GEANT4 Collaboration

GEANT4

OO Toolkit for Particle Detector Simulation

User Requirements Document

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Prepared By Katsuya Amako
John Apostolakis
Gabriele Cosmo
Simone Giani
Peter Urban

Abstract

This document describes the User Requirements for the GEANT4 project. The PSS-05 software engineering standards are followed. A general description of the main capabilities and constraints is provided. The users are characterized in different categories depending on the level of interaction with the system. Specific requirements are listed and classified.

Document Status Sheet

Table 1 Document Status Sheet

1. Document title: OO Toolkit for Particle Detector Simulation User Requirements Document			
2. Document Reference Number: GEANT4-URD			
3. Issue	**4. Revision**	**5. Date**	**6. Reason for change**
v5	0	31 October 1995	User comments on V4.0
v6	0	14 May 1997	LCRB and user comments on V5.0
v6	3	19 November 1998	Completion of the RD44 project
v6	4	23 September 2002	Updates and addition of new major requirements since first production version of the GEANT4 software

Document Change Record

Table 2 Document Change Record (of changes made since issue 6.3)

Document Change Record	**DCR No.**	4
	Date	23 September 2002
	Originator	GEANT4 Architecture Working Group
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1. Document Title	GEANT4 User Requirements Document	
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4. Page	**5. Paragraph**	**6. Reason for Change**
i, ii	Header, footer and front page	Update to current CERN official name. Update to list of editors, removed G.Ballocchi.
1	1.2	Update to sentence related to R&D phase of the project. Extension to better describe scope of the project.
3	1.3.2	Update to definitions of GEANT3 and GEANT4 acronyms. Addition of POOL definition.
4	1.4	Update to references [1] and [6] to most recent documents. Addition of reference to POOL project.
5, 7, 8, 9, 11	1.5, 2.1, 2.2, 2.3, 2.5	Update to verbs' tenses
11	2.5	Update to specify ISO C++ and generic Windows-PC support
12	2.6	Change of RD45 reference to POOL. Removal of last paragraph
13-36	3	Update or corrections to requirements: UR2-1, UR4-2, UR4-3, UR6-1, UR7-1, UR7-3, UR7-5, UR7-6, UR10-2, UR10-5, UR11-1, UR12-1, UR12-2, UR13-1, UR14-1, UR19-3, UR19-8, UR19-10, UR19-11, UR19-12, UR19-13, UR19-14, UR20-1, UR22-1, UR-23-4, UR23-5
32	3.2.8	Addition of new requirements: UR16-2, UR19-15, UR19-16, UR19-17

Table Of Contents

1 Introduction

1.1 Purpose

This document describes the user requirements for GEANT4 [1], an object-oriented toolkit for particle detector simulation.

This document follows the ESA standard PSS-05 for software development in the user requirements definition phase of a project [2].

This document is intended to be read by people with HEP experience. HEP terms are not defined unless their meaning is different in the context of simulation software.

1.2 Scope of the Software

The main aim of GEANT4 is to produce a toolkit which allows a user to construct a particle detector simulation program on various computing platforms and in various hardware and software environments as described in Section 2.5 of this document.

Its application areas include high energy physics and nuclear experiments, medical, accelerator and space physics studies. A complete range of functionalities must be included, among which tools for managing geometry, tracking, detector response, runs, events, particle definitions, visualisation and user interfaces. For many physics processes it must provide a choice of different physics models to be utilised.

The baseline product is available for public use since December 1998. The total duration of the project R&D phase was four years (1994-1998).

GEANT4 should replace the old FORTRAN simulation framework, GEANT3 [3].

1.3 Definitions, Acronyms and Abbreviations

1.3.1 Definitions

Event
An initial set of particle types, vertices, momenta and times. Also used to indicate the output after the tracking, i.e. including the digitized results.

Event parallelism
To process multiple events in parallel by multiple processors.

Logical model
In ESA standard, the logical model defines the conceptual framework for the system. This is basically equivalent to models created in various OOA / OOD methodologies [10], [11], [12].

Parameterisation
A simulation which replaces the detailed particle tracking, physics and response of the detector for some particle type inside some volume.

Subsystem component
A set of classes with related functionality.

Trajectory
The set of positions of the end of each step of the particle tracking process.

Sensitive Detector
A collection of one or more volumes for which data can be taken.

1.3.2 Acronyms

CAD Computer Aided Design.

ESA European Space Agency, Garching (Germany), and Noordwijk (The Nederlands).

GEANT A toolkit for constructing a particle detector simulator - GEometry ANd Tracking.

GEANT3 The old version of GEANT based on a FORTRAN framework [3].

GEANT4 The new simulation toolkit based on object-oriented technology [1]. See also RD44.

GUI Graphical User Interface.

HEP High Energy Physics.

OOA/OOD Object-Oriented Analysis, Object-Oriented Design.

OOP Object-Oriented Programming

MOOSE A CERN Research and Development project (RD41) to study the viability of the Object Oriented approach for software development for High Energy Physics reconstruction and analysis code at the LHC.

POOL A CERN project for providing a persistency framework for LHC computing (Pool Of persistent Objects for LHC) [9].

PSS Procedures, Specifications and Standards

RD44 A CERN Research and Development project described in the current document. See also GEANT4.

RD45 A CERN Research and Development project to investigate object persistency for HEP [8].

STEP ISO STandard for Exchange of Product data [4], [5].

1.3.3 Abbreviations

T.b.d. The expression T.b.d, which stands for ‘To be defined’, used to qualify the requirement stability attribute, indicates that the requirement is dependent on feedback from other phases of the software development and is subject to change.

1.4 References

[1] GEANT4 Collaboration, GEANT4 - a simulation toolkit, CERN-IT-2002-003 / KEK Preprint 2002-85 / SLAC-PUB-9350, 2002.

[2] Guide to user requirements definition phase, ESA PSS-05.

[3] GEANT Detector Description and Simulation Tool, CERN Program Library, W5013, 1994.

[4] ISO 10303, Industrial Automation Systems and Integration - Product Data Representation and Exchange - Part 1: Overview and Fundamental Principles, ISO TC 184/SC4, 1992.

[5] ISO 10303, Industrial Automation Systems and Integration - Product Data Representation and Exchange - Part 21: Clear Text Encoding of the Exchange Structure, ISO TC 184/SC4, 1992.

[6] ISO 14882, Final Draft International Standard - Programming Language C++, ISO/IEC 14882, 1998.

[7] M.A. Ellis and B. Stroustrup, The Annotated C++ Reference Manual, Addison-Wesley Pub., Inc., 1990.

[8] R. Zybert et al., A Persistent Object Manager for HEP, CERN/DRDC/P59, 1994.

[9] POOL, LHC Persistency Framework Project - http://cern.ch/db.

[10] G. Booch, Object-Oriented Analysis and Design with Application, The Benjamin/Commings Pub., Inc., 1994.

[11] J. Rumbaugh, et al., Object-Oriented Modeling and Design, Prentice-Hall, Inc., 1991.

[12] D. Coleman, et al., Object-Oriented Development, The Fusion Method, Prentice-Hall, Inc., 1994.

1.5 Overview of the Document

The 1st chapter of this document describes:

1. the purpose of the document,
2. the scope of the software,
3. definitions, acronyms and abbreviations,
4. references,
5. an overview of the document.

The 2nd chapter describes:

1. product perspective,
2. general capabilities,
3. general constraints,
4. user characteristics,
5. the operational environment,
6. assumption and dependencies.

The 3rd chapter describes specific requirements:

1. capability requirements,
2. constraint requirements.

The logical model of the GEANT4 system is created from this user requirement document.

2 General Description

2.1 Product Perspective

For the next generation experiments' software we envisage a framework of highly re-usable components for the engineering-simulation-reconstruction-analysis chain. The GEANT4 toolkit will provide the simulation component and

a. has to provide well-defined interfaces to parts of the other components and
b. has to provide parts to be used by the other components.

GEANT4 is an object-oriented toolkit which allows a user to construct a framework for a particular hardware and software environment which will then be tailored to a particular detector setup. The resulting computer program will then be used to simulate the behavior of particles in the detector. The framework must provide a set of subsystems covering the following elements of a detector simulator:

- Geometry
- Particle interaction in matter
- Tracking management
- Digitization and hit management
- Event and track management
- Visualization and visualization framework
- Interfaces

2.2 General Capabilities

The framework produced from the GEANT4 toolkit will offer the ability to make a geometrical model and define “sensitive” elements for which particular information (hits) will be recorded and ultimately gathered (digitizations). The simulated response of detectors is thus achieved by using of the 'hits' as input to the (user supplied) digitization codes. Events will arise from a variety of sources, both internal and external.

The geometrical model will be constructed through procedure calls, or via the graphics interface or by importing from CAD systems which conform to the STEP standard [4], [5].

The material of each element of the geometrical model will be chosen from a built-in set or composed by the user; the concepts of compounds and mixtures have to be supported. A comprehensive set of physics processes to model the behavior of particles must be provided, including decay and interaction with matter; the user will modify or add to this set.

A framework for fast MonteCarlo must be integrated with the full simulation capabilities.

In the interactive version, the user will communicate through a graphical interface which must offer the ability to set up the geometrical description, define the materials and to visualize the geometrical structure, the detector (in its entirety or in subsections or by individual component), events, particle trajectories, hits and digitizations. The user should use the built-in visualizer or choose to interface to other selected visualization systems.

Much of the above is a result of the toolkit approach, which allows the user to assemble the framework at compile time from chosen components, many of which can be user-supplied.

The operations that a GEANT4 process will support from start to finish are described below, mentioning the capabilities that users shall have. The headings used here for the listing of these operations are also used in section 3 for the classification of detailed user requirements.

2.2.1 Define Materials

The user shall be able to define the detector materials.

2.2.2 Define Processes

The user shall be able to define processes (e.g. ionization, particle decay, etc.).

2.2.3 Define Fields

The user shall be able to define the electromagnetic field map.

2.2.4 Define Detector Geometry

The user shall be able to define the geometry of the detector.

2.2.5 Define Particles

The user shall be able to:

1. Define the particles and their properties, although this is not normally done by most users (see Section 2.4).
2. Associate particles and processes.

2.2.6 Define Events

The user shall be able to define the events (e.g. set particle types, momenta, etc.).

2.2.7 Define Tracking Setup

The user shall be able to define:

1. The detector sensitivity.
2. What data is to be recorded.

2.2.8 Do Simulation

The user shall be able to:

1. Start the simulation (e.g. tracking the particles).
2. Stop / pause / abort the simulation.
3. Specify the action at each step of the tracking.

The user shall be informed of the results of the actions at each step of the processing.

2.2.9 Digitize events

The user shall be able to digitize each event or set of events.

2.3 General Constraints

The classes in the toolkit must be designed in a highly reusable and a compact way so that the user will easily extend or modify their services in a suitable way for his / her specific applications. The user will realize this by using the object-oriented technologies.

The design and implementation of the toolkit have to be done with some proper use of the experience acquired from the logical and algorithmic problems solved in the existing packages. The detailed requirements for each element are described below.

Since performance is a crucial issue for a detector simulator, the goal for GEANT4 is to demonstrate a performance comparable to GEANT3 or better, both in CPU usage and physics processes.

2.4 User Characteristics

There are basically three different types of users for GEANT4: the framework provider, the simulation application programmer and the end user.

2.4.1 Framework provider

The framework provider (FP) creates a detector simulation framework by using components in the GEANT4 toolkit and interfacing them to external class libraries. He/she knows the technique of OOP and actively sets the software requirements including components and interfaces.

2.4.2 Simulation application programmer

The simulation application programmer (SAP) creates a detector simulation program which is specific to his/her detector setup, based on the framework provided by a framework provider. The SAP doesn't need to know the complete structure of the simulator, but may write or modify user codes.

2.4.3 End User

The simulator end user (EU) runs the simulation program by controlling run time parameters such as the selection of physics processes and the setting of tracking conditions with the standard interface.

2.4.4 User-capability matrix

Table 3 shows the capabilities needed by each user type.

Table 3 User-capability matrix

	FP	SAP	EU
Define detectors	S1	S2	
Define particles	S1	(S2)	
Define events	S1	S2	
Do simulation	S1	S2	R
Digitize events	S1	(S2)	R

The following symbols are used:

- S1: set up the framework
- S2: set up the application
- R: run
- D: use the data
- (): Optional

2.5 Operational environment

The core GEANT4 toolkit is designed to be used in a software environment with at least an ISO / ANSI compliant C++ compiler [6], [7]. Currently, this will most typically be UNIX workstations and PCs, and Windows PCs.

GEANT4 must have well defined interfaces to external packages such as visualization tools, physics generators and CAD packages. The GEANT4 context diagram in Figure 1 describes the interaction between GEANT4, its different types of users and external packages.

GEANT4 CONTEXT DIAGRAM

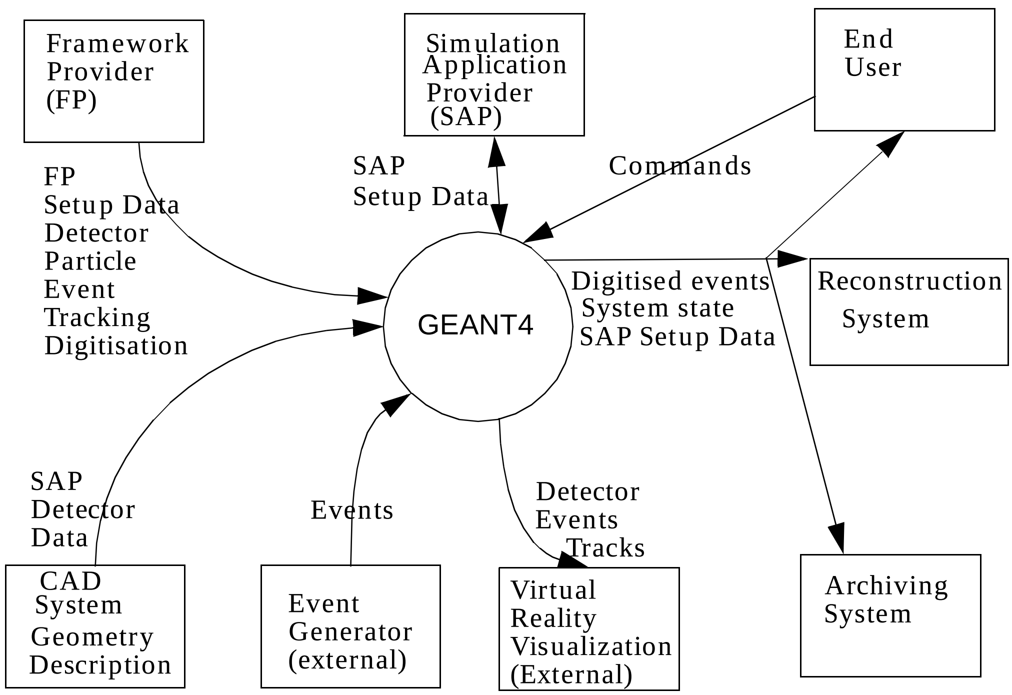

Figure 1 GEANT4 CONTEXT DIAGRAM

2.6 Assumptions and Dependencies

A basic I/O package is assumed to be provided elsewhere (for example by the LHC POOL Project [9]).

3 Specific Requirements

3.1 Capability Requirements

3.1.1 Define Materials

UR 1-1. The user shall be able to describe a material by its properties (A / Z numbers and density).

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 1-2. The user shall be able to define a material as a mixture or compound of basic materials.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 1-3. The user shall be able to define the optical properties of a material.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

3.1.2 Define Processes

UR 2-1. The user shall be able to specify the actual physical processes used in the simulation(and default sets will be provided).

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

NOTE: The following is a list of the most common physical processes considered in the tracking of the most common particles.

Photon

1. Pair conversion
2. Compton collision
3. Photo-electric effect
4. Photo fission of heavy elements
5. Rayleigh effect

Electron and Positron.

1. Multiple scattering
2. Ionisation and delta ray production
3. Bremsstrahlung
4. Annihilation of positron
5. Generation of Cherenkov and Scintillation light
6. Synchrotron radiation
7. Transition radiation

Muon

1. Decay
2. Multiple scattering
3. Ionisation and delta ray production
4. Ionisation by heavy ions
5. Bremsstrahlung
6. Direct e+/e- pair production
7. Nuclear interaction
8. Generation of Cherenkov and Scintillation light

Hadron.

1. Decay
2. Multiple scattering
3. Ionisation and delta ray production
4. Elastic, diffractive and inelastic scattering
5. Generation of Cherenkov and Scintillation light

3.1.3 Define Fields

UR 3-1 The user shall be able to define the electromagnetic field map.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

3.1.4 Define Detector Geometry

UR 4-1. The user shall be able to define a geometrical volume by assigning the parameters of geometrical entities.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 4-2. The user shall be able to define physical detector elements by specifying their geometrical representation and also their chemical, tracking and hit related information.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 4-3. The user shall be able to detect clashing / physically overlapping volumes.

Need Useful.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

3.1.5 Define Particles

UR 5-1. The user shall be able to define a particle by its physical properties (e.g. mass, charge, lifetime, spin, parity), including elementary particles, resonances, and ions.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 5-2. The user shall be able to define the decay modes and decay branching ratios for particles.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 5-3. The user shall be able to compute the cross section for each material, particle and process.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 5-4. The user shall be able to define the association between particles and processes.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

3.1.6 Define Events

UR 6-1. The user shall be able to define each event by providing a list of particles.

He/She must able to define for each particle in the list:

1. Its particle type
2. Its momentum
3. Its vertex point.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 6-2. The user shall be able to define the vertices of events.

By specifying:

1. The vertex position
2. The time when the vertex is created

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 6-3. The user shall be able to simulate event pile up (e.g. in a high luminosity collider environment).

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 6-4. The user shall be able to split events into subevents semiautomatically for further processing .

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Specification can evolve.
Verifiability Verified.

3.1.7 Define Tracking Setup

UR 7-1. The user shall be able to select different cases during the tracking.

I.e.:

1. The particle will be tracked in the same way as the primary particle.
2. There is no need to track the particle through the detector. Only the information about its energy is needed.

NOTE: The above cases correspond to the following selection for process control:

1. The process is considered and possible secondary particles generated are put into the list of particles to be tracked or parameterized.
2. The process is considered and possible secondary particles generated are simply accounted as energy loss for the primary particle.

Alternatively the process is completely ignored.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 7-2. The user shall not have to calculate the step size for integrating the equation of motion.

NOTE: To set the step size, the following factors have to be taken into account:

1. interactions integrated in space-time (like energy loss and multiple scattering),
1. the occurrence of processes which introduce a discontinuity in the spatial trajectory (decay, electromagnetic or hadronic interaction),
2. the occurrence of processes affecting the time of the tracks (processes at rest, fluorescence),
3. any combination of the above cases,
4. the step being limited by the path length to the volume boundary.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 7-3. The user shall be able to optimize the tracking by setting the maximum step size to enable a sufficiently precise treatment of energy loss or multiple scattering or time of flight.

Need Optional.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 7-4. The user shall be able to optimize the tracking by setting the accuracy for the trajectory in electromagnetic field.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 7-5. The user shall be able to achieve the required tracking accuracy by selecting the appropriate parameters.

Need Obsolete.
Priority Null.
Stability Stable.
Source RD44.
Clarity Ambiguous.
Verifiability Not verified.

UR 7-6. The user shall be able to optimize the tracking in field by setting the accuracy for boundary crossing.

Need Useful.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

3.1.8 Do Simulation

UR 8-1. The user shall be informed of the points calculated for a track (trajectory).

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 8-2. The user shall be informed of the components of the momentum at the points calculated for the track.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 8-3. The user shall be informed about the interaction between the particle and the material (hits) for each step inside the sensitive detector during the tracking.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 8-4 The user shall be able to store data taken during the simulation (hits).

NOTE: store selected information about the state of the system (detector and particles) at each step.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44 and RD45.
Clarity Clear.
Verifiability Verified.

UR 8-5. The user shall be able to store the genealogy relationship between generated tracks, vertices and hits in an event (see also UR6-4.).

Need Useful.
Priority Completed.
Stability Stable.
Source RD44 and RD45.
Clarity Clear.
Verifiability Verified.

3.1.9 Digitize Events

UR 9-1. The user shall be able to specify a sensitive detector as a volume or a set of volumes (tagging volumes for which data shall be digitized).

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 9-2. The user shall be able to digitize the response of each sensitive detector after each event or set of events.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 9-3. The user shall be able to store the results of digitization.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

3.1.10 Visualization and Visualization Framework

UR 10-1. The user shall be able to visualize the detector setup in its entirety or in subsections or by individual components.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear. ‘
Verifiability Verified.

UR 10-2. The user shall be able to visualize the individual geometrical entities representing a detector and to display their parameters.

Need Essential.
Priority Implemented. Display of parameters, designed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 10-3. The user shall be able to visualize particle trajectories at each step of the particle tracking.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 10-4. The user shall be able to visualize the detector response in sensitive elements of the detector.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 10-5. The user shall be able to navigate the genealogy relationships of information in an event (e.g. highlighting all hits from a given track, all tracks from a given parent track) by means of the visualization system.

Need Useful.
Priority Implemented.
Stability Can evolve.
Source RD44.
Clarity Specification can evolve.
Verifiability Verified.

UR 10-6. The user shall be able to visualize the geometry structure, i.e., the genealogy relationships of the geometry.

Need Useful.
Priority Implemented.
Stability Can evolve.
Source RD44.
Clarity Specification can evolve.
Verifiability Verified.

3.1.11 Interfaces

UR 11-1. The user shall be able to set control parameters in the initialization phase and at runtime by means of a GUI.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 11-2. A debug mechanism will be provided, giving the possibility to follow at the step level the simulation of the trajectory of each particle.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

3.2 Constraint requirements

3.2.1 Production of documents

UR 12-1. The user requirements document shall be in conformance with the ESA PSS-05 standard.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Continuous verification.

UR 12-2. The GEANT4 documentation, including the design documents, algorithm descriptions and the User Guide shall be made available electronically and kept up to date.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Continuous verification.

3.2.2 Resources

UR 13-1. The memory requirements for the GEANT4 object model for the geometry shall be comparable with the ones of GEANT3.

Need Desirable.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 13-2. The searching time scanning the geometrical data base during the tracking shall be comparable with the GEANT3.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified, and faster.

3.2.3 Define Detector Geometry

UR 14-1. GEANT4 shall be compliant with the STEP standard at the geometrical modeller level and also for the exchange of geometrical data.

Need Useful.
Priority Implemented.
Stability Stable, but can evolve.
Source RD44.
Clarity Clear.
Verifiability Continuous verification.

3.2.4 Define Events

UR 15-1. GEANT4 shall provide an interface to a variety of event generators.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified (via ASCII files, no need of interfaces to Fortran).

3.2.5 Define Tracking Setup

UR 16-1. The tracking of a particle shall be achieved by integrating the equation of motion in the magnetic and electric field over successive steps whilst simultaneously taking into account the effects of the presence of matter.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 16-2. The tracking of a particle's spin shall be achieved by integrating the Bargmann-Michel-Telegdi equation over successive steps.

Need Established.
Priority Completed.
Stability Stable.
Source TRIUMF.
Clarity Clear.
Verifiability Verified.

3.2.6 Digitize Events

UR 17-1. GEANT4 shall provide default digitization routines for commonly used sensitive detectors.

Need Useful.
Priority Implemented.
Stability Stable, but can evolve.
Source RD44.
Clarity Specification can evolve.
Verifiability Continuous verification.

3.2.7 Visualization and visualization framework

UR 18-1. GEANT4 shall provide a built-in visualizer.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified, for more than one.

3.2.8 Interfaces

UR 19-1. The user shall be able to easily plug in his/her own physics interaction procedures via the use of OO technology.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 19-2. The user shall be able to use experiment-specific electromagnetic and hadronic shower parametrizations.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 19-3. As a useful by-product, GEANT4 shall provide tools in the context of event reconstruction.

1. compute average trajectories, taking into account only of fields and mean energy loss, without fluctuations. This track evaluation will be forward or backward (i.e. time reversed)
2. together with the track evaluation, calculate and propagate the covariant error matrix due to the random processes (mainly multiple scattering and energy loss fluctuations)
3. fit track segments.

Need Useful (although not in the scope of simulation).
Priority To be addressed as man power permits.
Stability Stable.
Source ATLAS / CMS experiments.
Clarity Clear (analogous functionalities provided in GEANE FORTRAN package).
Verifiability To be verified.

UR 19-4. The user shall be able to integrate user written digitization routines.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 19-5. GEANT4 shall provide a standard interface towards the reconstruction framework, especially at the level of the geometry and of particles/tracks.

Need Useful.
Priority Completed.
Stability Stable.
Source RD44 and RD45.
Clarity Clear.
Verifiability Verified.

UR 19-6. GEANT4 shall provide a graphical user interface.

Need Essential.
Priority Completed.
Stability Stable
Source RD44
Clarity Clear.
Verifiability Verified.

UR 19-7. GEANT4 shall provide a well defined interface to the visualization tool. The framework provider shall be able to build a visualizer of his/her choice into the framework through some specific interfaces.

Need Established.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 19-8. GEANT4 shall be able to use simple GEANT3 geometry definitions.

Need Useful.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified (via ASCII files, no need of interfaces to Fortran).

UR 19-10. GEANT4 shall be able to process events in parallel.

Need Useful.
Priority Implemented.
Stability Evolving.
Source RD44.
Clarity Clear.
Verifiability Verified (using TOP-C communication layer based on AMPIC).

UR 19-11. User interfaces shall be based on the GUI framework and the native compiler together with dynamic linking whenever a language support is necessary.

Need Useful.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 19-12. The user shall be able to define a parameterisation for: a) particle entering in a volume; b) particle travelling inside a volume.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 19-13. The user shall be able to define a parameterisation that: a) kills the primary particle; b) puts the primary particle outside the volume; c) produces secondaries and puts them outside the volume.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 19-14. The user shall be able to perform neutron radiation background simulations based on: a) standard published data sets; b) applying event biasing techniques.

Need Essential.
Priority Completed. Further extensions within ESA joint project.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 19-15. The user shall be able to apply event biasing and sampling techniques, by specifying particle and geometry dependent importances

Need Essential.
Priority Implemented.
Stability Subject to change.
Source ESA joint project.
Clarity Clear.
Verifiability Verified.

UR 19-16. The user shall be able to apply event biasing, by specifying different production cuts according to geometrical regions of the detector setup.

Need Essential.
Priority Designed.
Stability Stable.
Source CMS experiment.
Clarity Clear.
Verifiability To be verified.

UR 19-17. The user shall be able to apply leading particle biasing filters.

Need Useful.
Priority To be addressed in 2003.
Stability Stable.
Source ESA joint project.
Clarity Clear.
Verifiability To be verified.

3.2.9 Platforms

UR 20-1. The GEANT4 toolkit shall be available on at least the most commonly used HEP computing platforms, which today means: major UNIX engines (Solaris), Linux systems and Windows PCs.

Need Essential.
Priority Completed.
Stability Subject to change.
Source RD44.
Clarity Clear.
Verifiability Continuous verification.

3.2.10 Language constraints

UR 21-1. GEANT4 shall provide a standard procedure to interface relevant GEANT3 user modules written in a language other than C++ (FORTRAN77, FORTRAN90) to the detector simulator constructed by the GEANT4 toolkit.

Need Relevant only for the case of UR 19-8, obsolete for the rest.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

3.2.11 Bug-reporting constraints

UR 22-1 The user shall be able to report bugs and provide feedback by means of a well-defined bug reporting procedure.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified (Problem Reporting System in production since 1999).

3.2.12 Physics Transparency

UR 23-1. The user shall be able to determine easily and, when necessary, modify the data and assumptions used in the simulation of the physics processes.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 23-2. The GEANT4 physics (and every other component) should be independent from the systems of units chosen by the user.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Continuous verification.

UR 23-3. GEANT4 will provide at least the same physics processes as available in GEANT3 with comparable quality or better.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

UR 23-4. GEANT4 will provide low energy extensions of electromagnetic interactions, down to the order of hundreds eV.

Need Essential.
Priority Implemented.
Stability Stable.
Source ESA joint project.
Clarity Clear.
Verifiability Verified.

UR 23-5. GEANT4 will provide low energy extensions of electromagnetic interactions, down to the order of the eV.

Need Potentially useful.
Priority Feasibility under evaluation.
Stability Stable.
Source ESA joint project.
Clarity Clear.
Verifiability To be verified.

3.2.13 Program speed

UR 24-1. In its final product form, the GEANT4 execution speed shall be comparable to, or better than, GEANT3 for a comparable simulation task.

Need Useful.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear, but can evolve.
Verifiability Continuous verification.

3.2.14 Version release

UR 25-1. Versions of the GEANT4 system shall be released according to a systematic procedure, with strict version control.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

3.2.15 Object libraries

UR 26-1. The GEANT4 systems shall use OO industrial object libraries that are or can be made available to HEP institutes at reasonable terms.

Need Essential.
Priority Completed.
Stability Stable.
Source RD44.
Clarity Clear.
Verifiability Verified.

4 List of User Requirements