Technical Evaluation Report

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ABSTRACT

Live-fire training ranges are an essential element for our nations' ability to develop and maintain a capable fighting force. To ensure that our ranges are capable of accommodating realistic live-fire training, restricted operations or even closure must be avoided. Sustainability of operations requires knowledge and practices that address and anticipate threats to operational flexibility. The purpose of AVT-RSM-335 was to bring experts from throughout NATO and out allies to share in knowledge on range management, risk assessment, range design, and look into the future at challenges range managers may encounter.

Sixteen papers from four countries were presented to an audience averaging over 60 people from up to 15 countries. The papers were informative, presenting new or updated material relevant to the theme of range sustainability. The papers were data-heavy, with well defined results. The venue, a WebEx virtual conference, constrained interaction among the attendees but limited outside distractions. The eleven time zones spanned by the audience was challenging for some attendees.

Summarizing the meeting is difficult due to the wide range of topics covered. The takeaway, though, was clear: To achieve sustainability of training ranges, a broad-based knowledge of range inputs, activities, weapon systems, and military operations is necessary. Training components can no longer be evaluated individually. Rather, each activity must be examined from a multitude of perspectives to ensure minimal impact to and maximum sustainability of our irreplaceable range assets.

1.0 INTRODUCTION

Militaries must be prepared for warfare in whatever form it may take. This requires training that resembles anticipated warfare conditions as closely as possible. For land-based forces, live-fire training must be conducted on open ranges, areas that are often both environmentally sensitive and proximate to habitation. To ensure continued access to training lands and a fully prepared military, live-fire training ranges must be designed, maintained, and operated in a sustainable manner.

The NATO Science and Technology Organization, through the Applied Vehicle Technology panel of the Collaboration Support Office, has sponsored a significant series of activities related to munitions, munition constituents, and sustainable range issues. These include Research Task Groups (RTG), Research Symposiums (RSY), Research Specialists Meetings (RSM), Collaborative Demonstrations of Technology

(CDTs), and a Specialists Team (ST) activity, the ST conducted in conjunction with the NATO Environmental Protection Working Group (EPWG). These activities have served several critical functions, including developing an awareness of the environmental impacts of range activities; dissemination of current knowledge and practices in the fields of risk assessment, range design and management, sustainability of ranges and range operations; and training in reproducible sampling of ranges for contaminants of concern (CoCs). The latter activity, AVT-ST-007, will result in the publication of a new NATO Standardized Agreement on range sampling and sample processing. Table 1 presents some of the relevant AVT-sponsored activities and their reports, if applicable.

Table 1: NATO CSO AVT Activities Leading Up to AVT-335.

Activity	Activity Title	Year	NATO Publication
AVT-RSY-115	Environmental Impact of Munitions and Propellant Disposal		RTO-TR-AVT-115
AVT-RSY-177	Munition and Propellant Disposal and its Impact on the Environment	2011	RTO-MP-AVT-177
AVT-RTG-197	Munitions Related Contamination – Source Characterization, Fate, and Transport	2015	STO-TR-AVT-197
AVT-RSM-244	Munitions Related Contamination	2015	STO-MP-AVT-244
AVT-RTG-249	Munitions Related Contamination – Range Characterization (CDT)	2016 2018	STO-TM-AVT-249
AVT-RTG-291	Range Design and Management for Reduced Environmental Impact	2020	
AVT-ST-007	Modification of NATO STANAGS to Incorporate Range Characterization	2022	

The next logical step following AVT-291 was deemed to be a Specialists Meeting with the theme of range design and management for sustainable live-fire training activities. The purpose of the meeting was to update NATO members and facilitate the exchange of information on the current state of the art in range sustainment practices. The scope of the meeting was limited to land-based ranges, including small arms and large calibre weapon systems. AVT-RSM-335 was approved in 2019 with a target symposium date of May 2020. Because of the COVID-19 pandemic, the meeting was postponed twice and ultimately held virtually in April 2021.

2.0 EVALUATION

Military live-fire training range sustainability is a relatively recent concept. With the advent of a general awareness of environmental impacts of human activities in the 1970s, the militaries of Europe and North America began to realize that to continue use of training ranges, environmental sustainability needed to be considered. In the United States, two major events occurred in the 1980s to hammer that fact home: the contamination of the Cape Cod water supply as a result of fuels and munitions constituents from the Massachusetts Military Reservation (MMR) and the massive waterfowl die-offs from white phosphorus contamination at the Eagle River Flats (ERF) impact area on Fort Richardson, Alaska. The MMR situation has cost billions of dollars US in clean-up and restoration and resulted in severe restrictions on the use of the facility. At ERF, the cost of remediation was in the tens of millions of dollars (US), with live-firing into the range now restricted to winter only. Battlefield and range clean-up costs in Europe, especially since the fall of the Soviet Union, are also significant. We now realize that without proper monitoring and care, we can lose our training ranges, a critical and irreplaceable resource.

The Specialists Meeting was formulated around four basic themes: Range Management, Risk Assessment, Range Design, and Future Challenges. All of these themes have been covered in the past by the various

activities listed in Table 1, but the state of the art is constantly progressing, helped immensely by these past activities. Periodic "refreshers" are necessary to bring concerned nations up to speed, evaluate research and implementation, and refocus efforts in areas of need. The four themes listed above were deemed by the technical team for the specialists meeting to be the areas most in need of coverage.

2.1 Keynote Address

The specialists meeting started with a very enlightening keynote address by Canadian BG Richard Giguére (Ret). I felt that GEN Giguére's address was an excellent introduction to the RSM, so I will summarize it here. GEN Giguére started his presentation pointing out that the environment is at the top of the list of concerns for training on Canadian range and training areas (RTAs). He stated that environmentally sustainable operations on ranges is critical as, like for most countries, live-fire ranges are no longer being developed. He then spoke about the past, present, and future of environmentally-sustainable training.

In the past, range operations were driven by the Cold War, a battle of military power and political influence. With a focus on "Armageddon warfare", full war training was required. There was little concern if any for the environment. In the 80s, with the fall of the Soviet Union, there was a slow shift large-scale warfare towards security, which can take many forms, from border security to health security, as we are seeing with the current pandemic. With the realization that irreplaceable ranges could be lost, considerations for the environment arose. By the 1990s, environmental impacts of training and environmental stewardship of RTAs became an important factor for the Canadian military. A new era had evolved.

Currently, the environment is a key component for Canadian RTA managers. It factors into the assessment of RTA operations, maintenance, and design. The key element from GEN Giguére's perspective is the environmental sustainability of RTAs. The Canadian emphasis on sustainability can be seen in the Canadian military's hosting of this seminar and the number of papers presented by Canadian researches. And sustainability necessarily focusses on the future.

The future is always a mystery, although the need for physical training will always be with us. There are new paradigms for warfare involving artificial intelligence, robotics, and even non-kinetic warfare. Asymmetric warfare now holds sway (Afghanistan), with large land battles seeming to be a thing of the past. But don't count out large-scale warfare: The invasion of Iraq was not that long ago. Multiple paths lie ahead – We must choose the best one for our future, while keeping all options open. "Training is essential for all forms of warfare."

2.2 Technical Sessions

Each session will be discussed separately and then discussed as part of the comprehensive meeting. This will allow more focused analysis of the session subject, how the papers relate to each other, and allow interrelated conclusions. Overall conclusions that can be drawn from the meeting and recommended further action (future themes) will be presented in the next section.

2.2.1 Session 1: Range Management

Session 1 addresses the question, "What are our current practices and trajectories?" There is overlap between this session and Session 2: Risk Assessment, with Session 1 more focussed on implementation of current solutions to established environmental problems. The five papers covered a broad range of subjects, highlighting what works and, just as important, what does not work.

In the past, environmental problems did not manifest themselves until contaminants of concern or physical impacts crossed the boundary of a military facility. In the US, the attitude was, "If it is on (or in) the range, it is not contamination." The problem with this interpretation is that by the time the "contamination" reached

an off-site receptor, the cost of correction, containment, or remediation is enormous. This is certainly the case for contaminants in surface and groundwater, which are difficult to even characterize because they are moving targets and, in the case of groundwater, neither visible nor easily detectable. Another shifting factor that needs to be considered is the changing boundaries of impact areas, firing points, safety zones, and buffer zones, which in the past helped isolate the effects of training on the adjoining populated civilian geographical area.

The narrowing of the distance between military training areas is caused by two phenomena: encroachment and expansion of ranges. Encroachment occurs when development creeps closer and closer to the range, dissolving the buffer zone that in the past helped attenuate impacts such as smoke, dust, and, especially, noise generated during live-fire training exercises. As one paper noted, solutions have been developed to attenuate noise, some physical and some logistical, but encroachment continues and the costs of firing point noise attenuation continue to grow, the result, in part, of larger, more powerful weapon systems (Wassim). Which brings up the issue of the need for larger ranges.

The effective ranges of indirect fire weapon systems are now pushing the capacity of many legacy ranges. Missile systems have ranges in many tens of kilometres, and even standard artillery systems, such as the 155-mm howitzer, now have significantly larger ranges, enabled by the use of base-bleed booster systems in the projectiles. The result? More of the ranges must now be utilized to enable training with these munitions, causing shifting of firing points, or training with more of these extended-range systems will be conducted on the few ranges with the capacity to handle the range. Both factors will exacerbate noise issues, smoke and dust problems, and may result in shorter distances between ranges and facility borders, diminishing the time natural attenuation can occur on migrating contaminants.

On many RTAs and test ranges with active environmental and range sustainability programs, migration and impacts of metals in ground and surface wates are being monitored. Two papers discussed mid- to long-term monitoring program results for dissolved and suspended metals (Krogstie et al., Laing et al.). Long-term monitoring is important for two reasons: It gives the facility a database upon which it can demonstrate compliance with environmental regulations or address emerging contamination issues and it allows data smoothing, putting an occasional small contaminant spike in prospective, thus avoiding unnecessary clean-up actions. Both programs have evolved with our increased knowledge of the effects of metal-based CoCs. Benthic and aquatic organisms, especially insect larvae, are being monitored as contaminant receptors / indicator species to evaluate environmental impacts. As GEN Giguére noted in his keynote address, range sustainment programs are a new and evolving phenomenon.

The development of remediation and mitigation methods are also evolving. This is being driven by three factors: Our increased knowledge of the impacts of munitions constituents, development of new energetic formulations, and changing clean-up action limits, often driven by increasing resolution of analytical instrumentation, which tends to drive action limits down. Biodegradation is preferred remediation method for in-situ treatment of contaminated soils. Many biodegradation methods work quite well in lab and even large bench-scale demonstrations, but problems arise in field applications. Papers by both Juck et al. and S. Brochu and Gagnon demonstrate this phenomenon, albeit for different reasons. For Juck, the variability of the environment demonstrated that particular care must be taken to tailor the application of an amendment (waste glycol) to a contaminated area to ensure that it will work properly. S. Brochu's allocation study pointed out that variability of the levels of contamination over a broad area will make the application of some amendments impractical, as the amount of amendment to be applied over the range will need to be enormous if it is based on the area of highest concentration or the cost of characterizing a range on a fine enough scale to reduce the volume of amendment over the total treatment area will be prohibitive.

This session was quite useful in demonstrating how to effectively implement sustainability programs on contaminated or problematic training ranges. As we gain knowledge through the implementation of remediation methods and monitoring methodologies, the cost and effectiveness of mitigation and

remediation will fall and thus the ability to sustain ranges will increase.

2.2.2 Session 2: Risk Assessment

Session 2 addresses the question, "Do we have a problem?" This may seem self-evident, but in the evolving field of environmental stewardship of RTAs, it is not an easy question to answer. The complexity of ecological and geological systems, seasonal and long-term environmental changes, and evolving munitions all contribute to the difficulty in developing a meaningful risk assessment (RA). We touched on this in the previous section, but with risk assessments, we need to dig deeper. Even the basic methodologies of water and soil characterization are changing, as noted in this session and the work being done by NATO AVT-ST-007 on developing a STANAG on sampling and sample processing for soils. Canada is perhaps the leader in the development of comprehensive range risk assessments, using the latest methodologies for soils and waters and incorporating a thorough list of possible CoCs. The importance of the topic of this session cannot be understated: Without a comprehensive, thorough, and **reproducible** risk assessment, there is no foundation upon which to base a range sustainability program. A bad assessment will result in the inability to correctly answer the question posed above.

Migration of contaminants by water transport is the most problematic risk to range sustainability. Drinking water standards are very low, in the parts per billion (ppb) range for several energetics constituents in propellants and explosives. Water also acts as the primary transport mechanism in the soil column, affecting organisms in the vadose zone. Transport to groundwater will usually result in wide contaminant dispersal and migration off-range. And with ever-falling action levels for groundwater contaminants, costly remediation and treatment methods will need to be implemented, with the possibility of the loss of the range.

Both the papers from Faucher and Aaneby & Johnsen describe risk assessments of water and soil contaminated with metals. Faucher's paper gives the reader a thorough roadmap of how an RA is conducted in Canada and what background regulatory information is needed before even starting. Those nations developing RA protocols would be wise to consult with Canada, the US, or several of the European nations on existing human health and ecological health standards. Aaneby and Johnsen's paper is interesting in describing the complexities of conducting a risk assessment for metals on ranges. For Pb, the factors affecting bioavailability are many, including particle size fraction, charge fraction of the lead ions, total organic content of the soils, the size of the compounds formed by lead in the soil, and the stability of these complexes. Even the age of the indicator species, earthworms, was a factor. There are no overarching standards that can adequately cover all the variables encountered in even the most basic segment of an RA at this time. Again, we have an evolving art.

The papers by Johnsen and D. Brochu et al. are more focussed assessments of risks. Johnsen's paper looks at metal uptake by grazing sheep on an open impact area. D. Brochu et al. concentrate on possible risk from the introduction of new explosives compounds in munitions. Both papers are quite useful in demonstrating how answers to specific questions on risks can be achieved.

Open ranges are common in many European countries, where land resources are limited and RTAs are utilized for other non-military purposes when training activities are not being conducted. In Johnsen's risk assessment, specific munitions constituents are addressed (metals) for a known receptor (grazing livestock). A focussed assessment such as this is quite informative to the range manager and outside user alike and will result in an action decision that can be backed up by hard (empirical) data, if done correctly.

In D. Brochu's paper, the aim of the risk assessment is to determine the deposition mass of energetic compounds following blow-in-place (BIP) disposal of insensitive munitions (IM). Introduction of new munitions to ranges can result in new CoCs with very different characteristics from conventional munitions, as Brochu points out. Disposal of IM is particularly problematic, as the energetic formulations are designed not to initiate from external stimuli. Brochu conducted an RA on a novel BIP procedure using a shaped

charge. Using a risk matrix developed to evaluate munitions impacts based on use and empirical post-detonation energetics deposition rates, Brochu's team was able to determine that for a given yearly number of BIP operations on the tested round, no restrictions were required for training with this round.

The papers in this session demonstrate the usefulness, the necessity in some cases, of conducting risk assessments. As the scope of the RA narrows, from a large multi- function, multi-range facility to a single operation on a munition, the complexity decreases and the results become more applied. All the Ras described in this session are necessary, and all the RAs are utilized for the same overarching function: the enhancement of range sustainability. It is interesting to note that each assessment type can be plugged into the assessment describe in the previous paper, demonstrating the interrelationship of the papers as well as the RA process.

2.2.3 Session 3: Range Design

Session 3 addresses the question, "Do we have solutions?" The answer to this question is, "Yes, a few." This session is perhaps the most significant in that much of the work conducted under the munitions thrust of the AVT is directed at coming up with solutions to existing and anticipated problems on training ranges. The effectiveness of solutions in the past was often determined qualitatively. With the advancement of assessment tools, a better understanding of ecological processes, and the ability to characterize the impacts of various training activities, design solutions for ecological risks are now both more effective and can be evaluated quantitatively.

All three papers in this session concentrated on the prevention of the migration of groundwater contamination from munitions constituents (metals and energetics). It is interesting that the three papers describe different systems, all effective for their specific situations. In Keiser & Morgenthaler's paper, the design solution was capture of potentially contaminated water that has infiltrated a backstop for small arms ranges. In Bolstadt et al., the solution was to alter the hydrology of an environmentally-sensitive small arms range on peat to enable the treatment of metals contamination at a downstream site using local materials as a reactive layer. Faucher et al. devised a reactive barrier system for use under open burn / open detonation ranges, potentially the most contaminated site of any range on an active (and inactive) military facility.

All the papers in this session also noted the typical constraints involved in new technology: Cost, effectiveness, and impact. Effectiveness can be measured in the effluent downstream of the final treatment site. It is interesting to note that, for all three options, provisions have been made for the collection of samples to monitor the long-term effectiveness of the installation. Impact indicates how the installation affects the environment. In sensitive areas, such as the peat bog on which the small arms range is located in Bolstadt's paper, great care must be taken to reduce the footprint and impact on the very slow-growing, sensitive peat. Cost is a factor in the complexity, size, and difficulty in installing the system and is greatly influence by both the environment and targeted effectiveness for the system.

The three systems described in this session have either been installed or are scheduled for installation in the near future. As with all new technology, the systems will be monitored following installation. The complexity of the environment and geological variability, as mentioned previously, has affected prototype system installations and will need to be an important design consideration in future installations where local soils and water characteristics (e.g. pH, TOC, etc) may influence performance. Again, we are dealing with the new field of range sustainability, and progress, though slow now, should increase thanks to these pioneers.

2.2.4 Session 4: Future Challenges

Session 3 addresses the question, "What challenges lie around the next bend?" Based on the papers for this session, the answer may be insensitive munitions (IM), specifically PAX-48, which three of the four papers

cover. This may be due to the fact that these three papers are all from Canada and were funded by the same organization. The fourth paper comprehensively addresses reduced-range ammunition, an emerging field of small arms training munitions manufactured by a company for which the author works. A wider range of subjects in this session would have been beneficial.

The papers by Martel et al., Monteil-Rivera et al., and Fillion et al. cover a comprehensive array of studies and tests into the environmental fate PAX-48 and its energetic constituents as well as some related insensitive high explosives (IHEs) and their constituents, primarily 2,4-dinitroanisole (DNAN), 3-nitro-1,2,4-triazol-5-one (NTO), nitroguanidine (NQ), and in Montiel-Riveras' paper, two FOX formulations, FOX-7 and FOX-12. One key feature is that the IHE formulations were examined *in toto* rather than just examining the constituent IHE compounds. This is important with explosives because of the varying dissolution rates of the constituents and the effect of the explosive matrix on dissolution. Grinding of PAX-48 in soil, as was done in one study, may mask this variable dissolution phenomenon. This background work is essential before bringing new munitions into inventory in order to prevent unintended environmental consequences, as what happened with the IHE PAX-21.

Degradation of the IHE compounds was examined for several mechanisms. These included sorption to soils, photodegradation, and biodegradation. The papers found that NTO and NQ are highly soluble and sorption or retardation will not be a factor in soil retention of the compounds. The rapidity of transport will greatly reduce these compounds' exposure to sunlight and biodegradation, leading to unhindered high-concentration aqueous transport to groundwater. Thus, for some IHE constituents, degradation will not be a factor in environmental fate.

The final paper, by Lemay, is very interesting in that it addresses various current range use problems in a comprehensive manner. Reduced-range ammo allows the use of much shorter length ranges with existing small arms, matching ballistic properties within that limited distance. It also allows more realistic training for military operations in urban terrain, allowing the use of non-lethal bullets to increase realism (train as you fight). Special bullet traps have also been designed to capture dust and particles from the frangible copper/polymer bullets. This is significant in that it illustrates that munitions manufacturers are starting to consider environmental impacts as well as ballistic performance in their ammunition design. Post presentation discussions indicated that more research needed to be done related to the frangible copper munitions and human health, specifically heavy metal fever.

These papers all examined cutting edge advances in munitions and their effects on the environment. Solutions to potential environmental problems are proposed or inferred, indicating a more holistic approach to munitions. Standardization of pre-production environmental testing of emerging munitions needs to be developed and formalized in a document as is being done with soil sampling through the STANAG mechanism. Again, these papers relate back to the previous sessions, tying the four sessions together in a well-designed progression of topics.

3.0 Conclusions

Range sustainability is a common driver in all the papers presented in AVT-RSM-335. Sustainability considerations, though, is still in their developing stages, and very few countries have comprehensive range sustainability programs. The possibility of the loss of range assets is the key factor why many nations, and NATO in particular, are supporting information exchanges such as AVT-335. Range design and management, risk assessment tied to proposed training activities and practices, and keeping an eye on impacts related to future training needs are critical to such large-scale programs as the Connected Forces Initiative, which will require integrated multi-national training on a scale never seen before.

All four topics covered in this specialists meeting are important to range sustainment. Proper management of ranges will avoid costly environmental problems both on military facilities and beyond the fences. Risk

assessments will alert range stewards to where problems may or may not arise. New and innovative training range facility designs to address legacy, current, and anticipated needs will be needed to ensure full and continued utilization of ranges. And it is never too early to consider future factors that will likely affect what is used on ranges, how ranges will be utilized, and what will be required to expand the utilization of ranges. All these aspects of RTA sustainability need to be fully integrated into range plans to ensure optimum training opportunities for our militaries.

As the art of range management for sustainability evolves, we will find that not every proposed solution will work. This is because of the complexities of ranges: their ever-evolving use; the application of more stringent health and environmental standards; and the scale, nature, and variability of the contamination on live-fire ranges. For example, as munitions evolve, contaminants of concern expand, and potential problems need to be addressed before these problems become real. Experience among member nations is invaluable in this respect, as partner nations can avoid the costs and loss of facilities that otherwise will occur. This is why activities like this specialists meeting are important.

Risk assessments are critical to avoid downstream problems, literally and figuratively: Water contamination is a primary cause of remediation and mitigation actions for ranges. A properly conducted risk assessment will always save money, both in avoiding unnecessary remedial actions and preventing massive remediation efforts caused by widespread migration of contaminants off-base. Sometimes, small deviations in range practices will greatly decrease risk related to an operation, such as energetics dispersion form the disposal of insensitive munitions, a topic of one of the papers in the Risk Assessment session. This feeds back to the topic of range management, demonstrating the interconnectedness of four topics of this meeting.

Risk assessment will also drive range design. The ever-present ground- and surface-water transport of CoCs is a strong driver in many new range designs, as evidenced in all three of the papers in this session. As noted in one of the papers, and as I have experienced during a large-scale clean-up operation on an Alaska impact range, care must be taken to craft the solution to a problem to the ecosystem. The most effective designs for remediation and mitigation will not be the best solution should they adversely affect the ecosystem. Small-scale and self-contained treatment systems have a smaller footprint and can be tailored to the microenvironment where the problem occurs. And always look for solutions to heavily contaminated, contained ranges, such as skeet ranges (PAH contamination) and OB / OD ranges (energetics compounds). Addressing “low-hanging fruit” is an excellent way to attenuate overall contamination on ranges and is a great approach to initiating a range design for sustainability program.

What does the future hold? Guessing is not an option. We must be aware of the evolving threats both to our nations and our ranges. Tracking developments in weapon systems and munitions, integrated operations and tactics, and standards and action levels for human health and the environment will all impact how we use our ranges and what will be required to sustain them. Action is always preferable to reaction. The loss of training assets because of an inability to maintain the environmental health of ranges should no longer be tolerated. The costs in both treasure and military preparedness are just too high.

4.0 Recommendations

Where do we go from here? The CFI should be used for guidance. What will be needed to ensure the ability of member nations to train as they will fight on a scale comparable to what is projected for the future? What will be needed are large, robust, multi-function training ranges. These are very limited, irreplaceable assets critical to our nations and to NATO. The best way to support our militaries with respect to ranges is to expand and disseminate knowledge on best practices for range sustainability.

Based on my 25 years of experience with range remediation, munitions testing and evaluation, and the development of range characterization methodologies, and after reviewing all the papers and participating in

the AVT-RSM-335, I recommend the following three thrusts to the AVT:

- An RTG with a follow-on RSY on the development of a guidance document on how to set up a risk assessment program for ranges. RAs are very complex documents that, in this case, address a very complex entity: training ranges. Just determining what areas need to be address can be a daunting task. Nations developing sustainable range management practices would benefit greatly from the transfer of knowledge, practice, and experience of nations with more established range programs. Even experienced nations will benefit, as we have seen with outcomes from other AVT-sponsored activities.

- A CDT on testing of munitions for environmental impact (to include high-order and blow-in-place operations). There may also be an opportunity for a follow-on ST in conjunction with the NATO EPWG to write a STANAG on environmental testing of munitions for the quantification of residues deposition from high-order and blow-in-place disposal. Current practice is to rely on predictive models, which have proven to be woefully inadequate.

- An RTG and RSM on OB/OD and Engineering Training Ranges. These ranges tend to be the most heavily contaminated and concentrated ranges on military facilities. As such, specific solutions on a manageable scale should be able to be developed and implemented, removing the most significant CoC sources from the range contamination equation. Follow-up thrusts could be directed ar hand grenade ranges, RPG firing points, and skeet shooting ranges, other proven problem ranges.

The Applied Vehicle Technology panel has supported many activities related to munitions, ranges, and environmental sustainability. I have been involved almost since the beginning and have seen the great benefit to member nations and our allies. The opportunity to interact with experts and specialists from the many nations who have participated in these AVT activities is invaluable. It is also very rewarding to the participants. To be able to tap into a network of like-minded people, to learn what the state of the art is in other countries, to have a participant tell me that, thanks to what he or she has learned over the course of an RTG, RSM, or CDT, their country is now implementing new procedures to ensure range integrity is gratifying. I strongly recommend that AVT both encourage and support more activities to further the dissemination of information on range design and management for sustainable live-fire training ranges.

There have been several spin-off activities resulting from munitions-related activities sponsored by the AVT. TNO in The Netherlands sponsored two conferences on Human and Environmental Toxicology of Munitions-Related Compounds. The Scandinavian countries have been conducting the European Conference of Defence and the Environment semi-annually as well, providing Europe with a venue for the dissemination of progress in the field of range sustainability. Cranfield University, which hosted two very successful cooperative demonstrations of technology, now conducts range-related short courses related to the activities sponsored by the AVT.