



29th INTERNATIONAL
COMMAND AND CONTROL
RESEARCH & TECHNOLOGY SYMPOSIUM
24-26 SEPTEMBER – LONDON, UK

2024

CALL FOR PAPERS

for up-to-date Symposium Information and Registration go to:
<http://internationalc2institute.org/29th-iccrtts-information-central>

The 29th ICCRTS will be a hybrid event; however, in-person participation is strongly encouraged.

The 29th ICCRTS will be hosted by the UK MOD Defence Science and Technology Laboratory [dstl]



Theme

Overcoming Barriers to Future C2

This year's ICCRTS Theme, Overcoming Barriers to Future C2, is designed to stimulate a set of papers, presentations, and discussions that focus on what needs to be done to realize the C2 concepts and related technologies that will advance the state of the art and practice of C2 in the near and mid-future. This theme builds upon our discussions at the 28th ICCRTS related to the 'Drivers of Future C2.'

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 event followed 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 Royal United Services Institute (RUSI) in London. Venue information will be posted on the website.

The 29th ICCRTS Theme: Overcoming Barriers to Future C2

This Symposium series was born out of a concern among senior leaders that advances in technology and their implications for C2 needed to be anticipated and understood for us to seize upon the opportunities they may present. Thus, ICCRTS themes and topics have repeatedly come back to our ability to adapt our C2 concepts, organizations, and doctrine to take advantage of advances in technology while meeting the challenges posed by technology-enabled adversaries.

In the 1990s, the focus was on information and communications technologies (ICT) particularly networks; today's focus has shifted to cyber, AI, robotics, 'big data' and autonomy and their implications for sensing, shared awareness, and decision-making in a contested and complex cyberspace environment.

There seems to be a growing gap between 'what is' and 'what could be' if C2 research was exploited. Areas for improvement that impact on delivery of C2 include organizational design, doctrine, capability development, education and training. Therefore, it is appropriate that we reflect upon barriers that impede our ability to leverage research and technology in order to better understand these impediments and develop ways to remove them and narrow the gap between 'what is' and 'what could be'. This year's theme, **Overcoming Barriers to Future C2**, builds upon last year's theme, **Drivers of Future C2**, where C2 challenges that need to be addressed were identified and discussed. The theme is designed to stimulate thinking and discussion about what needs to be done to maximize the returns on this community's excellent work. With this in mind, we invite papers that address the following questions:

- Is 'revolution' rather than 'evolution' required, as the rate of change seems to be outpacing our ability to keep up with incremental improvements?
- Can technology close gaps in C2 capability? For example, ways to improve education and training as current methods often appear to be inadequate. Does the solution lie in applying technology to help redesign training and education of the force?
- Are our models, testbeds, wargames, exercises, and simulators fit for future needs?
- Should we consider an "Ender's Game" approach? (Ender's Game is a 1985 military science fiction novel by American author Orson Scott Card. Set at an unspecified date in Earth's future, the novel presents an imperiled humankind. It suggests a unique approach to developing preparedness. It has become suggested reading for many military organizations, including the United States Marine Corps.)
- How to improve the organization and management of C2 research and its relationship with the operational community?

And, as in previous years, we welcome papers that address wider aspects of C2 research and technology.

The 29th ICCRTS Topic Areas

Among the topics of interest for this year's symposium are both those that pose challenges and opportunities to improve the state of the art and/or the state of the practice of C2 as well as improve our ability to change, adapt and transform.

There are many topics of interest that would meet the above criteria. The topics selected are those that need to be addressed with some urgency. As is traditional, we have included a 'catch-all' topic for submissions that authors do not believe fit in topics provided below.

Topic 1: Overcoming Barriers to Change

This topic is for papers that address this year's theme. Barriers include the need for fundamental scientific, strategic, and structural changes, including those that explore:

- Revolution vs. incremental change
- Accelerated DOTMLFP / DLODS co-evolution
- Closing gaps in our understanding
- Fixing shortcomings in our C2 systems and capabilities
- Eliminating outdated or inappropriate practices
- More effective partnering between the R&D and operational communities.

Papers are sought that discuss these and other barriers to the acceptance and introduction of new ideas, technologies, or ways of working.

Topic 2: C2 for Complex Enterprises (collections of military and civilian entities)

This topic was selected because the mission challenges that must be met require a heterogeneous mix of entities. Modern operations increasingly require a collective effort to bring entity capabilities effectively to bear to meet complex challenges. These operations have been referred to as:

- All or multi-domain operations, which feature activities in the physical domains of warfare (e.g., air, land, sea, and space) as well as activities in non-kinetic domains (information, cyberspace, health, economic, and social); and
- Multi-national, civil-military, Whole of Government (WoG), Partners Across Government (PAGs).

Thus, while C2 has traditionally had a military connotation (probably because C2 takes its most explicit and least ambiguous form within military organizations, particularly in warfare contexts) there is a compelling need to develop Enterprise-spanning "C2 solutions" to augment or complement the C2, management, and governance solutions that have been developed by individual entities.

These trans-organizational challenges require that individual entities find ways for their internal C2, management, and governance processes to support cross-entity interactions and harmonization mechanisms. As a result, it is reasonable to assume that organizational changes will be required to adapt the allocations of decision rights, develop trans-entity shared awareness, and synchronize

actions. Organizational barriers will need to be overcome. Organizations will need to learn new ways of thinking and new behaviors.

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:

- C2-Harmonization arrangements and their appropriateness for different collectives and operations
- Increasing organizational capacity for harmonization
- Facilitating organizational change and learning
- Effective exchange of information among (human and non-human) partners
- Organizational and process interoperability
- Integration, coordination, and collaboration in a multi-domain context
- Development and sustainment of trust
- 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 3: Cyberspace

This topic was selected for several reasons. First, without cyber capabilities, a large region of the C2 Approach Space would not be feasible. Since Cyberspace is a contested environment, we cannot assume that these capabilities will be there when we need them. Second, greater understanding is required to adopt the most appropriate C2 Approach for Cyberspace Operations, and to assess how C2 approach appropriateness is impacted by a loss of cyber capability. Third, virtually every major military undertaking will involve operations in both the Cyber Domain and one or more of the traditional military domains. Thus, Cyber and Kinetic C2 Approaches need to be integrated to some degree.

Cyberspace Operations (CSO) of many kinds are conducted throughout the competition continuum. The objectives, constraints, ways, and means of CSO differ not only from more traditional kinetic operations but also from CSO to CSO. Exemplar topics include:

- Differences between and among CSO that impact the appropriateness of a Cyber C2 Approach
- Harmonizing Cyber and Kinetic C2

Contested Cyberspace Environments (CCE) 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
- Managing Cyber Risk to Mission (also see Topic 3)
- Developing shared awareness to manage adverse impact on cyber-enabled operations

Topic 4: Uncertainty, constraints, and risk in Complex Military Operations

This topic was chosen because, while the ‘fog and friction’ of war that contributes to uncertainty and imposes constraints is nothing new, arguably the nature and extent of the fog and friction have changed. There are also new opportunities for innovative solutions that can help us to penetrate the fog and to reduce friction. Fog is also associated with ambiguity, a form of uncertainty that adversely impacts the quality of awareness. This is exacerbated by deception and disinformation campaigns that have become more sophisticated and difficult to counter. Advances in sensor technologies have resulted in huge amounts of data being collected that we are currently unable to adequately process in its entirety: this too contributes to fog. The extent of fog and friction constrains the selection of an appropriate C2 approach (delegation of decision rights, interactions, and dissemination of information). Other constraints are present in the form of Degraded or Denied Environments (C2D2E) such as a contested cyberspace, and remote, harsh, and inaccessible environments such as the Arctic or Space.

New sources of risk have emerged, including the targeting of civilian infrastructure and economic institutions using cyber capabilities. Multinational and multi-domain operations involve additional dependencies and require more interconnectedness. They also involve a more diverse effects space with inter-dependencies between and among these effects. High interconnectedness, combined with the diversity of systems and actors, will lead to increased ambiguity and unpredictable outcomes. These make risks more challenging to manage.

Authors are invited to submit papers that explore and discuss requirements, concepts and solutions to better cope with the constraints, complexity, and ambiguity of military 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
- Solutions that may, among other things, improve preparedness, insurance of business continuity, adaptation, agility, resilience, self-healing, command on the move and remote/mobile command posts, remote leadership and remote operations
- 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 from known or potential good practices for working under constraints, complexity, and ambiguity

Topics 4 and 5 were chosen because sophisticated information processing and forms of non-human ‘intelligence’ are increasingly being embedded into systems in ways in which they effectively shape

the information than humans have access to and, at times, even make 'decisions.' These capabilities offer potential solutions to meeting the challenges associated with increased complexity, fog, and friction.

Topic 5: Non-Human 'Intelligent' Collaboration and Autonomous Systems

This topic was chosen because 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 challenges that have arguably not yet been fully addressed.

The capabilities, capacity, and sophistication of the technological components have continued to develop apace, most latterly with the re-emergence of Artificial Intelligence (AI) and 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 and 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
- 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
- Cognitively Augmented warfighters
- Legal issues and constraints (*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
- Intelligent virtual assistants – Intelligent tutoring systems – Chatbots
- Machine and adversarial learning
- Pattern recognition, classification, reasoning, and decision making (under uncertainty)

Topic 6: Emerging Concepts and Theories

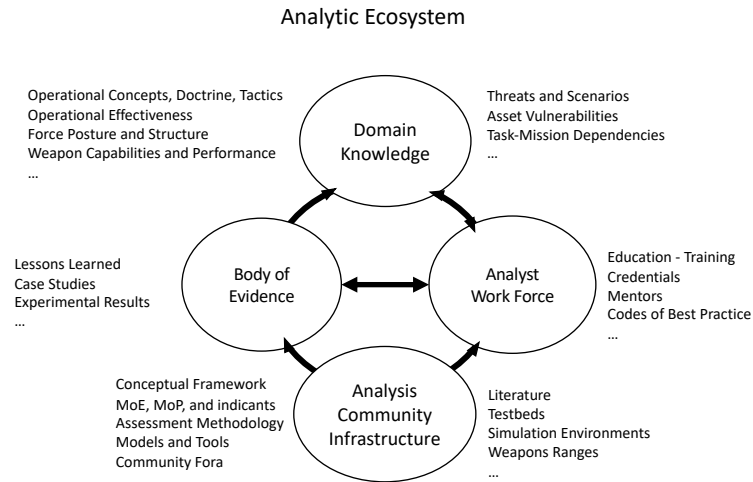
Several concepts and technologies have come to maturity or have witnessed significant developments in recent years. In addition to 'intelligent agents and systems' covered in Topic 4,

there have been breakthroughs in other areas, such as *data science* and *computer systems*. These have enabled a substantial increase in the capabilities, capacity, and sophistication of the technological components and have, or have the potential to provide, 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 actual and potential applications to C2 and the implications of these applications (e.g. for doctrine, tactics, techniques, training). Exemplar topics include:

- Implications of highly connected environments
- Automated forces, robotic/unmanned systems
- Mixed-initiative approaches for situation analysis and decision making
- Biomimicry – Swarm intelligence – Neuronal networks – Evolutionary computation
- Natural language processing
- Data science – Big data – Data mining – Knowledge discovery
- Data and information fusion
- System architecture
- Quantum computing
- Modelling and simulation – Embedded simulation – Digital twins
- Virtual reality – Augmented reality – Mixed reality
- Game theory
- Digital transformation 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: C2 Analytic Ecosystem

There is scope to improve the Analytic Ecosystem needed to provide the actionable, evidence-based, decision support needed for operations and for development of C2 capability. A representation of the Analytic Ecosystem' is shown below:



The papers received for ICCRTS have and will continue to contribute to Domain Knowledge and the Body of Evidence. This topic focuses on papers that address efforts to mature the ecosystem, particularly Analysis Community Infrastructure and Analyst Work Force aspects. This includes, but is not limited to:

- Integration, synthesis and exploitation of knowledge and lessons from operations, wargames, experiments, and research
- Metrics, measurement, and indicants
- Venue capabilities for experiments and wargames
- Approaches and tools to analyze and evaluate current and proposed future C2 and/or Cyber capabilities
- Education and training for C2 analysts and researchers
- Educating consumers of analysis
- Scenario and scenario-free analysis
- Visualization of results
- Problem characterization and formulation
- Requirement definition and specification
- Concepts of Employment (CONEMP) and Concepts of Operations (CONOPS)
- Prototypes and proofs of concepts
- Incorporating human dimension considerations

Topic 8: Other C2-related research and analysis

The 29th ICCRTS also welcomes contributions that do not fit neatly in any of the above topics.

The 29th ICCRTS Paper Submissions

ICCRTS seeks to encourage and publish professional, journal-quality papers that report on research and analysis activities related to C2. The core of the 29th ICCRTS remains a set of topic-oriented track sessions that explore the Symposium's theme from several different topical perspectives identified above. It is recognized that these topics are not mutually exclusive, and hence papers may simultaneously address more than one topic. Papers will be assigned by the Symposium and Track Chairs to sessions. However, the authors' assistance in identifying the most relevant topic is welcome. In addition to the specific topics detailed, submissions contributing to a critical examination of all C2-related subjects are always welcome.

The ICCRTS is an open, unclassified, international meeting with many nations present. Authors are responsible for ensuring that papers are unclassified and are approved for public release. Papers and presentations should not present sensitive material or proprietary information. Papers and presentation material presented at the conference will be posted to the IC2I website, accessible to all IC2I members (All ICCRTS attendees are provided with a one-year membership in IC2I.)

Research and Concept Papers

C2 Concepts, Technologies, and Practices are co-evolving at an increasingly rapid pace. Given that it may take over a year to collect empirical data and/or the build, test, and run simulation models and analyze the results so they can be submitted, ICCRTS accepts two types of submissions – Research and Concept papers. Research Papers will continue to form the core of ICCRTS. Concept Papers, however, are also appropriate for ICCRTS as they offer an opportunity to present ideas in a less mature form so that they can benefit from inputs from peers and perhaps inspire others in the hopes of maturing them more quickly to match the pace of C2 developments. Therefore, the 29th ICCRTS will continue the practice of encouraging both forms of submission. Research and Concept Papers will each be judged by an appropriate set of criteria.

- **Research Paper:** For example, reporting on a project that has matured to the point where findings are supported with appropriate evidence. These papers are expected to, as appropriate, contain references to foundations work, provide details about the research methodology, analysis approach, data collection and analysis, findings, and conclusions, and present recommendations or the next steps in pursuing this research or analysis.
- **Concept paper:** Discussion of a new idea, insight, or conjecture, which is either a potential topic for future research or is an effort that is in-process but has yet to have sufficient data to analyze or supporting evidence.

Presentation slots will be 30 minutes for all Research Papers and 15 minutes for all Concept Papers including Q&A.

Submission, Review and Acceptance Process

Thank you for your interest in contributing to the 29th ICCRTS. All submissions will be reviewed and feedback provided on an ongoing basis. **Early submissions are encouraged and will receive early**

feedback. ICCRTS accepts submissions via the upload form. The link to this form is posted on the 29th ICCRTS “Information Central” section of the website. The corresponding author should copy and paste the link for the form into their browser.

If accepted and presented at the 29th ICCRTS, a paper will be included in the proceedings and posted on the C2 and Cyber Research portal of the International C2 Institute (www.internationalc2institute.org).

This is the same website which houses CCRP books and ICCRTS archives.

Virtual Presentations

We understand that for various reasons authors may not be able to travel and present their papers in person. Therefore, we will continue to accept virtual presentations provided the authors are committed to being on-line for a live Q&A session following their presentation. However, this year we will only accept and schedule virtual presentation if they are pre-recorded (mp4 or PowerPoint with voice over). This will help ensure that the Symposium runs smoothly and that technical glitches are avoided.

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.

- * **1 April 2024** - Last date to submit abstracts
- * **15 June 2024** - Last date to submit full papers
- * **1 September 2024** - Last date for final paper submissions
- * **15 September 2024** - Last date to submit presentations

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The papers presented at ICCRTS **remain the intellectual property of their authors.** While they may be cited, they may not be reproduced without the authors' permission. IC2I does not hold any rights over these materials and cannot negotiate on the authors' behalf.

Abstract Acceptance Criteria (all papers)

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, one of the topics of the Symposium, or is of interest to the ICCRTS community.
- The abstract is specific enough to understand the nature of the concept or research effort.
- For Research Papers, the research approach described in the abstract, if implemented, would result in credible findings.
- For Concept Papers, the idea or preliminary work described would 1) stimulate productive

discussion, 2) foster collaboration, 3) advance the concept, and/or 4) improve the quality of the ultimate product(s).

Paper Acceptance Criteria

Additional information about the paper review process and criteria can be found at 29th ICCRTS Information Central.

Submission Process Steps

All paper submissions first require the submission of an abstract and notification of an invite to submit a paper.

- **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 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 for Research papers should not exceed 500 words while abstracts for Concept Papers should not exceed 300 words.
- **Step 4:** If you want to submit the full paper early, you can use the link provided for submissions at any time.
- **Step 5:** If, after a review of your abstract (see acceptance general abstract acceptance criteria above), it is determined that your submission is appropriate for ICCRTS, you will be invited to submit a draft of the full paper for 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 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, list the affiliation for each author separately with their name. Open the paper with an abstract paragraph. Abstracts embedded with the paper should not exceed 250 words. Only PDF format will be accepted.
- The length of submissions is expected to be in the range of 10 to 20 pages for research papers and 6 to 10 pages for concept papers, based on the provided template (available at 29th ICCRTS Information Central on the IC2I Website). 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 as 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 presentation link provide above

AND provide a copy of your presentation slides to the appropriate Track Chair.

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:

iccrtts@internationalc2institute.org