.10	Homogeneous matrix 4x4 transformation 3D .....	<a href="#">174</a>
7.3.3.11	Homogeneous matrix 3x3 transformation 2D .....	<a href="#">174</a>
7.3.3.12	Generalized Helmert transformation (PVR convention) .....	<a href="#">175</a>
7.3.3.13	Generalized Helmert transformation (CFR convention) .....	<a href="#">176</a>
7.3.3.14	Tait-Bryan z-y-x rotate-translate transformation .....	<a href="#">177</a>
7.3.3.15	Non-Greenwich prime meridian z rotate-translate transformation .....	<a href="#">178</a>
7.3.3.16	Geomagnetic z-y rotate transformation .....	<a href="#">179</a>
7.4	Object reference model .....	<a href="#">180</a>
7.4.1	Overview .....	<a href="#">180</a>
7.4.2	Definition .....	<a href="#">180</a>
7.4.3	Binding constraint .....	<a href="#">182</a>
7.4.4	ORM template .....	<a href="#">182</a>
7.4.5	Standardized ORMs .....	<a href="#">191</a>
7.4.6	Reference ORMs and reference transformations .....	<a href="#">191</a>
7.4.7	ORM specifications .....	<a href="#">192</a>
7.5	Object binding rules for ORMT BI_AXIS_ORIGIN_3D realisations .....	<a href="#">194</a>
7.5.1	Object binding rule set .....	<a href="#">194</a>
7.5.2	Equatorial inertial .....	<a href="#">196</a>
7.5.3	Solar ecliptic .....	<a href="#">198</a>
7.5.4	Solar equatorial .....	<a href="#">200</a>
7.5.5	Heliocentric Aries ecliptic .....	<a href="#">201</a>
7.5.6	Heliocentric planet ecliptic .....	<a href="#">202</a>
7.5.7	Heliocentric planet equatorial .....	<a href="#">203</a>
7.5.8	Celestiomagnetic .....	<a href="#">204</a>
7.5.9	Solar magnetic ecliptic .....	<a href="#">205</a>
7.5.10	Solar magnetic dipole .....	<a href="#">207</a>
8	Spatial reference frames .....	<a href="#">209</a>
8.1	Overview .....	<a href="#">209</a>
8.2	Spatial reference frame structure .....	<a href="#">209</a>

8.3	Spatial reference frame specification .....	<a href="#">210</a>
8.3.1	SRF definition .....	<a href="#">210</a>
8.3.2	SRF specification elements .....	<a href="#">210</a>
8.3.2.1	ORM and CS compatibility .....	<a href="#">210</a>
8.3.2.2	CS parameter binding .....	<a href="#">211</a>
8.3.2.3	Coordinate-component names .....	<a href="#">211</a>
8.3.2.4	Applicable region .....	<a href="#">211</a>
8.4	SRF relationships .....	<a href="#">213</a>
8.4.1	Overview .....	<a href="#">213</a>
8.4.2	Application-based SRF relationships .....	<a href="#">213</a>
8.4.3	Induced surface SRFs .....	<a href="#">215</a>
8.4.4	Lococentric SRFs .....	<a href="#">216</a>
8.4.5	SRFs for vector specification .....	<a href="#">218</a>
8.5	SRF templates .....	<a href="#">219</a>
8.5.1	Overview .....	<a href="#">219</a>
8.5.2	Celestiocentric SRFT .....	<a href="#">222</a>
8.5.3	Local space rectangular 3D SRFT .....	<a href="#">223</a>
8.5.4	Celestiodetic SRFT .....	<a href="#">224</a>
8.5.5	Planetodetic SRFT .....	<a href="#">225</a>
8.5.6	Local tangent space Euclidean SRFT .....	<a href="#">226</a>
8.5.7	Local tangent space azimuthal spherical SRFT .....	<a href="#">228</a>
8.5.8	Local tangent space cylindrical SRFT .....	<a href="#">231</a>
8.5.9	Lococentric Euclidean 3D SRFT .....	<a href="#">233</a>
8.5.10	Celestiomagnetic SRFT .....	<a href="#">234</a>
8.5.11	Equatorial inertial SRFT .....	<a href="#">235</a>
8.5.12	Solar ecliptic SRFT .....	<a href="#">235</a>
8.5.13	Solar equatorial SRFT .....	<a href="#">236</a>
8.5.14	Solar magnetic ecliptic SRFT .....	<a href="#">236</a>
8.5.15	Solar magnetic dipole SRFT .....	<a href="#">237</a>
8.5.16	Heliospheric Aries ecliptic SRFT .....	<a href="#">238</a>
8.5.17	Heliospheric Earth ecliptic SRFT .....	<a href="#">238</a>
8.5.18	Heliospheric Earth equatorial SRFT .....	<a href="#">239</a>
8.5.19	Mercator SRFT .....	<a href="#">239</a>
8.5.20	Oblique Mercator spherical SRFT .....	<a href="#">240</a>
8.5.21	Transverse Mercator SRFT .....	<a href="#">241</a>
8.5.22	Lambert conformal conic SRFT .....	<a href="#">242</a>
8.5.23	Polar stereographic SRFT .....	<a href="#">243</a>
8.5.24	Equidistant cylindrical SRFT .....	<a href="#">244</a>
8.5.25	Local space rectangular 2D SRFT .....	<a href="#">245</a>
8.5.26	Local space azimuthal 2D SRFT .....	<a href="#">246</a>
8.5.27	Local space polar 2D SRFT .....	<a href="#">246</a>
8.6	Standardized SRFs .....	<a href="#">247</a>
8.6.1	Overview .....	<a href="#">247</a>
8.6.2	British national grid .....	<a href="#">248</a>
8.6.3	UK ordnance survey GRS80 grid .....	<a href="#">249</a>
8.6.4	Delaware (US) state plane coordinate system .....	<a href="#">249</a>
8.6.5	Geocentric WGS 1984 .....	<a href="#">250</a>
8.6.6	Geodetic Australia 1984 .....	<a href="#">250</a>
8.6.7	Geodetic WGS 1984 .....	<a href="#">250</a>
8.6.8	Geodetic North American 1983 .....	<a href="#">251</a>
8.6.9	Irish Grid .....	<a href="#">251</a>
8.6.10	Irish transverse Mercator .....	<a href="#">251</a>
8.6.11	Lambert-93 .....	<a href="#">252</a>
8.6.12	Lambert II étendu (Lambert II wide) .....	<a href="#">252</a>
8.6.13	Mars planetocentric .....	<a href="#">253</a>
8.6.14	Mars planetographic .....	<a href="#">253</a>
8.6.15	Maryland (US) state plane coordinate system .....	<a href="#">254</a>
8.7	Standardized SRF sets .....	<a href="#">254</a>

8.7.1	Overview.....	<a href="#">254</a>
8.7.2	Alabama (US) state plane coordinate system.....	<a href="#">256</a>
8.7.3	GTRS global coordinate system (GCS).....	<a href="#">257</a>
8.7.4	Japan plane coordinate system.....	<a href="#">259</a>
8.7.5	Lambert NTF.....	<a href="#">264</a>
8.7.6	Universal polar stereographic.....	<a href="#">266</a>
8.7.7	Universal transverse Mercator.....	<a href="#">267</a>
8.7.8	Wisconsin (US) state plane coordinate system.....	<a href="#">269</a>
9	Designated spatial surfaces and vertical offsets.....	<a href="#">271</a>
9.1	Overview.....	<a href="#">271</a>
9.2	Designated spatial surface.....	<a href="#">271</a>
9.3	Vertical offset surface.....	<a href="#">272</a>
9.4	Geoidal separation.....	<a href="#">273</a>
9.5	Vertical offset height and elevation.....	<a href="#">273</a>
9.6	Use of vertical offset height in spatial referencing.....	<a href="#">274</a>
9.7	Other vertical measurements.....	<a href="#">274</a>
9.8	Standardized DSS specifications.....	<a href="#">275</a>
10	Operations.....	<a href="#">279</a>
10.1	Overview.....	<a href="#">279</a>
10.2	Symbols and terminology.....	<a href="#">279</a>
10.3	ORM operations.....	<a href="#">280</a>
10.3.1	Overview.....	<a href="#">280</a>
10.3.2	Relating different ORMs for the same object.....	<a href="#">280</a>
10.3.3	Relating ORMs for different objects.....	<a href="#">282</a>
10.4	Position operations.....	<a href="#">283</a>
10.4.1	Overview.....	<a href="#">283</a>
10.4.2	General case.....	<a href="#">284</a>
10.4.3	Matched normal embeddings.....	<a href="#">285</a>
10.4.4	Matched normal embeddings and map projection SRFs.....	<a href="#">286</a>
10.4.5	SRFs with Cartesian coordinate systems.....	<a href="#">287</a>
10.4.6	Instantiating abstract object-space SRFs.....	<a href="#">289</a>
10.5	Vector operations.....	<a href="#">292</a>
10.5.1	Overview.....	<a href="#">292</a>
10.5.2	Converting vectors between different vector reference frames.....	<a href="#">293</a>
10.5.3	Instantiating abstract object-space vectors.....	<a href="#">294</a>
10.6	Euclidean distance operation.....	<a href="#">295</a>
10.7	Geodesic operations.....	<a href="#">295</a>
10.7.1	Overview.....	<a href="#">295</a>
10.7.2	Auxiliary functions.....	<a href="#">297</a>
10.7.3	The direct problem.....	<a href="#">298</a>
10.7.4	The indirect problem.....	<a href="#">299</a>
11	Application program interface.....	<a href="#">301</a>
11.1	Overview.....	<a href="#">301</a>
11.2	Data types.....	<a href="#">301</a>
11.2.1	Overview.....	<a href="#">301</a>
11.2.2	SRFT abbreviated forms.....	<a href="#">301</a>
11.2.3	Numbers.....	<a href="#">303</a>
11.2.4	Logicals.....	<a href="#">303</a>
11.2.5	Object_Reference.....	<a href="#">303</a>
11.2.6	Enumerated data types.....	<a href="#">303</a>
11.2.6.1	Overview.....	<a href="#">303</a>
11.2.6.2	Axis_Direction_2D.....	<a href="#">304</a>
11.2.6.3	Axis_Direction_3D.....	<a href="#">304</a>
11.2.6.4	Interval_Type.....	<a href="#">305</a>
11.2.6.5	Polar_Aspect.....	<a href="#">305</a>

11.2.6.6	SRF_Region_Status .....	<a href="#">305</a>
11.2.6.7	SRF_Region_Type .....	<a href="#">306</a>
11.2.7	Selection data types .....	<a href="#">306</a>
11.2.7.1	Overview .....	<a href="#">306</a>
11.2.7.2	CS_Code .....	<a href="#">306</a>
11.2.7.3	DSS_Code .....	<a href="#">306</a>
11.2.7.4	ORM_Code .....	<a href="#">307</a>
11.2.7.5	ORMT_Code .....	<a href="#">307</a>
11.2.7.6	Profile_Code .....	<a href="#">307</a>
11.2.7.7	RT_Code .....	<a href="#">307</a>
11.2.7.8	SRF_Code .....	<a href="#">307</a>
11.2.7.9	SRFS_Code .....	<a href="#">307</a>
11.2.7.10	SRFS member types .....	<a href="#">307</a>
11.2.7.11	SRFT_Code .....	<a href="#">308</a>
11.2.7.12	Status_Code .....	<a href="#">308</a>
11.2.7.13	STT_Code .....	<a href="#">311</a>
11.2.8	Array data types .....	<a href="#">311</a>
11.2.8.1	Overview .....	<a href="#">311</a>
11.2.8.2	Coordinate2D_Array .....	<a href="#">311</a>
11.2.8.3	Coordinate3D_Array .....	<a href="#">311</a>
11.2.8.4	Direction_Array .....	<a href="#">312</a>
11.2.8.5	DSS_Code_Array .....	<a href="#">312</a>
11.2.8.6	Matrix_2x2 .....	<a href="#">312</a>
11.2.8.7	Matrix_3x3 .....	<a href="#">312</a>
11.2.8.8	Matrix_4x4 .....	<a href="#">312</a>
11.2.8.9	ORM_Code_Array .....	<a href="#">312</a>
11.2.8.10	Profile_Code_Array .....	<a href="#">313</a>
11.2.8.11	RT_Code_Array .....	<a href="#">313</a>
11.2.8.12	SRF_Code_Array .....	<a href="#">313</a>
11.2.8.13	SRF_Region_Status_Array .....	<a href="#">313</a>
11.2.8.14	SRFS_Code_Array .....	<a href="#">313</a>
11.2.8.15	SRFT_Code_Array .....	<a href="#">313</a>
11.2.8.16	VectorQuantity3D_Array .....	<a href="#">314</a>
11.2.8.17	Vector_3D .....	<a href="#">314</a>
11.2.9	Record data types .....	<a href="#">314</a>
11.2.9.1	Overview .....	<a href="#">314</a>
11.2.9.2	Interval .....	<a href="#">315</a>
11.2.9.3	ORM_Transformation_Parameters .....	<a href="#">316</a>
11.2.9.4	Rotation and Orientation representation parameters .....	<a href="#">316</a>
11.2.9.5	SRFT parameter record data types .....	<a href="#">317</a>
11.2.9.6	STT parameter record data types .....	<a href="#">321</a>
11.3	Object classes .....	<a href="#">324</a>
11.3.1	Overview .....	<a href="#">324</a>
11.3.2	Class specification format .....	<a href="#">326</a>
11.3.3	LifeCycleObject .....	<a href="#">327</a>
11.3.4	Coordinate and vector classes .....	<a href="#">328</a>
11.3.4.1	Overview .....	<a href="#">328</a>
11.3.4.2	Coordinate2D .....	<a href="#">329</a>
11.3.4.3	Coordinate3D .....	<a href="#">329</a>
11.3.4.4	Direction .....	<a href="#">329</a>
11.3.4.5	SurfaceCoordinate .....	<a href="#">329</a>
11.3.4.6	VectorQuantity3D .....	<a href="#">330</a>
11.3.5	Abstract classes .....	<a href="#">330</a>
11.3.5.1	BaseSRF .....	<a href="#">330</a>
11.3.5.2	BaseSRF2D .....	<a href="#">332</a>
11.3.5.3	BaseSRF3D .....	<a href="#">336</a>
11.3.5.4	BaseSRFMapProjection .....	<a href="#">354</a>
11.3.5.5	BaseSRFwithEllipsoidalHeight .....	<a href="#">357</a>

11.3.5.6	BaseSRFwithTangentPlaneSurface.....	361
11.3.6	SRF concrete subclasses of BaseSRF2D .....	364
11.3.6.1	Overview.....	364
11.3.6.2	LocalSpaceAzimuthal.....	364
11.3.6.3	LocalSpacePolar .....	365
11.3.6.4	LocalSpaceRectangular2D.....	366
11.3.7	SRF concrete subclasses of BaseSRF3D .....	367
11.3.7.1	Overview.....	367
11.3.7.2	Celestiocentric.....	367
11.3.7.3	Celestiomagnetic.....	368
11.3.7.4	EquatorialInertial .....	369
11.3.7.5	HeliosphericAriesEcliptic.....	370
11.3.7.6	HeliosphericEarthEcliptic.....	371
11.3.7.7	HeliosphericEarthEquatorial.....	372
11.3.7.8	LocalSpaceRectangular3D.....	373
11.3.7.9	LococentricEuclidean3D.....	374
11.3.7.10	SolarEcliptic.....	375
11.3.7.11	SolarEquatorial.....	376
11.3.7.12	SolarMagneticDipole.....	377
11.3.7.13	SolarMagneticEcliptic.....	378
11.3.8	SRF concrete subclasses of BaseSRFMapProjection.....	379
11.3.8.1	Overview.....	379
11.3.8.2	EquidistantCylindrical.....	379
11.3.8.3	LambertConformalConic .....	381
11.3.8.4	Mercator .....	382
11.3.8.5	ObliqueMercatorSpherical.....	383
11.3.8.6	PolarStereographic.....	385
11.3.8.7	TransverseMercator .....	386
11.3.9	SRF concrete subclasses of BaseSRFwithEllipsoidalHeight.....	387
11.3.9.1	Overview.....	387
11.3.9.2	Celestiodetic.....	387
11.3.9.3	Planetodetic.....	389
11.3.10	SRF concrete subclasses of BaseSRFwithTangentPlaneSurface.....	390
11.3.10.1	Overview.....	390
11.3.10.2	LocalTangentSpaceAzimuthalSpherical .....	390
11.3.10.3	LocalTangentSpaceCylindrical.....	391
11.3.10.4	LocalTangentSpaceEuclidean .....	392
11.3.11	Rotation and Orientation classes .....	394
11.3.11.1	Overview.....	394
11.3.11.2	Rotation .....	394
11.3.11.3	Orientation.....	398
11.4	Functions.....	402
11.4.1	Function to create instances of standardized SRFs .....	402
11.4.2	Function to create instances of standardized SRF set members .....	403
11.4.3	Implementation support query functions .....	403
11.5	Data storage structures .....	408
11.5.1	Overview.....	408
11.5.2	Selection data types .....	408
11.5.2.1	OBRS_Code.....	408
11.5.2.2	RD_Code.....	408
11.5.2.3	Spatial_Coordinate_Code .....	409
11.5.2.4	SRF_Parameters_Info_Code.....	409
11.5.3	Record data types .....	410
11.5.3.1	Coordinate structures .....	410
11.5.3.2	Coordinate.....	413
11.5.3.3	SRF_Parameters_Info.....	414
11.5.3.4	SRF_Reference_Surface_Info.....	414
11.5.3.5	SRFS_Info.....	415

11.5.3.6	SRFT_Parameters .....	<a href="#">415</a>
12	Profiles .....	<a href="#">417</a>
12.1	Overview .....	<a href="#">417</a>
12.2	Profile specification .....	<a href="#">417</a>
12.3	Default profile .....	<a href="#">419</a>
13	Registration .....	<a href="#">423</a>
13.1	Overview .....	<a href="#">423</a>
13.2	Specification elements for SRM registered items .....	<a href="#">423</a>
13.2.1	Overview .....	<a href="#">423</a>
13.2.2	Label .....	<a href="#">423</a>
13.2.3	Code .....	<a href="#">425</a>
13.2.4	Description .....	<a href="#">425</a>
13.2.5	References .....	<a href="#">426</a>
13.2.5.1	Overview .....	<a href="#">426</a>
13.2.5.2	Citation format .....	<a href="#">426</a>
13.3	Guidelines for specific SRM concepts .....	<a href="#">426</a>
13.3.1	Guidelines for registration of abstract CSs .....	<a href="#">426</a>
13.3.2	Guideline for registration of temporal CSs .....	<a href="#">427</a>
13.3.3	Guidelines for registration of RDs .....	<a href="#">427</a>
13.3.4	Guidelines for registration of STTs .....	<a href="#">428</a>
13.3.5	Guidelines for registration of ORMTs .....	<a href="#">429</a>
13.3.6	Guidelines for registration of ORMs .....	<a href="#">429</a>
13.3.7	Guidelines for registration of RTs .....	<a href="#">430</a>
13.3.8	Guidelines for registration of OBRs .....	<a href="#">430</a>
13.3.9	Guidelines for registration of SRFTs .....	<a href="#">430</a>
13.3.10	Guidelines for registration of SRFs .....	<a href="#">432</a>
13.3.11	Guidelines for registration of SRF sets and their members .....	<a href="#">432</a>
13.3.12	Guidelines for registration of DSSs .....	<a href="#">434</a>
13.3.13	Guidelines for registration of profiles .....	<a href="#">434</a>
14	Conformance .....	<a href="#">437</a>
14.1	Overview .....	<a href="#">437</a>
14.2	Functional implementation conformance .....	<a href="#">437</a>
14.2.1	Functional accuracy .....	<a href="#">437</a>
14.2.2	Functional conformance .....	<a href="#">438</a>
14.3	Conformance of exchange formats .....	<a href="#">439</a>
14.4	Conformance of language bindings of the SRM API .....	<a href="#">439</a>
14.5	Conformance of applications that use the SRM API .....	<a href="#">439</a>
14.6	Conformance of specifications that reference this document .....	<a href="#">440</a>
Annex A	Mathematical foundations (normative) .....	<a href="#">441</a>
A.1	Overview .....	<a href="#">441</a>
A.2	$\mathbb{R}^n$ as a real vector space .....	<a href="#">441</a>
A.3	The point set topology of $\mathbb{R}^n$ .....	<a href="#">442</a>
A.4	Smooth functions on $\mathbb{R}^n$ .....	<a href="#">442</a>
A.5	Functional composition .....	<a href="#">443</a>
A.6	Smooth surfaces in $\mathbb{R}^3$ .....	<a href="#">443</a>
A.6.1	Implicit definition .....	<a href="#">443</a>
A.6.2	Ellipsoid surfaces .....	<a href="#">444</a>
A.7	Smooth curves in $\mathbb{R}^n$ .....	<a href="#">445</a>
A.7.1	Parametric definition .....	<a href="#">445</a>
A.7.1.1	Smooth curve .....	<a href="#">445</a>
A.7.1.2	Tangent to a smooth curve .....	<a href="#">445</a>
A.7.1.3	Angle between curves .....	<a href="#">446</a>
A.7.1.4	Closed curve .....	<a href="#">446</a>
A.7.1.5	Surface curves, connected and orientable surfaces .....	<a href="#">446</a>

A.7.2	Implicit definition .....	<a href="#">447</a>
A.7.3	Arc length .....	<a href="#">448</a>
A.7.4	Geodesics on an ellipsoid .....	<a href="#">448</a>
A.8	Special functions .....	<a href="#">448</a>
A.8.1	Double argument arctangent function .....	<a href="#">448</a>
A.8.2	Jacobian elliptic functions .....	<a href="#">449</a>
A.9	Projection function .....	<a href="#">449</a>
A.9.1	Geometric projection functions into a developable surface .....	<a href="#">449</a>
A.9.2	Planar projection functions .....	<a href="#">449</a>
A.9.2.1	Orthographic projection function .....	<a href="#">449</a>
A.9.2.2	Perspective projection function .....	<a href="#">450</a>
A.9.2.3	Stereographic projection function .....	<a href="#">451</a>
A.9.3	Cylindrical projection function .....	<a href="#">451</a>
A.9.4	Conic projection function .....	<a href="#">452</a>
A.10	Quaternion algebra .....	<a href="#">452</a>
A.11	Body-fixed rotations in terms of space-fixed axes .....	<a href="#">453</a>
A.12	Rotation and change of basis equivalence .....	<a href="#">455</a>
Annex B	Implementation guidelines (informative) .....	<a href="#">459</a>
B.1	Overview .....	<a href="#">459</a>
B.2	Error types considered in this document .....	<a href="#">459</a>
B.2.1	Measurement and modelling error .....	<a href="#">459</a>
B.2.2	Implementation error .....	<a href="#">460</a>
B.2.3	Finite precision .....	<a href="#">460</a>
B.2.4	Approximation error .....	<a href="#">460</a>
B.3	General observations on implementations .....	<a href="#">461</a>
B.4	Guidelines for algorithm development for spatial operations .....	<a href="#">461</a>
B.4.1	Overview .....	<a href="#">461</a>
B.4.2	The computational environment .....	<a href="#">461</a>
B.4.3	Domain of application .....	<a href="#">462</a>
B.4.4	Define a meaningful error measure .....	<a href="#">463</a>
B.4.5	Avoid excessive computational accuracy .....	<a href="#">463</a>
B.4.6	Determine the acceptable error before starting .....	<a href="#">463</a>
B.4.7	Mathematical approaches .....	<a href="#">463</a>
B.4.8	Good programming and formulation practices .....	<a href="#">464</a>
B.4.9	Design in context .....	<a href="#">465</a>
B.4.10	Software verification and computational error testing .....	<a href="#">465</a>
B.4.11	Singularities and near singularities .....	<a href="#">466</a>
B.4.12	Performance testing .....	<a href="#">466</a>
B.5	Practical considerations .....	<a href="#">467</a>
B.5.1	Distortion considerations .....	<a href="#">467</a>
B.5.2	Validity checking .....	<a href="#">467</a>
B.5.3	Spherical ORMs .....	<a href="#">467</a>
Annex C	Hierarchical diagrams for SRM concepts (informative) .....	<a href="#">469</a>
C.1	Overview .....	<a href="#">469</a>
C.2	SRM concepts .....	<a href="#">469</a>
C.3	Reference datum hierarchy .....	<a href="#">469</a>
C.4	ORM template realisation examples .....	<a href="#">470</a>
Annex D	RDs associated with physical objects (normative) .....	<a href="#">473</a>
D.1	Overview .....	<a href="#">473</a>
D.2	RDs .....	<a href="#">473</a>
Annex E	ORM specifications (normative) .....	<a href="#">489</a>
E.1	Overview .....	<a href="#">489</a>
E.2	ORMs .....	<a href="#">489</a>

E.2.1	Reference ORMs	<a href="#">489</a>
E.2.2	Standardized ORMs	<a href="#">493</a>
E.2.2.1	Abstract ORMs	<a href="#">494</a>
E.2.2.2	Object-fixed ERMs	<a href="#">495</a>
E.2.2.3	Dynamic ERMs	<a href="#">593</a>
E.2.2.4	Object-fixed planet (non-Earth) ORMs	<a href="#">602</a>
E.2.2.5	Dynamic planet (non-Earth) ORMs	<a href="#">609</a>
E.2.2.6	Object-fixed satellite ORMs	<a href="#">613</a>
E.2.2.7	Dynamic satellite ORMs	<a href="#">632</a>
E.2.2.8	Object-fixed stellar ORMs	<a href="#">632</a>
E.2.2.9	Dynamic stellar ORMs	<a href="#">633</a>
Annex F	Abbreviated forms used in the construction of labels (normative)	<a href="#">635</a>
F.1	Overview	<a href="#">635</a>
F.2	Table of abbreviated forms	<a href="#">635</a>
Annex G	Change and deprecation plan (normative)	<a href="#">637</a>
G.1	Overview	<a href="#">637</a>
G.2	Addition	<a href="#">637</a>
G.3	Change	<a href="#">637</a>
G.3.1	Overview	<a href="#">637</a>
G.3.2	Correction	<a href="#">638</a>
G.3.3	Update	<a href="#">638</a>
G.4	Deprecation	<a href="#">638</a>
G.4.1	Overview	<a href="#">638</a>
G.4.2	Deprecation of SRM standardized concept instances	<a href="#">638</a>
G.4.3	Deprecation of SRM registered items	<a href="#">639</a>
G.5	Reinstatement	<a href="#">639</a>
G.5.1	Overview	<a href="#">639</a>
G.5.2	Reinstatement of SRM standardized concept instances	<a href="#">639</a>
G.5.3	Reinstatement of SRM registered items	<a href="#">639</a>
Annex H	Templates for registration proposals (normative)	<a href="#">641</a>
H.1	Overview	<a href="#">641</a>
H.2	Proposal for the registration of a CS	<a href="#">641</a>
H.3	Proposal for the registration of a temporal CS	<a href="#">642</a>
H.4	Proposal for the registration of an RD	<a href="#">642</a>
H.5	Proposal for the registration of an STT	<a href="#">643</a>
H.6	Proposal for the registration of an ORMT	<a href="#">643</a>
H.7	Proposal for the registration of an ORM	<a href="#">644</a>
H.8	Proposal for the registration of a reference transformation	<a href="#">644</a>
H.9	Proposal for the registration of an OBRS	<a href="#">645</a>
H.10	Proposal for the registration of an SRFT	<a href="#">645</a>
H.11	Proposal for the registration of an SRF	<a href="#">646</a>
H.12	Proposal for the registration of an SRF set and its members	<a href="#">646</a>
H.13	Proposal for the registration of a DSS	<a href="#">647</a>
H.14	Proposal for the registration of a profile	<a href="#">647</a>
H.15	Proposal for the registration of a reference	<a href="#">648</a>
Annex I	Conformance testing for SRF operations (informative)	<a href="#">649</a>
I.1	Overview	<a href="#">649</a>
I.2	Computational error	<a href="#">649</a>
I.3	SRF operations baseline	<a href="#">649</a>
I.4	Implementations	<a href="#">649</a>
I.5	Fundamental measure of conformance	<a href="#">650</a>
I.6	Error metrics for SRF operations	<a href="#">650</a>
I.7	Computational error evaluated over test data sets	<a href="#">652</a>
I.8	Level of conformance	<a href="#">652</a>

Annex J	Deprecated SRM concept instances (normative).....	<a href="#">655</a>
J.1	Overview.....	<a href="#">655</a>
J.2	Deprecated RDs .....	<a href="#">655</a>
J.3	Deprecated ORMs.....	<a href="#">661</a>
J.4	Deprecated DSSs.....	<a href="#">689</a>
	Bibliography.....	<a href="#">691</a>
	Index.....	<a href="#">697</a>

<b>Tables</b>	<b>Page</b>
Table 3.1 — Mathematical notation .....	<a href="#">6</a>
Table 3.2 — Symbols .....	<a href="#">6</a>
Table 3.3 — Abbreviated terms .....	<a href="#">9</a>
Table 4.1 — Coordinate system types .....	<a href="#">18</a>
Table 5.1 — Coordinate system types .....	<a href="#">38</a>
Table 5.2 — Localization operators .....	<a href="#">45</a>
Table 5.3 — Localization inverse operators .....	<a href="#">45</a>
Table 5.4 — Localized CS type relationships .....	<a href="#">46</a>
Table 5.5 — Coordinate system specification elements .....	<a href="#">61</a>
Table 5.6 — Common parameters and functions of an oblate ellipsoid .....	<a href="#">62</a>
Table 5.7 — CS specification directory .....	<a href="#">63</a>
Table 5.8 — Euclidean 3D CS .....	<a href="#">64</a>
Table 5.9 — Lococentric Euclidean 3D CS .....	<a href="#">65</a>
Table 5.10 — Equatorial Spherical CS .....	<a href="#">67</a>
Table 5.11 — Lococentric Equatorial Spherical CS .....	<a href="#">68</a>
Table 5.12 — Azimuthal Spherical CS .....	<a href="#">70</a>
Table 5.13 — Lococentric Azimuthal Spherical CS .....	<a href="#">72</a>
Table 5.14 — Geodetic 3D CS .....	<a href="#">73</a>
Table 5.15 — Planetodetic 3D CS .....	<a href="#">76</a>
Table 5.16 — Cylindrical CS .....	<a href="#">77</a>
Table 5.17 — Lococentric Cylindrical CS .....	<a href="#">79</a>
Table 5.18 — Mercator CS .....	<a href="#">80</a>
Table 5.19 — Oblique Mercator Spherical CS .....	<a href="#">82</a>
Table 5.20 — Transverse Mercator CS .....	<a href="#">85</a>
Table 5.21 — Lambert Conformal Conic CS .....	<a href="#">89</a>
Table 5.22 — Polar Stereographic CS .....	<a href="#">91</a>
Table 5.23 — Equidistant Cylindrical CS .....	<a href="#">93</a>
Table 5.24 — Surface Geodetic CS .....	<a href="#">95</a>
Table 5.25 — Surface Planetodetic CS .....	<a href="#">96</a>
Table 5.26 — Lococentric Surface Euclidean CS .....	<a href="#">98</a>
Table 5.27 — Lococentric Surface Azimuthal CS .....	<a href="#">100</a>
Table 5.28 — Lococentric Surface Polar CS .....	<a href="#">101</a>
Table 5.29 — Euclidean 2D CS .....	<a href="#">103</a>
Table 5.30 — Lococentric Euclidean 2D CS .....	<a href="#">104</a>
Table 5.31 — Azimuthal CS .....	<a href="#">106</a>
Table 5.32 — Lococentric Azimuthal CS .....	<a href="#">107</a>
Table 5.33 — Polar CS .....	<a href="#">109</a>
Table 5.34 — Lococentric Polar CS .....	<a href="#">110</a>
Table 5.35 — Euclidean 1D CS .....	<a href="#">112</a>
Table 5.36 — Azimuthal Cylindrical CS .....	<a href="#">113</a>
Table 5.37 — Lococentric Azimuthal Cylindrical CS .....	<a href="#">114</a>
Table 5.38 — Temporal coordinate system specification elements .....	<a href="#">119</a>
Table 5.39 — Temporal coordinate system specifications .....	<a href="#">120</a>
Table 6.1 — Principal rotation matrices .....	<a href="#">136</a>
Table 6.2 — Rotation and change-of-basis operators .....	<a href="#">137</a>
Table 6.3 — Summary of representation attributes .....	<a href="#">146</a>
Table 6.4 — Principal rotation factors for the Euler angle z-x-z convention .....	<a href="#">148</a>
Table 6.5 — Equivalence of z-x-z principal rotation factor sequences .....	<a href="#">149</a>
Table 6.6 — Principal rotation factors for the Tait-Bryan angle x-y-z convention .....	<a href="#">149</a>
Table 6.7 — Principal rotation factors for the Tait-Bryan angle z-y-x convention .....	<a href="#">150</a>
Table 6.8 — Equivalence of x-y-z or z-y-x principal rotation factor sequences .....	<a href="#">151</a>

Table 7.1 — RD categories.....	<a href="#">156</a>
Table 7.2 — RD specification elements.....	<a href="#">156</a>
Table 7.3 — RD specification directory .....	<a href="#">156</a>
Table 7.4 — 2D RDs of category point.....	<a href="#">157</a>
Table 7.5 — 3D RDs of category point.....	<a href="#">157</a>
Table 7.6 — 2D RDs of category directed curve .....	<a href="#">157</a>
Table 7.7 — 3D RDs of category directed curve .....	<a href="#">157</a>
Table 7.8 — 3D RDs of category oriented surface.....	<a href="#">157</a>
Table 7.9 — Physical object RD specification elements .....	<a href="#">159</a>
Table 7.10 — Physical RD specification table locations.....	<a href="#">160</a>
Table 7.11 — STT specification elements.....	<a href="#">166</a>
Table 7.12 — Similarity transformation template directory.....	<a href="#">166</a>
Table 7.13 — Identity 3D STT .....	<a href="#">167</a>
Table 7.14 — Identity 2D STT .....	<a href="#">167</a>
Table 7.15 — Translation 3D STT.....	<a href="#">168</a>
Table 7.16 — Translation 2D STT.....	<a href="#">168</a>
Table 7.17 — Simplified Helmert STT (PVR convention).....	<a href="#">169</a>
Table 7.18 — Simplified Helmert STT (CFR convention).....	<a href="#">170</a>
Table 7.19 — Molodensky-Badekas STT (CFR convention).....	<a href="#">171</a>
Table 7.20 — General rotate-scale-translate 3D STT .....	<a href="#">172</a>
Table 7.21 — General rotate-scale-translate 2D STT .....	<a href="#">173</a>
Table 7.22 — Homogeneous matrix 4x4 3D STT.....	<a href="#">174</a>
Table 7.23 — Homogeneous matrix 3x3 2D STT.....	<a href="#">174</a>
Table 7.24 — Generalized Helmert STT (PVR convention).....	<a href="#">175</a>
Table 7.25 — Generalized Helmert STT (CFR convention).....	<a href="#">176</a>
Table 7.26 — Tait-Bryan z-y-x rotate-translate STT.....	<a href="#">177</a>
Table 7.27 — Non-Greenwich prime meridian z rotate-translate STT .....	<a href="#">178</a>
Table 7.28 — Geomagnetic z-y rotate STT .....	<a href="#">179</a>
Table 7.29 — ORMT specification elements .....	<a href="#">183</a>
Table 7.30 — ORMT specification directory.....	<a href="#">183</a>
Table 7.31 — 2D ORMT specifications .....	<a href="#">184</a>
Table 7.32 — 3D ORMT specifications .....	<a href="#">185</a>
Table 7.33 — ORM specification elements .....	<a href="#">192</a>
Table 7.34 — Reference transformation specification elements.....	<a href="#">193</a>
Table 7.35 — OBRS for ORMT BI_AXIS_ORIGIN_3D specification elements .....	<a href="#">195</a>
Table 7.36 — OBRS for ORMT BI_AXIS_ORIGIN_3D specification directory .....	<a href="#">195</a>
Table 7.37 — Equatorial inertial OBRS .....	<a href="#">196</a>
Table 7.38 — Equatorial inertial ORM directory .....	<a href="#">198</a>
Table 7.39 — Solar ecliptic OBRS.....	<a href="#">198</a>
Table 7.40 — Solar ecliptic ORM directory.....	<a href="#">199</a>
Table 7.41 — Solar equatorial OBRS.....	<a href="#">200</a>
Table 7.42 — Solar equatorial ORM directory.....	<a href="#">200</a>
Table 7.43 — Heliocentric Aries ecliptic OBRS .....	<a href="#">201</a>
Table 7.44 — Heliocentric Aries ecliptic ORM directory .....	<a href="#">202</a>
Table 7.45 — Heliocentric planet ecliptic OBRS .....	<a href="#">202</a>
Table 7.46 — Heliocentric planet ecliptic ORM directory .....	<a href="#">202</a>
Table 7.47 — Heliocentric planet equatorial OBRS .....	<a href="#">203</a>
Table 7.48 — Heliocentric planet equatorial ORM directory .....	<a href="#">203</a>
Table 7.49 — Celestiomagnetic OBRS .....	<a href="#">204</a>
Table 7.50 — Celestiomagnetic ORM directory .....	<a href="#">205</a>
Table 7.51 — Solar magnetic ecliptic OBRS .....	<a href="#">205</a>
Table 7.52 — Solar magnetic ecliptic ORM directory.....	<a href="#">206</a>
Table 7.53 — Solar magnetic dipole OBRS .....	<a href="#">207</a>
Table 7.54 — Solar magnetic dipole ORM directory .....	<a href="#">208</a>

Table 8.1 — Compatible CS types .....	210
Table 8.2 — SRFT specification elements .....	220
Table 8.3 — SRFT directory .....	221
Table 8.4 — Celestiocentric SRFT .....	222
Table 8.5 — Local space rectangular 3D SRFT .....	223
Table 8.6 — Celestiodetic SRFT .....	224
Table 8.7 — Planetodetic SRFT .....	225
Table 8.8 — Local tangent space Euclidean SRFT .....	226
Table 8.9 — Local tangent space azimuthal spherical SRFT .....	228
Table 8.10 — Local tangent space cylindrical SRFT .....	231
Table 8.11 — Lococentric Euclidean 3D SRFT .....	233
Table 8.12 — Celestiomagnetic SRFT .....	234
Table 8.13 — Equatorial inertial SRFT .....	235
Table 8.14 — Solar ecliptic SRFT .....	235
Table 8.15 — Solar equatorial SRFT .....	236
Table 8.16 — Solar magnetic ecliptic SRFT .....	236
Table 8.17 — Solar magnetic dipole SRFT .....	237
Table 8.18 — Heliospheric Aries ecliptic SRFT .....	238
Table 8.19 — Heliospheric Earth ecliptic SRFT .....	238
Table 8.20 — Heliospheric Earth equatorial SRFT .....	239
Table 8.21 — Mercator SRFT .....	239
Table 8.22 — Oblique Mercator spherical SRFT .....	240
Table 8.23 — Transverse Mercator SRFT .....	241
Table 8.24 — Lambert conformal conic SRFT .....	242
Table 8.25 — Polar stereographic SRFT .....	243
Table 8.26 — Equidistant cylindrical SRFT .....	244
Table 8.27 — Local space rectangular 2D SRFT .....	245
Table 8.28 — Local space azimuthal 2D SRFT .....	246
Table 8.29 — Local space polar 2D SRFT .....	247
Table 8.30 — Standardized SRF specification elements .....	247
Table 8.31 — Directory of standardized SRFs .....	248
Table 8.32 — British national grid SRF .....	248
Table 8.33 — UK ordnance survey GRS80 grid SRF .....	249
Table 8.34 — Delaware (US) state plane coordinate system SRF .....	249
Table 8.35 — Geocentric WGS 1984 SRF .....	250
Table 8.36 — Geodetic Australia 1984 SRF .....	250
Table 8.37 — Geodetic WGS 1984 SRF .....	250
Table 8.38 — Geodetic North American 1983 SRF .....	251
Table 8.39 — Irish Grid SRF .....	251
Table 8.40 — Irish transverse Mercator SRF .....	251
Table 8.41 — Lambert-93 SRF .....	252
Table 8.42 — Lambert II étendu (Lambert II wide) SRF .....	252
Table 8.43 — Mars planetocentric SRF .....	253
Table 8.44 — Mars planetographic SRF .....	253
Table 8.45 — Maryland (US) state plane coordinate system SRF .....	254
Table 8.46 — SRF set specification elements .....	255
Table 8.47 — SRF set member specification elements .....	255
Table 8.48 — Directory of SRF sets .....	256
Table 8.49 — Alabama (US) state plane coordinate system SRF set .....	256
Table 8.50 — SRF set membership Alabama (US) state plane coordinate system .....	256
Table 8.51 — GTRS global coordinate system (GCS) SRF set .....	257
Table 8.52 — SRF set membership GTRS global coordinate system (GCS) .....	258
Table 8.53 — GTRS natural origin and applicable region by code index .....	258
Table 8.54 — Japan plane coordinate system SRF set .....	259
Table 8.55 — SRF set membership Japan plane coordinate system .....	260
Table 8.56 — Lambert NTF SRF set .....	264
Table 8.57 — SRF set membership Lambert NTF .....	265
Table 8.58 — Universal polar stereographic (UPS) SRF set .....	266

Table 8.59 — SRF set membership Universal polar stereographic (UPS) .....	<a href="#">266</a>
Table 8.60 — Universal transverse Mercator (UTM) SRF set.....	<a href="#">267</a>
Table 8.61 — SRF set membership Universal transverse Mercator (UTM).....	<a href="#">268</a>
Table 8.62 — Wisconsin (US) state plane coordinate system SRF set .....	<a href="#">269</a>
Table 8.63 — SRF set membership Wisconsin (US) state plane coordinate.....	<a href="#">269</a>
Table 9.1 — Geoidal and equipotential DSS specification elements .....	<a href="#">276</a>
Table 9.2 — Geoidal and equipotential DSS specifications .....	<a href="#">276</a>
Table 10.1 — Symbols.....	<a href="#">279</a>
Table 11.1 — SRFT abbreviated forms .....	<a href="#">302</a>
Table 11.2 — Integer data types .....	<a href="#">303</a>
Table 11.3 — Logical data type .....	<a href="#">303</a>
Table 11.4 — Array data type notation .....	<a href="#">311</a>
Table 11.5 — Class specification elements.....	<a href="#">326</a>
Table 11.6 — LifeCycleObject .....	<a href="#">327</a>
Table 11.7 — Coordinate2D .....	<a href="#">329</a>
Table 11.8 — Coordinate3D .....	<a href="#">329</a>
Table 11.9 — Direction .....	<a href="#">329</a>
Table 11.10 — SurfaceCoordinate .....	<a href="#">329</a>
Table 11.11 — VectorQuantity3D .....	<a href="#">330</a>
Table 11.12 — BaseSRF .....	<a href="#">332</a>
Table 11.13 — BaseSRF2D .....	<a href="#">333</a>
Table 11.14 — BaseSRF3D .....	<a href="#">339</a>
Table 11.15 — BaseSRFMapProjection.....	<a href="#">355</a>
Table 11.16 — BaseSRFwithEllipsoidalHeight.....	<a href="#">358</a>
Table 11.17 — BaseSRFwithTangentPlaneSurface .....	<a href="#">362</a>
Table 11.18 — LocalSpaceAzimuthal.....	<a href="#">364</a>
Table 11.19 — LocalSpacePolar .....	<a href="#">365</a>
Table 11.20 — LocalSpaceRectangular2D .....	<a href="#">366</a>
Table 11.21 — Celestiocentric.....	<a href="#">367</a>
Table 11.22 — Celestiomagnetic.....	<a href="#">368</a>
Table 11.23 — EquatorialInertial .....	<a href="#">369</a>
Table 11.24 — HeliosphericAriesEcliptic.....	<a href="#">370</a>
Table 11.25 — HeliosphericEarthEcliptic .....	<a href="#">371</a>
Table 11.26 — HeliosphericEarthEquatorial.....	<a href="#">372</a>
Table 11.27 — LocalSpaceRectangular3D .....	<a href="#">373</a>
Table 11.28 — LococentricEuclidean3D .....	<a href="#">374</a>
Table 11.29 — SolarEcliptic .....	<a href="#">375</a>
Table 11.30 — SolarEquatorial.....	<a href="#">376</a>
Table 11.31 — SolarMagneticDipole .....	<a href="#">377</a>
Table 11.32 — SolarMagneticEcliptic.....	<a href="#">378</a>
Table 11.33 — EquidistantCylindrical.....	<a href="#">379</a>
Table 11.34 — LambertConformalConic .....	<a href="#">381</a>
Table 11.35 — Mercator .....	<a href="#">382</a>
Table 11.36 — ObliqueMercatorSpherical.....	<a href="#">383</a>
Table 11.37 — PolarStereographic .....	<a href="#">385</a>
Table 11.38 — TransverseMercator .....	<a href="#">386</a>
Table 11.39 — Celestiodetic.....	<a href="#">387</a>
Table 11.40 — Planetodetic .....	<a href="#">389</a>
Table 11.41 — LocalTangentSpaceAzimuthalSpherical .....	<a href="#">390</a>
Table 11.42 — LocalTangentSpaceCylindrical.....	<a href="#">391</a>
Table 11.43 — LocalTangentSpaceEuclidean .....	<a href="#">392</a>
Table 11.44 — Rotation .....	<a href="#">394</a>
Table 11.45 — Orientation.....	<a href="#">398</a>
Table 11.46 — CreateStandardizedSRF .....	<a href="#">402</a>
Table 11.47 — CreateStandardizedSRFSetMember .....	<a href="#">403</a>

Table 11.48 — QueryDSSSupport .....	<a href="#">404</a>
Table 11.49 — QueryDSSSupportList .....	<a href="#">404</a>
Table 11.50 — QueryRTRegionSpecification .....	<a href="#">404</a>
Table 11.51 — QueryORMSupport .....	<a href="#">405</a>
Table 11.52 — QueryORMSupportList .....	<a href="#">405</a>
Table 11.53 — QueryProfileSupport .....	<a href="#">406</a>
Table 11.54 — QueryProfileSupportList .....	<a href="#">406</a>
Table 11.55 — QueryRTSupportList .....	<a href="#">406</a>
Table 11.56 — QuerySRFSetSupport .....	<a href="#">406</a>
Table 11.57 — QuerySRFSetSupportList .....	<a href="#">407</a>
Table 11.58 — QuerySRFSupport .....	<a href="#">407</a>
Table 11.59 — QuerySRFSupportList .....	<a href="#">407</a>
Table 11.60 — QuerySRFTSupport .....	<a href="#">407</a>
Table 11.61 — QuerySRFTSupportList .....	<a href="#">408</a>
Table 11.62 — QueryVersion .....	<a href="#">408</a>
Table 12.1 — SRM profile specification elements .....	<a href="#">417</a>
Table 12.2 — Default profile specification .....	<a href="#">419</a>
Table D.1 — RD specification directory .....	<a href="#">473</a>
Table D.2 — Oblate ellipsoid RD specifications .....	<a href="#">474</a>
Table D.3 — Sphere RD specifications .....	<a href="#">479</a>
Table D.4 — Prolate ellipsoid RD specifications .....	<a href="#">483</a>
Table D.5 — Tri-axial ellipsoid RD specifications .....	<a href="#">483</a>
Table E.1 — Reference ORM directory .....	<a href="#">489</a>
Table E.2 — ORM specification directory .....	<a href="#">493</a>
Table E.3 — Abstract ORM specifications .....	<a href="#">494</a>
Table E.4 — Abstract ORM reference transformation specifications .....	<a href="#">494</a>
Table E.5 — Object-fixed ERM specifications .....	<a href="#">495</a>
Table E.6 — Object-fixed ERM reference transformation specifications .....	<a href="#">521</a>
Table E.7 — Dynamic ERM specifications .....	<a href="#">593</a>
Table E.8 — Time-fixed instances of dynamic ERM specifications .....	<a href="#">594</a>
Table E.9 — Time-fixed instances of dynamic ERM reference transformation specifications .....	<a href="#">599</a>
Table E.10 — Object-fixed planet (non-Earth) ORM specifications .....	<a href="#">602</a>
Table E.11 — Object-fixed planet (non-Earth) ORM reference transformation specifications .....	<a href="#">607</a>
Table E.12 — Dynamic planet (non-Earth) ORM specifications .....	<a href="#">609</a>
Table E.13 — Time-fixed instances of dynamic planet (non-Earth) ORM specifications .....	<a href="#">611</a>
Table E.14 — Time-fixed instances of dynamic planet (non-Earth) ORM reference transformation specifications .....	<a href="#">612</a>
Table E.15 — Object-fixed satellite ORM specifications .....	<a href="#">613</a>
Table E.16 — Object-fixed satellite ORM reference transformation specifications .....	<a href="#">625</a>
Table E.17 — Time-fixed instances of dynamic satellite ORM specifications .....	<a href="#">632</a>
Table E.18 — Time-fixed instances of dynamic satellite ORM reference transformation specifications .....	<a href="#">632</a>
Table E.19 — Object-fixed stellar ORM specifications .....	<a href="#">632</a>
Table E.20 — Object-fixed stellar ORM reference transformation specifications .....	<a href="#">632</a>
Table E.21 — Dynamic stellar ORM specifications .....	<a href="#">633</a>
Table E.22 — Time-fixed instances of dynamic stellar ORM specifications .....	<a href="#">633</a>
Table E.23 — Time-fixed instances of dynamic stellar ORM reference transformation specifications .....	<a href="#">633</a>
Table F.1 — Abbreviated forms used in labels .....	<a href="#">635</a>
Table H.1 — Common registration proposal specification elements .....	<a href="#">641</a>
Table H.2 — Coordinate system registration proposal elements .....	<a href="#">641</a>
Table H.3 — Temporal coordinate system registration proposal elements .....	<a href="#">642</a>
Table H.4 — RD registration proposal elements .....	<a href="#">642</a>
Table H.5 — Similarity transformation template registration proposal elements .....	<a href="#">643</a>
Table H.6 — ORMT registration proposal elements .....	<a href="#">643</a>

Table H.7 — ORM registration proposal elements ..... 644

Table H.8 — RT registration proposal elements ..... 644

Table H.9 — OBRS registration proposal elements ..... 645

Table H.10 — SRFT registration proposal elements ..... 645

Table H.11 — SRF registration proposal elements ..... 646

Table H.12 — SRF set registration proposal elements ..... 646

Table H.13 — SRF set member registration proposal elements ..... 647

Table H.14 — DSS registration proposal elements ..... 647

Table H.15 — Profile registration proposal elements ..... 647

Table H.16 — Reference registration proposal elements ..... 648

  

Table J.1 — Deprecated RD specification directory ..... 655

Table J.2 — Deprecated oblate ellipsoid RDs ..... 656

Table J.3 — Deprecated sphere RDs ..... 656

Table J.4 — Deprecated prolate ellipsoid RDs ..... 657

Table J.5 — Deprecated tri-axial ellipsoid RDs ..... 658

Table J.6 — Deprecated ORM specification directory ..... 661

Table J.7 — Deprecated abstract object ORMs ..... 661

Table J.8 — Deprecated object-fixed ERMs ..... 661

Table J.9 — Deprecated dynamic ERMs ..... 661

Table J.10 — Deprecated time-fixed instances of dynamic ERMs ..... 662

Table J.11 — Deprecated time-fixed instances of dynamic ERM RTs ..... 665

Table J.12 — Deprecated object-fixed planet (non-Earth) ORMs ..... 667

Table J.13 — Deprecated object-fixed planet (non-Earth) RTs ..... 669

Table J.14 — Deprecated dynamic planet (non-Earth) ORMs ..... 671

Table J.15 — Deprecated time-fixed instances of dynamic planet (non-Earth) ORMs ..... 671

Table J.16 — Deprecated object-fixed satellite ORMs ..... 672

Table J.17 — Deprecated object-fixed satellite RTs ..... 682

Table J.18 — Deprecated dynamic satellite ORMs ..... 687

Table J.19 — Deprecated time-fixed instances of dynamic satellite ORMs ..... 687

Table J.20 — Deprecated object-fixed stellar ORMs ..... 688

Table J.21 — Deprecated object-fixed stellar RTs ..... 688

Table J.22 — Deprecated dynamic stellar ORMs ..... 689

Table J.23 — Deprecated time-fixed instances of dynamic stellar ORMs ..... 689

Table J.24 — Deprecated DSSs ..... 689

<b>Figures</b>	<b>Page</b>
Figure 4.1 — Coordinate-space, position-space, and object-space relationships .....	<a href="#">14</a>
Figure 4.2 — A coordinate-space (for spherical coordinates) .....	<a href="#">15</a>
Figure 4.3 — 3D position-space and its canonical Cartesian basis .....	<a href="#">16</a>
Figure 4.4 — Object-spaces for the Earth and for a CAD model .....	<a href="#">16</a>
Figure 4.5 — Abstract equatorial spherical coordinate system example .....	<a href="#">17</a>
Figure 4.6 — A normal embedding of an abstract coordinate system .....	<a href="#">19</a>
Figure 4.7 — An ellipsoid reference datum .....	<a href="#">21</a>
Figure 4.8 — Reference datums bound to abstract and physical objects .....	<a href="#">22</a>
Figure 4.9 — A reference datum binding .....	<a href="#">23</a>
Figure 4.10 — An object reference model .....	<a href="#">24</a>
Figure 4.11 — A vertical offset surface for ellipsoidal height .....	<a href="#">27</a>
Figure 4.12 — Change of spatial reference frame operation applied to a coordinate .....	<a href="#">28</a>
Figure 5.1 — A coordinate-space (including the domain for spherical coordinate n-tuples) .....	<a href="#">32</a>
Figure 5.2 — A right-handed orthonormal frame .....	<a href="#">32</a>
Figure 5.3 — 3D position-space, its orthonormal frame, and its canonical Cartesian basis .....	<a href="#">33</a>
Figure 5.4 — Object-spaces for the Earth and for a CAD model .....	<a href="#">34</a>
Figure 5.5 — A normal embedding that maps position-space to an object-space .....	<a href="#">35</a>
Figure 5.6 — Two distinct normal embeddings that map position-space to an object-space .....	<a href="#">36</a>
Figure 5.7 — Abstract equatorial spherical coordinate system example .....	<a href="#">38</a>
Figure 5.8 — Polar CS geometry .....	<a href="#">39</a>
Figure 5.9 — The Polar CS generating function .....	<a href="#">39</a>
Figure 5.10 — The geodetic coordinate system geometric and trigonometric relationships .....	<a href="#">40</a>
Figure 5.11 — Surface geodetic CS geometric and trigonometric relationships .....	<a href="#">40</a>
Figure 5.12 — Geodetic 3D CS geometry, and coordinate-component surface and curves .....	<a href="#">43</a>
Figure 5.13 — Induced surface CS with localization .....	<a href="#">47</a>
Figure 5.14 — Lococentric Euclidean CS on a local tangent plane .....	<a href="#">49</a>
Figure 5.15 — Lococentric azimuthal spherical CS on a local tangent plane .....	<a href="#">50</a>
Figure 5.16 — A map projection generating function .....	<a href="#">52</a>
Figure 5.17 — Geodetic azimuths $\alpha_1$ from $p_1$ to $p_2$ .....	<a href="#">55</a>
Figure 5.18 — Convergence of the meridian .....	<a href="#">56</a>
Figure 5.19 — Polar Stereographic map projection .....	<a href="#">57</a>
Figure 5.20 — Tangent and secant cylindrical map projections .....	<a href="#">58</a>
Figure 5.21 — Tangent and secant conical map projections .....	<a href="#">59</a>
Figure 5.22 — Vertical distortion .....	<a href="#">60</a>
Figure 5.23 — Coordinate-space, position-space, and object-space relationships .....	<a href="#">116</a>
Figure 5.24 — A spatial CS of type surface .....	<a href="#">117</a>
Figure 5.25 — Two spatial coordinate systems for the same object-space .....	<a href="#">117</a>
Figure 6.1 — Change of basis relationships .....	<a href="#">122</a>
Figure 6.2 — Rotation operator applied to a point, a line segment, and a 3D object .....	<a href="#">127</a>
Figure 6.3 — Origin-fixed rotation .....	<a href="#">128</a>
Figure 6.4 — Consecutive rotation operations: axis n followed by axis m .....	<a href="#">129</a>
Figure 6.5 — Consecutive rotation operations: axis m followed by axis n .....	<a href="#">130</a>
Figure 6.6 — Space-fixed, body-fixed, and space-fixed equivalent of body-fixed conventions .....	<a href="#">131</a>
Figure 6.7 — Space-fixed convention .....	<a href="#">132</a>
Figure 6.8 — Body-fixed convention .....	<a href="#">132</a>
Figure 6.9 — Space-fixed equivalent of body-fixed convention .....	<a href="#">133</a>
Figure 6.10 — Rotation of a position-vector within an orthonormal frame .....	<a href="#">134</a>
Figure 6.11 — Rotation of the basis vectors in the same direction as the position-vector .....	<a href="#">135</a>
Figure 6.12 — Euler z-x-z convention rotation sequence .....	<a href="#">142</a>
Figure 6.13 — Tait-Bryan angles .....	<a href="#">143</a>
Figure 7.1 — Oblate and prolate ellipsoids .....	<a href="#">158</a>
Figure 7.2 — An ellipsoid reference datum .....	<a href="#">160</a>

Figure 7.3 — Two RDs bound to an abstract object and to a physical object..... 161

Figure 7.4 — A reference datum binding..... 162

Figure 7.5 — 3D normal embedding relationships ..... 163

Figure 7.6 — Oblate ellipsoid ORMT binding ..... 181

  

Figure 8.1 — The components of a spatial reference frame ..... 209

Figure 8.2 — Examples of SRF relationships..... 215

Figure 8.3 — Coordinate-space, position-space, and object-space directions compared ..... 219

Figure 8.4 — Local tangent space Euclidean SRFT ..... 228

Figure 8.5 — Local tangent space azimuthal spherical SRFT ..... 230

Figure 8.6 — Local tangent space cylindrical SRFT ..... 233

  

Figure 9.1 — Vertical offset surface for ellipsoidal height ..... 272

Figure 9.2 — Vertical offset surface tangent plane ..... 273

Figure 9.3 — Geoidal separation..... 273

Figure 9.4 — Vertical coordinate-component with respect to a vertical offset surface..... 274

Figure 9.5 — Orthometric height ..... 275

  

Figure 10.1 — Composed transformations for a single object ..... 281

Figure 10.2 — Composed transformations for two different objects ..... 282

Figure 10.3 — Change of SRF operation – applied to coordinates..... 284

Figure 10.4 — Change of SRF operation for Lococentric Euclidean 3D SRFs..... 288

Figure 10.5 — Abstract object realised in another abstract object-space ..... 291

Figure 10.6 — Abstract object realised using a geodetic reference point..... 291

Figure 10.7 — Abstract object realised using a geocentric reference point..... 292

Figure 10.8 — Four examples of geodesic segments ..... 296

  

Figure 11.1 — Class inheritance hierarchy summary..... 325

Figure 11.2 — BaseSRF class hierarchy..... 331

Figure 11.3 — BaseSRF2D class hierarchy ..... 333

Figure 11.4 — BaseSRF3D class hierarchy ..... 338

Figure 11.5 — BaseSRFMapProjection class hierarchy ..... 355

Figure 11.6 — BaseSRFwithEllipsoidalHeight class hierarchy ..... 357

Figure 11.7 — BaseSRFwithTangentPlaneSurface class hierarchy ..... 362

  

Figure A.1 — Tangent to a curve..... 445

Figure A.2 — Angle between two curves..... 446

Figure A.3 — Tangent plane to a surface..... 447

Figure A.4 — Orthographic projection ..... 450

Figure A.5 — Perspective projection ..... 450

Figure A.6 — Stereographic projection..... 451

Figure A.7 — Cylindrical projection ..... 452

Figure A.8 — Conic projection ..... 452

  

Figure C.1 — SRM concepts and their relationships..... 469

Figure C.2 — Reference datum hierarchy ..... 470

Figure C.3 — Sphere-based ORM template realisation example ..... 471

Figure C.4 — Oblate ellipsoid-based ORM template realisation example ..... 471

Figure C.5 — Object-dynamic ORM template realisation example ..... 472