Construction of an Object-Oriented Interface to an Enhanced EGS Monte Carlo Code

CRADA No.: SLAC 127

Research Partnerships & Technology Commercialization

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CRADA Final Report   **Date   November 14, 2018**

PI   Walter R. Nelson

CRADA No. SLAC 127

1.   Parties:
       Quantum Research Services (QRS) and Stanford Linear Accelerator Center (SLAC)

2.   Title of the Project:
       Construction of an Object-Oriented Interface to an Enhanced EGS Monte Carlo Code

3.   Summary of the specific research and project accomplishments:
       The version of SLAC's EGS Code System (known as EGS4) was clearly recognized throughout the world as a "gold standard" for solving physics and engineering problems related to the transport of electrons and photons in any element, compound, or mixture. However, EGS4 was written in a computer language called Mortran3 and the learning curve for this rather obscure language was difficult and steep. One major objective of this project was to convert the EGS4 Mortran3 coding into Fortran77, making it much simpler for first-time users to understand and appreciate. In addition, since the introduction of EGS4 in 1985, a number of enhancements in electron-photon transport, as well as a growing need for additional physics processes, had been developed, and the new code (called EGS5) would incorporate more than 20 of these improvements. Of course, many key benchmark simulations had to be made during its development in order to prove that EGS5 was just as credible as its predecessor, EGS4. All of the above was tasked to SLAC, with outside support coming from colleagues at the University of Michigan (Nuclear Engineering Department) and at the High Energy Accelerator Research Organization (KEK) in Japan.

       The second major objective of this CRADA was to create a completely new way of setting up and running problems using EGS5. This task was assigned to QRS, whose objectives were to
       a)   create a Visual User Interface (VUI)*,
       b)   using a modern object-oriented language (i.e., C++),
       c)   that will be very "user friendly" as an input-output tool,
       d)   for defining simple, as well as complex, geometries, and for
       e)   monitoring and plotting results during each simulation.

       * Also called a Graphic User Interface (GUI) or, using today's computer nomenclature, an "application" (or App).

Meeting the goals listed above, SLAC and QRS went forward to produce two work products at the completion of this CRADA project---a new EGS5 Code System and a Virtual User Interface (VUI) to facilitate the running of the code.

[Note: Unfortunately, a lightning storm occurred near the headquarters of QRS in North Carolina, which destroyed most of the VUI code on their computer, hard drive, and back-up system. After a lot of effort by both QRS and SLAC, nothing useful was recovered. As a result, only the new EGS5 Code System can be reported as deliverable.]

4. Deliverables:

Deliverables Achieved	Party (SLAC, Participant, Both)	Delivered to Other Party?
EGS5 Code System, including more than 20 physics and other enhancements.	SLAC (with University of Michigan and KEK)	yes
A significant speed-up in running relative to EGS4.	SLAC (with University of Michigan and KEK)	yes
EGS5 was completely benchmark-tested	SLAC	yes

5. Identify publications or presentations at conferences directly related to the CRADA:

a) Y. Namito, H. Hirayama, A. Bielajew, S. Wilderman and W. R. Nelson, "Outline of EGS5", presented at the ANS 2006 Winter Meeting, Albuquerque, NM (15 November 2006).
b) H. Hirayama, Y. Namito, A. Bielajew, S. Wilderman and W. R. Nelson "The EGS5 Code System", SLAC-R-730 (December 2005).
c) W. R. Nelson, J. C. Liu, H. Hirayama, Y. Namito, A. Bielajew and S. Wilderman, "Benchmark Calculations for EGS5", presented at the Third International Workshop on EGS held at KEK, Tsukuba, Japan (4-6 August 2004) [SLAC-PUB-10752 (2004)].
d) A. M. Yacout, W. L. Dunn, W. R. Nelson, P. Lui, A. F. Bielajew, H. Hirayama and Y. Namito, "Status of the Object-oriented EGS Interface Project", presented at the Second International Workshop on EGS4 held at KEK, Tsukuba, Japan (8-10 August 2000).
e) A. M. Yacout, W. L. Dunn, W. R. Nelson, P. Lui, H. Hirayama and A. Bielajew, "An Object-Oriented Interface to the EGS Monte Carlo Code: Toward GS5+VUI1", presented at the Industrial Radiation and Radioisotope Measurement Applications (IRRMA) International Meeting, held in Rayleigh, NC (October 1999).
f) A. F. Bielajew, H. Hirayama, Y. Namito and W. R. Nelson, "The Physics of EGS5", presented at the Industrial Radiation and Radioisotope Measurement Applications (IRRMA) International Meeting, held in Rayleigh, NC (October 1999).

6. <u>List of Subject Inventions and software developed under the CRADA</u>:
   A major (441 page) SLAC Report was published:

   > H. Hirayama, Y. Namito, A. Bielajew, S. Wilderman and W. R. Nelson "The EGS5 Code System", SLAC-R-730 (December 2005)

   A portion of this report, which gets included with every distribution of EGS5, contains a User Manual with Tutorials.

7. <u>A final abstract suitable for public release</u>:
   The EGS5 Code System was released in 2005 and documented as a SLAC Report (SLAC-R-730). The entire source code and documentation can be obtained, free of charge, from the EGS Web Site: http://rcwww.kek.jp/research/egs/

8. <u>Benefits to DOE, SLAC, Participant and/or the U.S. economy</u>:
   The development and understanding of many <u>detector systems in high-energy physics</u> have relied on versions of EGS ever since introduction of the first EGS Code System (EGS3) in 1978. EGS4 was used in the design of the Mark II detector at the SPEAR storage ring, which produced new physics leading to two Nobel Prizes for SLAC. Shortly thereafter, virtually every high-energy laboratory around the world relied on EGS in the design of their detectors. During that same time period <u>hadronic cascade</u> programs were also being developed (e.g., Geant and FLUKA), and initially they relied on the coupling of EGS for the transport of electrons and photons.

   Starting around 1985, when EGS4 came out, the use of the code went viral in the field of <u>medical physics</u>. Literally multiple hundreds of papers related to radiotherapy treatment of humans have resulted [see W. R. Nelson and A. Bielajew, *EGS - A Technology Spinoff to Medicine*, SLAC Beam Line 21(1) (1991) 7]. This work continues today with the EGS5 Code System.

9. <u>Financial Contributions to the CRADA</u>:

DOE Funding to SLAC	$160,000
Participant Funding to SLAC	$ 10,000
Participant In-Kind Contribution Value	$590,000
Total of all Contributions	$760,000