

THE CANADIAN TRACKING AND FUSION GROUP ACROSS THE YEARS: THE 10TH ANNIVERSARY

The Canadian Tracking and Fusion Workshop (CTFG) was born in the fall of 2010. In May of that year, Garfield Mellema had hosted the two-day North Atlantic Treaty Organization (NATO) Research and Technology Organization (RTO) Sensors and Electronics Technology Panel (SET)-157 lecture series on *Multisensor Fusion: Advanced Methodology and Applications* in Halifax. The series was presented by Peter Willett, Stefano Coraluppi, Wolfgang Koch, and Roy Streit. All experts in the field and well-known to International Society of Information Fusion (ISIF) members. The meeting room was packed, with attendees from across the country. At lunch on the second day, Garfield Mellema, Jack Ding, and Bhashyam Balaji (all of whom work for Defence Research & Development Canada (DRDC)) were noting the level of interest in this field and discussing what could be done to both encourage it and to support collaboration in Canada. Jack Ding got the ball rolling with an email list, then a Google group. Soon after that, an organizing committee was formed and the CTFG Workshop series began.

The CTFG was established to bring together tracking and fusion researchers and practitioners from across government, industry, and academia with the objective of providing a forum for issues of com-

mon interest across diverse fields of application, including land, air, space, maritime, and underwater. This diversity was reflected in the composition of the initial organizing committee, which was composed of Zhen (Jack) Ding (DRDC Ottawa), Garfield Mellema (DRDC Atlantic), Pierre Valin (DRDC Valcartier), Thia Kirubarajan (McMaster University), Tony Ponsford (Raytheon Canada), and Rami Abielmona (Larus Technologies).

Discussions focused on aspects of target tracking and fusion, including sensors, signal processing, detection, tracking, low-level fusion, high-level fusion, classification, resource management, information flow, performance evaluation, fusion architectures, decision support systems, registration, software, data sets, benchmarks, and data modeling. Through the years, the discussions have been fed by stimulating keynote talks from fusion scientists, military, or Canadian research programme directors.

To mark the first decennial anniversary, we present here a review of the CTFG's activities across the ten years of its existence through the lens of the annual workshops.

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Figure 1
CTFG Workshop 2011 report, E. Blasch, IEEE A&E Systems Magazine, Jan 2012, pp. 42-43.



Figure 2
CTFG Workshop 2012 attendance, DRDC Ottawa.



Figure 4
CTFG Workshop 2014 attendance, DRDC Ottawa.

CANADIAN TRACKING AND FUSION GROUP (CTFG)
CTFG WORKSHOP 2013

HOME ORGANIZING COMMITTEE INVITED SPEAKERS PROGRAM ANNOUNCEMENT VENUE CONTACT

TECHNICAL PROGRAM

10 September 2013, DAY 1 (Technical Presentations)

08:00-08:40	Registration			
08:40-08:50	Thia Kirubarajan	Announcements	McMaster University	
08:50-09:50	Tony Ponsford	Keynote Address	Raytheon Canada	Maritime Domain Awareness
9:50-10:10	Coffee Break	Sponsor	AUG Signals	
Session: Sensors (Chair: Garfield Mellema, DRDC Atlantic)				
10:10-10:30	Jack Ding, Peter Moo and Edwin Riseborough	Presentation	DRDC Ottawa	Electronic Protection for Naval Phased Array Radar
10:30-10:50	Maria Rey	Opening Remarks	DRDC Ottawa	
10:50-11:10	Alain Gosselin*, Jack Ding* and Yongkui Wang*	Presentation	*DRDC Ottawa, *RMC	Multiple Criteria Optimization for Phased Array Radar Resource Management
11:10-11:30	Jing (Jane)* He and Qingsheng Zeng*	Presentation	*CRC, *Carleton University	Maximal Length Sequence and Perfect Sequence in UWB Radar Applications
11:30-11:50	Sutharsan Sivagnanam and Michel Pelletier	Presentation	FLIR Radar	Experimental Results and Demonstration of the R20SS Digital Beamforming Surveillance Radar
11:50-12:00	Group Picture			
12:00-13:00	Lunch: Executive Dining Room, CRC Cafeteria (not provided)			
Session: Tracking (Chair: Jack Ding, DRDC Ottawa)				
13:00-13:20	Bhashyam Balaji*, Kai Wang*, Anthony Damini*, Martie Goulding* and Kurt Hagen*	Presentation	*DRDC Ottawa, *MDA	Comparison of Filtering and Smoothing Algorithms for Airborne Radar Data
13:20-13:40	Abhijit Sinha	Presentation	AUG Signals	Robust Detection and Tracking Procedure for Weak Targets On and Near Roadways
13:40-14:00	Garfield Mellema	Presentation	DRDC Atlantic	Use of Feature Information for Improved Multistatic Sonar Tracking
14:00-14:20	Dominic Schaub	Presentation	DRDC Atlantic	Estimating Target Identity in Wide-Area Surveillance
14:20-14:40	Jack Ding and Bhashyam Balaji	Presentation	DRDC Ottawa	Comparison of the Unscented and Cubature Kalman

CTFG Homepage
English French

IMPORTANT DATES

August 15, 2013: Submission of proposals

August 20, 2013: Notification of acceptance/rejection

September 4, 2013: Submission of final presentations and workshop registration

September 10-11, 2013: CTFG 2013 Workshop

SPONSORS

IEEE Ottawa Section

ISIF

Airborne Underwater Geophysical Signals

LARUS TECHNOLOGIES

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Figure 3
Excerpt of the CTFG Workshop 2013 technical programme.

BUILDING THE COMMUNITY

The first event (CTFG Workshop 2011) took place at DRDC Ottawa at the Communications Research Centre Canada (CRC). Focusing on research areas of target tracking, radar beam scheduling, sensor management, communications, and decision support, CTFG Workshop 2011 gathered around 40 participants over three days while discussions were stimulated by invited lectures, working panels, technical sessions, and live demonstrations. Keynote talks from four invited speakers set the tone for this first CTFG workshop. Fred Daum from Raytheon Integrated Systems (IDS) US talked on the first day about industrial strength nonlinear filters. Erik Blasch from the US Air Force Research Laboratory (AFRL), visiting scientist at DRDC Valcartier at that time, presented his lecture on the second day about the performance evaluation of seismic and acoustic track and identification fusion. Pierre Valin from DRDC Valcartier detailed the issues and challenges that exist in the field of High-Level Information Fusion (HLIF), while the last lecture was provided by Tony Ponsford, Technical Director at Raytheon Canada Limited at that time, who spoke about the effective maritime domain awareness based on appropriate layered surveillance and a multilevel decision support system. The technical programme gathered more than twenty presentations over the two first days covering low-level and high-level fusion topics, such as methods for high-level information fusion including user coordination, situation awareness from a common reference, and standards to promote interoperability. Four working panels addressed topics on reasoning, decision support and user refine-



Figure 5
CTFG Workshop 2015 attendance, DRDC Ottawa.

ment, multiple target tracking, and radar resource and sensor management. Finally, three live demonstrations of tools and technologies illustrated operational implementation of some solutions: Raytheon's Digital Command Ground Station (DCGS) activities and its future extensions, Larus Technologies' Nexus Fusion Engine, and McMaster University's High Performance Multitarget Tracker and Tracking/Fusion Testbed.

A year later, the CTFG Workshop 2012 gathered about 50 participants, featuring more than thirty presentations. The first day of the workshop was focused more on the low-level fusion and tracking while the second day of the workshop addressed more high-level fusion topics, reflected in the two keynote talks from two experts from the fusion community. Yaakov Bar-Shalom from the University of Connecticut (US) explained how to get the most out of sensors through target tracking and data fusion. James Llinas from the State University of New York (US) talked about algorithmic, architectural, and employment concept challenges involved in the Hard and Soft data fusion problems. The workshop concluded with five live demonstrations from Canadian companies: McMaster University's *High Performance Multitarget Tracker and Tracking/Fusion Testbed*, FLIR Radars Canada's *Dual-Mode Perimeter Surveillance Radar Systems*, the National Research Council of Canada's *Interactive Virtual Reality Visualizations for Multi Sensor/Multi Source Information Fusion*, Larus Technologies' *Risk Management Framework*, and Thales Raytheon System's *BCS-F Tracking and Fusion in Support of NORAD Air and Maritime Missions*.

FROM TRACKING TO SITUATION AWARENESS

The CTFG Workshop 2013 was held under the theme of *Maritime Domain Awareness*, while covering classical topics such as sensors, tracking, and fusion. Tony Ponsford (Raytheon Canada), the first invited speaker, talked about the Maritime Domain Awareness and chaired a panel discussion on the same topic, in conclusion of the workshop. Two other invited speakers were Éloi Bossé from Laval University who presented the fusion of information to improve dependability in cyber-physical and social systems (CPSS), while Cdr. Rob Hudson from the Canadian



Figure 6
Andre Dupuis, presenting the Conformational Analyzer with Molecular Dynamics and Sampling (CAMDAS) program at the CTFG Workshop 2016, Ottawa.

Department of National Defence (DND) talked about the information and decision advantage within DND. During the demonstration session, Thales Canada presented the *tactical picture compilation (TPC) demonstrator tool* and *FUSEWARE*—a data/information fusion service to be used in a service-oriented architecture. TrackGen Solutions presented a *Tracking, Fusion, Resource Management and Situational Awareness Toolset* and Larus Technologies presented the *Total::Insight™ High Level Information Fusion Engine (HLIFE)*.

The CTFG Workshop 2014 continued in a two-day format driven by two major lectures providing Canadian operational perspectives. Col. Gregory D. Burt from the Canadian Forces Intelligence Group presented a keynote talk, the Canadian Forces Intelligence Command (CFINTCOM) providing a perspective on information related challenges. He presented a view from the standpoint of the end-user, which drives the value of a system while the value of information is measured by its effectiveness in achieving the end-result. In the context of defence intelligence, Col. Burt raised the question of how information fusion could provide more effective tools to shift the balance of human activities from searching to analysing. Kurt Salchert, retired captain from the Royal Canadian Navy (RCN) and part of the Beyond the Border Consulting, provided unique insight into the end user's view of information fusion in the context of naval surveillance and security. The technical programme complemented these operational views with 14 authors presenting recent research in four specific topics: source evaluation and performance, target tracking and filtering, detection and localization algorithms, and video processing and surveillance.

In 2015, after being hosted by the DRDC Ottawa for the first four years, the workshop venue moved to the Shaw Centre in downtown Ottawa. It has stayed in downtown Ottawa ever since, alternating between the Shaw Centre and the Les Suites Hotels. CTFG Workshop 2015 was cohosted with the NATO Lecture Series IST-134 *Advanced Algorithms for Effectively Fusing Hard and Soft Information*, offering participants to attend both events and exchange on synergic topics. Fifteen presentations across three ses-



Figure 7

High attendance for the presentation of Hossein Chahrour (DRDC Ottawa & Carleton University) during CTFG Workshop 2017, Ottawa.

sions focused on maritime applications for tracking and situational awareness, while still exhibiting contributions on general target tracking. A special session on space provided the opportunity for five invited speakers to present the challenges and opportunities related to the Earth Observation and the surveillance of the Canadian borders. The workshop concluded with a panel discussion on trends, gaps, and requirements in tracking and fusion.

BRIDGING THE DOMAINS

Held under the theme of *Tracking and Fusion for Intelligence Based Decision Support*, the CTFG Workshop 2016 featured

about 30 technical presentations and keynote talks. A special session was dedicated to the *All-Domain Situation Awareness (ADSA)* Canadian program, a five-year program which intended to enhance domain awareness of air, surface, and subsurface approaches to Canada's northern regions. Pierre Lavoie, Assistant Deputy Minister (ADM) (Science & Technology (S&T)) Director General Science and Technology Force Employment, introduced the ASDA program followed by Maria Rey and Andre Dupuis who shared the floor for reporting a feasibility study conducted on behalf of the Canadian Space Agency and DRDC Ottawa on the development of a concept of operations and high-level system architecture for a Canadian All-Source Maritime Domain Awareness System (CAMDAS). Finally, Jim Chan (DRDC Centre for Operational Research and Applications (CORA)) presented the ASDA Underwater Surveillance—Underwater Environment in Northern Canada, discussing aspects of submarine navigation, bathymetry in the Arctic Archipelago, and analysis of choke points where underwater surveillance could be focused, and seasonal characteristics of sea ice in the region. James Llinas (University of Buffalo) concluded this special session with a US perspective on *All Domain Situational Awareness and Information Fusion Technology—Achieving Agility*. His presentation offered a range of ideas and issues associated with developing multidomain robustness and cost-effective approaches to agile Information Fusion capabilities. James Llinas provided a second presentation entitled *Designing and Developing a Data Fusion Capability into an Internet of Things Framework* which offered some thoughts on the systems engineering approach to designing a Data Fusion (DF) process into the Internet of Things (IoT) environment.



Figure 8

Participants of CTFG Workshop 2018, Ottawa.

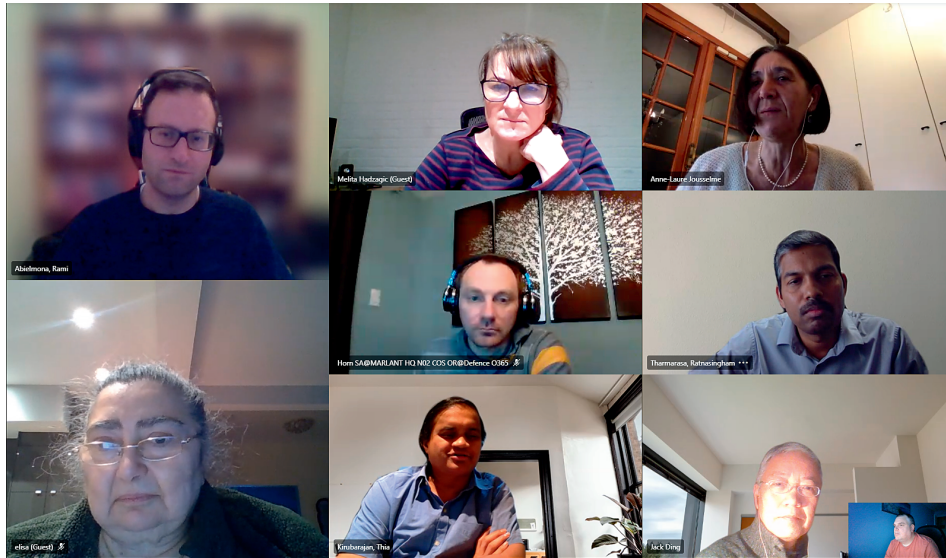


Figure 9
CTFG committee meeting after CTFG Workshop 2020+, January 2021.

He discussed using defined architectural primitives for both DF and the IoT as one basis for such designs, and addressed Middleware and Information Quality issues that will impact the realization of good designs for any DF process within an IoT environment. The second and last day hosted a special session on *human factors related to tracking and fusion enabled capabilities within Canada's fleet of CP-140 aircraft*, with a presentation from Christopher Bryan from the Canadian Armed Forces.

In 2017, the seventh annual CTFG workshop included four special talks by invited speakers and 28 regular talks divided into four tracking sessions (sensor and resource management, detection and tracking, and clutter, estimation, and fusion) and four fusion sessions (optimisation and planning, system design and concepts, and high-level fusion). Eric Fournier, Director General S&T Strategic Decision Support provided information about the Innovation for Defence Excellence and Security (IDEaS) program. The IDEaS program is an augmentative approach to accessing innovation allowing Canada's military to better tap into extraordinary talent and ingenuity resident in Canada. James Llinas (University of Buffalo) talked about the knowledge requirements for the design of distributed multisensor multitarget tracking systems. During the second day, Roy Streit from Metron presented the *Analytic combinatorics in tracking and information fusion*. Finally, the last keynote talk was provided by Mr. Srikanth, associated with the Build in Canada Innovation Program (BCIP) which is a research and development (R&D) procurement program aimed at procuring, testing, and evaluating R&D precommercialized goods and services in the late stage development.

The CTFG Committee		Chair
Rami Abielmona	Larus Technologies	2011, 2020+
Bhshyam Balaji	DRDC-Ottawa	2021
Zhen (Jack) Ding	DRDC-Ottawa	2011, 2015
Mihai Florea	Thales Canada	2016, 2017
Melita Hadzagic	OODA Technologies	2018
Steven Horn	DRDC-Atlantic	2018
Anne-Laure Joussetme	NATO STO CMRE	2014
Thia Kirubarajan	McMaster University	2011
Garfield Mellema	DRDC-Atlantic	2011, 2012
Tony Ponsford	Raytheon Canada Limited	2011, 2013, 2015
Sreeraman Rajan	Carleton University	2021
Ratnasingham Tharmarasa	McMaster University	2020+
Elisa Shahbazian	OODA Technologies	2016, 2017
Pierre Valin	DRDC-Valcartier	2011

TOWARD EMERGING TECHNOLOGIES AND NEW APPLICATION AREAS

Over two days in October 2018, with the increased number of participants (70), the CTFG Workshop 2018 continued the trend from the previous years of extending the usual workshop topics covering multitarget and video tracking, sensor fusion, resource management to the topics of high-level fusion, hard and soft data fusion, and also including the new topics addressing emerging technologies such as machine learning, deep learning, and blockchain, where the main ap-

plication domains were maritime, air, and space. The importance of emerging technologies, hard and soft data fusion, and distributed computing in current and future decision support systems were supported by the three plenary talks given by Dale Reding, Director General Science and Technology Air Force and Navy (DGSTAN), DND Canada, who discussed the main S&T trends for Canadian Armed Forces (CAF) and highlighted the significance of emerging technologies such as quantum science, nontraditional sensing, and their impact on the future of computing and digital devices (deep learning, artificial intelligence, next generation encryption, etc.), and the future of decision making. Galina Rogova, a Research Professor at the State University of New York at Buffalo presented the challenges and computational approaches for higher level fusion and situation management while Chee-Yee Chong provided an overview of forty years of distributed filtering. CTFG Workshop 2018 held in Ottawa also presented a good networking opportunity for the 2019 edition of the International Conference on Information Fusion (FUSION 2019) which was to also be held in Ottawa, Canada, and created a perfect forum for the FUSION 2019 organizing committee to discuss the upcoming conference in person.

Indeed, since the FUSION 2019 conference was held in Canada (Ottawa), the CTFG organizing committee decided to encourage participation in this international event and chose not to hold a CTFG workshop in 2019.

In 2020, due to the COVID-19 pandemic, the CTFG Workshop 2020+ was held in January 2021 using an online format for the first time, with a record attendance of 100 participants. The workshop focused on Tracking and Data, Information and Knowledge Fusion for a New Era, and was divided in four half-day presentations instead of two full days. Two invited speakers talked about the link between artificial intelligence/machine learning and data fusion (Erik Blasch, AFRL) and about the IDEaS Program, two years after the beginning of this program which provides funding mechanisms to assist Canadian innovators in solving defence and security

challenges (Eric Fournier, Director General Innovation for DND Canada). Thirty-four presentations covered classical topics of video tracking, multitarget tracking, signal processing, sensor fusion, high level fusion, resource management, but also COVID-19 prediction, satellite scheduling, machine learning, as well as biomedical engineering.

Over the 10 years of the CTFG's existence, the Canadian Tracking and Fusion research community has matured as the result of the connectivity and visibility into the advanced data/information fusion solutions supporting the decision making in a multitude of domains in Canada and internationally provided by the CTFG. The CTFG community has also grown, involving new researchers and practitioners from across government (e.g., DRDC agency), industry (e.g., Larus, OODA Technologies, TrackGen), and academia (e.g., Universities of Ottawa, Carleton, McMaster, and Dalhousie), involved in research on new state of the art topics, supporting the requirements of applications of interest to governmental organizations, as well as medical, environmental, financial, and other domains. Since its birth, the CTFG maintains a close relationship with the ISIF experts outside Canada who stimulate fruitful discussions and ideas, within the rooms, during the coffee breaks, and during dinners. We would like to thank Yaakov Bar-Shalom, Erik Blasch, Chee-Yee Chong, Fred Daum, James Llinas, Galina Rogova, and Roy Streit for their enthusiastic participation and support over the years.

The growth of the tracking and fusion research community in Canada has been possible thanks to the ongoing support of the International Society of Information Fusion (ISIF) to the CTFG Workshop series. The IEEE Ottawa Section, and its Computer and Computational Intelligence Chapters, have also been great supporters of the CTFG Workshop over the years. CTFG Workshop 2021 is planned to be held in December in Ottawa.

Information about past and future activities of the CTFG can be found at www.ctfg.ca. Presentations are available upon request.