International Command and Control Institute

**26th ICCRTS**

International Command and Control Research and Technology Symposium
18-22 and 25-29 October 2021 - Virtual

**CALL FOR PAPERS**

For up-to-date information and registration, go to: [http://internationalc2institute.org/26th-iccrts-information-central](http://internationalc2institute.org/26th-iccrts-information-central)

Artificial Intelligence, Automation and Autonomy:
C2 Implications, Opportunities and Challenges
History of the ICCRTS

In 1995, the US DoD Command and Control Research Program (CCRP), within the Office of the Secretary of Defense, organized the first International Command and Control Research and Technology Symposium (ICCRTS) at the National Defense University in Washington, DC. This meeting was built upon a series of meetings organized during the 1970s by the Office of Naval Research and the Massachusetts Institute of Technology that brought together interested researchers to exchange ideas on command and control (C2), its measurement and assessment, and the impact of new technologies on C2 processes. The 1995 event was also arguably a follow-on to a similar international event held at Eynsham Hall, Oxford UK in 1994, on C2 and Information Systems Research. This event was supported by both the UK Defence Research Agency and the US Joint Directors of Laboratories.

While the initial ICCRTS meeting was modest in size and included only a handful of non-U.S. participants, the event has grown substantially over the years to include participants from many nations. This Symposium series provides an unparalleled opportunity for professional researchers, academics, active duty and reserve officers, and policymakers to interact with one another to discuss future challenges and concepts, understand the current state of the art, and influence future thinking and practice across coalition partners.

ICCRTS has evolved to include (a) leading-edge concepts in C2, (b) new science and technology and their potential impact on C2 and the conduct of Multi-Domain Operations, and (c) feedback and evidence from experiments, exercises, and real-world operations. The Symposium is also an important forum for discussion of coalition and collective C2 issues and for examining the challenges emerging from complex endeavours (e.g., hybrid warfare, counter-terrorism, stabilization operations, disaster relief) that involve a variety of entities including military, civilian, government, international organizations, Private Voluntary Organizations (PVOs) and Non-Governmental Organizations (NGOs).

In 2015, a real test of the value of this activity emerged when Government funds were no longer available to cover the costs of organizing and administering the Symposium. The challenge to the C2 Research Community was to find a way for this event to survive as an independent activity. Ultimately, it would require the combined efforts of the international research community to ensure that its annual Symposium and the body of literature associated with the CCRP would endure without direct Government funding. The fact that this did indeed happen provides evidence of the importance of this resource and opportunity to the community. In 2016, the non-profit International Command and Control Institute (IC2I) assumed responsibility for the organization and running of future ICCRTS and hosting the research community’s website and research archives. This website can be found at http://internationalc2institute.org

The 26th ICCRTS will, due to the COVID-19 uncertainties be a Virtual event with the same format as was used for the 25th ICCRTS. The 27th ICCRTS planned for 2022, to be hosted in Quebec City by Defence Research and Development Canada (DRDC) and Université Laval’s Big Data Research Center, will find the event back in Canada for the third time.
The 26th ICCRTS Theme:
Artificial Intelligence, Automation and Autonomy
C2 Implications, Opportunities and Challenges

ICCRTS themes, over the years, have served to highlight many C2-related problems and challenges that require attention. The theme for this 26th ICCRTS is Artificial Intelligence, Automation and Autonomy: Implications, Opportunities and Challenges. In recent years, C2 processes, tasks and environments have evolved to contend with increasingly complex endeavours, requiring automation-powered systems that, to varying degrees, can perceive, infer, decide or act autonomously and intelligently to create an information dominance and decision superiority. It is anticipated that the recent and significant advances in many technological areas, such as machine learning, data science, and computer systems, will accelerate this trend to create both greater effectiveness and efficiency. From a C2 perspective, this reality enables unprecedented access to extended C2 approach space regions, creating the need to consider what (when and how) decision rights can be delegated to these intelligent systems to enable a C2 advantage. The various implications of this delegation, such as the trust that can be placed in those systems, and the data and information they provide, will also need to be considered. The 26th ICCRTS plenaries and track sessions are intended to offer the participants a venue to discuss these opportunities and challenges. This edition of the Symposium will focus on the following topics and the related ideas, concepts, problems and solutions:

1. Complex enterprise C2- harmonization
2. Operating in a Contested Cyber Environment
3. Coping with constraints, complexity and ambiguity
4. C2 and human-AI/autonomy teaming
5. Emerging concepts and technologies, and their implications for C2
6. Connected battlespaces and forces
7. Experimentation, analysis, assessment and metrics
8. Military C2 applications, requirements, concepts and solutions
9. Other C2-related research and analysis

Contributors and attendees are reminded that ICCRTS is a public forum. Papers, presentations, and discussions must be suitable for general public release.

Topics of Interest

ICCRTS seeks to encourage and publish professional journal-quality papers, reporting on research and analysis activities related to C2. Thus, the 26th ICCRTS event will be partly comprised of presentational tracks exploring the Symposium's central theme from several different perspectives. Authors are requested to consider these perspectives as they prepare their papers. It is recognized that these topics are not mutually exclusive, and hence papers may simultaneously address more than one of them. Therefore, those papers will be assigned by the committee mostly based on their primary focus, but the authors' assistance in identifying the most relevant track is welcome. The above are proposals, with the eventual symposium tracks being developed based on the number and actual content of the papers received. In addition to the specific topics detailed below, submissions contributing to a critical examination of C2-related subjects are always welcome.
Initial paper abstracts are invited on the following topics:

**Topic 1: Complex Enterprise C2-Harmonization**

Modern operations increasingly require collective and coordinated actions across multiple dimensions: (a) multi-domain (the traditional physical domains of warfare of air/land/sea with those of information, space, cyberspace, economic and social), (b) multi-level (strategic, operational, tactical), and (c) multi-partner (e.g., nations, Partners Across Government [PAGs], civilian government, and Non-Governmental Organizations [NGOs]). This reality imposes on the (heterogeneous) participating organizations/entities to optimize, in addition to their internal C2, management, and governance processes, the interaction and harmonization mechanisms with their inter-dependent mission partners. Note that the requirement for such Multi-Domain Operations (MDO) is not new. It has been discussed, at least, since the 1st ICCRTS, through previous concepts such as Effect-Based Operations (EBO), Whole of Government (WoG) and Coalition and Joint Interagency Multinational (CJIM). Authors are invited to submit papers that explore and discuss requirements, concepts and solutions that enable more effective conduct of various missions involving a heterogeneous set of partners through the planning, coordination and delivery of both kinetic and non-kinetic effects within and across multiple domains. Exemplar topics include:

- Identification and characterization of the implications (e.g., requirements, gaps, solutions) for C2-harmonization for complex endeavours (e.g., MDO).
- Interoperability and effective exchange of information among (human and non-human) partners.
- Integration, coordination and collaboration in a multi-domain context.
- Development and sustainment of trust in complex endeavours (e.g., MDO).
- Automation and collaboration support technologies for complex endeavours.
- Management and governance of C2 as a holistic capability.
- Lessons learned regarding assumed good practice for working across domains and organizations.

**Topic 2: C2 in Contested Cyber Environments**

Contested cyber environments are now the norm. They have the potential to render the preferred approach to C2, management, governance and harmonization less effective, even inappropriate for the mission at hand. Authors are invited to submit papers that explore and discuss the challenges related to operating in these environments and their implications for how individual entities and organizations manage themselves and their interactions with each other. Exemplar topics include the impact of contested cyber environments on:

- The appropriateness of selected C2-harmonization approaches.
- The cyber risk to mission.
- The exploitation of automation, AI, and autonomous systems.
- Development of shared awareness.
- Requirement to harmonization C2 in physical and cyber spaces.
Topic 3: Coping with constraints, complexity and ambiguity

Conflicts and crises (e.g., COVID-19) are characterized by high and continually increasing complexity, unpredictability, interconnectedness, dynamics and nonlinearity. Operations and activities in such situations are also conducted simultaneously by multiple actors (adversarial, supporting and neutral) and across multiple domains. High interconnectedness, combined with the diversity of systems and actors, will lead to increased ambiguity and unpredictable outcomes. Challenges related to these constraints include, but are not limited to: (a) the understanding and management of battlespaces; (b) the conduct of C2 in environments prone to deception and disinformation; (c) the conduct of C2 in constrained environments (e.g., C2 in Degraded or Denied Environments [C2D2E]); (d) the conduct of C2 in remote, harsh and inaccessible environments (e.g., the Arctic); and (e) C2 for management of major crises and emergencies (e.g., COVID-19). Concepts and requirements related to these challenges include, but are not limited to: (a) preparedness and insurance of business continuity; (b) adaptation, agility, resilience and self-healing; (c) command on the move and remote/mobile command posts; (d) remote leadership and remote operations.

Authors are invited to submit papers that explore and discuss requirements, concepts and solutions that enable coping with the constraints, complexity and ambiguity during C2 operations, as mentioned above. Exemplar topics include:

- Characterization of the nature of modern multi-faceted conflicts and crises, prediction of their evolution, and assessment of their impact on C2.
- Identification and characterization of the impact of constraints, complexity, and ambiguity on organizations’ ability to conduct activities and operations.
- Development and assessment of effective strategies, techniques and solutions to mitigate the effect of constraints, complexity and ambiguity on activities and operations.
- Lessons learned regarding know or potential good practices for working under constraints, complexity and ambiguity.

Topic 4: C2 and human-AI/autonomy teaming

C2 is a prime example of a socio-technical system, i.e., a system with technological and human (both individual and organizational) components using complex and sometimes unpredictable interaction patterns. There is a need for effective C2 solutions/systems that combine the strengths of each class of components to create a synergistic whole. This requirement gives rise to many significant challenges that have arguably not been fully addressed yet. The capabilities, capacity, and sophistication of the technological components have continued to develop apace, most latterly with the re-emergence of Artificial Intelligence and the recent breakthroughs in machine learning. Thanks to this progress, automation-powered technological components have become increasingly intelligent, dictating a paradigm shift and a change in their roles within socio-technical systems: from mere support tools to team members or even commanders. This change is expected to have significant psychological, social and organizational impacts. The progress made on the technological side has also paradoxically brought additional challenges to the already complex task of developing C2 systems involving interacting human and non-human components. One of the most significant of these challenges concerns the allocation and management of decision rights within and among mixed teams and resulting accountability. Authors are invited to submit papers that explore and
discuss requirements, concepts, and solutions that enable the exploitation of socio-technical systems to support C2 and operations conduct. Exemplar topics include:

- Cognitive and socio-technical challenges.
- Human-Artificial Intelligence/autonomy teams.
- Mixed-initiative approaches for situation analysis and decision making.
- Human-System and Human-Information Interaction: How humans interact with automation-powered systems and their information to improve C2. Interaction encompasses mechanisms for querying / searching, visualization, comprehension, sharing, and exploitation of information across multiple modalities (visual, auditory, somatosensory) in real, virtual, and augmented/mixed reality environments.
- Ethical, legal (e.g., military legislation, international legislation) and social perspectives in socio-technical systems (including AI-powered systems and solutions).
- Ethics, responsibility, explainability, and trust considerations in human-AI/autonomy teams.

**Topic 5: Emerging concepts and technologies, and their implications for C2**

Several concepts and technologies, key for C2, have come to maturity or have witnessed significant developments in recent years. Breakthroughs in many areas, such as *machine learning, data science* and *computer systems*, enabled a substantial increase in the capabilities, capacity, and sophistication of the technological components and gave, or have the potential to give, unprecedented access to new regions of the C2 approach space. Authors are invited to submit papers that explore and discuss the full range of emerging concepts and technologies and discuss their actual and potential applications to C2 and the implications (on doctrine, tactics, techniques, training, etc.) of these applications. Exemplar topics include:

- Artificial intelligence-powered command decision support.
- Highly-automated and autonomous systems, including robotic/unmanned systems.
- Machine reasoning and decision making (under uncertainty).
- Intelligent agents – Multi-agent systems.
- Natural language processing.
- Data science – Big data – Data mining – Knowledge discovery.
- Data and information fusion.
- System architecture
- Quantum computing.
- Virtual reality – Augmented reality – Mixed reality.
- Intelligent virtual assistants – Intelligent tutoring systems – Chatbots.
- Game theory.
- Digital transformation.
**Topic 6: Connected battlespaces and forces**

Highly automated forces and heavily connected battlespaces will become the norm and profoundly change C2 and operations conduct. This reality is enabled by the fast progress made in developing ubiquitous networked sensors, effectors, embedded automation, fully autonomous systems, and augmented humans. This topic covers operational and technical issues and challenges related to operating in highly connected environments (e.g., Internet of Everything [Pepole, Data, Processes, Things]) and the use of highly automated forces and their implications on the state-of-the-art and practice of C2. Authors are invited to submit papers that explore and discuss requirements, concepts and solutions that enable C2 and the conduct of operations for highly automated and connected forces. Exemplar topics include:

- Connected / Augmented soldiers.
- Internet of Things (IoT) – Internet of Everything (IoE).
- Intermittent / non-persistent connectivity.
- Communication technology – 5G connectivity.
- Combat cloud – Cloud computing – Serverless computing.
- Cyber-security challenges
- Blockchain.

**Topic 7: Experimentation, analysis, assessment and metrics**

Developing effective and practical means of experimenting, analyzing and evaluating current and proposed future C2 capability has been challenging. This topic covers the design, conduct, and analysis of experiments related to any aspect of C2, including management or governance, interoperability, information sharing, trust, shared awareness, shared understanding, decision making, collaboration, planning, coordination execution, and assessment of operations. Authors are invited to submit papers that explore and discuss requirements, concepts, tools, methodologies, results, and lessons learned related to experimentation and field trials. Exemplar topics include:

- Experimentation methodologies and plans
- Experimentation tools, environments, and setups
- Scenarios
- Metrics and measures of merit
- Analysis of results
- Lessons learned

**Topic 8: Military C2 applications, requirements, concepts and solutions**

Although it remains essential for all kinds of organizations and all kinds of situations, C2 has always retained a military connotation, probably because C2 takes its most explicit and least ambiguous form within military organizations, particularly in warfare contexts. Authors are invited to submit papers that explore and discuss requirements, concepts, applications, solutions and lessons learned related to military C2. Exemplar topics include:

- Problem characterization
- Requirement definition and specification
• Scenarios, trials and exercises
• Measures of Merit
• Capability development challenges
• Concepts of employments (CONEMP) and Concepts of Operations (CONOPS)
• Prototypes and proofs of concepts
• Human dimension considerations

Topic 9: Other C2-related research and analysis

As in previous editions, the 26th ICCRTS will welcome contributions that do not fit neatly in any of the above topics. These contributions may be related to one or a combination of the following long-standing, cross-cutting themes:

• C2 concepts, theory, policy, methodology and approaches
• Theoretical propositions and insights
• Models: Conceptual, analytic and computational
• Observations and reflections based on current practices
• Longitudinal studies and historical analyses

The Symposium, Program, and Track Chairs will assign contributions to appropriate reviewers.

Submission, Review and Acceptance Process

Please note: All submissions will be reviewed and feedback provided on an ongoing basis. Early submissions are encouraged.

Thank you for your interest in contributing to the 26th ICCRTS. If accepted and presented at the 26th ICCRTS, your paper will be posted on the member-only webpages of the C2 and Cyber Research portal of the International C2 Institute (www.internationalc2institute.org), where ICCRTS archives can also be found. Note: All ICCRTS attendees are provided with a one-year membership in IC2I.

Submission Platform

As in previous years, ICCRTS will continue to use the online service EasyChair to manage all submissions. Therefore, authors who do not have an EasyChair account need first to create a free EasyChair account. They will be then directed to the paper submissions page.

Instructions for sign up to EasyChair and submission abstracts can be found on the IC2I site (www.internationalc2institute.org) by going to the 26th ICCRTS Information Central. If you have any problems, please contact us at info@internationalc2institute.org. The link to the 26th ICCRTS (2021) section of EasyChair is:

https://easychair.org/conferences/?conf=26thiccrtts
Paper Types

The 26th ICCRTS welcomes two different types of paper.

- **Technical paper**: For example, reporting on initial or mid-term findings or conclusions of ongoing research activities.
- **Concept paper**: Discussion of a new idea, insight or conjecture, which is a potential topic for future research and has little or no supporting evidence at this stage.

Key Dates

Key dates are the same for both Technical and Concept Papers. Please try to avoid waiting until the last possible day to submit. Early submissions are encouraged and will receive early feedback.

* Last date to submit paper abstracts – **16 April 2021**
* Feedback on abstracts – 14 May 2021 or before
* Last date to submit full papers – **25 June 2021**
* Feedback and decision on submissions – 31 July 2021 or before
* Last date for final submissions – **7 August 2021**
* Decisions (if not provided previously) – 5 September 2021 or before
* Last date to submit presentations – **1 October 2021**

Review Criteria

Abstract Acceptance Criteria

The following criteria will be used by track chairs, peer reviewers, and symposium staff in their review process:

- The abstract's content is sufficiently aligned with the general theme or at least one of the topics of the Symposium.
- The abstract is specific enough to understand the research effort that will result in a paper.
- The proposed research promises to result in a paper that satisfies the acceptance criteria (see below).

Technical Paper Acceptance Criteria

The following criteria will be used by track chairs, peer reviewers, and symposium staff in their review process:

- The paper is sufficiently aligned with the theme and one or more topics of the Symposium.
- The paper is intellectually stimulating.
- The literature review is adequate/appropriate.
- The research design is adequate/appropriate.
- The data analysis is adequate/appropriate.
- The conclusions are reasonable and follow from any evidence provided.
• The paper advances the state of knowledge for C2.
• The paper is logical and consistent.
• The paper’s argument is persuasive.
• The writing is clear and readable.

Concept Paper Acceptance Criteria

The following criteria will be used by track chairs, peer reviewers, and symposium staff in their review process:

• The paper is of the appropriate type, i.e., clearly putting forward a new idea or concept, and is no more than seven pages in length.
• The paper is sufficiently aligned with the theme and one or more topics of the Symposium.
• The paper is intellectually stimulating.
• The arguments are reasonable.
• The writing is clear and readable.

Technical or Concepts Papers will not be accepted if:

• Topics stray from the conceptual focus of the Symposium.
• Attempts are made to promote or sell specific goods or services.
• Claims are unsubstantiated, or facts are inaccurate.
• Scientific merit is lacking.
• Writing and explanations are inadequate.

Submission Process

All paper submissions require the submission of an abstract.

• **Step 1:** Identify the main topic of your paper. If it does not fit neatly into one of the topics of the Call for Papers, pick the topic that you feel is the best fit.

• **Step 2:** Provide information about all authors (affiliations and complete addresses) and identify the corresponding author we will use as the contact point for all correspondence.

• **Step 3:** The title and abstract of your paper should be entered as plain text, and three keywords for the abstract must be provided. Abstracts should be no longer than 250 words.

• **Step 4:** If you want to submit the full paper early, you can upload it via the "Uploads" section of the EasyChair website.

• **Step 5:** If, after a review of your abstract (see acceptance criteria above), it is determined that your paper is appropriate for ICCRTS, you will be invited to submit a draft of the full paper for peer review. Invitations may also include suggestions designed to improve your paper and increase the probability of it being accepted.

• **Step 6:** Submit a draft paper for peer review. Please provide a cover sheet with your paper.
This sheet should contain the name of the Symposium, the topic of your paper, the title of your submission and author(s) information (affiliations and complete addresses). Please refrain from using ALL CAPS. If your paper has multiple authors, please list the affiliation for each author separately with their name. Open the paper with an abstract paragraph. Abstracts should not exceed 250 words. If this abstract is not the same as the one provided during the abstract submission step, please update the plain text abstract window on the EasyChair website accordingly. Only PDF format will be accepted. The length of submissions is expected to be in the range of 6 to 10 pages for concept papers and 10 to 15 for technical papers, based on the provided template. When reporting any set of statistical results, make sure that any data used are fully reported (central tendency, distribution, number of cases in the analysis, confidence intervals, etc.). These may be presented in the body of the paper or an appendix. When reporting experimental results, you must provide sufficient information to permit the experiment to be repeated, as per the accepted scientific method, including an overview of the experimental design (within-subject, between-subject, Latin square, etc.), the statistical processing methods used (ANOVA, Regression Analysis, etc.), the measure of statistical validity for any conclusions you draw, and the implications of your conclusions. Any statement on statistical validity must be contained in the body of the paper. References can be acknowledged as footnotes throughout the text or as a list at the end of your document.

- **Step 7:** You will receive peer review feedback on your paper (see Technical Paper Acceptance Criteria above). At this time, your paper will be:
  - Accepted with or without suggestions for improvement: **Go to Step 10**;
  - Conditionally Accepted provided you revised following reviewer feedback: **Go to Step 8**;
  - Accepted as a Concept Paper: **Go to Step 10**; or
  - Rejected.

- **Step 8:** For Conditionally Accepted Papers, submit a revised paper that incorporates reviewers' feedback.

- **Step 9:** You will receive peer review feedback on your revised paper and whether or not the paper is accepted.

- **Step 10:** Provide your presentation slides using the following link
  
  https://script.google.com/a/internationalc2institute.org/macros/s/AKfycbxy7gAwChB_OA-Y5CtxUcEmSebm5EP0imaLRHI31fk1RmuFDeTm/exec

  AND provide a copy to the appropriate Track Chair.

**Public Release of the Information**

The ICCRTS is an open, unclassified, international meeting with many nations present. Authors are responsible for ensuring that papers are unclassified for public release and should not present sensitive material. Papers and presentation material presented at the conference will be posted to the IC2I website, accessible to all members. Note that ICCRTS participants receive a one-year
membership as part of their registration package. For this reason, proprietary information should be avoided in all ICCRTS submissions: abstracts, papers, and presentations. All ICCRTS papers and presentations must be unclassified and any potentially sensitive material removed. Multiple versions will not be accepted.

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Inquiries

Please continue to monitor the conference website at www.internationalc2institute.org for updates and the latest information. If you have any questions, please contact us at info@internationalc2institute.org