The Future is Now: Occupational Robotics

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National Institute for Occupational Safety and Health

Yuma Pacific-Southwest Section

45th Annual Meeting

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ROBOTS OPERATED IN CAGES AWAY FROM HUMANS

TRADITIONAL ROBOTS HAVE A GOOD SAFETY RECORD

- Estimated 61 robot-related deaths, 1992-2015, CFOI*
  - Identified using keywords

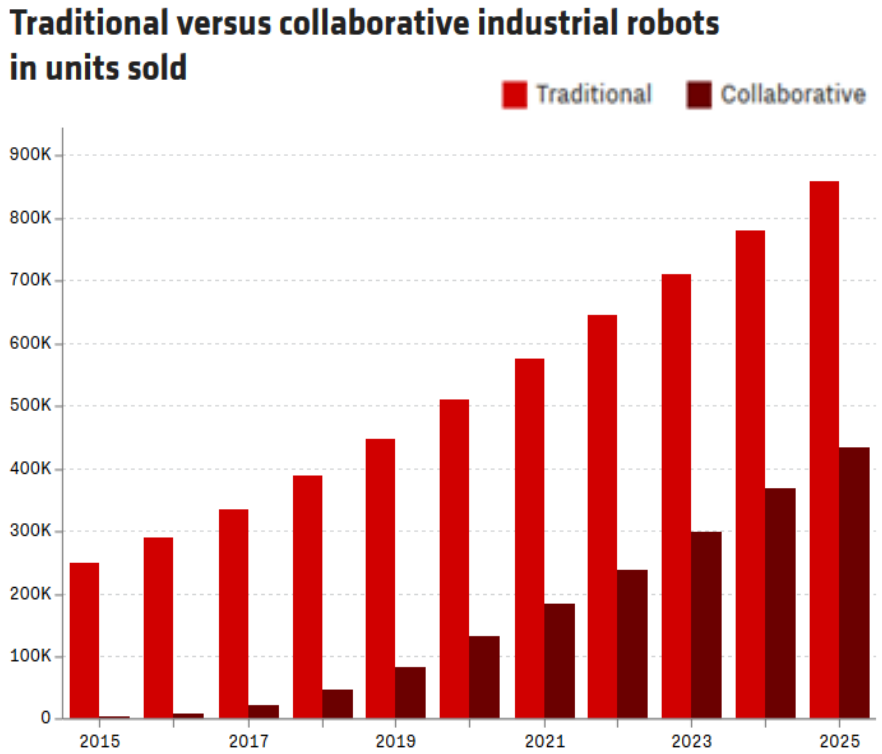
- < 1% of more than 190,000 workplace injury deaths during that timeframe**

Image by © 2016 Thossaphol/Getty Images

*Unpublished analyses by NIOSH. Through a MOU with BLS, NIOSH receives Census of Fatal Occupational Injury (CFOI) research files with restricted access requirements. Views expressed herein do not necessarily reflect the views of BLS.

** Data from publicly available CFOI data.

TRADITIONAL AND COLLABORATIVE ROBOT SALES INCREASING



https://www.recode.net/2017/6/22/15763106/industrial-robotics-market-triple-ten-years-collaborative-robots

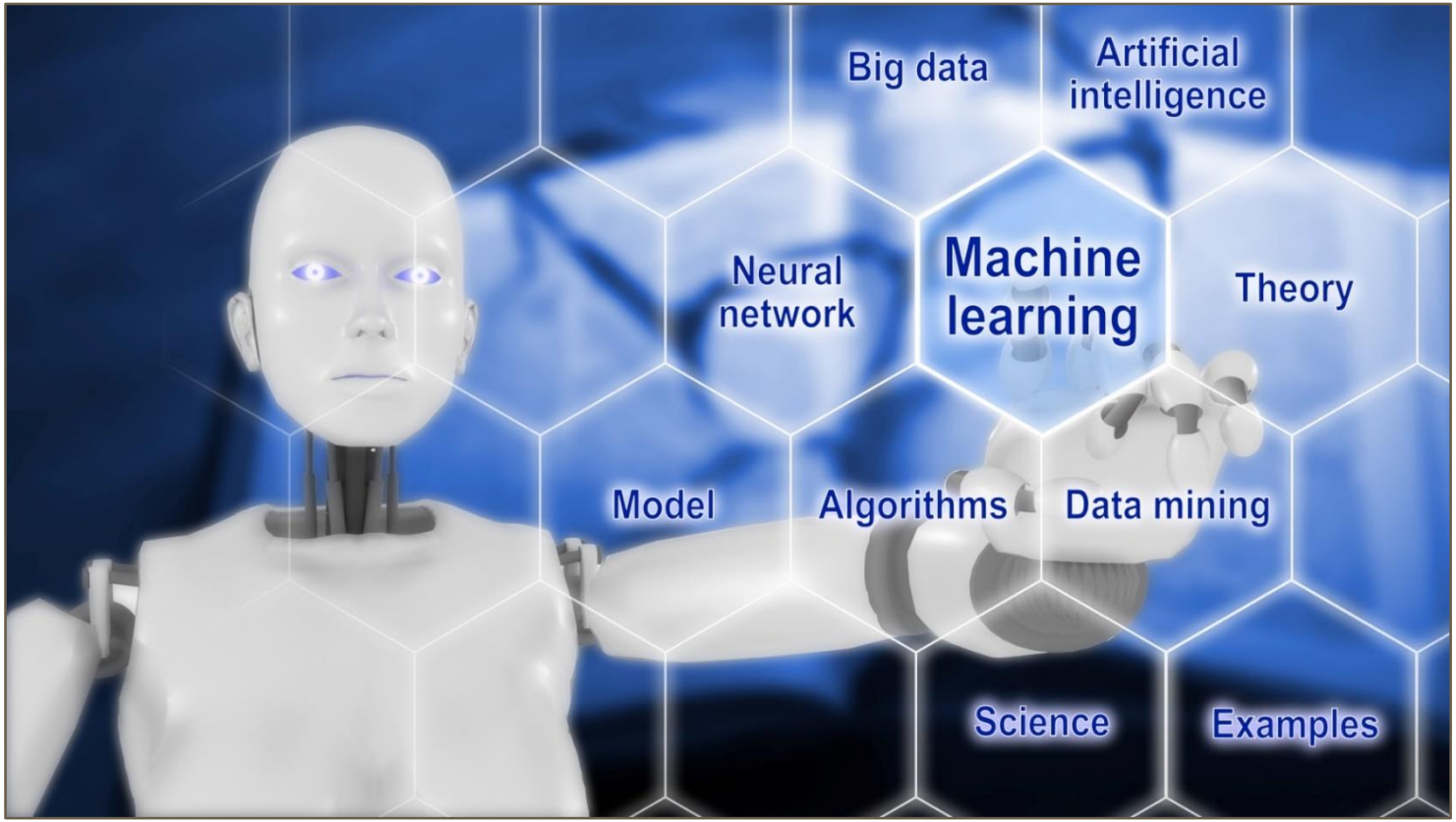
ROBOTS ARE BEING LET OUT OF THEIR CAGES

INTRODUCED TO NEW BUSINESSES

USED IN OUTDOOR WORK SPACES, PILOTED ON PUBLIC ROADS

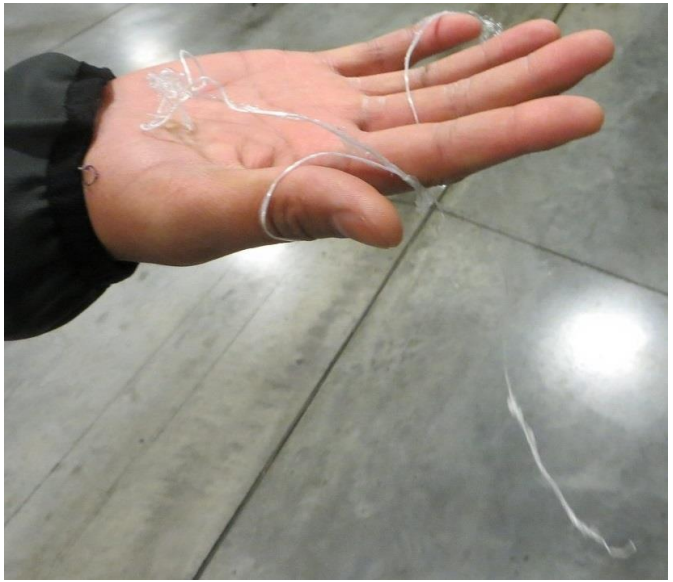
DESIGNED TO BE WORN BY WORKERS

WILL INCREASINGLY USE ARTIFICIAL INTELLIGENCE



CASE STUDY: WORKER CRUSHED WHEN THE ELEVATED FORKS OF A DRIVERLESS FORKLIFT CAME DOWN ON HIM

Plastic stringer from pallet obstructed LGV sensor



Washington State FACE Program [2018]. Warehouse worker crushed by forks of laser guided vehicle. Supported in part by NIOSH cooperative agreement. http://www.lni.wa.gov/Safety/Research/FACE/Files/WorkerCrushedByLGVForks.pdf

CASE STUDY: WORKER SEVERELY INJURED USING REMOTE CONTROLLED DEMOLITION ROBOT

Source: Washington State FACE Program (2019): Workers severely injured using demolition robots

ROBOTICS AND WORKER SAFETY AND HEALTH

Potential

- Expand dangerous work done by robots
- Robotic systems augment workers' abilities

Concerns

- Injuries
- New types of robots will require refined and new protection strategies
- Rapid advances in technology may outpace standards setting
- Stress associated with changing workplace and concerns about worker displacement

Concerns: Human Workers' Mental Health

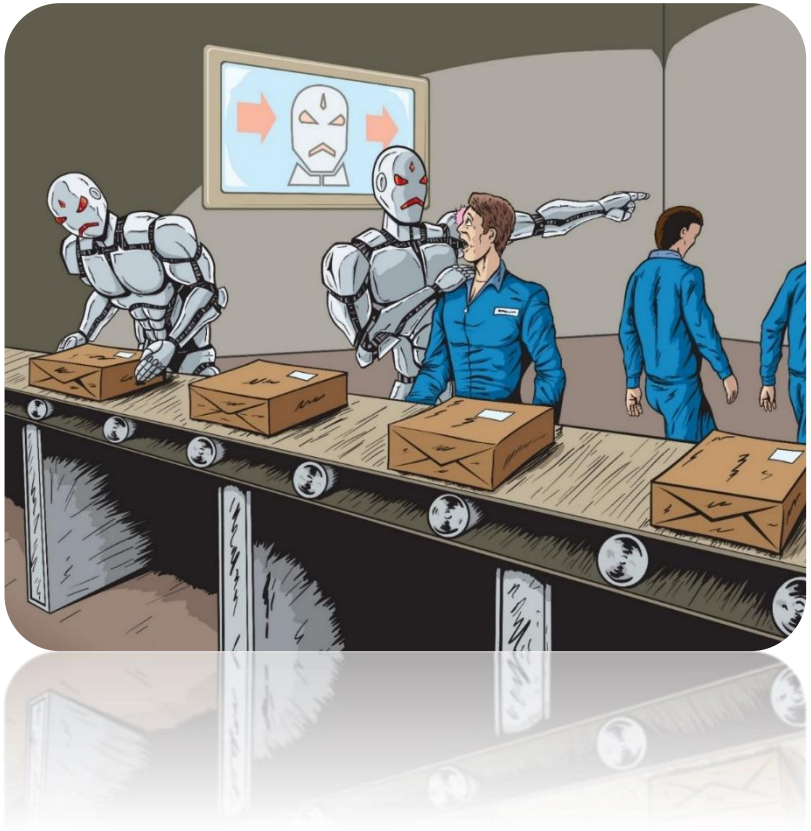
- Stress associated with working with robots
- Disrupted workplace
- Unfamiliar interactions and communication
- Existential threat to occupational security

Naomi has more on this element next

https://www.callcentrehelper.com/will-robots-replace-humans-in-the-contact-centre-101371.htm

WORKER STRESS

- Worker fears are real whether this scenario proves to be true or overblown



Center for Occupational Robotics Research

CENTER MISSION

Provide scientific leadership to guide the development and use of occupational robots that enhance worker safety, health, and well-being.

Photo by © 2014 ndoeljindoel/Getty Images

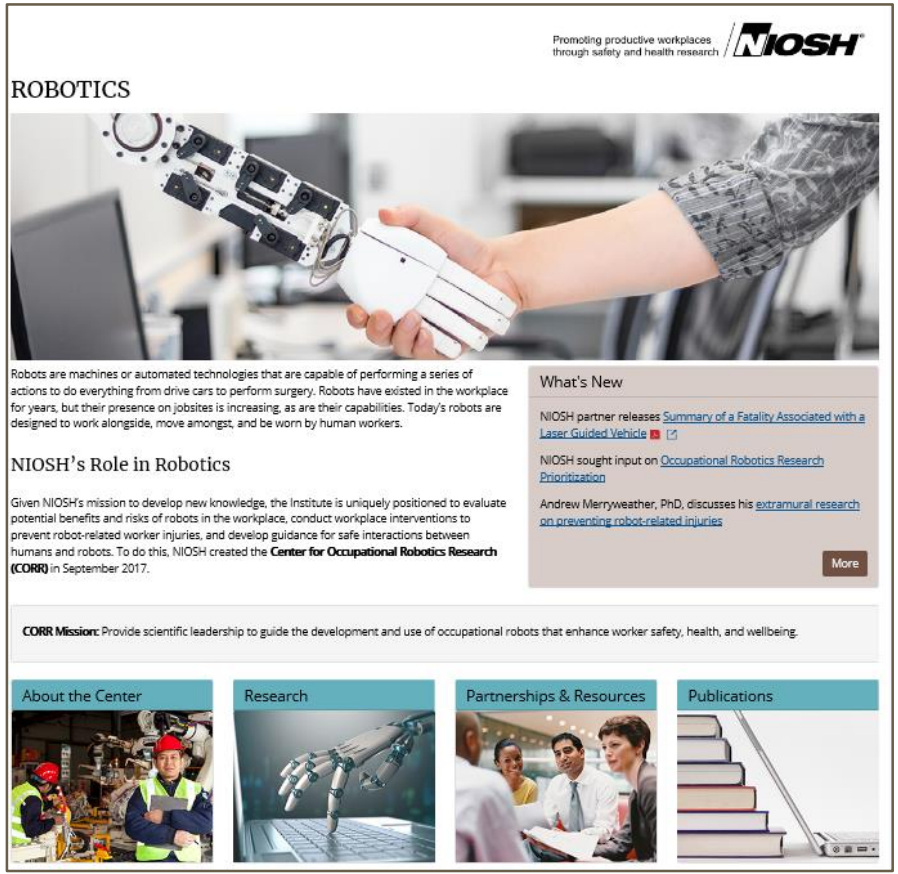
CENTER SCOPE

- Traditional industrial robots
- Emerging robotics technologies
  - Collaborative robots
  - Mobile robots
  - Powered exoskeletons/exosuits
  - Remotely controlled and autonomous vehicles and drones
  - Future robots using advanced artificial intelligence

WHAT THE CENTER DOES

- Monitors trends in injuries
- Evaluates robotics technologies as sources of, and as interventions for, workplace injuries and illnesses
- Establishes risk profiles of robotic workplaces
- Identifies research needs and conducts research
- Supports the development and adoption of consensus standards
- Develops and communicates best practices, guidance and training for safe interactions between human workers and robotics technologies

CENTER WEBSITE



https://www.cdc.gov/niosh/topics/robotics/

PARTNERS

- Academic researchers
- Trade associations
- Robotics manufacturers
- Employers using robotics technologies
- Labor organizations
- Other federal agencies

October 5, 2017 signing ceremony, OSHA, NIOSH, Robotics Industries Association Alliance

PARTNERSHIPS

alliance
An OSHA Cooperative Program

ria
Robotic Industries Association

NITRD
Networking and Information Technology Research and Development

Intelligent Robotics and Autonomous Systems Interagency Working Group

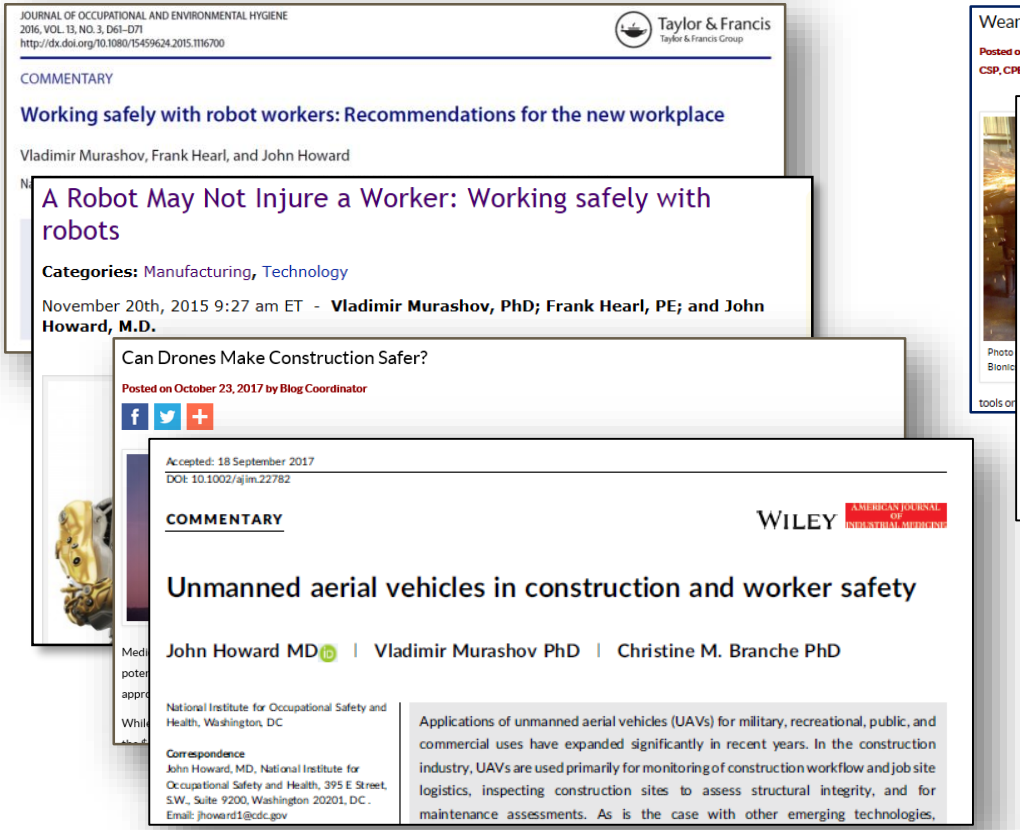
HFES
Human Factors and Ergonomics Society

ARM
ADVANCED ROBOTICS FOR MANUFACTURING

NC STATE UNIVERSITY
ise

Japan Organization of Occupational Health and Safety
JNIOSH
JNIOSH National Institute of Occupational Safety and Health, Japan

SCIENTIFIC COMMENTARIES AND BLOGS



JOURNAL OF OCCUPATIONAL AND ENVIRONMENTAL HYGIENE
2016, VOL. 13, NO. 3, D61–D71
http://dx.doi.org/10.1080/15459624.2015.1116700

Taylor & Francis
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COMMENTARY

Working safely with robot workers: Recommendations for the new workplace

Vladimir Murashov, Frank Hearl, and John Howard

A Robot May Not Injure a Worker: Working safely with robots

Categories: Manufacturing, Technology

November 20th, 2015 9:27 am ET - **Vladimir Murashov, PhD; Frank Hearl, PE; and John Howard, M.D.**

Can Drones Make Construction Safer?

Posted on October 23, 2017 by Blog Coordinator

Accepted: 18 September 2017
DOI: 10.1002/ajim.22782

COMMENTARY

WILEY

AMERICAN JOURNAL OF INDUSTRIAL MEDICINE

Unmanned aerial vehicles in construction and worker safety

John Howard MD | Vladimir Murashov PhD | Christine M. Branche PhD

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Applications of unmanned aerial vehicles (UAVs) for military, recreational, public, and commercial uses have expanded significantly in recent years. In the construction industry, UAVs are used primarily for monitoring of construction workflow and job site logistics, inspecting construction sites to assess structural integrity, and for maintenance assessments. As is the case with other emerging technologies,

Wearable Exoskeletons to Reduce Physical Load at Work

Posted on March 4, 2016 by Brian D. Lowe, PhD, CPE; Robert B. Dick, PhD, Captain USPHS (Ret.); Stephen Hudock, PhD, CSP; and Thomas Bobick, PhD, CSP, CPE

Exoskeletons in Construction: Will they reduce or create hazards?

Posted on June 15, 2017 by Alissa Zingman, MD; G. Scott Earnest, PhD, PE, CSP; Brian D. Lowe, PhD, CPE; Christine M. Branche, Ph.D., FACE;

Wearable exoskeleton devices can reduce some of the mechanical stress of manual labor (1). These wearable machines can be powered by electricity or by human motion, and they can be as large as a space suit or as small as a glove. (1; 2) They are used to amplify or transform worker movements, improve biomechanics and efficiency, and are increasingly prevalent in the public and private sectors. NIOSH published its first blog on this topic in 2016 (3). As these devices are deployed more widely in the workplace, sound research is required to assess potential dangers and benefits of this new technology.

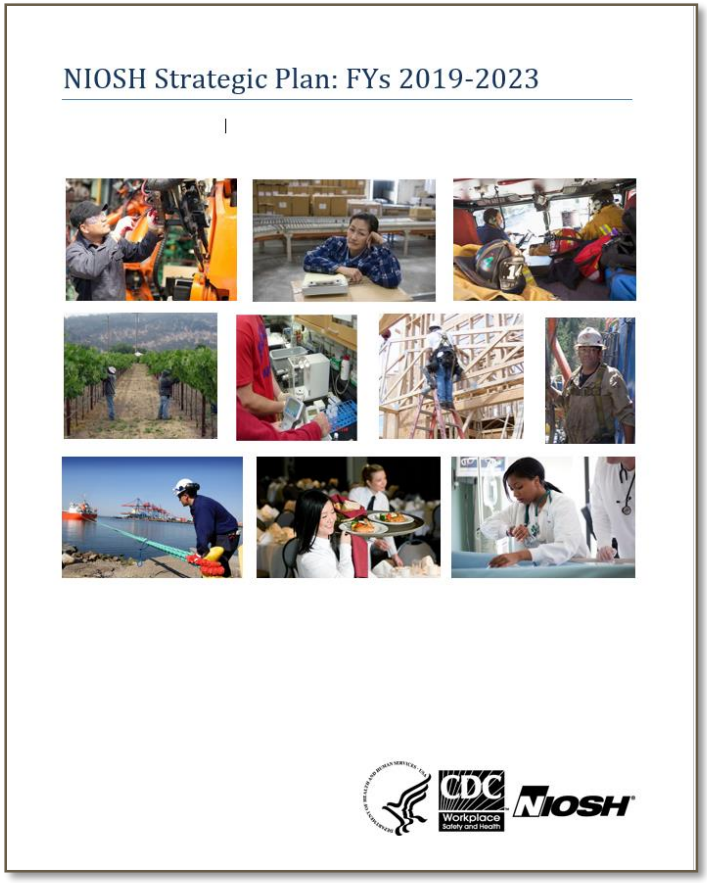
Construction is a physically demanding, labor-intensive industry with heavy manual material handling and awkward work postures. Musculoskeletal disorders (MSDs) are a leading cause of injury among construction workers (4; 5), with overexertion in lifting causing over one-third of these injuries. (6) The rate of work-related musculoskeletal disorders in construction is 16% higher than in all industries combined(5). Since back injuries are the most prevalent work-related musculoskeletal disorders in construction, (5) and shoulder and other joint injuries are also major causes of injury, exoskeletons present an attractive possibility.

In a study of forward bend lifting using an exoskeleton designed to decrease load to the spine and improve posture, researchers found that exoskeletons decrease total work, fatigue and load while improving posture. (1) This is supported by additional studies (1; 7). In addition to decreasing load on the spine, exoskeletons have been shown to decrease shoulder discomfort while increasing productivity and work quality among painters and welders (8).

While these benefits are promising, exoskeletons also introduce new risk factors. The same study also demonstrated increased chest pressure due to wearing the device.(1) This could negatively impact workers, particularly those with pre-existing conditions, such as chronic obstructive pulmonary

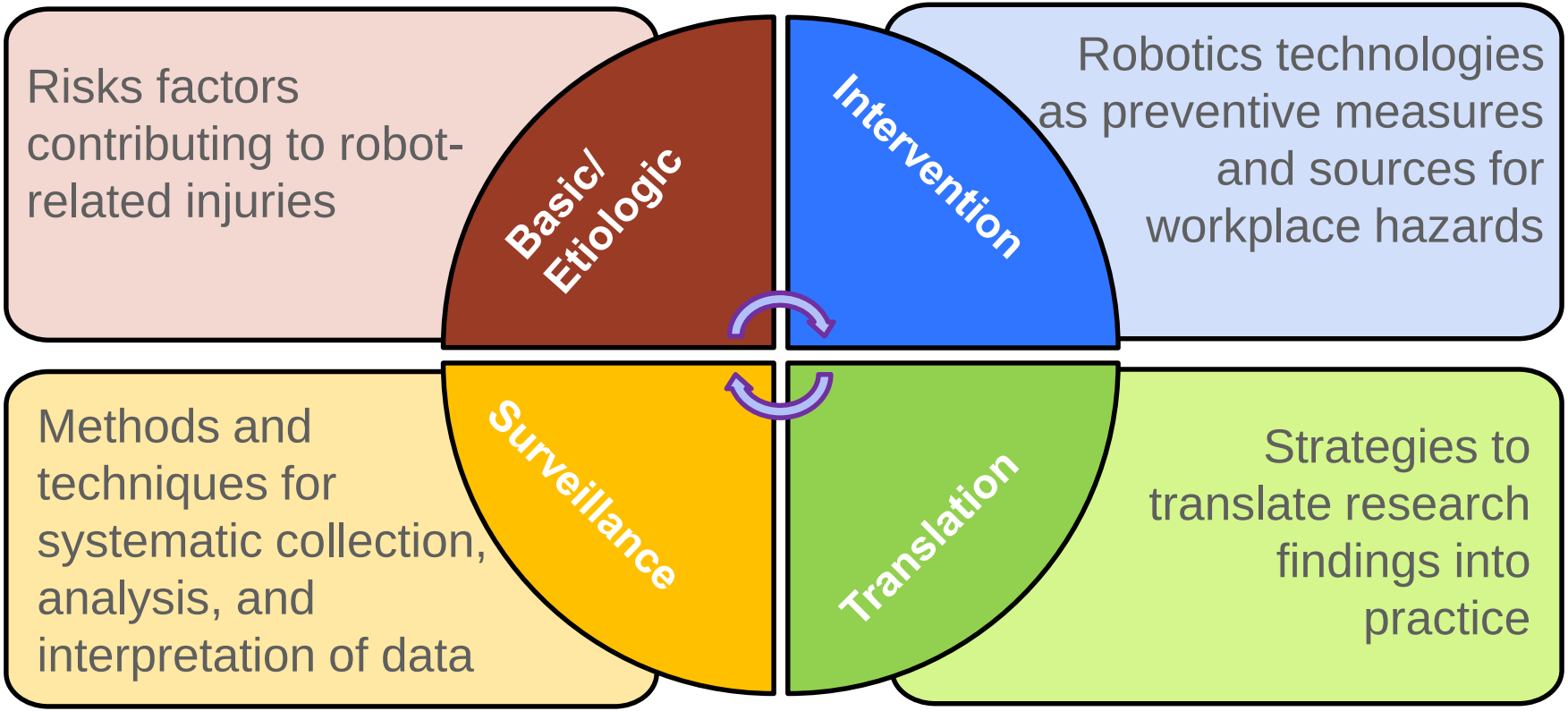
ROBOTICS RELATED RESEARCH GOALS

- Included in Strategic Goals for
  - Traumatic Injury Prevention
  - Musculoskeletal Health
  - Healthy Work Design and Well-being
- Considered burden, need and potential for impact by industry sector



https://www.cdc.gov/niosh/about/strategicplan/

OCCUPATIONAL ROBOTICS RESEARCH NEEDS



DETAILED RESEARCH NEEDS

- Complement general goals in Strategic Plan
- Reviewed by key federal partners
- Revised based on input received through public docket
- https://www.cdc.gov/niosh/topics/robotics/research.html

Basic/Etiologic Example

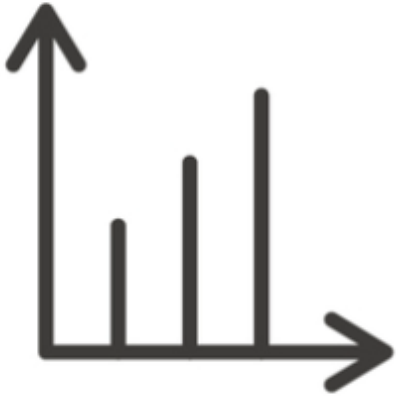
Development of science-based pain tolerance thresholds for human worker contact with robots in the workplace.

INTRAMURAL RESEARCH PORTFOLIO

- Surveillance analyses
- Fatality investigations
- 3 one-year pilot projects
- 8 research projects
- Mining program research on robotics technologies and automation

Photo by © 2016 nd3000/Getty Images

SURVEILLANCE

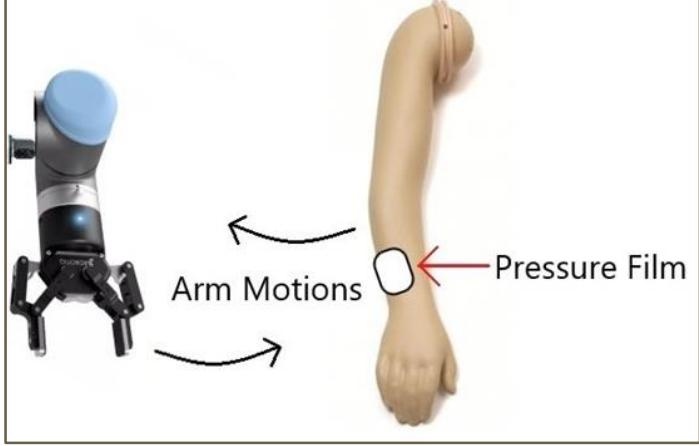


- Refining keyword searches and methods
- Exploring ability to identify cases in different databases
- Made recommendations to Bureau of Labor Statistics (BLS) for potential changes to Occupational Injury and Illnesses Classification System
- Analyzing data from BLS Census of Fatal Occupational Injuries
- Will explore analyses of workers' compensation data

Contact: Larry Layne

A PILOT STUDY TO MEASURE DYNAMIC FORCE IMPACTS OF COLLABORATIVE ROBOTS ON HUMANS

- Evaluate the pressure and force limits for collaborative robots on the human body during dynamic human-robot contact events
  - Human arm swing towards robot
  - Human fall onto robot
- Methods: formative data collection followed by simulations
- Partner: National Institute of Standards and Technology



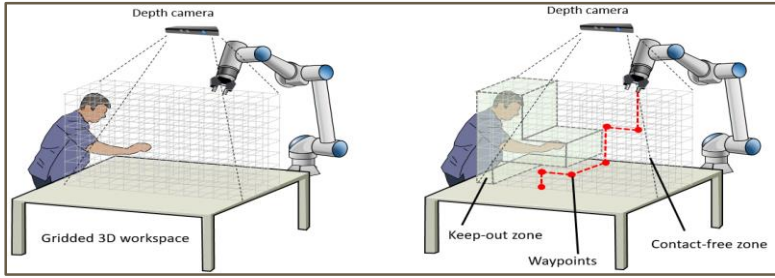
Simulated contacts between a robot and human

Contacts: Bryan Wimer, HeeSun Choi

PILOT: CONTACT AVOIDANCE BETWEEN HUMAN WORKERS AND COLLABORATIVE ROBOTS

- Investigate
  - motion recognition of human workers
  - path planning strategies for a collaborative robot
  - effectiveness of a synthesized control strategy
- Methods: human subjects to identify “contact free zones”; machine learning for path planning
- Partner: West Virginia University

Contacts: Marvin Cheng, Hongwei Hsiao



Gridded workspace of the human worker- collaborative robot

PILOT: DRONES IN CONSTRUCTION AND THEIR EFFECTS ON WORKERS AT HEIGHTS

- Hypothesis: A drone operating in close proximity to an elevated worker may contribute to imbalance
- Methods: virtual reality cave and human subject measurements of sway, heart rate and perceived distraction
- Partners: WVU Safety and Health Extension, Thrasher Group

Contacts: Darlene Weaver, Jim Green

REVIEW OF OS&H INTERVENTION CASE STUDIES OF ROBOTIC EQUIPMENT IN MANUFACTURING

- Evaluate workers compensation grants for robotic equipment to prevent worker injuries
- Methods: quantitative and qualitative case studies
  - Analyze worker's comp experience before and after grant
  - Evaluate employer's narrative reports, including risk factor abatement and employee acceptance and adoption
- Partner: Ohio Bureau of Workers' Compensation
- Oct 2018 – Sep 2021

Contact: Brian Lowe

Grant to purchase robotic ribbon tie machine to reduce injuries from awkward postures and repetitive motion

PREVENTION OF MANUAL MATERIALS HANDLING (MMH) INJURIES IN MINING

- Reduce MMH injuries through increased use of solutions and safe practices;
- Includes determining the efficacy of exoskeletons
- Methods:
  - Analyze mining data to identify MMH tasks associated with shoulder overexertion injuries
  - Determine physical requirements
  - Assess feasibility of exoskeletons to reduce these injuries
- Oct 2018 – Sep 2022

Worker performing manual materials handling while palletizing 100 pound bags of sand.

Contact: Jonisha Pollard

IMPROVING SAFETY OF HUMAN-ROBOT INTERACTION

- Examine human behaviors while interacting with collaborative and mobile robots
- Methods: virtual simulation of robot and robot interface
  - Varying physical characteristics of robot
  - Different interface design
- Partners: North Carolina State University, Advanced Robotics for Manufacturing Institute
- Oct 2018 - Sep 2021

Examples of robots with different physical characteristics

Contacts: HeeSun Choi, Hongwei Hsiao

EFFECT OF VEHICLE AUTOMATION ON TRUCK DRIVER SITUATION AWARENESS AND ROAD SAFETY

- Specific aims:
  - Determine minimum time for a driver to regain situational awareness and take back vehicle control
  - Evaluate effects of different automation levels
- Methods: Driving simulation with human subjects
- Partners: AAA Foundation, Crash Safety Solutions, Mississippi State University
- Oct 2018 - Sep 2022

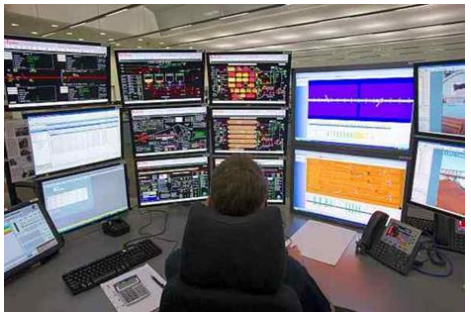
NIOSH Virtual Driving Simulator

Contacts: Md Mahmudur Rahman, Hongwei Hsiao

MINING PROGRAM RESEARCH ON ROBOTICS TECHNOLOGIES AND AUTOMATION

- Engaged for several years in supporting development of robotics technologies to improve mine worker safety and health
- In the process of prioritizing research to reflect trends towards increased automation in mining

Prototype snake robot for mine rescue



Trends toward remotely controlled and digitized mines

Contacts: Jeff Welsh, Todd Ruff

STANDARDS

Updating

- ANSI/RIA R15.06 – Industrial **Robots and Robot Systems Safety**

Under development

- ANSI/RIA R15.08 – Industrial **Mobile Robot Safety**
- ASTM F48 – **Exoskeletons and Exosuits**

Pre-Standard

- ANSI **Unmanned Aircraft Systems** Standardization Collaborative Roadmap
- ANSI/ASSP/NSC Z15.3- Safety Management of **Partially and Fully Automated Vehicles** *(Technical report)*

CASE REPORTS

WASHINGTON State FACE Program
Fatality Assessment & Control Evaluation

AUTOMATION/ ROBOT
FATALITY NARRATIVE

FACE NIOSH

Warehouse Worker Crushed by Forks of Laser Guided Vehicle

INCIDENT FACTS

REPORT #:
71-171-2018

REPORT DATE:
5/10/2018

INCIDENT DATE:
12/9/2015

VICTIM:
45 years old
Employed at facility for approximately one year

INDUSTRY:
Bottled water manufacturing

OCCUPATION:
Warehouse dock coordinator

SCENE:
Water bottling plant warehouse

EVENT TYPE:
Crush

Example of a plastic "stringer" torn from pallet wrapping that often obstructed LGV sensors.

For a slideshow version, click here.

SHARP Safety & Health Assessment & Research for Prevention

Washington State Department of Labor & Industries

SUMMARY

In December 2015, a 45-year-old warehouse dock coordinator at a water bottling company died after he was crushed when the elevated forks of an automatic laser guided vehicle came down on him.

Photo of LGV involved in the incident.

The company used driverless forklifts, known as laser guided vehicles (LGVs), in the warehouse to move pallets of water bottles. LGVs automatically navigated using a system of vehicle mounted lasers and reflectors positioned throughout the warehouse. Each LGV had safety sensors designed to detect objects or workers in the vehicle's path. When a sensor detected an obstacle, the LGV would stop moving and an alarm would sound until a worker removed the obstacle.

The manufacturer's manual required workers to initiate an emergency stop before removing an obstacle detected by the LGV. An LGV would then have to be manually reset before restarting its task. Without initiating an emergency stop, the LGVs would resume automatic function immediately after an obstruction was removed.

The victim was working in the warehouse when an LGV alarm was activated. Shortly after, another worker heard noises over the radio and looked into the warehouse to investigate. He saw the victim slumped over one of the LGVs. The LGV then started moving again, and the other worker hurried to it and initiated an emergency stop. He could see that the victim had severe injuries to his chest and jaw. He called for help and called 911. Emergency responders arrived within minutes and transported the victim to a local hospital where he was pronounced dead.

Investigators believe that the victim attempted to remove a piece of plastic from under the elevated forks of the LGV without first initiating an emergency stop. Long strips of plastic wrap often tore off of pallets during loading and unloading and stuck to the forks of the LGVs. If the plastic entered the safety detection field of the LGV, it would be recognized as an obstacle. Other employees said that these plastic "stringers" frequently triggered LGV alarms. The victim was likely bending or kneeling under the forks outside of the safety sensor field to reach the plastic stringer. Because the LGV was not in emergency stop mode, the system reset when the obstacle was removed, bringing the elevated forks down, crushing him against the wheel cover of the vehicle.

There were warning signs affixed to the vehicle indicating that workers should avoid standing beneath the elevated forks.

REQUIREMENTS

- Employers must protect workers around PITs (powered industrial trucks), and not allow them under the elevated part of any PIT, whether it is loaded or empty. See WAC 296-863-4005(2)(a).

RECOMMENDATIONS

FACE investigators concluded that, to help prevent similar occurrences, employers should:

- Incorporate manufacturer safety requirements into written company safety procedures for automated guided industrial vehicles.
- Train workers about the specific hazards and safety requirements associated with automated guided industrial vehicles, like LGVs. Emphasize that workers are expected to follow required safety procedures every time, and ensure compliance through periodic refresher training and spot checks.

This narrative is an alert about the tragic loss of life of a worker and is based on preliminary data ONLY and does not represent final determinations regarding the nature of the incident or the cause of the fatality. Developed by WA State Fatality Assessment and Control Evaluation (FACE) Program and the Division of Occupational Safety and Health (DOSH), WA State Dept. of Labor & Industries. The FACE Program is supported in part by a grant from the National Institute for Occupational Safety and Health (NIOSH grant# 2U60OH008487). For more information visit www.lni.wa.gov/Safety/Research/FACE.

WASHINGTON State FACE Program
Fatality Assessment & Control Evaluation

CONSTRUCTION
HAZARD ALERT

FACE NIOSH

Workers Severely Injured Using Demolition Robots

Two construction workers were severely injured in separate incidents involving remote controlled-demolition machines also known as demolition robots. Workers operated similar machines with three-part articulating arms powered by electric-controlled hydraulics. Both used remote controllers intended to keep them outside the machine's risk zone, which varies by specific machine, attachment, and task.

OPERATOR CRUSHED BETWEEN DEMOLITION ROBOT AND WALL

Industry: Specialty Trade Contractors

An operator was using a machine fitted with a shear attachment to demolish an HVAC system. He wore a waist-mounted remote controller connected to the machine by wire (Photo 1).

After he repositioned the machine, he had to move the power cable before lowering the outrigger. As he attempted to move the cable, he bumped the remote control against the machine. He had not put the machine into emergency stop mode, so it moved and pinned him between the outrigger and the wall. He tried to free himself but lost consciousness.

A coworker saw that he was pinned and slumped over the machine. The coworker tried using the remote control but the machine wouldn't move. Other workers then cut power to the machine and tried pushing it with a skid steer. After multiple attempts, they were able to rescue him. His chest was severely crushed causing him to be out of work for several months.

He had been with his employer six months and was reported to be an experienced operator of these machines. He usually worked with a partner but was alone at the time of the incident.

Photo 1: Remote control box with red emergency stop button.

OPERATOR'S FOOT CRUSHED UNDER OUTRIGGER

Industry: Highway, Bridge, and Street Construction

An operator was using a machine with a breaker attachment to chip concrete as part of a generator installation project. He stood in a tight spot between the excavation wall and the machine (Photo 2). As he tried to apply more pressure on the tip of the breaker, the front outrigger raised off the ground. The machine suddenly shifted forward and the outrigger came down, crushing his foot. He was able to use the remote control to raise the outrigger but suffered broken bones and nerve damage.

Photo 2: Machine and approximate location of operator (indicated by red "X").

The employer conducted a job hazard analysis that identified the swing radius of the arm as a hazard, but did not recognize the potential of being crushed under an outrigger. The manufacturer's safety instructions warn to never stand where there is a risk of being crushed.

He had worked in construction for 23 years but had only operated the machine for five days. His training consisted of a hands-on demonstration and a brief review of the operator's manual.

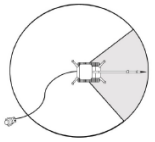


Figure 1: Example of machine operating risk zone and remote operator position.

RECOMMENDATIONS

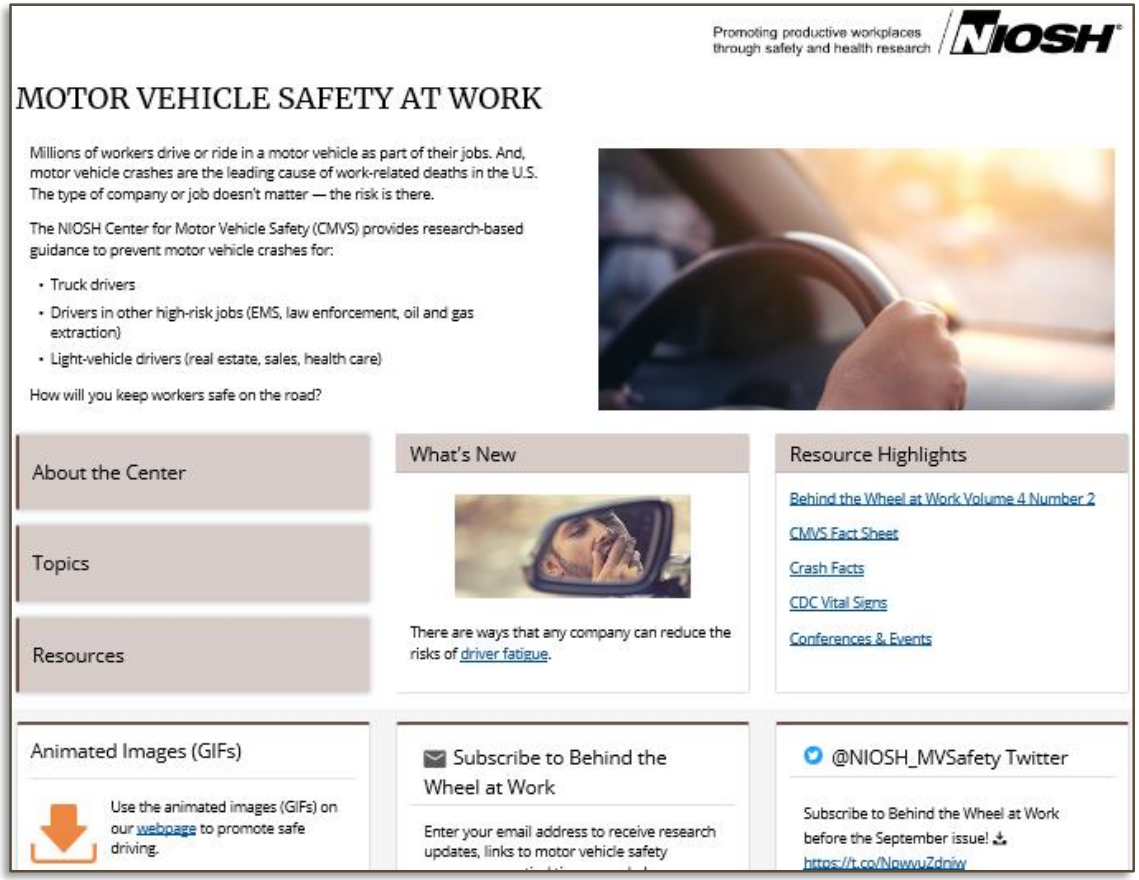
- Prepare a job hazard analysis with operators for each new job to identify and control hazards. Use the manufacturer's safety instructions to establish the risk zone for the specific machine, attachment, and task.
- Always stay outside the risk zone when the machine is in operation (Figure 1), and do not enter until the machine is put into emergency stop mode or deenergized.
- Consider using a proximity warning system, such as those based on radio frequency identification (RFID), to maintain a safe worker-to-machine distance.
- Train operators to manage power cables and to continually monitor the process for hazards and redefine the risk zone.
- Ensure operators always read and follow manufacturer's provided safety instructions.
- Consider using a spotter to assist the operator.

Washington State Department of Labor & Industries

SHARP Publication No. 47-26-2019

SHARP Safety & Health Assessment & Research for Prevention

This alert is based on preliminary data and does not represent final determinations regarding the nature of the incidents or the cause of injuries. Developed by the WA Fatality Assessment and Control Evaluation (WA FACE) Program and the Division of Occupational Safety and Health (DOSH), WA State Dept. of Labor & Industries. The FACE Program is supported in part by a grant from the National Institute for Occupational Safety and Health (# 5U60OH008487). For more information: www.lni.wa.gov/Safety/Research/FACE.



https://www.cdc.gov/niosh/motorvehicle/

PRESENTATION TAKE-AWAYS

- Robotics technology is an important emerging area for research
- The new NIOSH Center aims to provide scientifi leadership
- Research goals in the NIOSH Strategic Plan will guide NIOSH intramural and extramural robotics research
- The NIOSH intramural and extramural program is small, but growing

Thank You!

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https://www.cdc.gov/niosh/topics/robotics/