CONSTRUCTION
SAFETY RESEARCH ALLIANCE



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2021

SAFETY THROUGH SCIENCE.





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LETTER FROM THE CHAIR



Brad MacLean,
Wolfcreek Group
Senior Vice President

As the founding Chair of the Board for the Construction Safety Research Alliance, there were a few goals I had in mind for my tenure. Namely, I wanted to effectively leverage the role of advisory board chair to contribute to the CSRA's foundations of a robust membership, a healthy balance sheet to fund the research and an advisory board function that the CSRA could use at its "highest and best purpose" to help it realize our vision. And as anyone's tenure in a leadership position transitions, that leader should reflect on whether or not their contributions are sustainable after they "pass the baton." I think that the CSRA has achieved more than I could have hoped for. The membership has grown leaps and bounds, the CSRA is on a very stable financial footing, and the advisory board is well staffed, effectively functioning, and highly additive to the CSRA's operations and vision.

As I reach the end of my time in this leadership position for the CSRA, I have asked myself the question – am I leaving things better than I found them? Within the CSRA, we are all together part of a greater purpose. And that purpose is building a legacy for the kind of construction safety that really can keep people from suffering serious injuries and fatalities. The members of this alliance are all part of this grand purpose to bring transformative research to bear so we can eliminate serious injuries and fatalities across the construction industry.

I am truly moved by what has already been done in these first years. The vision, the growth, the attraction of like-minded leaders to this cause are all reasons to believe that the promise of the CSRA will be fulfilled. After two years in the role of chair of the board, there is one thing that we can all agree on maybe the most successful element of the CSRA: the sum is more than the parts – i.e., the partnership between safety academics and industry safety practitioners is where the success of the CSRA is most deeply rooted.

Perhaps we can think about my term as the chair as founding a leadership legacy and the next chair's mission can therefore be about curing that legacy so it can be successfully and sustainably conveyed as a firm foundation of what is to come for the next chapter of leadership for the CSRA. With that in mind, it is my honor to confidently pass the baton to our next Chairman, Mike Court, and by extension the entire next generation of leadership that will grow the CSRA's body of work for years to come. For as long as there are committed people working hard to bring our vision to life, I know we will change lives and save lives for years to come.

I'll end with something I learned from Teddy Roosevelt: "Far and away the best prize that life has to offer is the chance to work hard at work worth doing" and my time as the Chair of the Board for the CSRA has certainly been work worth doing.

Thank you.



ALTERNATIVES TO TRIR



IF NOT TRIR, THEN WHAT...?

In 2020, the CSRA statistically proved that TRIR is almost completely random and is not predictive of future performance. The implication is that TRIR should not be used to pre-qualify contractors, compare companies or business units, or to track safety performance over time. With this in mind, the CSRA Board of Advisors spent the last year identifying and evaluating potential alternatives to TRIR.

Specifically, we posed the following questions:

1 What are the attributes of a good metric?

2 What are potential alternative safety performance metrics?

3 What are the strengths and weaknesses of the alternatives?

4 How might we combine alternative metrics into a balanced scorecard?

To begin, we conducted a comprehensive literature review to understand how the scientific community judges the quality of different metrics within their fields. Using knowledge from other scientific disciplines, we identified 6 fundamental attributes that defines the quality of any scientific metric:

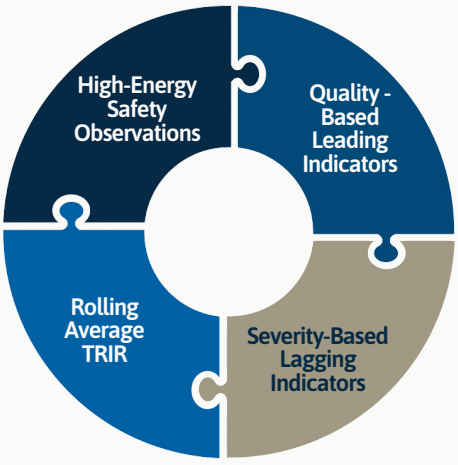
Attributes of Good Metric:

Predictive | Objective | Valid | Clear | Functional | Important

We evaluated both emerging and completely new metrics. Existing metrics included: Leading Indicators, Precursor Analysis, Safety Climate, Near Misses, First Aid Rate, TRIR, DART, and Fatality Rate.

Each existing and new safety performance metric was evaluated according to these 6 criteria. Empirical research evidence and consensus within literature was used by the academic team to evaluate the first 3 criteria (predictive objective, and valid). Since the other 3 criteria (clear, functional, important) are based on subjective perception and values, a panel of industry experts was engaged to build consensus using the Delphi process. With over 200 years of experience the panel systematically and empirically evaluated the quality of each safety metric by evaluating the extent to which it is: (1) built on a consistent definition (clear); (2) reasonable to collect given existing resources (functional); and (3) reflective of organizational priorities and values (important). With these evaluations complete, we are now analyzing how the potential alternatives to TRIR may synergize to provide a complete understanding of safety performance. The results of this project will be published and shared in early 2022.

The new metrics included:



PREDICTIVE ANALYTICS



WHAT FACTORS BEST FORECAST THE RISK OF SIF CONDITIONS?

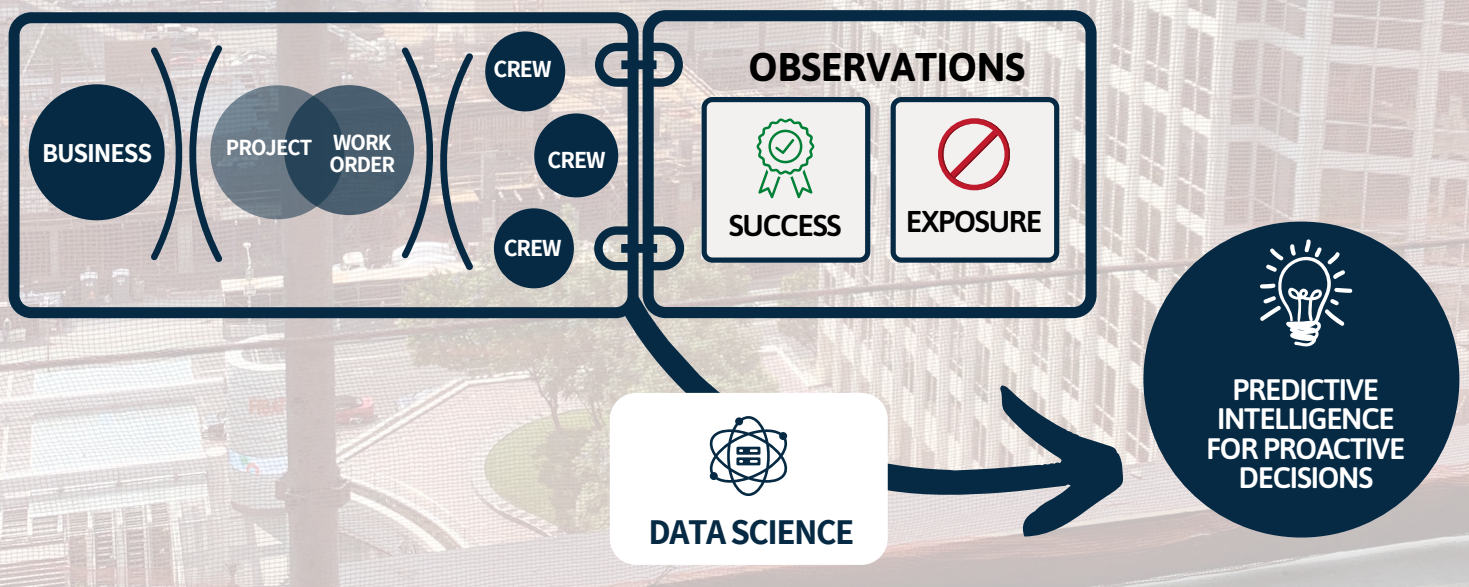
The Predictive Analytics project was kicked-off in 2019 with a vision to create an analytical model that reliably assesses the risk of serious injuries and fatalities (SIFs). A unique aspect of this project is that we are not attempting to predict rare SIF events. Instead, *we are attempting to identify the key predictors of SIF conditions* (i.e., given the conditions observed, what is the likelihood that we will see a high-energy hazard that is uncontrolled if we were to visit the site today?). Once the key predictors are known and algorithms are created using empirical data and advanced analytical methods, we will package the results into a dashboard capable of producing real-time SIF risk assessments, sensitivity analyses, and actionable recommendations.

In 2020, we created an unprecedented catalog of 254 potential predictors of SIF conditions. We then used the Delphi method to assess the extent to which each potential predictor is actionable, measurable, simple, and predictive.

We reached consensus on the 41 most promising predictors, which were the subjects of field data collection.

In Phase II, we collected data with over 35 industry partners across the United States and Canada. Analytically, we aimed to identify which of these factors best differentiate conditions with uncontrolled high-energy hazards (exposure) from those with the presence of direct controls (success). This completely new dataset containing both success and exposure, allows our team to make unrivaled SIF predictions and risk assessments.

To this date, over 80 projects and 36 different businesses have contributed to the database that has sampled over 820 workers from 661 different crews across the United States and Canada. The data are now being analyzed using multivariate statistical models and machine learning. This study will be published, and the resulting dashboard will be delivered to the CSRA community in early summer of 2022.



FROM INVESTIGATION TO LEARNING

When an incident occurs, how do we ensure that we are learning and not simply reaching a convenient conclusion?



+ Years of Experience

The goal of this project is to identify and test the best practices for learning from safety incidents. Current investigative methods are largely based on the assumption that one has acquired high-quality information. This project demonstrates that most methods of information collection are fraught with bias. Only scientific method provides the framework to transition from incident investigation (reaching a conclusion) to organizational learning (discovering something new). Like an ethnographic research project, our position is that incident learning requires awareness of biases and thoughtful efforts to address them. Otherwise, we will reach pre-destined conclusions that confirm our prior beliefs and dispositions, which will stifle progress.



Our team of 24 industry professionals and 7 academic researchers are collaborating to:

- **Identify how cognitive biases influence the information that we acquire when an incident occurs**
- **Create and test new methods to increase awareness and minimize biases when collecting information after an incident**
- **Leverage scientific methods to ensure high-quality learning**
- **Establish organizational practices for responding to incidents and communicating learning that build trust and support continuous improvement**

In pursuit of this goal, we have leveraged the 300+ collective years of experience in our team to provide actionable guidance. We are also running controlled experiments to understand how biases permeate to conclusions and empirically demonstrate how the fidelity of information improves when actions are taken to improve bias awareness. The output of this project will be a guidebook for incident learning and training seminars. The results of this project are expected in November of 2022.



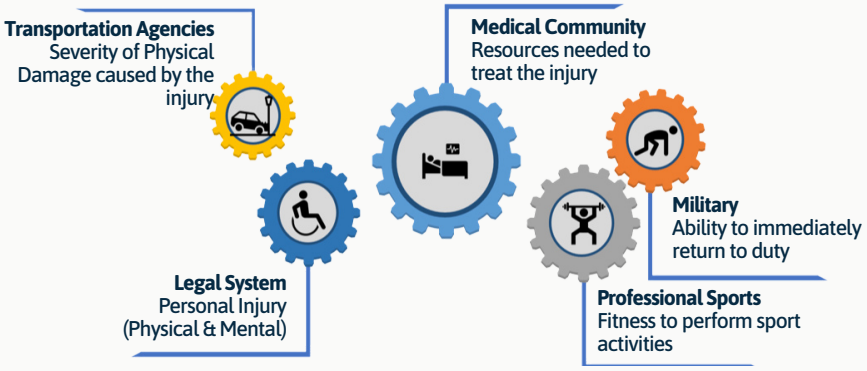
UNIQUE PRECURSORS OF SIFs

The CSRA's mission is to eliminate serious injuries and fatalities (SIF). Currently, there is massive inconsistency in how the term 'serious' is defined and used in practice. Industry associations and major companies impose different definitions of serious, which impedes shared learning and scientific communication. Additionally, many notable safety leaders have flippantly claimed that, "SIFs happen for different reasons." However, to date, there is no evidence to support this claim or understanding of which precursors, if any, are present in SIFs but are absent in *less serious* incidents. Uncovering unique precursors of SIFs would enable SIF-specific safety programs and more efficient resource allocation.

Phase 1: What makes an injury 'serious'?

Any mature scientific discipline has a consistent set of definitions that guide communication. For example, cell biologists have a definition of cell, glaciologists have a common definition of a glacier, and astronomers have a definition of a planet. Although there is consensus that serious injuries and fatalities are our primary concern in safety, we do not have a shared definition of 'serious.' The goal of Phase 1 is to create and test a definition of serious that is grounded in medical science but can be also easily and consistently deployed across organizations.

Existing perspectives outside construction



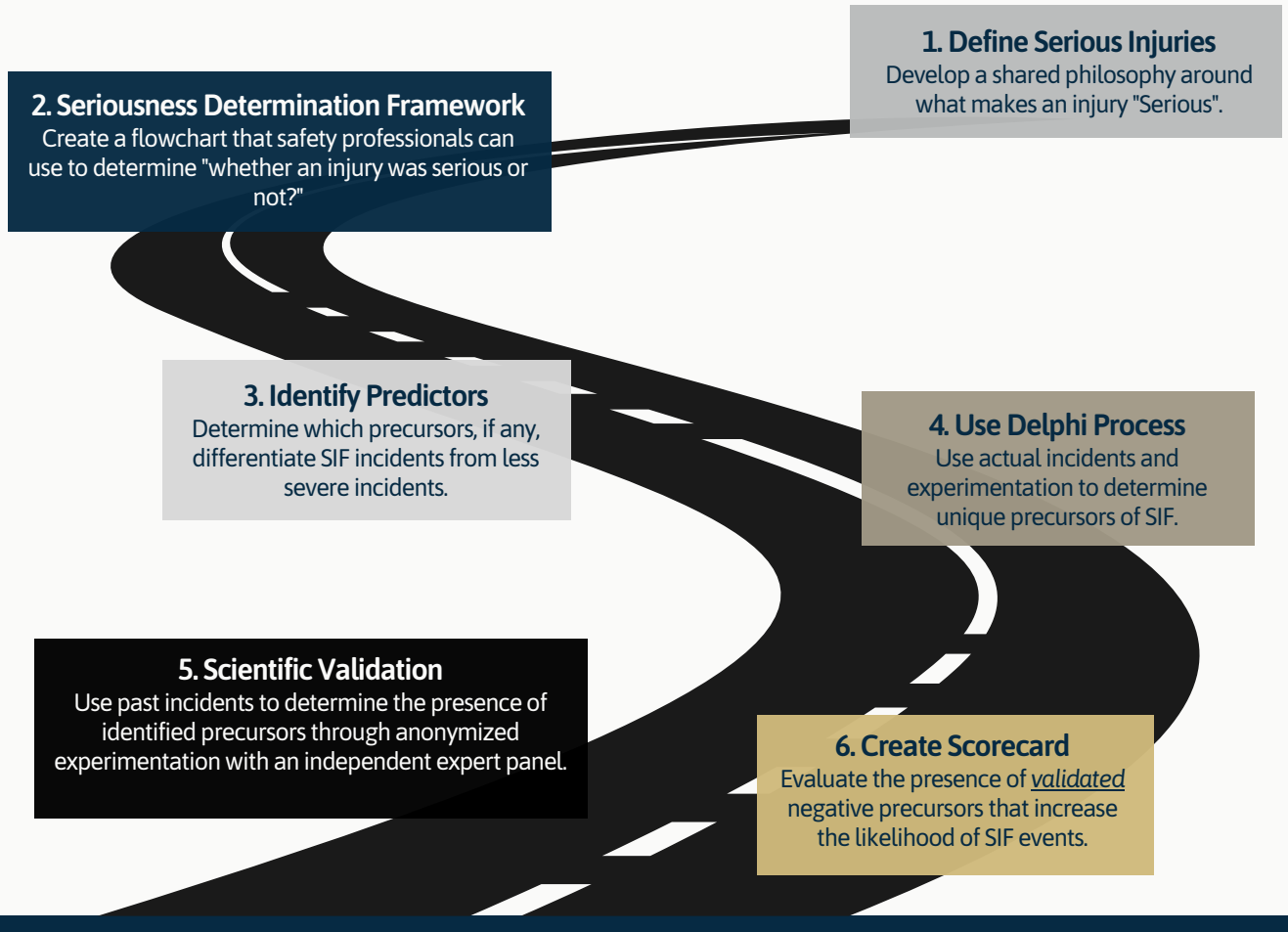
To this end, the team began by conducting independent assessments of common injuries (e.g., herniated disks, fracture, heat stress etc.). We found that there is near perfect inconsistency in our classifications of serious and less than serious. We then strived to create a methodology for assessing the seriousness of an incident by considering knowledge and practice from medical science, military standards, transportation industry requirements, professional sports norms, and legal literature. With over 200 collective years of experience, our research team created a new model to determine the seriousness of an injury that has proven to be internally valid and reliable with initial tests across industry sectors. The team has organized the findings into a simple flow chart that poses key questions and provides clear guidance on consistent use.

Phase 2: Are There Factors That Only Predict SIF Events?

With the new definition of serious, the team is now exploring which precursors, if any, are unique to SIFs. This work builds on research in two areas: energy-based safety and precursor analysis. We know that SIF incidents are typically associated with high energy (i.e., work situations involving more than 1500 Joules of energy) and less than serious incidents typically involve less than 1500 Joules. Additionally, from the precursor studies, we know common human factors associated with SIF cases. However, we still do not know which human and organizational factors, if any, are associate with less severe incidents. Do low-severity incidents happen for different reasons than success or SIF?

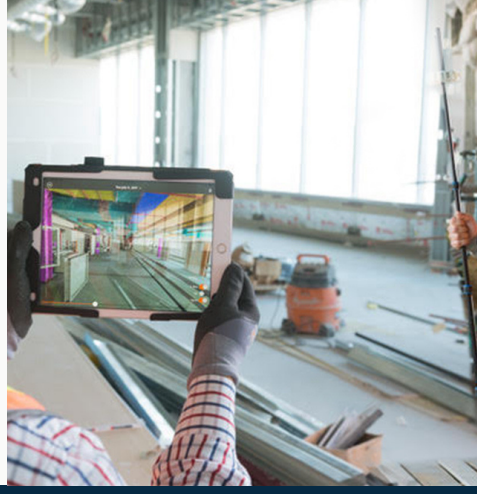
Can we anticipate, observe, and act upon human and organizational conditions that are indicative of SIF? This study addresses these key questions, potentially transforming SIF prevention.

The team is actively brainstorming potential work-related factors that could be unique to SIFs. We are considering industry, organizational, business unit, project, crew, and individual factors. Using real SIF and non-SIF incidents, the research team will experimentally and statistically determine any unique SIF precursors. The results of this study are expected in November of 2022.



EXPLORING AUGMENTED & VIRTUAL REALITY

Are emerging technologies like augmented and virtual reality delivering on their promises?



Technologies are advancing at a breakneck speed and technology developers often make big promises. However, there is no independent testbed for safety technologies. The CSRA is filling this void by positioning itself as the leader in safety technology testing. With advanced university lab spaces, partnership with psychology and computer science, and natural collaboration with industry professionals, the CSRA can objectively determine the extent to which new safety technologies deliver on their promises.

With funding from the National Science Foundation and partnership with Arizona State University, Colorado State University, Virginia Tech, University of Nebraska, Oregon State University, and University of Alabama we are actively testing the effectiveness of both augmented reality (AR) and virtual reality (VR). As these technologies become financially viable, we must understand the extent to which they improve hazard recognition, situational awareness, controls assessments, and other cognitive functions. This will help avoid the potential wild goose chase where individual companies pilot test multiple new technologies based on the promises of the developers without the rigor and structure needed to achieve reliable conclusions.

Augmented Reality (AR):

AR is the projection of information in the form of text, graphics, and other virtual enhancements on the real world. A classic example is the virtual projection of the line of scrimmage on the field during a football game or the digital projection of warnings on the windshield of a vehicle while driving. AR for construction applications usually involves the projection of design and assembly information in a heads-up display (e.g., through specialized safety glasses or face shield). In this project we are studying if the projection of digital information with AR reduces situational awareness and the ability to address hazards in one's environment, especially those associated with change.



Our controlled laboratory experiments involve a full-size pipe rack and the deployment of design information through the Microsoft Hololens AR system. While completing the pipe assembly, participants must identify and control hazards that emerge. By changing the level of detail of design information projected with AR, we will test how the density of information in the display influences efficiency and awareness. Laboratory experiments are under way and the results are expected in November 2022.

Virtual Reality (VR):

VR is a digital simulation of the real world. Although the public often thinks of VR as only gaming environments, some construction practitioners consider VR to be the future of safety training. In theory, VR can be used to train workers in highly realistic virtual construction environments where they can be exposed to hazards without any potential for actual harm. Although many have claimed that VR leads to better safety training outcomes, there are no studies that have explored if VR training enables improved hazard recognition, hazard prioritization, or controls assessment when *compared to* traditional training. More importantly, it is still unknown if training in the virtual world translates to improved awareness and safer practices in the real world.



Our experiments begin by providing traditional energy-based safety training in a lecture format to all participants. Then, some participants receive the opportunity to practice in a VR environment while others remain the control group (no VR experience). We then test hazard recognition, hazard prioritization, and controls assessment performance of all participants determine effects.

Finally, social constructivism – an open method of understanding the human experience – will be used to explain the experimental results (why, for example, the VR environment does or does not improve learning outcomes). The experiment will also help us to better understand how emotional engagement in training influences learning and retention.



With funding from the National Science Foundation, this study is an intimate collaboration between computer scientists and theatre faculty at Arizona State University, learning experts at Virginia Tech and the University of Nebraska, and safety researchers from the University of Colorado's CSRA team. The outcome of this study will be a hyper-realistic VR training environment with avatars trained from theatre professionals, work processes modeled from extensive input from CSRA professional members, audio from active construction sites, and haptic feedback representing the intensity of an injury. All features are built into a sophisticated and robust gaming platform, Unity.

This project is expected to finish in November 2023. Preliminary results will be shared in 2022.



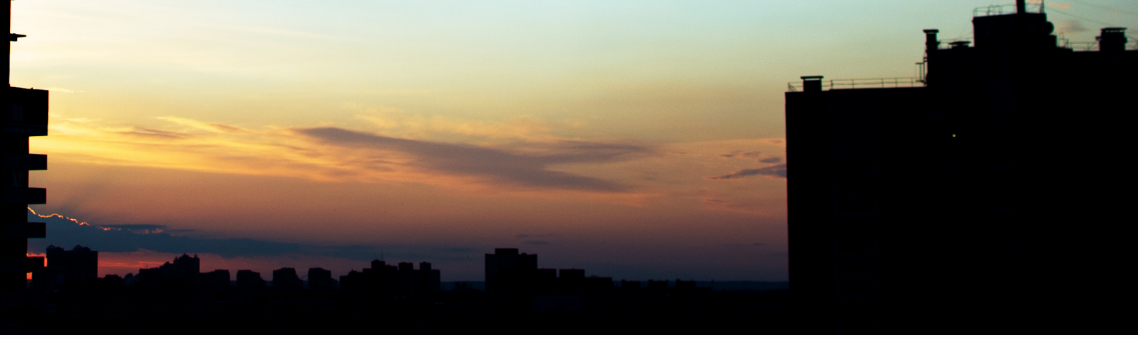
COMMUNITIES OF PRACTICE

For the second year, the CSRA has continued to create and maintain monthly Communities of Practice as a means of open sharing of safety best practices across all sectors of the construction industry. This year, we continued with the topics of precursor analysis/field safety engagements and energy-based hazard recognition. Additionally, we held ad hoc meetings to discuss Covid-19 response and identifying causes of SIF related to the pandemic. To close out the year, we will be discussing multimedia safety training via live demos; the role of virtual reality; and interventions (new training strategies or protocols) used by the Communities of Practice industry members.

The Community of Practice calls are consistently well attended with the group more than doubling in size over the past year. On average, 75 participants attend each meeting representing over 60 companies. As Jeremy Hakes from Adolfson and Peterson Construction stated, “these calls are an extraordinary forum to discuss the next useful steps in the evolution of proactive safety thoughts and processes.” The CSRA is thrilled to support sharing of evidence-based safety strategies and candid dialogue among industry leaders. We are deeply appreciative of our many speakers who have dedicated time and energy to sharing their experiences.

The communities are open to both members and non-members of the CSRA. We encourage all who are interested to attend. For more information, contact Dr. Katie Welfare at dewlanek@colorado.edu.

RESEARCH ON THE HORIZON



Safety Return on Investment (ROI)

How do we measure the impact of a safety intervention and its eventual return on investment?

With the Alternatives to TRIR project completed, the CSRA will take on another ambitious project attempting, for the first time, to create and validate a method for computing return on investment (ROI) for safety. Companies spend millions of dollars each year on injury prevention but, unlike other organizational functions, the ROI for these safety interventions remains elusive. Additionally, organizations are continually presented with many competing safety investment opportunities with no structured approach to determine which will yield the greatest benefits. Although past researchers have quantified the direct and indirect costs of both injuries and injury prevention strategies, there is no robust and valid method to measure safety impact. Because construction is a complex system and organizations implement numerous safety programs, it is very difficult to isolate the impact of any single intervention and, therefore, inappropriate to attribute improvement to an intervention. However, using emerging knowledge and modeling techniques from economics, risk analysis, complexity theory, and systems dynamics, we believe that we can create the first scientifically valid method for isolating and measuring safety impact. Our interdisciplinary team with expertise in business, engineering, risk analysis, and safety is uniquely poised to tackle this moonshot project. If we are successful, we would have a potentially transformative tool to measure the impact of our various safety program elements, objectively evaluate potential safety investments, and compute ROI after implementation. This work would also enable the eventual integration of safety as a value-adding business function, where allocation of safety resources can be justified with objective financial data and proper economic modeling. Dr. Nathalie Moyen, Chair of the Finance Division, in the Leeds School of Business at University of Colorado Boulder will be serving as a co-Investigator on this project.

Science of Safety Training

How do we deliver training to optimize learning, retention, and application of new safety knowledge?

Safety training is a cornerstone of any safety program. Any new training initiative requires significant time, energy, and resources to deliver. Therefore, it is of the utmost importance that we deliver the training in the most effective way possible to ensure that the effort results in optimally improved outcomes. This project will not study the subject of training; rather, we will explore how training is delivered. New safety training modalities have been busting at the seams with advancements in virtual reality, artificial intelligence, live demonstrations, inductive learning, self-directed learning, mixed-methods delivery, and adult learning theory. This project will experimentally test if, why, and how new combinations of safety training modalities improve knowledge acquisition, retention, and application. In pursuit of these goals, we are assembling a team with knowledge of safety, learning, behavior psychology, and computer science. This interdisciplinary team has the potential to transform safety training from passive delivery to an intentionally designed multi-modal approach based on the principles of effective adult learning and made efficient with technology. Dr. Logan Perry is an Assistant Professor at the University of Nebraska - Lincoln specializing in Discipline-based Engineering Education and he will be serving as a co-Investigator on this project.

2022 BOARD MEMBERS



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LETTER FROM THE INCOMING CHAIR



Mike Court,
Graham Group Ltd.
Health Safety
Environment & Quality
Senior Vice President

It is my honor to have been elected Chair of the Construction Safety Research Alliance (CSRA) board. I want to acknowledge Brad MacLean for his support and leadership of the CSRA as the Chair of the Board for the first two years. He played a significant role in the establishment and vision of the CSRA, and I know I have big shoes to fill.

I have spent my 30-plus year career working in the construction sector on projects of all sizes and scopes and complexities, from major oil & gas to small commercial. As I begin my tenure as the Chair of the Board, I will lean heavily on the experiences I've had over my professional career to continue our mission to eliminate serious injuries and fatalities (SIF's) in The construction industry.

Over the next few years, I have a few specific goals for the CSRA:

- We will continue our commitment to CSRA's vision and mission
- We will be the source the construction industry seeks out for guidance and defensible scientific initiative in preventing SIF's
- We will look for a collaborative approach with other safety associations and partners within the construction sector. After all, we should not have competing objectives, and it will take all of us to move our industry and our clients forward.
- We will focus on future technology within the construction sector and its role in the reduction of SIFs.
- We will shape the next generation of safety leadership (including operational leaders), working to define the attributes and skills required to stop or slow down the rate of SIF's in the construction industry.
- We will use sustainability, specifically the ESG reporting standards, to highlight the requirement for change of the TRIR as a globally accepted measure of performance.

I look forward to continuing the great work of the CSRA and pushing the limits on where safety through science can go in the construction industry. **The construction industry is my passion, and safe, productive construction is my *vision*—**as Chair of the Board, I promise to use this passion and experience to support the CSRA.

Thank you.





MEMBER COMPANIES



CSRA
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We are always looking for energetic and passionate members. If your organization is interested in becoming a member of the CSRA, please contact Dr. Katie Welfare at the University of Colorado via email: dewlanek@colorado.edu and feel free to visit our website at www.colorado.edu/lab/csra



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