CSRA

Annual Review

2020

"Without data, you're just another person with an opinion."

- W. Edwards Deming

Contents

Letter From The Chair

Brad MacLean, Wolfcreek Group

Senior Vice President

Just over a year ago, a vision came to life and the Construction Safety Research Alliance (CSRA) hit the ground running. In just one year, the CSRA has attracted over 30 like-minded member companies representing oil and gas, power generation and delivery, infrastructure, commercial buildings and shared services. We have selected and begun three research projects on the topics of Total Recordable Injury Rates, Quality-Based Safety Leading Indicators and Predictive Analytics and we have worked to provide other useful resources for the industry through Communities of Practice. As Ralph Waldo Emerson said, "The purpose of life is not to be happy. It is to be useful, to be honorable, to be compassionate, to have it make some difference that you have lived and lived well." I firmly believe that the CSRA is making a difference, and a significant difference at that.

In safety, and here at the Construction Safety Research Alliance, we believe that transformative research and defendable science is crucial for the prevention of serious injuries and fatalities. We consider ourselves, in many ways, to be the industry's shared safety R&D function. Our objectives are to create and disseminate new and reliable safety knowledge, connect industry and academia together on collaborative teams, incubate and test new ideas and overall to accelerate safety research output which allows evidence-based safety strategies to be put into practice more quickly.

Surrounded by so many world-class safety professionals, I was honored to serve as the chairman of the CSRA during our inaugural year. During this crucial year, I had three main objectives:

1. Stand up a healthy and sustainable Advisory Board function for the CSRA Executive Director & staff
2. Advocate far and wide on behalf of the first generation of work products
3. Help build up a robust & active membership

Leaders aren't judged by their good works, but rather their good works that "stick" once they have passed the baton of leadership to another. I want to finish what I started and make sure the CSRA is left with an enduring framework that continues giving high quality, research-based safety solutions and practices.

The CSRA will always be judged – rightly so – by the body of research work we produce and the impact it can have on construction safety performance. And so far, so good. The first flight of research approaching completion is meaningful, impactful, practical, and well-aligned with our vision of producing a world-class body of work that prevents serious injuries and fatalities.

Our team, both industry and academic, and our incredible successes in our first year have prepared the CSRA to begin to play a leading role in improving safety and health in the construction industry. We look forward to all our future collaborations as we pursue new research endeavors and wrap up those we have already completed as we keep our eyes on our mission to prevent serious injuries and fatalities with defendable science.

I look forward to seeing the excellence in safety science that the CSRA will continue to bring to the construction community at large.

CSRA AT A GLANCE

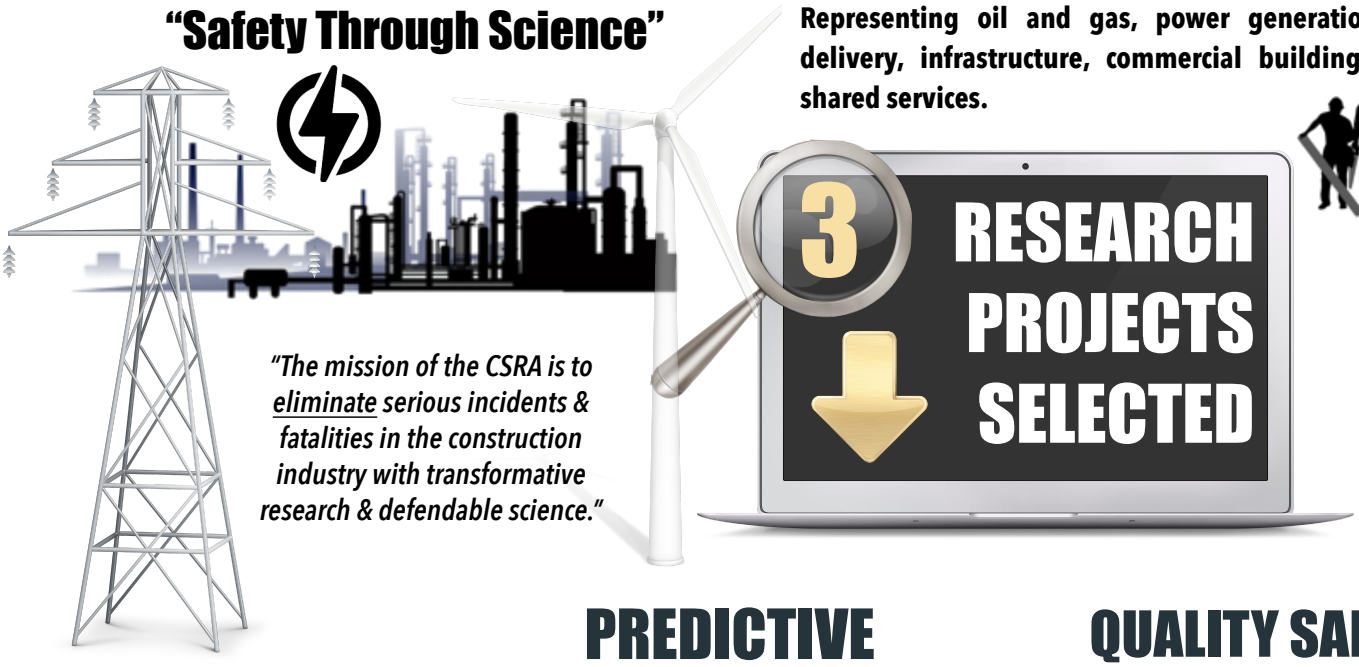
YEAR 1

CSRA CONTINUES TO GROW

30 New Member Companies

Representing oil and gas, power generation and delivery, infrastructure, commercial buildings, and shared services.

"Safety Through Science"



"The mission of the CSRA is to eliminate serious incidents & fatalities in the construction industry with transformative research & defendable science."

TRIR

PREDICTIVE ANALYTICS

QUALITY SAFETY LEADING INDICATORS

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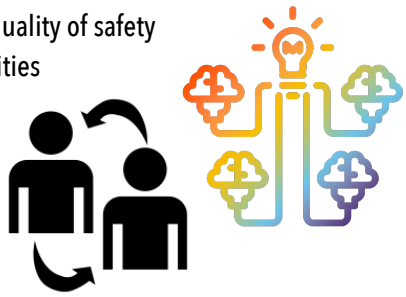
17 YEARS OF DATA

3.2 TRILLION WORKER HOURS

TEAM PRODUCED OVER 30K Individual Delphi Ratings

+ *Established an unprecedented list of* **254** Unique Potential Predictors

Yielded over **100 UNIQUE** competencies that characterize the quality of safety activities



+ Delphi Process collected over

900 INDIVIDUAL RATINGS

TRIR RESEARCH

TYRANNY OF TRIR: $\frac{n_S + \frac{z^2}{2}}{n + z^2} \pm \frac{z}{n + z^2}\sqrt{\frac{n_S n_F}{n} + \frac{z^2}{4}}$

To better understand the validity of TRIR as a performance metric, the CSRA Board of Advisors aimed to answer the basic question:

> *Given the way that it's used, to what extent is TRIR statistically valid?*

TRILLION WORKER HOURS

Total recordable injury rate (TRIR) has been used as the primary measure safety of performance for nearly 50 years. Since organizations conform to the same definition, the TRIR metric has been used to compare industries, sectors, companies, and even projects. TRIR is used in many ways and dominates discussions about safety performance from the worksite to the board room.

Despite the pervasive use of TRIR, its limitations are being recognized. For example, a four-stich cut to the finger is counted the same as a fatality, and a near miss with the potential to be fatal is not counted at all. More recently, some have begun to question the statistical validity of TRIR, suggesting that recordable injuries happen so infrequently that the metric is not stable or reliable.

This study was performed via a collaboration among ten CSRA Board Members and four academic researchers. The collaboration resulted in direct access to over 3 trillion worker-hours of internally reported injury data, which were analyzed by the academic team using a variety of diagnostic and predictive analytics. Both empirical and parametric analyses were used to study TRIR.

EMPIRICAL ANALYSIS

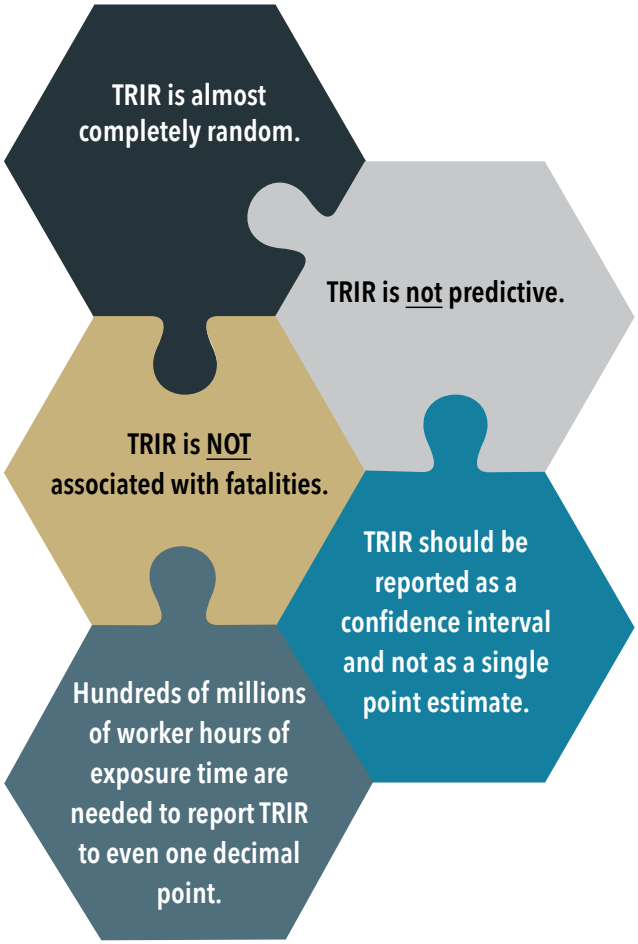
The empirical analysis used the historical TRIR data to create a set of predictive equations and test how well those equations correctly estimate future TRIR. This simulation showed how much of the final result is due to random variation and the extent to which past TRIR is predictive of future TRIR or fatalities.

PARAMETRIC ANALYSIS

Based on logical assumptions and the results of the empirical analysis, a parametric analysis was performed to better understand the nature of TRIR as a metric and how it should be reported. The team found that TRIR follows a Poisson distribution, which is associated with well-known equations that allowed for the assessment of the tradeoff between the number of incidents, the number of worker hours, and the level of precision that can be reported.

> *For all practical purposes, TRIR is not a statistically stable, precise, or predictive measure of safety.*

RESULTS



RECOMMENDATIONS

1. The safety profession must change how it communicates TRIR.

TRIR is almost always communicated as a precise number as if it was the only possible outcome. Since recordable injuries are so infrequent and are a product of so much random variation, a single precise number is meaningless.

2. TRIR should not be used to track internal performance or compare companies, business units, or projects.

Since the average company requires tens of millions of worker-hours to return a confidence interval with one decimal point of precision, organizations should be very careful making any comparisons using TRIR.

3. Companies should not place much stock in short-term changes in TRIR.

It is tempting to track TRIR over time to identify when performance is improving or degrading. However, as observed in the empirical analysis, changes that occur from month-to-month are mostly random and do not necessarily reflect any actual change in the safety system.

4. A new approach to safety measurement is needed.

In addition to statistical invalidity, the use of TRIR also does not describe why the performance – good or bad – was achieved and what can be done to improve. This leaves organizations wondering, 'Are we truly good, or simply lucky?' or worse, 'Are we truly bad, or do we simply need to log more worker hours?'

5. The safety profession should consider pursuing a balanced scorecard approach to safety measurement.

Lagging measures of safety performance like TRIR remain undeniably important to executives because they are the bottom-line descriptors of safety outcomes. If combined with leading indicators, predictive analytics, and diagnostics, TRIR and other lagging metrics may serve as a valuable components of a balanced scorecard approach.

QUALITY OF SAFETY LEADING INDICATORS

"Our vision is to create a protocol for assessing the quality with which safety activities are implemented that is precise, accurate, and reliable."

As leading indicators have been pursued, we have relied heavily on quantitative assessments of the safety system, like the frequency of pre-job safety meetings and safety audit scores. However, this research team tested the hypothesis that the quality of key safety activities is the primary determinant of safety performance and defines capacity for success.

To test this hypothesis, this CSRA team of 24 safety leaders and 5 academic researchers aimed to:

1. Develop and validate a protocol for measuring the quality of safety leading indicators;
2. Assess the extent to which measures of quality predict safety performance;
3. Create scoring tools and pocket guides for use in the field.

The team developed and tested the protocol for creating quality-based safety leading indicators by focusing on three key safety activities. ***Considering over 20 different activities, the team selected pre-job safety meetings, safety observations, and leadership engagements*** based on the assessment that they are all measurable, actionable, and predictive of future safety performance. The team divided into three subcommittees, each addressing one safety activity.

Leveraging over 200 collective years of experience and guided by the academic research team, each subcommittee followed the same general process for building their quality-based safety leading indicator.

This research method leveraged the extraordinary experience of the team and knowledge of rigorous group-base decision making. This resulted in research-validated methods for assessing the quality of key safety activates that are scientifically rigorous, professionally relevant, and will stand the test of time. Fortunately, the calibration and validation activities also confirmed that the tools yield measurements of quality that are consistent, valid, and reliable, meaning that they can be used for tracking, benchmarking, learning, and continuous improvement.

"Is construction safety about how much we do, or how well we do it?"

Identified Core Attributes for Each Activity
"What does it mean to perform this activity in the first place?"

Brainstormed the Competencies
What are the actions, skills, and behaviors that differentiate how well each activity is performed. *"What does excellent performance look like?"*

Used the Delphi Process
Using the Delphi process to rate the importance of each competency relative to the others. *"Which competencies matter most?"*

Created Scorecards
Creating scorecards for measuring the quality of each safety activity based on the ratings of the core competencies. *"How do we measure the quality?"*

Calibrated Scoring
Calibrating to ensure that team members arrive at the same scores when using the scorecards. *"Do we all score the same observed activity the same way?"*

Created Field Guides
Using the results of many discussions to create field guides for each activity. *"How can we put these to use?"*

Conducted Pilot Testing
Pilot testing the scorecards and field guides on actual projects. *"How usable are the tools?"*

Validated Metrics
Validating the quality of metrics as predictive using field data.

PREDICTIVE ANALYTICS

The goal of the Predictive Analytics research team is to identify the business factors, work characteristics, and crew demographics that best predict serious injury and fatality (SIF) incidents. The project will produce a dashboard to enable an objective and dynamic method to assess SIF risk.

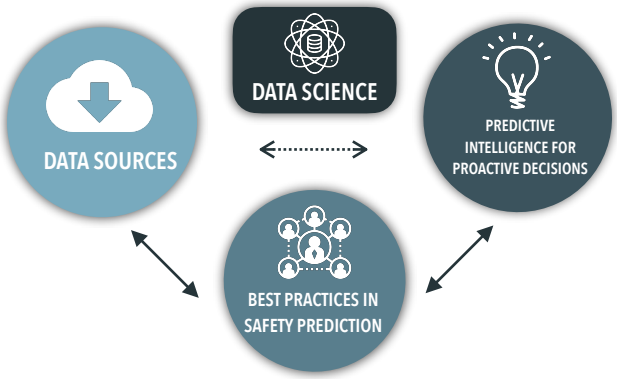
Phase I of Predictive Analytics Project was completed. Representing oil and gas, electric power generation and delivery, infrastructure, and building construction, our diverse team of 22 professionals and 5 academic researchers brainstormed 393 potential predictors. This unprecedented catalog includes: business factors, project characteristics, and crew demographics. To select a manageable set of predictors for data collection, the team went through a multi-round consensus building approach (Delphi) and rated the extent to which each is actionable, measurable, simple, and predictive. ***In total, the team produced 30,420 individual ratings***, which are being used to strategically select the predictors for field data collection. The top 20 predictors are shown in the table.

Phase II of Predictive Analytics Project has been launched. The team is currently designing a field data collection protocol to ensure consistency, validity, and feasibility. The data collected will be used to build analytical and predictive models that will serve as the engine for the SIF risk prediction dashboard.

"If you can predict it, you can prevent it."

Currently Underway with 4 Phases:

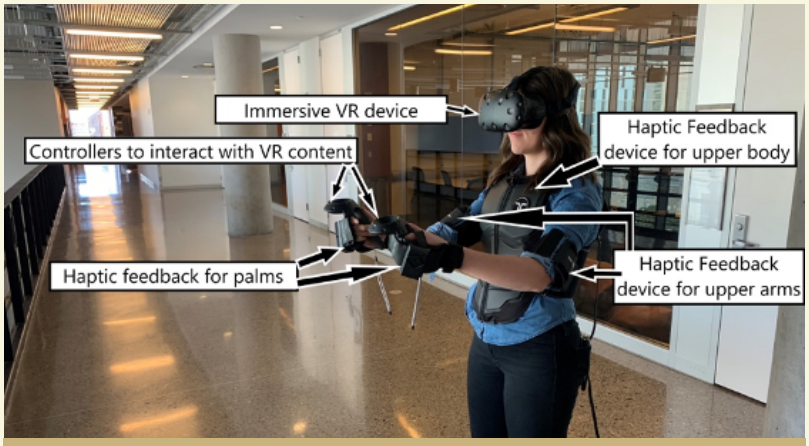
1. **Identify & Prioritize Predictors**
2. **Collect Empirical data**
3. **Predictive Models & Validation**
4. **Dashboard Creation & Pilot Testing**



TOP 20 POTENTIAL PREDICTORS of SIF EVENTS

	CATEGORY	PREDICTOR
1	Project / Work	Presence of a Project Manager
2	Crew	Field Management to Worker Ratio
3	Project / Work	Supervisor to Worker Ratio
4	Business	Intervention Protocol
5	Project / Work	Validation Project Leading Indicators
6	Business	Investment in Safety R & D
7	Business	Go/No Go (Safety Stop)
8	Business	Overdue Corrective Actions
9	Business	Quality of Incident Investigation
10	Business	Safety in Performance Evaluations
11	Business	Training for Leaders to Engage
12	Crew	Newly Formed Crew
13	Project / Work	Complete Written Safety Procedures
14	Project / Work	Supervisor Review of the Pre-Job Meeting
15	Project / Work	Document Control - Latest Versions
16	Crew	Crew Size
17	Crew	Days on Shift
18	Crew	Clear Assigned Rules / Responsibility
19	Project / Work	Equipment Inspections
20	Project / Work	Job Safety Orientation

RESEARCH BRIEFS



Virtual Reality Simulation is a computer-generated synthetic immersive environment that allows a person to interact with simulated reality.

Haptic Feedback is a simulated sensory feedback is physically experienced (vibration, smell, pain, temperature changes).

There are many companies across the industry that are putting their faith into virtual training programs to improve hazard recognition skills and to condition worker behavior. However, there is no empirical evidence that shows training provided in virtual environments is better than traditional training. Our goal is to address this question and help organizations decide whether virtual reality (VR) is a worthy investment for safety applications. This project focuses on testing the effectiveness VR and measuring its value proposition for safety training purposes. By leveraging the innovative capabilities of advanced VR and supporting technologies (such as Haptic Feedback) for construction safety training, users will be able to navigate a virtual construction site to assess it for safety concerns. Several specific safety hazards will be programmed into the environment that would require the user's attention. Thus, the experience will allow workers to have an opportunity to interact with hazards and allow them to "fail" in safe, yet realistic environments. These virtual experiences will be utilized to provide an impetus for real change behavior by increasing their risk perception and lowering their risk tolerance. The workers are likely to experience a potentially transformative training activity that may reinforce the criticality of safe construction practices beyond what is typically observed in traditional construction safety courses (i.e., OSHA 30-hour course).

IMMERSIVE VIRTUAL REALITY WITH HAPTIC FEEDBACK TO IMPROVE:

- ➡ SAFETY HAZARD RECOGNITION
- ➡ ASSESSMENT
- ➡ DECISION-MAKING

This project is made possible through a three-way partnership with Arizona State University, Virginia Polytechnic Institute and State University (also known as Virginia Tech), and the Construction Safety Research Alliance (CSRA). Each institution plays a vital function in the project:

Role on this project is to create software and hardware of the VR system, which will be used to run the scientific tests and gather all data.

Role on this project is to aid with the designing phase of the software and hardware to meet the learning objectives and, once all of the necessary apparatus is created to run the scientific testing, the CSRA team will be responsible for gathering all data.

Role on this project is to measure human performance and to analyze the cognitive learning of the test subjects of the VR system.

Immediate Deliverables from this Project:

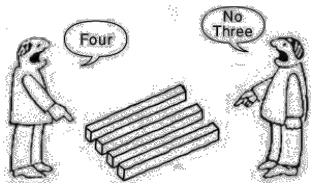
- High-fidelity virtual reality (VR) safety training platform for construction with Haptic Feedback
- Measure impact on learning and retention
- Understanding of role of psychological and human factors in the training process

**The status of this project is still in the design process of the software and hardware for the VR system, with testing and data gathering expected to start during the Fall of 2020.*

PERCEPTIONS OF CONSTRUCTION

RESEARCH BRIEFS

"Why Social Constructionism?"



Reality can be so complex that equally valid observations from differing perspectives can appear to be contradictory.

With increasing demands for new infrastructure and decreased availability of skilled construction craft workers, the need to recruit and retain workers is becoming critical. To better understand the preferences of construction workers, 222 interviews were conducted with workers on active commercial construction sites in Colorado. Workers were asked simple, open-ended questions about their jobs to enable a social constructionist approach and the use of discursive data analysis, thereby preserving the richness of the discussion.

The results indicated that workers most enjoy seeing tangible results, social interaction with co-workers, problem solving, challenging and diverse work tasks, and working with their hands. Conversely, negative attributes were work pressure, indirect communication, mandates from upper management, dangerous work, and a feeling of indifference perceived of their co-workers. These results improve understandings of the fundamental reasons why construction workers are attracted to their profession.

The findings can also be used in industry, especially when considering and implementing agents of change like deployment of a new technology or changing means and methods. Such consideration may increase likelihood and enthusiasm of adoption and help with retaining human resources. Further, understanding the attributes that attract or detract human resources to the construction industry may aid in partially addressing labor shortages and ensuring worker well-being and job satisfaction.

THE HUMAN FACTORS CLIMATE

The Human Factors (HF) climate fills a significant gap in existing research as is introduced for the first time here. Defined as the perceived psychological, physiological, and emotional experience of an individual at work, the HF climate aims to assess and improve human experiences on construction sites by creating a holistic way to study factors that have previously been primarily studied independently. Improving the human experience on a construction jobsite will promote work performance and the long-term holistic wellbeing of workers – a primary and vital asset in the construction industry.

The overarching relationship found in our study are as follows:

Fatigue ↑ as Stress & Negative Emotions ↑ Fatigue ↓ as Job Satisfaction ↑ as aligned with previous research

Stress ↑ when Negative Emotions ↑ Stress ↓ when Job Satisfaction, Climate Safety, & Positive Emotions

Job Satisfaction ↑ when Safety Climate, Motivation, & Positive Emotions ↑ Job Satisfaction ↓ When Negative Emotions, Fatigue, & Stress ↑

Motivation ↑ when Job Satisfaction, Safety Climate, & Positive Emotions ↑ Motivation when Stress ↑

Safety Climate ↑ when Job Satisfaction, Motivation, & Positive Emotions ↑ Safety Climate ↓ when Negative Emotions & Stress ↑

RESEARCH ON THE HORIZON

SAFETY ROI

Organizations spend millions of dollars annually on safety programs, but how can we know if we are putting effort into the most useful programs? As new initiatives or improvements to existing programs are considered, it is important to consider effort versus reward (i.e., the organization's return on their safety investment). Such information would allow organizations to strategically design safety programs with the greatest overall impact when resources are inevitably limited. A methodology to compute return on investment, and example case studies could improve how organizations invest in safety and transform the function from a budget-oriented to a value-adding function. This study will explore the extent to which emerging methods from economics, pharmaceuticals, and healthcare can be adapted to construction safety. This inquiry will address fundamental questions like: How do we isolate and measure the impact of a safety intervention? How do we measure our monetary and non-monetary return on investment?

This will be a multi-year effort for the CSRA and will aim to produce methodology to measure the following:

- The cost of safety program elements
- The reduction of the likelihood of injuries resulting from each program element
- The cost of injuries
- The return on investment of a safety program element
- The return on investment of an entire program

This project is a bold step forward, challenging the long-standing assumption that safety impact cannot be assessed objectively. The findings could transform safety-related business decisions and enable more effective use of limited resources.

SAFETY TECHNOLOGIES

New safety technologies are constantly being developed, but how do we test whether or not they are helping us to improve and causing the impact we are hoping they cause? The CSRA has learning opportunities in adjacent National Science Foundation supported research where we are studying and testing the validity of augmented reality and virtual reality. For example, in current COVID-19 circumstances, suppose there is a camera that can determine whether or not workers are wearing masks. This camera could be tested in a lab to determine how well it works, when it does and when it does not work, etc. In essence, we can try to "trick" new technology to determine just how well they work and serve as unbiased brokers and experimentalists.

QUALITY OF SAFETY LEADING INDICATORS PHASE 2

This project will further the CSRA objective of creating safety metrics that reflect the quality of the safety system. Building on the transformative work of the original quality leading indicators team, this new study will involve creating quality standards for three additional safety activities: (1) incident investigation and learning; (2) stop work authority; and (3) safety communication. With these new standards and metrics, we will continue to scientifically investigate the extent to which safety performance is predicated on how well we implement key safety activities. Additionally, this project will result in practical field guides for each activity that harness best practices across oil and gas; power generation and delivery; infrastructure construction; and commercial building construction.

UNIQUE PRECURSORS OF SIF

Are the causes of high and low severity injuries different? Although this has emerged as popular opinion, it has not been objectively studied. We will tackle this fundamental question by creating a scientific definition of 'serious' injury and exploring how severity can be graded. Then, building upon the definition, we will conduct an experiment to explore which precursors if any are unique to serious injuries. With this new insight, we will begin to understand how to design interventions that are specifically designed to eliminate serious injuries and fatalities. This project will result in an operational definition of serious injury and guidance for targeted prevention.

COMMUNITIES OF PRACTICE

As a unique way to contribute to the construction community at large, the CSRA has created and maintains two standing Communities of Practice, one on precursor analysis and field safety engagements, and the other on energy-based hazard recognition.

Chaired by Justin Seet of Enbridge Pipelines, these communities of practice meet once a month to discuss best practices, ask questions, and share resources. As Justin explained, "the COP is such an appropriately named team – it is truly a "community" of professionals that are learning from one another and offering up their own experiences so that we learn and grow collectively." James Upton with Ergon Inc. described that the COPs are unique due to the "true collaborative nature of the discussion - It's a true community in the sense that we are all working towards a common goal and great ideas are shared that promote that goal."

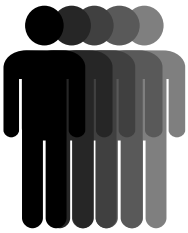
These have been consistently well attended with over 60 companies attending at least one meeting this year. In addition to the standing communities of practice, the CSRA established a working group for managing COVID-19 in the workplace. This ad hoc group has dealt with the unique challenges of COVID-19 as they rapidly emerge. The communities are open to anyone and we encourage people to attend by contacting Dr. Katie Welfare (dewlanek@colorado.edu) if interested in finding out more!

Standing COPs

Energy-Based Hazard Recognition

25-30

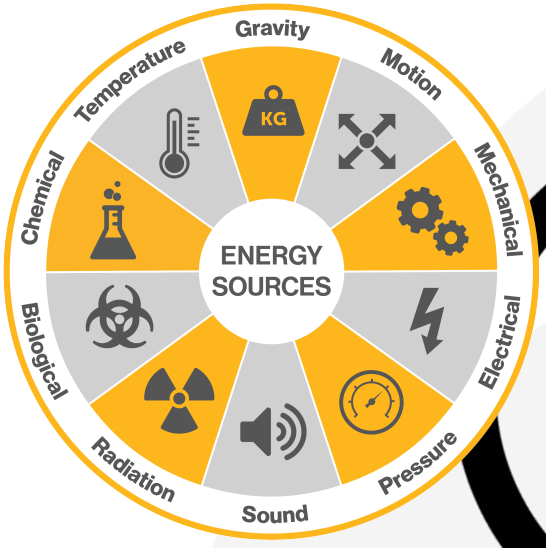
Participants



Precursor Analysis Field Safety Engagement

20-25

Participants

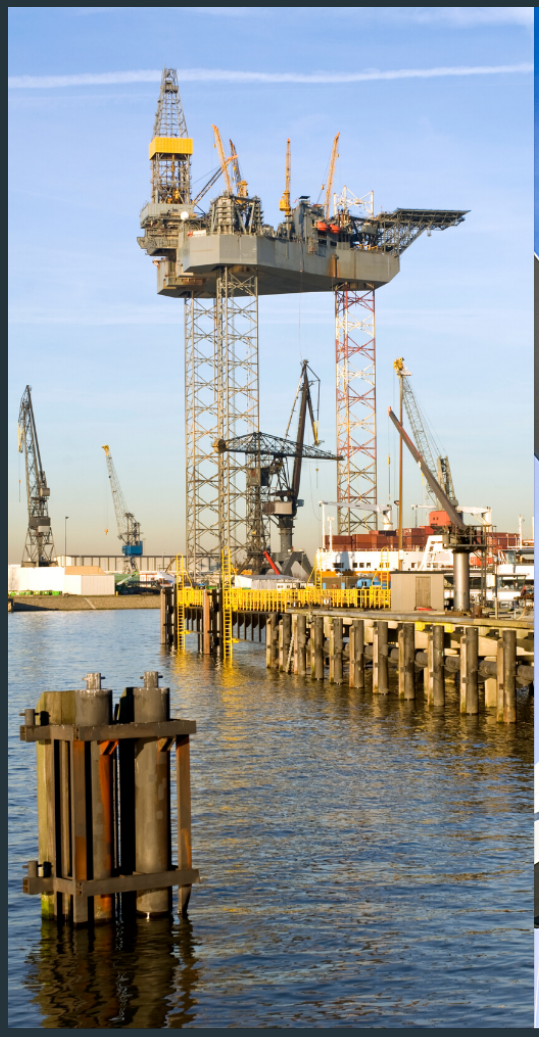


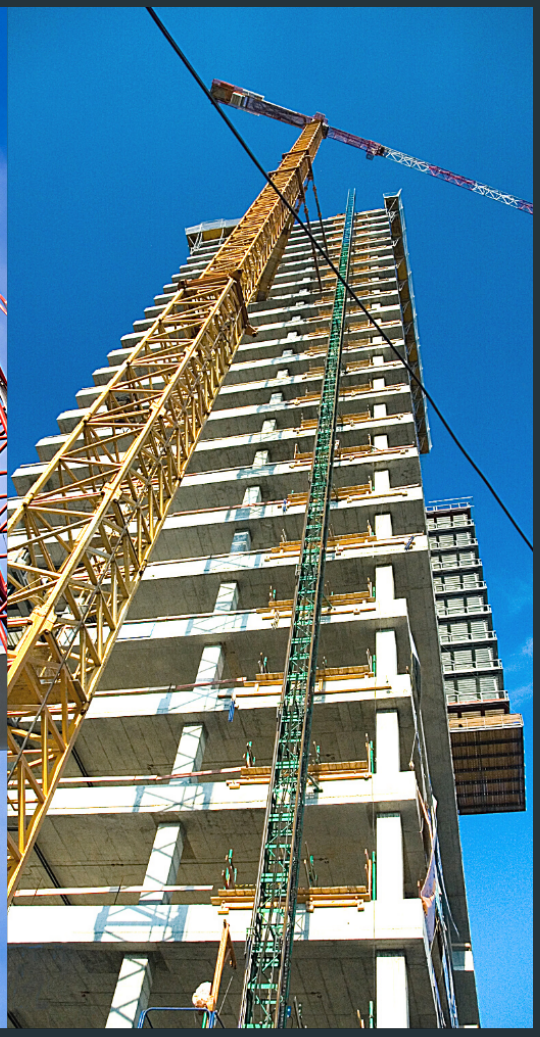
Ad Hoc COP

COVID-19 INFORMATION FOR WORKERS

30-35

Participants





Current Member Companies

1. California Resources Corporation
2. Caterpillar
3. CenterPoint Energy
4. Cheniere
5. Chevron
6. ConocoPhillips
7. Consolidated Edison
8. Enable Midstream
9. Enbridge
10. Entergy
11. Eversource
12. Exelon
13. Flynn Group of Companies
14. Graham Construction
15. Honeywell
16. Laney Group
17. Marsh
18. Mastec
19. Otis Elevator Company
20. PLH Group
21. Portland General Electric
22. Price Gregory International
23. Quanta Services
24. Remote Medical International
25. Sabic IP
26. Southern Company
27. Southern California Edison
28. TC Energy
29. TechnipFMC
30. Tennessee Valley Authority
31. TransCanada
32. Wolfcreek Group
33. Xcel Energy

CSRA
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SAFETY RESEARCH ALLIANCE

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

MEET THE BOARD

Brad MacLean
Senior Vice President
Wolfcreek Group

Ellen Quinn
Consultant
Otis Elevator

Dr. Matthew Hallowell
Executive Director
University of Colorado

Jenny Bailey
Director of Safety & Health
Xcel Energy

Ester Brawley
Director of Risk Engineering
California Resources Corporation

Bruno Cagnart
VP Global HSE & HSE Subsea
TechnipFMC

Len Colvin
Senior Manager, Safety Operations
Tennessee Valley Authority

Matt Compher
VP, Safety Health Environmental Quality
Quanta Services

Mike Court
Health Safety Environment & Quality Senior VP
Graham Group Ltd.

Nick DiMartino
VP of Corporate Safety
MasTec

Taco Franssen
HES Superintendent
Chevron

Greg Kelly
Manager Canadian Projects Safety
Enbridge

Joe Parham
Corporate Safety & Health Manager
Alabama Power

Mike Quashne
Performance Assessment & Business Transformation Manager
Baltimore Gas & Electric

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Consolidated Edison Company

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