

# GEANT4 GEOMETRY

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## Traceability matrix

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DETECTOR CONSTRUCTION

UR	Design	Implementation	Use case	Unit test	System test
1.1	geom.mdl	geometry/solids/* classes	<p><b>1.1.1</b> – Specific construction of solids, through one or more constructors (see 3.1 and 3.2 for specific cases)</p> <p><b>1.1.2</b> – Explicit deletion of solids from a dynamic geometry setup</p>	testG4* tests	test01 test10 Any test
1.2	geom.mdl	G4LogicalVolume G4VPhysicalVolume & subclasses	<p><b>1.2.1</b> – Specific construction of physical volumes through constructors or successive <i>set</i> methods</p> <p><b>1.2.2</b> – Setting of material to logical volume (LV)</p> <p><b>1.2.3</b> – Setting of sensitive detector to LV</p> <p><b>1.2.4</b> – Setting of region to LV</p> <p><b>1.2.5</b> – Setting of visualization attributes to LV</p> <p><b>1.2.6</b> – Setting of field manager to LV</p> <p><b>1.2.6</b> – Setting of parameterization to LV</p> <p><b>1.2.7</b> – Setting of importance biasing to LV</p> <p><b>1.2.8</b> – Dynamic modification of geometry (switching and/or explicit deletion)</p>	testG4Volumes testG4Parameterised/Solid1/Material	Placement: any Replicas: N02, N04, N07
1.3	none	navigation/G4GeomTest* classes OLAP standalone tool DAVID graphics tool	<p><b>1.3.1</b> – UI verification through recursive grid</p> <p><b>1.3.2</b> – UI verification through recursive line</p> <p><b>1.3.3</b> – UI verification through recursive cylinder</p> <p><b>1.3.4</b> – UI verification through non recursive mode</p> <p><b>1.3.5</b> – UI verification with limited recursion</p> <p><b>1.3.6</b> – UI verification with high/low grid resolution</p> <p><b>1.3.7</b> – UI verification with higher/lower tolerance</p> <p><b>1.3.8</b> – Verification overlap mother-daughter</p> <p><b>1.3.9</b> – Verification overlap (partial and totally overlapping) daughter-daughter</p>	none	N03 OLAP
1.4	geom.mdl CutsPerRegion.mdl	G4Region, G4RegionStore	<p><b>1.4.1</b> – Disjoint root regions definition</p> <p><b>1.4.2</b> – Nested root regions definition</p>	none	N07 test26

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			<b>1.4.3</b> – Deletion of regions (disjoint and/or nested)		
<b>1.5</b>	geom.mdl	G4LogicalVolume	<b>1.5.1</b> – See cases from 1.2.2 to 1.2.7	none	Any test
<b>1.6</b>	STEPinterface.mdl GDML web page	Future integration in persistency module	<b>1.6.1</b> – Import of persistent geometry (details for shapes from 3.1 and 3.2) from file together with material definitions and attributes	none	gdml
			<b>1.6.2</b> – Export of transient geometry (details for shapes from 3.1 and 3.2) to file together with material definitions and attributes		
			<b>1.6.3</b> – Import/export of a CAD geometry (details for shapes from 3.1 and 3.2)		
<b>A.1</b>	geom.mdl BREPS.mdl STEPinterface.mdl	CSG solids BREPS solids	<b>A.1.1</b> – See case 1.6.3	CSG tests, BREPS tests	CSG: any test BREPS: none
<b>A.2</b>	geom.mdl	G4VPhysicalVolume G4PVPlacement G4PVReplica, GaPVParameterised	<b>A.2.1</b> – Placement of a volume in a mother when a replica is placed already	none	Not applicable
			<b>A.2.2</b> – Replica NOT filling a mother volume		
			<b>A.2.3</b> – Not applicable replications or parameterizations		
			<b>A.2.4</b> – Not allowed axis for division of a volume		
			<b>A.2.5</b> – Degenerated solids: trap/prism, disjoint polyhedrons/polycones		
<b>A.2.6</b> – Invalid Boolean constructions (disjoint constituent solids, subtraction/intersections of solids with shared surfaces)					
<b>A.3</b>	none	Navigation/G4GeomTest* classes	<b>A.3.1</b> – See case 1.3.5	none	none

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ELECTROMAGNETIC FIELD

UR	Design	Implementation	Use case	Unit test	System test
2.1	geom.mdl field.mdl	G4Field and derivatives G4FieldManager	2.1.1 – Definition of a uniform magnetic field	???	???
			2.1.2 – Definition of a non-uniform magnetic field		
			2.1.3 – Definition of an electric field		
			2.1.4 – Combination of fields according to a map		
2.2	field.mdl	G4EquationOfMotion G4Mag*Driver, G4Mag*Stepper	2.2.1 – Definition of a generic equation of motion	magneticfield/test/*	N02, N04 field01 field02 field03
2.3	field.mdl	G4ChordFinder G4FieldManager	2.3.1 - ...	???	???
2.4	field.mdl	G4Mag*Stepper G4Field and derivatives	2.4.1 – Runge-Kutta stepper 2.4.2 - ...	OtherFields, NTST, ???	field01 ???
2.5	field..mdl	G4FieldTrack G4FieldManager	2.5.1 - ...	???	???
2.6	geom..mdl field.mdl	G4Field and derivatives	2.6.1 – See 2.1.1 and 2.1.2	???	Non uniform: field03
2.7	field.mdl	G4ElectricField	2.7.1 – See 2.1.3	???	field02
B.1	geom.mdl	G4EquationOfMotion G4FieldManager	B.1.1 - ...	???	See 2.2
B.2	field..mdl	G4Mag_EqRhs G4Mag_SpinEqRhs	B.2.1 - ...	testProPerpSpin	none
B.3	geom..mdl	G4FieldManager G4LogicalVolume	B.3.1 - ...	???	field03
B.4	geom..mdl	G4FieldManager	B.4.1 – Definition of sub-detectors with no field associated	???	none
B.5	geom.mdl	magneticfield classes	B.5.1 – Looping mouns	???	???
			B.5.2 - ...		

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SOLIDS & VOLUMES

UR	Design	Implementation	Use case	Unit test	System test
3.1	geom.mdl	Classes in: solids/CSG solids/specific	3.1.1 – Construction of a box (G4Box)	Tests in: CSG/test specific/test See Appendix.	test10
			3.1.2 – Construction of a cone (G4Cons) + section		
			3.1.3 – Construction of a tube (G4Tubs) + section		
			3.1.4 – Construction of a shell-sphere (G4Sphere) + section		
			3.1.5 – Construction of a full-sphere (G4Orb/G4Sphere) + section		
			3.1.6 – Construction of a generic trapezoid (G4Trap)		
			3.1.7 – Construction of a trapezoid along Z (G4Trd)		
			3.1.8 – Construction of a parallelepiped (G4Para)		
			3.1.9 – Construction of a torus (G4Torus) + section		
			3.1.10 – Construction of a polyhedron (G4Polyhedra) + section		
			3.1.11 – Construction of a polycone (G4Polycone) + section		
			3.1.12 – Construction of an hyperbolic tube (G4Hype)		
			3.1.13 – Construction of an elliptical tube (G4EllipticalTube)		
			3.1.14 – Construction of a twisted tube (G4TwistedTube)		
			3.1.15 – Construction of a twisted trapezoid (G4TwistedTrap)		
			3.1.16 – Combination of cases above with major functionalities (see additional use-cases table T.3.1 in Appendix)		
			3.1.17 – Visualization of above shapes (3.1.1 to 3.1.15)		
			3.1.18 – Generation of NURBS for above shapes (3.1.1 to 3.1.15)		
3.2	BREPS.mdl	Classes in: solids/BREPS	3.2.1 – Construction of a BREP box	Tests in: BREPS/test See Appendix.	none
			3.2.2 – Construction of a BREP cone		
			3.2.3 – Construction of a BREP cylinder		
			3.2.4 – Construction of a BREP polycone		
			3.2.5 – Construction of a BREP open-polycone		
			3.2.6 – Construction of a BREP polyhedron		
			3.2.7 – Construction of a BREP sphere		
			3.2.8 – Construction of a BREP torus		

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			<p><b>3.2.9</b> – Combination of cases above with major functionalities (see additional use-cases table T.3.2 in Appendix)</p> <p><b>3.2.10</b> – Visualization of above shapes (3.2.1 to 3.2.8)</p> <p><b>3.2.11</b> – Generation of NURBS for above shapes (3.2.1 to 3.2.8)</p>		
<b>3.3</b>	BREPS.mdl G4Curve.mdl	Classes in: solids/BREPS	<p><b>3.3.1</b> – Composition from linear surfaces</p> <p><b>3.3.2</b> – Composition from spherical surface</p> <p><b>3.3.3</b> – Composition from cylindrical surface</p> <p><b>3.3.4</b> – Composition from conical surface</p> <p><b>3.3.5</b> – Composition from elliptical surface</p> <p><b>3.3.6</b> – Composition from hyperbolic surface</p> <p><b>3.3.7</b> – Composition from rectangular trimmed surface</p> <p><b>3.3.8</b> – Composition from surface revolution</p> <p><b>3.3.9</b> – Composition from surface extrusion</p> <p><b>3.3.10</b> – Composition from BSpline surface</p> <p><b>3.3.11</b> – Composition from Bezier surface</p> <p><b>3.3.12</b> – Combination of cases above with major functionalities (see additional use-cases table T.3.3 in Appendix)</p> <p><b>3.3.13</b> - Visualization of above shapes (3.3.1 to 3.3.11)</p> <p><b>3.3.14</b> – Generation of NURBS for above shapes (3.3.1 to 3.3.11)</p>	none	none
<b>3.4</b>	geom..mdl	G4BooleanSolid and derivatives	<p><b>3.4.1</b> – Union of a combination of CGS/specific solids</p> <p><b>3.4.2</b> – Intersection of a combination of CSG/specific solids</p> <p><b>3.4.3</b> – Subtraction of a combination of CSG/specific solids</p> <p><b>3.4.4</b> – Combination of cases above with major functionalities (see additional use-cases table T.3.4)</p> <p><b>3.4.5</b> – Visualization of Boolean solids with/without shared surfaces</p>	Tests in Boolean/test	none
<b>3.5</b>	geom.mdl	G4LogicalVolume	<b>3.5.1</b> – See cases in 1.2	none	Any test
<b>3.6</b>	geom..mdl	G4PVReplica	<p><b>3.6.1</b> – Replication along single axis (Cartesian, phi, rho) for major CSG and specific solids (box, cone, tube, sphere, trap/trd, polycone, polyhedron, torus)</p> <p><b>3.6.2</b> – Replications along multiple axes or replication containing replications</p> <p><b>3.6.3</b> – Visualization of replicated volumes</p>	testG4ReplicaNavigation replicaCal	N03, N04

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3.7	geom..mdl	G4PVParameterised G4VPVParameterisation	3.7.1 – Parameterization by dimension and/or position for major CSG and specific solids (box, cone, tube, sphere, trap/trd, polycone, polyhedron)	testG4Parameterised testG4ParameterisedMaterial testG4ParameterisedSolid1	N02, N04
			3.7.2 – Parameterization by solid shape		
			3.7.3 – Parameterization by material		
			3.7.4 – Visualization of parameterized volumes		
3.8	none	Classes in: geometry/divisions	3.8.1 – Division along specified Cartesian/phi/rho axis for major CSG and specific solids (box, cone, tube, sphere, trap/trd, polycone, polyhedron)	testG4PVDivision ExDivisions	none
			3.8.2 – Definition of offsets in divisions		
			3.8.3 – Visualization of divided volumes		
3.9	geom..mdl	G4ReflectedSolid G4ReflectionFactory	3.9.1 – Reflection of a single volume of hierarchy of volumes (only placements)	testG4ReflectedSolid	none
			3.9.2 – Reflection of a hierarchy of volumes including replicas		
			3.9.3 – Reflection of a hierarchy of volumes including parameterizations or divided volumes		
			3.9.4 – Reflection of attributes of a logical volume and daughters		
3.10	geom.mdl	G4ReflectionFactory	3.9.5 – Visualization of reflected volumes	none	none
			3.10.1 – Retrieval of a pointer to the reflected volume		
3.11	geom..mdl	G4AssemblyVolume G4AssemblyTriplet	3.10.2 – Retrieval/customization of the name/ID associated to a reflected volume	TestAssemblyVolume	test01
			3.11.1 – Composition of major CSG solids (box, tube, cone, sphere, trap/trd) into an assembly		
3.12	geom..mdl	G4LogicalVolume	3.11.2 – Retrieval/customization of the name/ID associated to an assembly component	none	none
			3.11.3 – Automatic handling of allocated objects in the assembly		
3.12	geom..mdl	G4LogicalVolume	3.12.1 – Definition of a volume hierarchy with partial optimization	none	none
3.13	none	Future development	3.13.1 – Computation of volume mass or density of a generic hierarchy of volumes (including replicas/parameterized/divided volumes) with different materials associated	none	none
C.1	geom..mdl	G4DisplacedSolid	C.1.1 – Definition of Boolean solids (union, intersection, subtraction) with defined displacement (translation, rotation)	testG4DisplacedSolid	none

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<b>C.2</b>	geom..mdl	Classes in: solids/CSG solids/specific	<b>C.2.1</b> – See cases in 3.1	Tests in: CSG/test Specific/test	test10
<b>C.3</b>	geom..mdl	G4PVReplica G4ReplicaNavigation G4ParameterisedNavigation G4SmartVoxelHeader and related	<b>C.3.1</b> – Replication/parameterization of many volumes compared to normal placements, with/without optimization	CPU benchmarks: replicaCal Memory benchmarks: <b>none</b>	<b>none</b>
<b>C.4</b>	geom.mdl	G4SmartVoxelHeader and related	<b>C.4.1</b> – Verification of optimization for generic hierarchies including different parameterizations/replications along different axes	testG4SmartVoxelProxy testG4SmartVoxels testG4VoxelLimits TestDrawVox	N04

## NAVIGATION & TRANSPORTATION

UR	Design	Implementation	Use case	Unit test	System test
<b>4.1</b>	geom.mdl	G4Navigator	<b>4.1.1</b> – Define customized navigator with slightly different behavior from the default	testG4Navigator*	<b>none</b>
<b>D.1</b>	geom..mdl	G4Navigator and related G4SmartVoxelHeader and related G4VTouchable and subclasses	<b>D.1.1</b> – Definition of a flat geometry structure with more or less “dense” areas of placements	See C.4 testG4AffineTransform testG4Touchables testG4NavigationHistory testG4BlockingList calorimeter	Any test
			<b>D.1.2</b> – Definition of a reasonably complex structured geometry		
			<b>D.1.3</b> – See cases C.3.1 and C.4.1		
<b>D.2</b>	geom..mdl	G4TouchableHistory G4NavigationHistory and related	<b>D.2.1</b> – Location of points in geometry structure with multiple placements, replicas/parameterized volumes, divisions. Identification of the copy-number	TestG4NavigationHistory	N02, N03, N04, N05, N06, N07 Others in tests and extended...
<b>D.3</b>	geom..mdl field.mdl	G4Transportation G4PropagationInField	<b>D.3.1</b> – Transportation of charged-geantinos in a geometry structure with mixed field setups	<b>none</b>	Any test

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BIASING

UR	Design	Implementation	Use case	Unit test	System test
5.1	biasing.mdl	Classes in: geometry/biasing processes/transportation	5.1.1 – Importance biasing and scoring of particles in the real tracking geometry	none	B01, B02, B03
			5.1.2 – Importance biasing and scoring of particles in a parallel simplified geometry		

GENERAL

UR	Design	Implementation	Use case	Unit test	System test
E.1	geom..mdl	G4VPhysicalVolume G4SmartVoxelHeader and related	E.1.1 – Definition of reasonably complex structured geometry and measurement of memory consumption with/without optimization (see also D.1.2)	calorimeter G3 comparison tests	Any advanced test
E.2	geom..mdl	G4SmartVoxelHeader and related	E.2.1 – Definition of a tracker setup without field E.2.2 – Definition of a tracker setup with field	See E.1	Any advanced test
E.3	geom..mdl	Classes in 'g3tog4' module	E.3.1 – Import a structured/not-structured geometry setup with placements, replicas, parameterized volumes, divisions, reflections	none	clGeometry cltog4
			E.3.2 – Import a geometry setup with materials assigned		
			E.3.3 – Import a geometry setup with field-map assigned		
			E.3.4 – Import a setup with sensitive readout areas E.3.5 – Import a setup with a variety of G3 solids		
E.4	geom..mdl	G4SolidStore G4RegionStore G4LogicalVolumeStore G4PhysicalVolumeStore	E.4.1 – Switch of the geometry setup at run-time	none	N03 TestEm1/2/3/6/7/9 Field01/2/3 underground_physics
			E.4.2 – Replacement (with deletion) of whole or part of the geometry setup at run-time (see also 1.2.8)		
			E.4.3 – Explicit deletion of solids and/or volumes (see also 1.1.2)		

# APPENDIX

TABLE T.3.1 – CSG Solids

Solid	Function	Unit test	System test
<b>G4Box</b>	DistanceToOut / DistanceToIn / Inside	testG4Box	Any test
	SurfaceNormal	SolidsChecker	N06, test10
<b>G4Cons</b>	DistanceToOut / DistanceToIn / Inside	testG4Cons1, testG4Cons2	Any test
	SurfaceNormal	SolidsChecker	test10
<b>G4Tubs</b>	DistanceToOut / DistanceToIn / Inside	testG4Tubs	Any test
	SurfaceNormal	SolidsChecker	test10
<b>G4Sphere</b>	DistanceToOut / DistanceToIn / Inside	testG4Sphere, testG4Sphere2	test10
	SurfaceNormal	SolidsChecker	test10
<b>G4Orb</b>	DistanceToOut / DistanceToIn / Inside	testG4Orb	test10
	SurfaceNormal	SolidsChecker	test10
<b>G4Trap</b>	DistanceToOut / DistanceToIn / Inside	testG4Trap	test10
	SurfaceNormal	SolidsChecker	test10
<b>G4Trd</b>	DistanceToOut / DistanceToIn / Inside	testG4Trd	test10
	SurfaceNormal	SolidsChecker	test10
<b>G4Para</b>	DistanceToOut / DistanceToIn / Inside	testG4Para1, testG4Para2	test10
	SurfaceNormal	SolidsChecker	test10

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<b>G4Torus</b>	DistanceToOut / DistanceToIn / Inside	testG4Torus	test10
	SurfaceNormal	SolidsChecker	test10
<b>G4Polyhedra</b>	DistanceToOut / DistanceToIn / Inside	none	test10
	SurfaceNormal	SolidsChecker	test10
<b>G4Polycone</b>	DistanceToOut / DistanceToIn / Inside	testG4Polycone	test10
	SurfaceNormal	SolidsChecker	test10
<b>G4Hype</b>	DistanceToOut / DistanceToIn / Inside	testG4Hype	test10
	SurfaceNormal	SolidsChecker	test10
<b>G4EllipticalTube</b>	DistanceToOut / DistanceToIn / Inside	none	none
	SurfaceNormal	none	none
<b>G4TwistedTube</b>	DistanceToOut / DistanceToIn / Inside	none	none
	SurfaceNormal	none	none
<b>G4TwistedTrap</b>	DistanceToOut / DistanceToIn / Inside	none	none
	SurfaceNormal	none	none

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TABLE T.3.2 – BREP specific Solids

Solid	Function	Unit test	System test
<b>Box</b>	DistanceToOut / DistanceToIn / Inside	G4BREPSolidBoxTest	none
	SurfaceNormal	none	none
<b>Cone</b>	DistanceToOut / DistanceToIn / Inside	G4BREPSolidConeTest	none
	SurfaceNormal	none	none
<b>Cylinder</b>	DistanceToOut / DistanceToIn / Inside	G4BREPSolidCylinderTest	none
	SurfaceNormal	none	none
<b>PCone</b>	DistanceToOut / DistanceToIn / Inside	G4BREPSolidPConeTest	none
	SurfaceNormal	none	none
<b>OpenPCone</b>	DistanceToOut / DistanceToIn / Inside	testBREPSolidOpenPCone	none
	SurfaceNormal	none	none
<b>Polyhedra</b>	DistanceToOut / DistanceToIn / Inside	G4BREPSolidPolyhedraTest	none
	SurfaceNormal	none	none
<b>Sphere</b>	DistanceToOut / DistanceToIn / Inside	G4BREPSolidSphereTest	none
	SurfaceNormal	none	none
<b>Torus</b>	DistanceToOut / DistanceToIn / Inside	G4BREPSolidTorusTest	none
	SurfaceNormal	none	none

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TABLE T.3.3 – BREP advanced Solids

Solid	Function	Unit test	System test
<b>PatchedBREP</b>	DistanceToOut / DistanceToIn / Inside	G4FPlaneTest, CurveTest	none
	SurfaceNormal	none	none
<b>Spherical</b>	DistanceToOut / DistanceToIn / Inside	none	none
	SurfaceNormal	none	none
<b>Cylindrical</b>	DistanceToOut / DistanceToIn / Inside	none	none
	SurfaceNormal	none	none
<b>Conical</b>	DistanceToOut / DistanceToIn / Inside	none	none
	SurfaceNormal	none	none
<b>Ellipsoid</b>	DistanceToOut / DistanceToIn / Inside	none	none
	SurfaceNormal	none	none
<b>Hyperboloid</b>	DistanceToOut / DistanceToIn / Inside	none	none
	SurfaceNormal	none	none
<b>Trimmed</b>	DistanceToOut / DistanceToIn / Inside	none	none
	SurfaceNormal	none	none
<b>Revolution</b>	DistanceToOut / DistanceToIn / Inside	none	none
	SurfaceNormal	none	none
<b>Extrusion</b>	DistanceToOut / DistanceToIn / Inside	none	none
	SurfaceNormal	none	none

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<b>BSpline</b>	DistanceToOut / DistanceToIn / Inside	none	none
	SurfaceNormal	none	none
<b>Bezier</b>	DistanceToOut / DistanceToIn / Inside	none	none
	SurfaceNormal	none	none

TABLE T.3.4 – Boolean Solids

<b>Solid</b>	<b>Function</b>	<b>Unit test</b>	<b>System test</b>
<b>G4UnionSolid</b>	DistanceToOut / DistanceToIn / Inside	testG4UnionSolid	none
	SurfaceNormal	none	none
<b>G4IntersectionSolid</b>	DistanceToOut / DistanceToIn / Inside	testG4IntersectionSolid	none
	SurfaceNormal	none	none
<b>G4SubtractionSolid</b>	DistanceToOut / DistanceToIn / Inside	testG4SubtractionSolid	none
	SurfaceNormal	none	none