Experiences of the Geant4 Collaboration

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Preamble

The development of Geant4 (RD44) started in 1994 and the international Geant4 Collaboration was formed in December 1998 at the time of the first production-ready release of Geant4. Since then, the Geant4 Collaboration has taken responsibility for further development, maintenance and user support of the Geant4 simulation toolkit. The Geant4 Collaboration is one example of an international collaboration that aims at producing open source software of general usage with a user community far larger than the collaboration itself. We note here our experiences of the Geant4 Collaboration, as we believe sharing them would be beneficial for building the proposed *HEP Software Foundation*.

How the Geant4 Collaboration was launched

In the late 1980s, there were several spontaneous independent research activities for the new generation of HEP software targeting the SSC and LHC, some of which addressed detector simulation. They met from time to time at conferences and other occasions and exchanged results, findings and even future plans, which resulted in the launch of RD44 in 1994. It should be noted that these pilot projects of more than five years had strongly influenced the approach to be adopted by RD44, making us confident in the choice of programming language, tools, methodologies, etc. Without such exploratory pilot projects, we would not have been able to jump-start the development of Geant4. In addition, periodical reviews during the RD44 phase helped a lot in shaping the scope and the structure of the Geant4 Collaboration.

Since the beginning of the development we aimed for a general purpose toolkit, with the immediate targets of the LHC experiments as energy frontier experiments, and BaBar as a luminosity frontier experiment. We also collected requirements from space engineering and medical communities. We note here that many of such requirements and new ideas from these communities were quite meaningful and beneficial for simulations in HEP experiments as well. Four years from the start of RD44, we made, on schedule, the first production-ready release, which BaBar immediately adopted and used to start their simulation production in early 2000. It must be stressed that, during the four years of RD44, we were helped very much by the BaBar experiment, which had already decided to use OO/C++. We had many discussions and iterations with BaBar developers (in particular the BaBar simulation framework developers and database system developers). These synchronized developments with BaBar had fundamentally helped Geant4 to come to reality, stressing in particular the reliability and integration aspects. We believe such concurrent development with HEP experiment users, or users in general, is an essential part of the development of a software tool of general usage.

At around the time of the first public release of Geant4 version 1.0 in December 1998, ATLAS, CMS and LHCb launched internal projects to shift their simulation engines to Geant4. Key Geant4 developers had direct involvement in these experiments and contributed to this process. Such direct involvement was one of the key ingredients in the rapid widespread of the use of Geant4. Also, extensive user support, including tutorials, was and continues to be an essential part of the rapid spread of Geant4.

Another key factor in the rapid adoption of Geant4 by many users was its nature as a toolkit that complied with the standards for all aspects of software development such as technology, programming language, methodology and development model. Given it is a flexible toolkit based on object-oriented technology, experiments with different software frameworks could adapt and tailor Geant4 quite easily and efficiently. A Monte Carlo package for detector simulation is mostly used and even tailored by physicists. Thus easily customizable flexibility and robustness against misuse must coexist. We believe Geant4 has offered these characteristics since its early versions. Together with the toolkit nature of Geant4, its open source distribution allowed advanced users to extend the functionalities of the toolkit, and sometimes fed us back their extensions.

How the Collaboration handled evolutions of Geant4

Since the first production-ready release, Geant4 has experienced several major architectural revisions. While the interests and expertise of individual developers made possible many extensions to the Geant4 toolkit, major architectural evolutions were driven by users' demands. Users' demands were captured through various regular communication channels and analyzed, and then major architectural revisions were planned and coordinated among the developers.

Yet another aspect which became important once Geant4 started to be used in production, was the way we handled its evolution, or in other words, the stability of its major APIs. We paid extra attention to the portability of users' software to newer versions by ensuring as much as possible the stability of the interfaces and physics results. We have made several major architecture revisions since our first public release and introduced lots of new functionality. Still, the cost of user code migration for each major release was kept minimal. For example, while the recent major release of Geant4 version 10.0 introduced multithreading capability, a user could start making use of all of its new or improved features, except multithreading, without code migration. Adoption of multithreading could be then achieved at minimal cost.

Several factors contributed to make above evolutions possible, which are worth to be underlined here. The early effort of having a well-defined architecture helped in the modularity of the toolkit components, and in identifying the long-lasting stable interfaces. A strongly typed language like C++ was also precious. On the other hand, the need for developers' long-lived deep involvements and understanding of the toolkit and/or underlying physics could not be overcome by any modern computing technologies. Enabling such long-term stable commitment of developers is essential aspect as well.

How the Geant4 Collaboration is organized

One reason why the Geant4 Collaboration attracted many additional developers was its organizational style. The Collaboration has members of large national or international laboratories who are tasked to work for Geant4, as well as members of universities (or even companies) who contribute to Geant4 as part of their voluntary research activities. The Collaboration is driven by a bottom-up collaborative spirit that encourages individual or small group of individuals from all around the world on a voluntary basis. We note that this model makes it possible also for retired people to continue as active members of the Collaboration, making it benefiting from their expertise. This works in balance with the contributions of large laboratories, which make it possible to undertake the heavy but critical tasks of testing, validation, etc., as well as the hosting of computing resources.

The Geant4 Collaboration is governed by the Steering Board, which consists of working group coordinators elected by respective working group members. The Geant4 Collaboration currently has 17 working groups, each of which is responsible for a well-defined software component (e.g. hadronic physics, geometry, visualization, etc.) or task (e.g. documentation, testing and quality assurance, etc.). The Steering Board is the place to coordinate developments affecting more than one component, and to manage/arrange collaboration-wide issues (e.g. release procedures, overall validations, coding guidelines, publications, etc.). This democratic structure contributes much to the collaboration spirit, and helps, by seeking as much as possible for consensus, to define long term solutions. In the same spirit, the Steering Board is chaired by the Spokesperson, who is elected by the Collaboration members.

The Steering Board (and all collaboration activities in general) is monitored by the Oversight Board, which is composed of representatives from major resource providers. The Steering Board regularly reports to the Oversight Board, and the Oversight Board conducts external reviews. Major resource providers (major laboratories and funding agencies) signed the Collaboration Agreement, which is the constitution of the Collaboration and defines the basic structure of the Collaboration. In so doing, they commit stable resources (manpower and/or other forms) to the Collaboration.

References

- Geant4 Collaboration home page
  http://geant4.cern.ch/
- Geant4 Collaboration Agreement
  https://geant4.cern.ch/collaboration/agreement/geant4-agreement-2005.pdf