

Utilizing a human centered design approach for mine automation

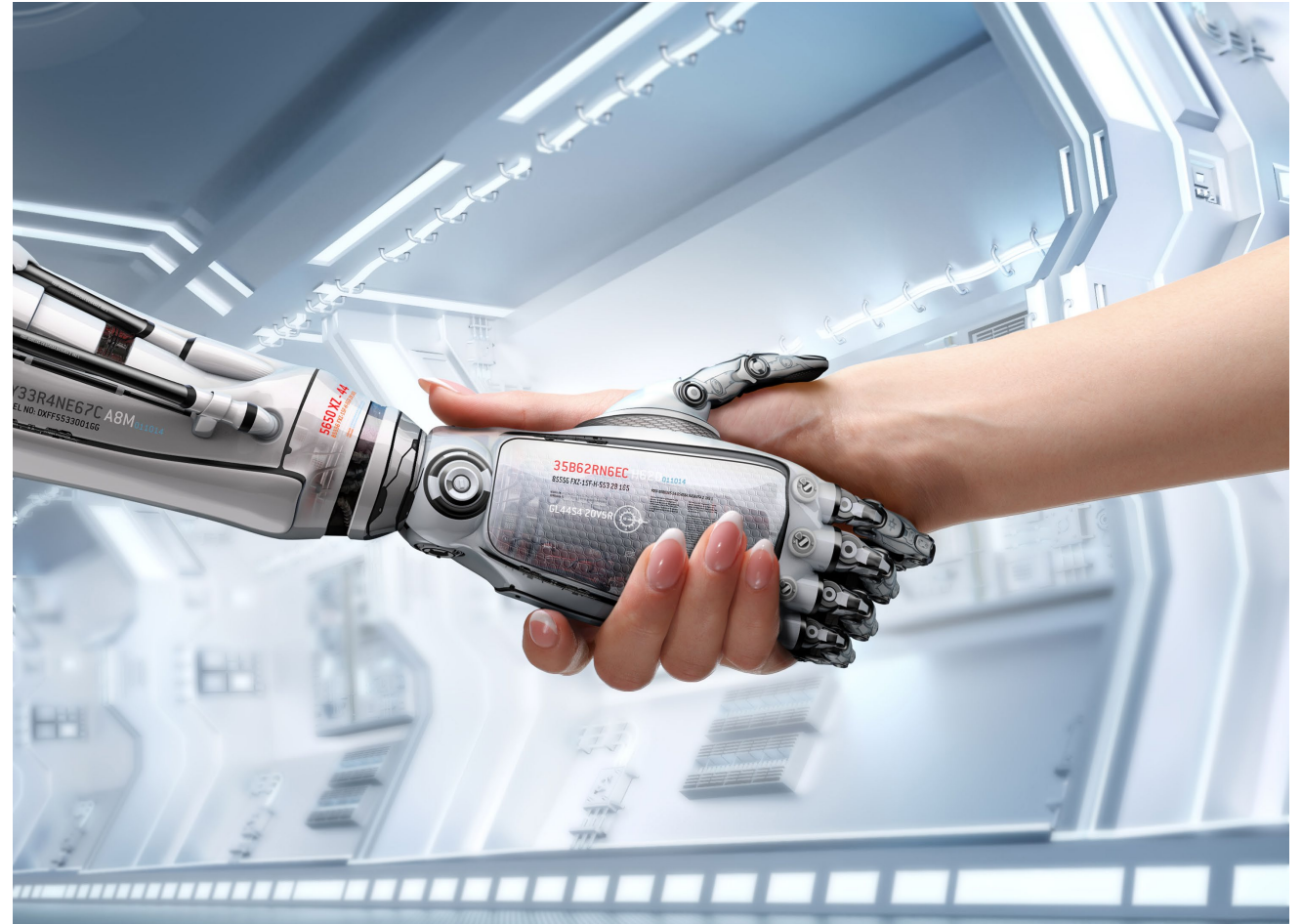
Pilot project update

Dr. Mahiyar Nasarwanji

Dr. Lisa Steiner

Dr. Brianna Eiter

Automation Partnership Meeting
September 14-15, 2022



Defining Human Centered (centred) Design

“Human-centred design is an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques.”

Automation at mines is increasing

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EXPLORATION/DEVELOPMENT FINANCE COMMODITIES VIEWPOINT METS INVESTOR MINE RISK MANAGEMENT FUTURE OF MINING ALL SECTIONS

Industry could fast-track automation amid COVID-19 fallout

Depending on how long this COVID-19 pandemic crisis lasts, the mining industry could see big moves into autonomous mining technologies in the not-too-distant future, says SAP Africa mining advisor Shabir Ahmed.



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SURFACE MINING UNDERGROUND MINING PROCESSING ASSET MANAGEMENT INFRASTRUCTURE FUTURE OF MINING ALL SECTIONS

Cab-less haul truck approaching

The first cab-less, autonomous mine haul truck is "not far away" according to Caterpillar surface mining and technology division vice president Jean Savage, pointing to the mining industry's growing confidence in technological change

Press release



Miners speed up automation as safety concerns linger

Cecilia Jamasmie | October 21, 2020 | 3:01 am Careers & Education Ore Potash

Mining Technology

Comment

Australian haul truck

GlobalData | 17 March 2020

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Autonomous trucks collide at Jimblebar

Another two autonomous trucks have crashed in Western Australia's Pilbara, this time at BHP's Jimblebar mine site



Research objective

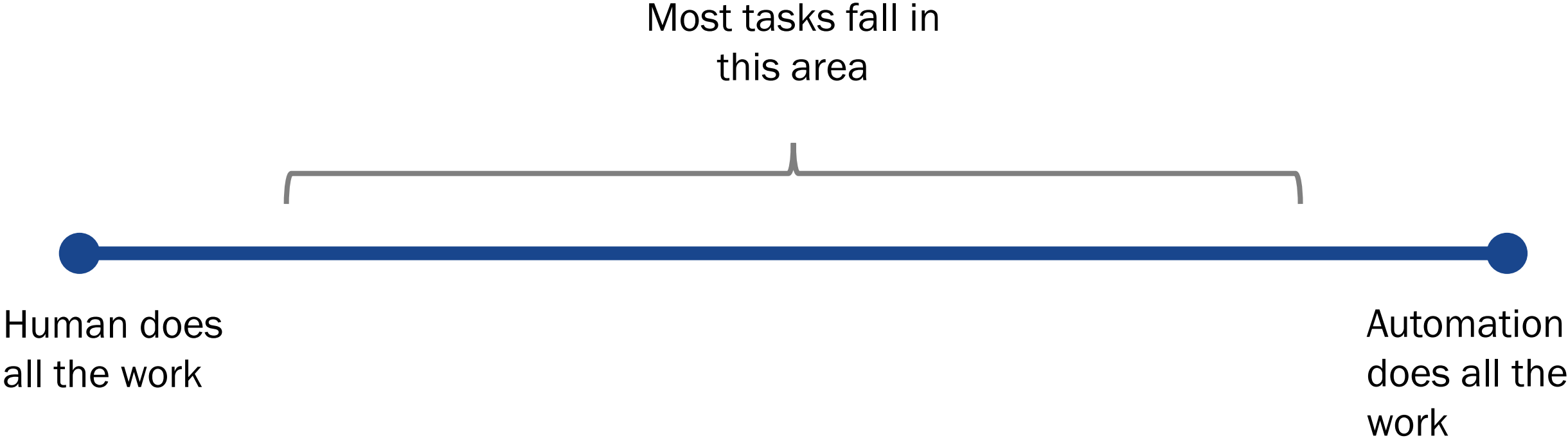
- To identify, understand, and document **human factors considerations and expectations** when designing, deploying, and implementing automation along its continuum as part of a **human system integrated approach** to improve mineworker's health and safety.



Until we can design truly independent systems humans will be involved and need to interact with the system

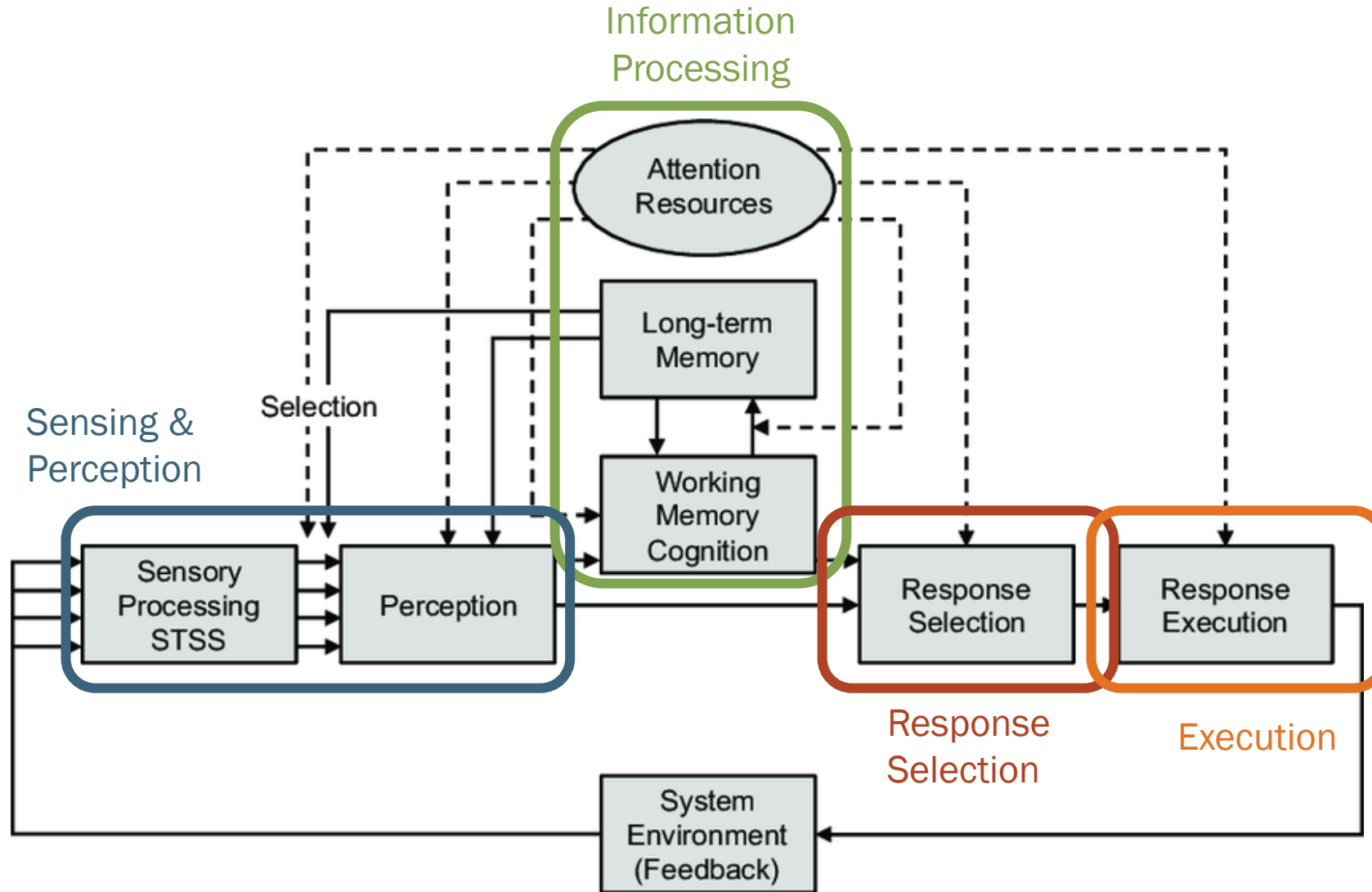


The continuum of automation



Humans interacting at different levels with the automated system

Human information processing model



Simple human information processing model



Levels of automation in the human context

(based on decision making and response selection and execution)

1. Manual	The human performs all the required tasks.
2. Action Support	System assists the operator with performance of the selected action (eg tele-operation).
3. Batch Processing	Human generates and selects options to be performed, which are turned over to the system to be carried out automatically.
4. Shared Control	Both human and system generate possible decision options, human selects which option to implement, carrying out actions is shared.
5. Decision Support	The system automatically generates a list of decision options, human selects from list or generates own, then turned over to system to implement.
6. Blended Decision Making	The system automatically generates a list of decision options, which it selects from and carries out if human consents.
7. Rigid System	The system presents a limited set of actions to the human, human must select from list, the system will then implement the actions.
8. Automated Decision Making	The system selects the best option (from a system and human generated list) and implements it.
9. Supervisory Control	The system generates options, selects and implements the option, human monitors and intervenes if required, who can select a different option.
10. Full Automation	The system carries out all actions, human completely out of control loop and cannot intervene.

Taxonomies

Lots of different taxonomies with lots of different levels

Levels

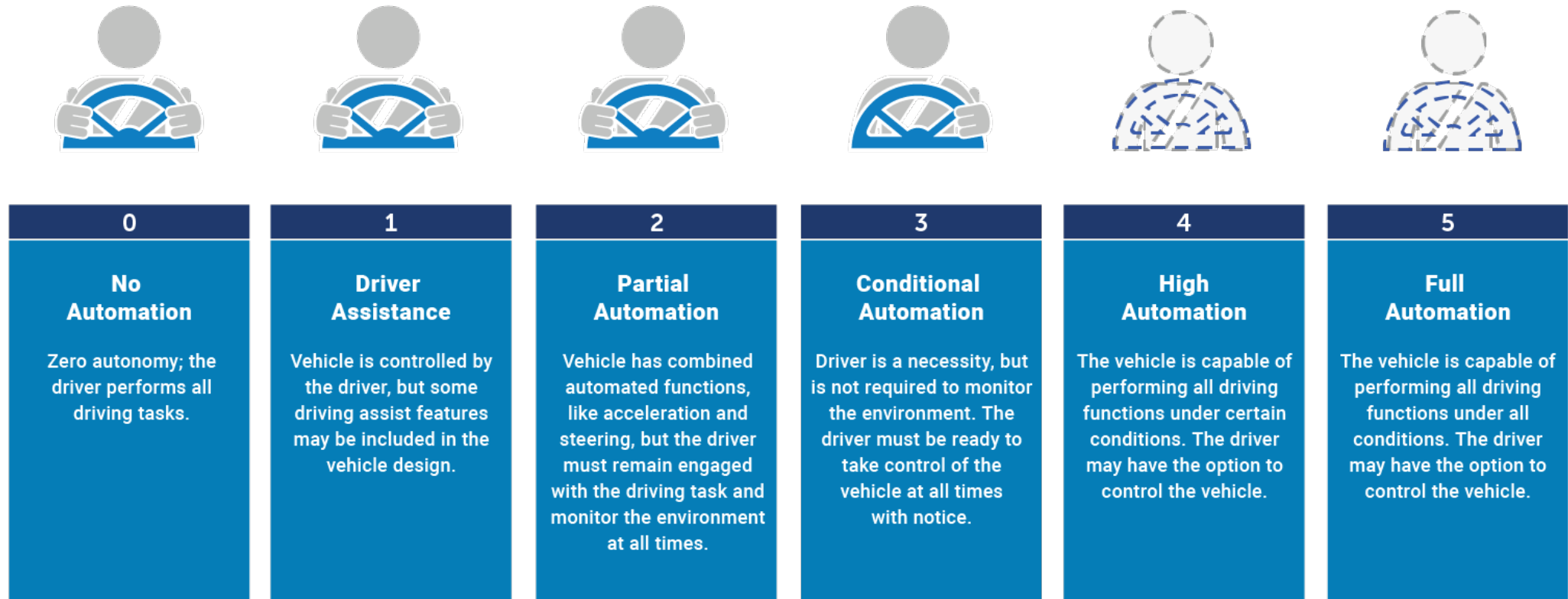
Level characteristic / Authors	Sheridan & Verplank [63,65] (10 LOA)	Endsley [13] (4 LOA)	Ntuen & Park [39,40] (5 LOA)	Riley [55] (12 LOA)	Milgram [35] (5 LOA)	Endsley & Kaber [15] (5 LOA)	Draper [12] (5 LOA)	Endsley & Kaber [14] (10 LOA)	Lorenz et al. [32] (3 LOA)	Clough [8] (4 LOA)	Proud et al. [54] (6 LOA)	Ferrelundian et al. [16,17] (11 LOA)
Manual (a)	Level 1		Level 1	Level 1	Level 1	Level 1	Level 1	Level 1	Level 1 (Low Level)	Level 1	Level 1	Level 0
Data Acquisition (b)				Level 2 (Information Fuser)							Level 2	Level 1
Telepresence (c)					Level 2							
Manual Control with intelligent Assistance (d)							Level 2					
Remotely Operated (e)										Level 2 (Remotely Operated)		
Computer offers decisions (f)	Level 2	Level 1 (Decision Support)	Level 2 (Decision Support)	Level 3 (Simple Aid)		Level 2		Level 2 (Action support)	Level 2 (Medium Level)		Level 3	Level 2
Narrows down selection (g)	Level 3							Level 7 (Rigid system)				Level 3
Director/Agent Control (h)				Levels 4,5,6 (Advisor, Interactive/Adaptive Advisor)	Level 3 (Director/Agent Control)			Level 3 (Batch Processing)				
Shared Control (i)							Level 3	Level 4 (Shared Control)				
Suggests one alternative (j)	Level 4											Level 4
Executes with human approval (k)	Level 5	Level 2 (Conceptual AI)	Level 3 (Conceptual AI)	Levels 7,8 (Servant, Assistant)		Level 3		Level 6 (Banded Decision Making)			Level 4	Level 5
Decision Support (l)								Level 5		Level 3 (Remotely Supervised)		
Executes if no human veto (m)	Level 6	Level 3 (Monitored AI)	Level 4 (Monitored AI)			Level 4				Level 3 (High Level)	Level 5	Level 6
Executes and informs human (n)	Level 7			Level 9 (Associate)							Level 6	Level 7
Partner (o)				Level 10			Level 4 (Traded Control)					
Informs human if asked (p)	Level 8										Level 7	Level 8
Informs human, if decides (q)	Level 9							Level 8 (Automated Decision-making)				Level 9
Supervisor (r)				Level 11	Level 4		Level 5	Level 9				
Autonomous System (s)	Level 10	Level 4	Level 5	Level 12	Level 5	Level 5		Level 10		Level 4	Level 8	Level 10

Vagia, M., Transeth, A. A., & Fjerdingen, S. A. (2016). A literature review on the levels of automation during the years. What are the different taxonomies that have been proposed?. *Applied ergonomics*, 53, 190-202.

In general, taxonomies are decision support and action based

- Full manual control
- Decision support where the automated system provides
 - Information → Human decides what to do
 - Response options (potentially prioritized) → Human decides which option they want
- Limited action where the automated system provides
 - One option → Human has to approve action (consent)
 - One option → Human can veto
- Automatic action
 - Human informed of action
 - Human can ask for information on action
 - Human out of the loop

Example of levels of automation for self driving cars



<https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety>

The focus is on the technology

SAE J3016 Levels of Driving Automation

What does the human in the driver's seat have to do?


What do these features do?




Example Features

SAE LEVEL 0™	SAE LEVEL 1™	SAE LEVEL 2™	SAE LEVEL 3™	SAE LEVEL 4™	SAE LEVEL 5™
You <u>are</u> driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You <u>are not</u> driving when these automated driving features are engaged – even if you are seated in “the driver’s seat”		
You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
These are driver support features			These are automated driving features		
These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/acceleration support to the driver	These features provide steering AND brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met	This feature can drive the vehicle under all conditions	
<ul style="list-style-type: none"> • automatic emergency braking • blind spot warning • lane departure warning 	<ul style="list-style-type: none"> • lane centering OR • adaptive cruise control 	<ul style="list-style-type: none"> • lane centering AND • adaptive cruise control at the same time 	<ul style="list-style-type: none"> • traffic jam chauffeur 	<ul style="list-style-type: none"> • local driverless taxi • pedals/steering wheel may or may not be installed 	<ul style="list-style-type: none"> • same as level 4, but feature can drive everywhere in all conditions

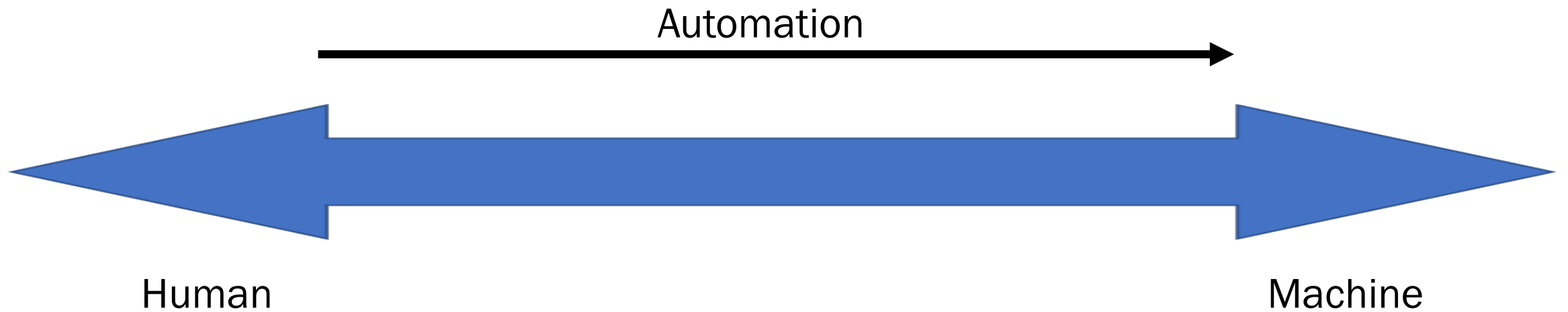
Merging capability with reliability

Automation Capability 

		Machine capability	Sensing	Computation / analysis	Programmed / learned decision	Motor Action
		Human	Sensing & Perception	Information processing	Response selection	Execution
Automation reliability 	No automation	Full human control	X	X	X	X
	Assistance	Provide information to human	✓✓	✓	✓	X
	Partial automation	Constant human attention	✓✓✓	✓✓	✓✓	✓✓
	Supervisory	Human attention at request	✓✓✓✓	✓✓✓	✓✓✓	✓✓✓✓
	Conditional	Independent except in predefined conditions	✓✓✓✓✓	✓✓✓✓	✓✓✓✓	✓✓✓✓✓
	Full	Independent	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓✓

This is not the end

- Still need to combine this into a single continuum.



Preliminary human factors considerations

- Based on literature
 - Trust
 - Acceptance of technology
 - Overreliance
 - Situation awareness
 - Boredom associated with vigilance
 - Skill degradation



Thank you!

Mahiyar Nasarwanji, PhD, CPE
MNasarwanji@cdc.gov
(412) 386-5113

The screenshot shows the NIOSH Mining website homepage. At the top, there is the CDC logo and the text "Centers for Disease Control and Prevention CDC 24/7. Saving Lives. Protecting People™". A search bar and a "Mining" dropdown menu are visible. Below the header, the "NIOSH Mining" title is displayed, followed by social media icons and the NIOSH logo with the tagline "Promoting productive workplaces through safety and health research". The main content area is titled "What's New" and features four featured items: 1. "COVID-19" with a sub-heading "CDC-developed resources for mine workers to prevent the spread of COVID-19." and an image of a hard hat. 2. "Infographic" with the sub-heading "Are your boots worn down? They could be compromised and unable to protect you from work hazards." and an image of a worn boot. 3. "App" with the sub-heading "Download the updated ErgoMine mobile app. New in 2.0 are MSD risk factor evaluation forms, stair, ladder, and walkway checklists, and a fix list manager." and a list of categories: AUDITS, FORMS, CHECKLISTS, and FIX LIST. 4. "Recognition" with the sub-heading "NIOSH Mining mechanical engineer Jennica Bellanca was honored with the 2020 Robert M. Peele Award during the Society for Mining and Metallurgy Exploration's all-virtual 2021 conference and expo." and an image of Jennica Bellanca. Below the featured items is a link to "Browse the Mining site by subject". At the bottom, there are four navigation boxes: "Tools You Can Use" (Videos, Software, Training, etc.; Data & Statistics; MSHA Data Files; NIOSH Mining en Español); "Information Resources" (Mining Safety and Health Topics; News & Articles; Mining Links; Publications; COVID-19 Guidance for Mining); "Research" (Mining Program; Projects; Contracts; Strategic Plan; Funding Opportunities); and "About NIOSH Mining" (About Us; Contact NIOSH Mining; Employment; Visitor Information; Technology Innovations Awards; Partnerships). A footer contains the text "Page last reviewed: 3/10/2021 Page last updated: 3/10/2021 Content source: National Institute for Occupational Safety and Health; Mining Program".



NIOSH Mining Program
www.cdc.gov/niosh/mining