The Consortium for Verification Technology Model for University and National Laboratory Collaboration

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Abstract
The Consortium for Verification Technology (CVT) is a multi-institution, multi-disciplinary effort aimed at developing new technologies for nuclear treaty verification while training the next-generation of professionals in this area. The CVT's success relies on strong university and national laboratory collaborations. This paper presents some of the highlights of our activities to date, with particular emphasis on our model for university and national laboratory collaboration.

1. Introduction
Since the discovery of fission, nuclear chain reactions, and nuclear weapons, preventing the spread of nuclear weapons has become a top priority for our nation and the world. Several international treaties have been designed, negotiated, and entered into force to curb the expansion of nuclear capabilities. Nevertheless, there are states that may be pursuing elements of an overt or covert nuclear weapons program. New science and technology developments are needed to verify the existing or proposed treaties in this area and to ensure that nuclear weapons are never used again.

The CVT is a five-year project established in 2014 through an open competition by the National Nuclear Security Administration (Department of Energy). The winning proposal, led by the University of Michigan, established the CVT, a consortium of 12 universities and nine national laboratories working together on the development of new technologies for nuclear treaty verification and training for the next generation of nuclear scientists and engineers. The 12 university members of the CVT are: the University of Michigan (UM), Massachusetts Institute of Technology (MIT), Princeton University, Columbia University, North Carolina State University (NCSU), University of Hawaii (UH), Duke University, University of Wisconsin (UW), University of Florida (UF), Oregon State University (OSU), Yale University, and University of Illinois at Urbana-Champaign (UIUC). The university participants are executing research projects in collaboration with the DOE national laboratories, including: Brookhaven National Laboratory (BNL), Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), Sandia National Laboratory (SNL), Idaho National Laboratory (INL), Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), Lawrence Berkeley National Laboratory (LBNL), and Princeton Plasma Physics Laboratory (PPPL). Figure 1 shows the map of our collaborating institutions.

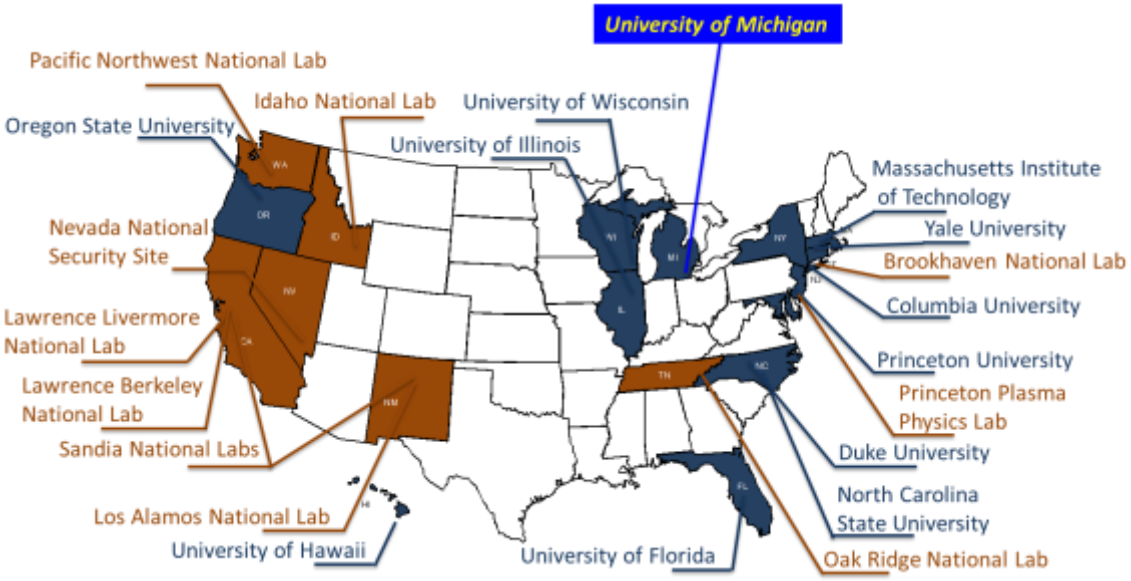


Figure 1. Map of the Consortium for Verification Technology University and Laboratory Collaborators

2. Research and Development

The CVT is organized into six thrust areas: (i) treaty verification: characterizing existing gaps and emerging challenges, (ii) fundamental data and techniques, (iii) advanced safeguards tools for accessible facilities, (iv) detection of undeclared activities and inaccessible facilities, (v) disarmament verification, and (vi) education and outreach. In each of these areas, graduate and undergraduate students play a central role in interdisciplinary research projects led by faculty and laboratory experts in the consortium. Research projects are conducted by universities in conjunction with the partnering national laboratories. Direct student involvement is an integral component of the CVT research effort.

Figure 2 shows a schematic diagram of the thrust areas, their interaction, and the expected project outcomes.

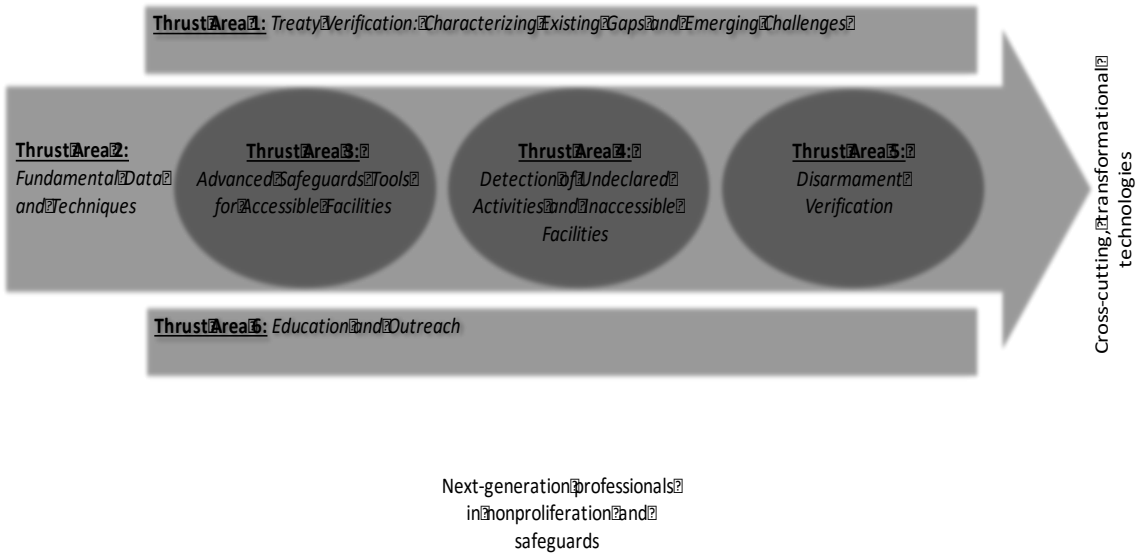


Figure 2. Consortium for Verification Technology Thrust Areas, their interaction, and expected outcomes.

3. Expected Outcomes and Project Highlights

The CVT is educating the next-generation of professionals in nonproliferation and safeguards, with strong ties to the national laboratories. The CVT is also delivering transformational technologies to address the open challenges in treaty verification.

For example, in Thrust Area 3, Advanced Safeguards Tools for Accessible Facilities, CVT researchers are developing tools for the detection and characterization of highly enriched uranium and weapons-grade plutonium. We conducted the first university-led experiments with Category-I special nuclear material at the Device Assembly Facility at the Nevada National Security Site. These experiments included imaging using a room temperature gamma ray imaging detector and a dual particle (neutron and gamma ray) imager. We are in the process of coordinating with the national laboratories, industrial partners, and the International Atomic Energy Agency (IAEA) to transition our technology development to the field. Figure 3 shows a CVT student testing a tool developed within our data visualization projects. The technology developed in these projects allows users to visualize a nuclear facility, interact virtually with facility operators and inspectors, and see 3D radiation images in real-time.

Figure 3. CVT student Matthew Marcath tests the virtual reality environment for nuclear facility verification.

4. Academic Courses

Several new courses were developed or significantly enhanced since the CVT's inception. *Nuclear Safeguards,* taught at the University of Michigan's Department of Nuclear Engineering and Radiological Sciences in collaboration with Oak Ridge National Laboratory, and *Unmaking the Bomb,* taught at Princeton University, are two examples of such courses. *Nuclear Safeguards* is a three-credit graduate-level course that covers the tools and techniques for nuclear safeguards treaty verification. The course includes weekly lectures and a one-week practicum held at ORNL. During the practicum, the students obtain hands-on experience using the tools and techniques used by safeguards inspectors. Experiments include neutron multiplicity measurements on fissile samples and hold-up measurements on nuclear materials inside pipes and valves. *Unmaking the Bomb* is a course that covers the science and technology underlying existing and emerging nuclear security issues. The first part of this course introduces the principles of nuclear fission and nuclear weapons (and their effects); the second part develops the concepts required to model and analyze nuclear systems. Finally, applications such as nuclear forensic analysis, nuclear archaeology, and nuclear warhead verification are explored.

For the first time, in 2017, the University of Michigan Department of Nuclear Engineering and Radiological Sciences offered a course taught entirely by national laboratory scientists: Paul Rockett (LLNL) and Lorraine Sadler (SNL) taught a course on the technical and policy aspects of nuclear weapons dismantlement, including a historical overview of Arms Controls Treaties.

5. Student Internships at the National Laboratories

CVT students participate in research internships at the national laboratories. Figure 4 shows photographs of CVT students on recent internships. These internships provide valuable training and research opportunities for the students and are frequently executed in close collaboration with the students' academic advisors. The duration of the internships varies for each student but can be as long as one or two years when the students prepare their thesis work at the laboratory.

Figure 4. Consortium for Verification students during their internships at the National Laboratories.

6. National Laboratory Scientist Fellowship

In 2015, the CVT established the National Laboratory Scientist Fellowship. These competitively-awarded fellowships enable scientists at the national laboratories to travel to CVT universities to strengthen collaborations or establish new ones. The scientists typically spend one or two weeks on campus giving seminars, teaching courses, and serving on dissertation committees. To date, the CVT has awarded 13 fellowships to scientists from the following national laboratories: PNNL, LLNL, LANL, LBNL, BNL, and SNL. The university hosts included: Princeton University, Duke University, Columbia University, MIT, University of Wisconsin, University of Hawaii, and University of Michigan.

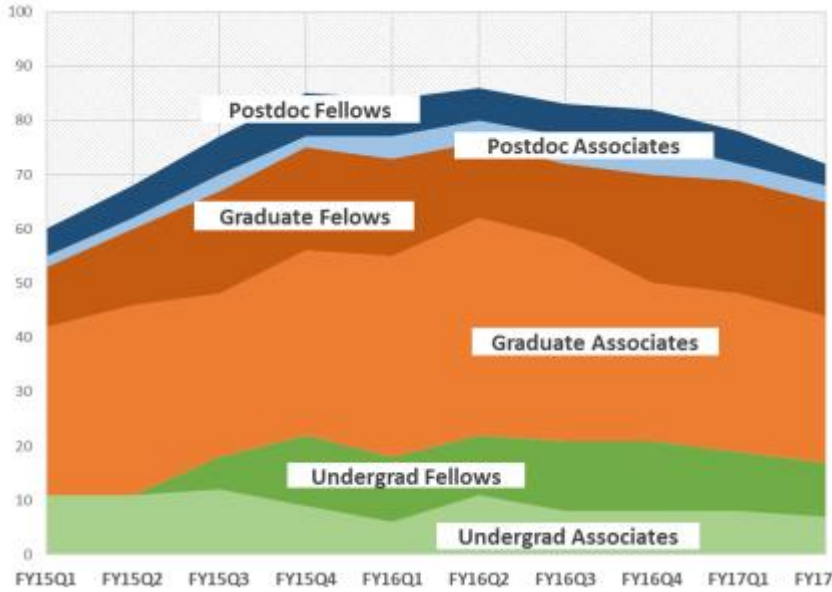
7. Outreach

The CVT community is committed to outreach to underrepresented segments of the student body. We work with middle-school and high-school students to introduce them to the science and technology of nuclear science. Figure 5 shows photographs from one of these activities where, for example, students built ionization chambers and worked with other types of detectors in our introduction to nuclear science.

Figure 5. Photographs from CVT outreach activities, introducing elementary and middle school students to nuclear science.

8. Student Output

We are nearing the end of the third year of the CVT project. Figure 6 shows the number of students involved with the CVT over the course of the project. Student fellows are fully funded by the CVT, associates are partly funded (i.e. the bulk of their funding comes from other sources such as external fellowships). A total of 60 to 86 students and postdoctoral fellows have been engaged with the CVT in a given quarter.



	FY15Q1	FY15Q2	FY15Q3	FY15Q4	FY16Q1	FY16Q2	FY16Q3	FY16Q4	FY17Q1	FY17Q2
Postdoc Fellows	5	6	7	8	7	6	6	6	6	4
Postdoc Associates	2	2	3	2	4	4	5	6	3	3
Graduate Felows	11	14	19	19	18	15	15	21	22	22
Graduate Associates	31	35	30	34	37	40	39	31	31	29
Undergrad Fellows	0	0	6	13	12	10	12	12	10	9
Undergrad Associates	11	11	12	9	6	11	8	8	8	7
Subtotals	60	68	77	85	84	86	85	84	80	74

Figure 6. Consortium for Verification Technology student involvement at the undergraduate, graduate, and postdoctoral level.

Figure 7 shows the cumulative number of undergraduate, graduate, and post-doctoral students who have graduated from our program as a function of quarter since the program's inception. To date, we have 45 graduates, and we expect to have at least 80 graduates by the end of the project.

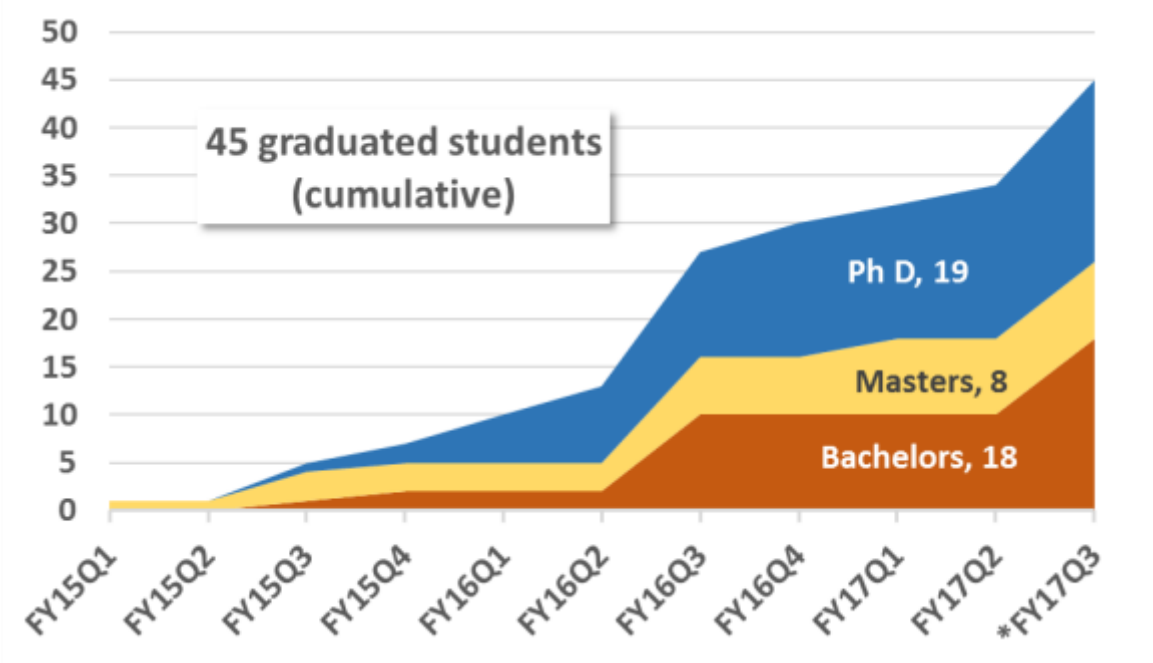


Figure 7. Consortium for Verification Technology graduated students at the undergraduate, graduate, and postdoctoral level.

Figure 8 shows the career trajectory of one of our students as an example of the CVT student advancement model. The figure shows the education, interaction with the national laboratories, involvement of the student with the CVT, and final student placement at a national laboratory.

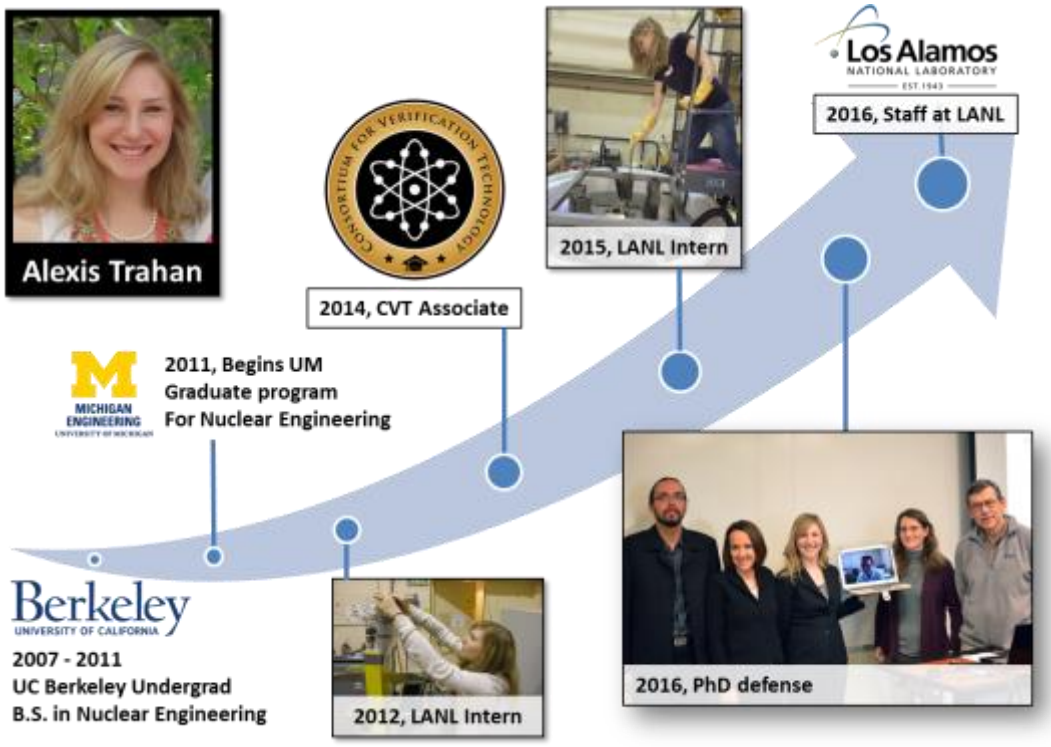


Figure 8. Sample CVT student advancement model: timeline and milestones.

9. Research Output

The CVT universities and national laboratories are at the forefront of research in the areas of interest. The CVT's output to date (September 2014 to June 2017) includes 109 peer-reviewed journal publications, 84 invited talks, and 267 conference presentations. Further details on our research output can be found on our website: https://cvt.engin.umich.edu.

10. Conclusions

The CVT and national laboratory collaboration model has proven to be very effective. The effort has impacted over 200 students and faculty, so far. The positive outcomes of our consortium in the first three years are expected to continue and be expanded for years to come.

11. Acknowledgments

The work of all CVT members — university and national laboratory participants — is gratefully acknowledged. Figures 6, 7, and 8 are a result of the efforts from the entire CVT leadership team, including Dr. Shaun Clarke, Dr. Angela Di Fulvio, and Mr. John Rodriquez. The Consortium for Verification Technology is funded by the Department of Energy National Nuclear Security Administration award number DE-NA0002534.

12. References

1. A. Glaser, Z. Mian, S. H. Mousavian, and F. von Hippel, "Building on the Iran Deal: Steps Toward a Middle Eastern Nuclear-Weapon-Free Zone," Arms Control Today, December 2015
2. R.S. Kemp, A. Danagoulian, R.R. Macdonald, J.R. Vavrek, "Physical Cryptographic Verification of Nuclear Warheads," Proceedings of the National Academy of Sciences, vol. 113 no. 31 (2016), doi:10.1073/pnas.1603916113
3. A. Glaser, B. Barak, and R. Goldston, "A Zero-knowledge Protocol for Nuclear Warhead Verification," Nature, 510, June 2014, pp. 497–502.
4. Paul G. Richards, "The History and Outlook for Seismic Monitoring of Nuclear Explosions in the Context of the Comprehensive Nuclear Test Ban Treaty", The Nonproliferation Review, 23: 3–4, pp 287–300,
5. M. Monterial, P. Marleau, M. Paff, S. Clarke, S. Pozzi, "Multiplication and Presence of Shielding Material from Time-Correlated Pulse-Height Measurements of Subcritical Plutonium Assemblies", Nuclear Instruments and Methods in Physics Research Section A, vol. 851, pp. 50-56, 2017. (http://dx.doi.org/10.1016/j.nima.2017.01.040)
6. "Variations in AmLi source spectra and their estimation utilizing the 5 Ring Multiplicity Counter", R. Weinmann-Smith, D.H. Beddingfield, A. Enqvist, M.T. Swinhoe, Nuclear Instruments and Methods A 856 (2017) pp 17–25.
7. M. Streicher, S. Brown, Y. Zhu, D. Goodman, and Z. He. "Special Nuclear Material Characterization using Digital 3-D Position Sensitive CdZnTe Detectors and High Purity Germanium Spectometers." IEEE TNS 2016, vol. 63, pp. 2649-2656, id 2593631.
8. M. Schoeppner and A. Glaser, "Present and Future Potential of Krypton-85 for the Detection of Clandestine Reprocessing Plants for Treaty Verification," Journal of Environmental Radioactivity, 162-163, 2016: 300–309.
9. Di Fulvio, T. H. Shin, T. Jordan, C. Sosa, M. L. Ruch, S. D. Clarke, D. Chichester, S. A. Pozzi, "Fast Neutron Multiplicity Counter for the Assay of Plutonium Metal Plates", Nuclear Instruments and Methods in Physics Research Section A, vol. 855, pp. 92-101, 2017.
10. M. Monterial, P. Marleau, S. Pozzi, "Single-View 3D Reconstruction of Correlated Gamma-Neutron Sources" submitted to IEEE Transactions on Nuclear Science (TNS) on July 1, 2016; Accepted on 12-21-2016. (http://dx.doi.org/10.1109/TNS.2017.2647952)