MAKING POWER WHEELCHAIRS SMARTER

Michelle L. Lange, OTR/L, ABDA, ATP/SMS

LUCI

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Learning Objectives

1. The participant will be able to define smart technologies in the context of power wheelchairs.
2. The participant will be able to list 3 features of smart technologies.
3. The participant will be able to describe 3 clinical applications of smart technologies.

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What we will be covering today:

- The Need: Power Wheelchair Limitations
  - Efficiency
  - Safety
- The Technology: Definitions, Terminology, and Classification
- The Human: Clinical Applications
- The Products: New Smart Technologies

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Power Wheelchairs – the main goal

- Power wheelchairs are designed to provide an alternative means of moving throughout the environment for people who are unable to **ambulate** or **self-propel** any manual wheelchair
  - Ambulation:
    - The client may not be able to ambulate at all, is inefficient, or is unsafe (i.e. fall risk)
  - Self-propulsion
    - The client may not be able to functionally self-propel

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Power Wheelchairs – what else do they do?

- In addition to Driving (varies by PWC electronics system):
  - Power seating
  - Bluetooth (BT) Mouse emulation or switch output
  - Interfacing to external AT devices
  - Infrared transmission
  - Charging port for USB devices
  - Some information provision
    - Battery status, speed, miles traveled, clock, diagnostics
    - Monitoring: i.e. daily drive time/distance, how many hours PWC on, power seating activity
    - Notifications: reminders

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Power Wheelchair Limitations

- Power wheelchairs do have limitations:
  - Transportation
    - Heavy, requires accessible transportation
  - Accessibility
    - Getting in and out of buildings and throughout crowded spaces
  - Efficiency…
  - Safety…

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Power Wheelchair Efficiency

Efficiency

- Driving a PWC can be inefficient. After completing a turn, the casters are skewed, and the driver must compensate for this.
- Tracking Technologies improve efficiency and are available on PWCs, but are often optional and may not be recommended by the team
  - Drive wheel configuration impact
  - Alternative driving method impact

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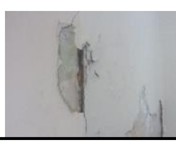
Power Wheelchair Safety

Safety

- Current design of complex rehab PWCs is unable to prevent:
  - collision with obstacles (including people, walls, and doorways)
  - going over a drop off (like a curb)
  - tipping over if the user has driven to an unsafe angle
- Reliance on the driver to note potential hazards and be able to avoid these



MHRA

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Safety Facts

- A study of US emergency room visits for children ages 2-10 using mobility aids found that **67% of injuries were related to falls from wheelchairs**
  - Alison M Barnard, Nicolas G Nelson, Huiyun Xiang, and Lara B McKenzie. Pediatric mobility aid–related injuries treated in us emergency departments from 1991 to 2008. *Pediatrics*, 125(6):1200–1207, 2010.
- **87% of wheelchair users report at least one tip or fall** during the last 3 years
  - Wan-Yin Chen, Yuh Jang, Jung-Der Wang, Wen-Ni Huang, Chan-Chia Chang, Hui-Fen Mao, and Yen-Ho Wang. Wheelchair-related accidents: relationship with wheelchair-using behavior in active community wheelchair users. *Archives of physical medicine and rehabilitation*, 92(6):892–898, 2011.

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Safety Facts

- Forces of impact from tip and roll accidents result in **significant risk for mild to severe head injury**, depending on chair position and restraint at the time of incident.
  - Brett Erickson, Masih A. Hosseini, Parry Singh Mudhar, Maryam Soleimani, Arina Aboon- abi, Siamak Arzanpour, and Carolyn J. Sparrey. The dynamics of electric powered wheelchair sideways tips and falls: experimental and computational analysis of impact forces and injury. *Journal of NeuroEngineering and Rehabilitation*, 13(1):20, 2016.
- Over half of the accidents reported in a 10-year period result from drivers **impacting a stationary object or encountering environmental hazards like uneven terrain**.
  - Anna Carlsson and Jörgen Lundälv. Acute injuries resulting from accidents involving powered mobility devices (pmds)—development and outcomes of pmd-related accidents in sweden. *Traffic Injury Prevention*, 20(5):484–491, 2019.

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Smart Wheelchairs: the Need

- Driving a power wheelchair is harder than it looks!
- Some of the main reasons that caregivers are reluctant to pursue a power wheelchair:
  - Worry that the driver won't be safe
  - Worry that the driver will hurt someone else
  - Worry that the driver will damage the environment, like those walls
- Smart wheelchairs can provide increased driving efficiency and safety, protecting the driver, others around them, and the environment

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Definitions, Terminology, and Classification

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An Example

- This is all very new, so let's get some context

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Smart Wheelchairs: a Definition

"***A Smart Wheelchair is integrated or retrofitted **self-monitoring** technology for a power wheelchair that **provides enhanced, independent mobility** to a wheelchair user, is able to **collect and report** user health and wellness data and provides **connectivity** to integrate with the connected world."

***S**elf-**M**onitoring **A**nalysis and **R**eporting **T**echnology

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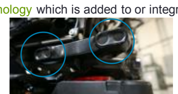
So, what would be needed to make a Wheelchair Smart?

- Self- Monitoring Sensors that can provide environmental surveillance.
  - Able to detect obstacles
  - Able to detect steps and curbs
  - Able to detect the slope of an incline or ramp
- Software to provide Analysis of the sensor data taking into account the user's reaction time.
- A brain to send a response to the PWC electronics to avoid a collision or drop-off or otherwise modify navigation and speed
- A communication/ Reporting system to store and report machine data, situational data, and data regarding the health and safety of the rider.
- Technology which is added to or integrated into a power wheelchair



Sensors

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And what does that actually look like?

- This technology is available along a continuum, so Smart Wheelchairs may include any of the following:
  - Sensors that warn of a potential collision
  - Backup camera that warns of a potential collision
  - Tracking technologies that increase driving efficiency
  - Sensors that prevent collisions or drop-offs, but still allow driving
  - Sensors that monitor the environment and modify speed to allow driving without collision
  - Sensors that follow a pre-programmed map or tape on the floor for nearly automated driving

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What is a Smart Wheelchair?

- SMART wheelchairs can also provide:
  - Communications to external devices
  - Monitoring of driver health information

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A Continuum

- Let's take a closer look at this continuum and product options
  - Also, see handout "Smart Wheelchair (SWC) Automation Levels"

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The Driver monitors the Environment

SWC Level	Name	Definition	Functional Example	Product feature example	Product Example
Human driver monitors the driving environment					
0a	No Automation	Driver is in full control of power wheelchair Sensors warn the driver of potential hazards but are not integrated into the electronics of the PWC.	Driver controls all driving options	Sensors that warn driver of potential collisions or other hazards	Braze Mobility: warning systems (auditory, visual, and haptic warnings) ASL: 404 Four Sensor Alert & 405 Two Sensor Alert, warning system, (auditory) LUCI: Incline warning
0b	No Automation	Driver is in full control of power wheelchair Backup camera warns the driver of potential hazards but is not integrated into the electronics of the PWC.	Driver controls all driving options	Backup camera warns driver of potential collisions or other hazards prior to driving in Reverse	Cheelcare Aware A1 / A2 / A3 backup Cameras Tadibrothers backup camera Quantum Rehab backup camera

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Sensors that provide a warning

- Adaptive Switch Labs
  - Photo-electric switches in a 2 or 4 switch array provide auditory feedback that the PWC is approaching an obstacle
  - Can be adjusted to 'alert' between 4-24" distance
  - Do not detect drop-offs

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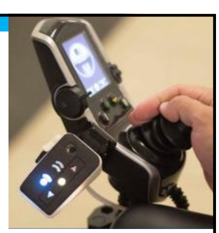
Sensors that provide a warning

- Braze Mobility
  - Sensors (Ultrasonic) can be placed at rear, sides, and/or front of PWC
  - Feedback can be visual, auditory, and/or haptic (vibration)
  - Sentina (below) provides 180 degrees horizontal and 50 degrees vertical coverage



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Braze Mobility video

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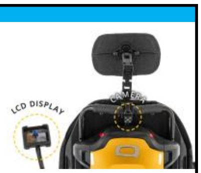
Backup Cameras

- Cheelcare
  - Aware A1 / A2 / A3
- Tadibrothers
- Quantum Rehab

Cheelcare



Quantum Rehab

Tadibrothers

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The Driver and the System Monitor the Environment

SWC Level	Name	Definition	Functional Example	Product feature example	Product Example
Human driver and automated driving system monitor the driving environment					
1a	Emergency Stop	Driver is in full control of power wheelchair except for emergency stop. Sensors warn the driver, stop the PWC, and are integrated into the electronics of the PWC.	Driver controls all driving options except for emergency stops in response to detected collisions or other hazards	Sensors that warn driver of potential collisions or other hazards and the system stops the wheelchair if the driver does not respond appropriately	None
1b	Driver Assistance	Tracking technology	Increases driving efficiency by reducing compensatory movement, for example driving on a side slope.	Reduced joystick movements or switch activations and reduced time to move between locations	Quantum Rehab PWCs (Accu-Trac) Invacare PWCs (G-Trac) Permobil PWCs (ESP) Some Quickie PWCs (SureTrac)
2a	Driver Assistance	Driver assistance system of steering	Driver can steer. System will avoid collisions, drop-offs, and/or tipping	Driver can continue driving, but not in the direction of a hazard. System imposes a restriction in travel that can be overridden	LUCI Navigation assistance Drop-off protection Tracks number of 'assists'
2b	Driver Assistance	Driver assistance system of acceleration / deceleration	Driver can control speed. System will automatically slow, as needed	Driver can increase speed, but system will slow in response to environment, such as walking in a crowd	LUCI
2c	Driver Assistance	Driver assistance system of both steering and acceleration / deceleration	See 2a and 2b	See 2a and 2b	LUCI

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Tracking Technologies

- Complex rehab power wheelchairs include a feature called Tracking
- However, it is usually optional (meaning it can be denied) and is often not ordered for clients who can benefit from this technology
- Reduces joystick movement and switch activations required to get from Point A to Point B
- Increases driving efficiency
- Particularly important for alternative access

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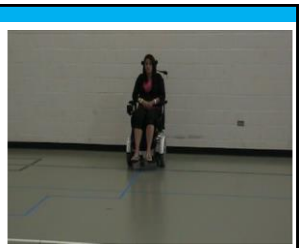
Tracking Technologies

- Quantum Rehab PWCs (Accu-Trac)
- Invacare PWCs (G-Trac)
- Permobil PWCs (ESP)
- Some Quickie PWCs (SureTrac)



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Driver Assistance: Steering and Speed

- *Navigation / Steering
  - If Sensors detect obstacle or drop-off, the PWC will no longer move in that direction, but can move into another direction
  - Example: moving through a doorway
- *Speed Assistance: Acceleration / Deceleration
  - If Sensors detect a moving obstacle(s) around the PWC, speed will automatically slow to prevent collision and then allow the Driver to increase speed as possible
  - Example: moving through a crowd
- LUCI

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Steering Assistance

- LUCI video

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Speed Assistance

- LUCI video

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Sensors

- Let's talk Sensors for a minute
  - *Systems may use one or a combination of sensors to detect potential obstacles, drop-offs (steps, curbs), and slopes
  - Each sensor has pros and cons

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Sensors

Stereo Vision

- Pros: Measures depth (stereo, like our eyes) to each pixel in image, can map ground, used for collision avoidance
- Cons: Won't see clean glass
- Infrared (reflected light waves) assists Stereo Vision in all lighting conditions

Ultrasonic

- Pros: detects obstacles at night, glass, and how far away something is
- Cons: Won't detect soft surfaces (i.e. curtains) and doesn't determine where the obstacle is (just how far)

Radar

- Pros: works well for uneven surfaces, sees farther than ultrasonic, more specific distance and placement measures, detects at night, detects glass
- Cons: Can't see everything, more expensive, more power hungry

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Sensors – Braze Mobility

- Ultrasonic sensors

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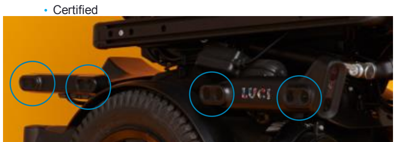
Sensors - LUCI

- LUCI uses a combination of 3 primary sensors
  - Stereovision, ultrasonic, radar
- Sensors work together – all data is fused
- Sensor transmissions are not harmful to the driver and will not cause interference with other devices in the environment
  - Certified



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The System Monitors the Environment

SWC Level	Name	Definition	Functional Example	Product feature example	Product Example
Automated driving system monitors the driving environment					
3a	Conditional Automation	Automated steering, stopping, acceleration / deceleration	The driver can initiate and stop movement, as desired, but stopping is not required	System follows a preprogrammed 'map' and modifies driving in response to sensor feedback	None
3b	Conditional Automation	Automated steering, stopping, acceleration / deceleration	The driver can initiate and stop movement, as desired, but stopping is not required	System follows a tape on the floor and modifies driving in response to sensor feedback	Smile Smart System (SSS) -driver initiates and stops movement with switch
4	High Automation	Automated steering, stopping, acceleration / deceleration	The system controls all features in specific environments	The system controls all features in specific environments	None
5	Full Automation	Automated steering, stopping, acceleration / deceleration	The system controls all features, everywhere, at all times, in all conditions	The system controls all features	None

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Product Options: Conditional Automation

- Smile Smart System (SSS)
  - Driver initiates and stops movement with switch
  - The PWC follows a tape track (line following capacity)
  - Sensors prevent collision (anti-collision sensors)

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Connectivity to Integrate with the Connected World

SWC Level	Name	Definition	Functional Example	Product feature example	Product Example
	Automated driving system provides connectivity to integrate with the connected world				
1	BT Connection to external technologies for Mouse Emulation	System has the ability to connect with external technologies outside of the PWC	Driver can emulate a mouse on a computer, tablet, smartphone, or speech generating device	Driver can use the PWC driving method to emulate a mouse using integrated Bluetooth	Invacare LiNX Permobil R-net Quickie R-net Quantum Q-Logic
2	BT Connection to Apps for specific monitoring	System has the ability to connect with external technologies outside of the PWC	Driver can monitor whether the battery needs charging and where they are on a map (Permobil) Driver can monitor how often and how far power seating changes are made and share those 'reports' in an email (Quickie).	Driver can monitor chair activity and receive limited information from the system. Some information can be shared via email.	Permobil -MyPermobil App monitors and tracks battery status, distance, and seating activity. Integrated map, GPS. Android, iOS. Quickie -Switch-It Remote Seating App (on Sedeo) measures and tracks duration of seating angles. Can email info to others. Alerts user to adjust seating. Android, iOS.
3	BT Connection to external technologies	System has the ability to connect with external technologies outside of the PWC	Driver or caregivers can receive active notifications on a smartphone or consumer technologies (i.e. Intelligent Virtual Assistants like Alexa)	System can be programmed to send notifications or alerts to driver and others	LUCI -MyLuci portal -notifications of obstacle avoidance occurrences, tip alerts, and GPS location -power seating reminders -Alexa & Google Assistant – LUCI supports nearly 100 phrases and commands -Android, iOS, web portal

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Health and Wellness Data Collection

SWC Level	Name	Definition	Functional Example	Product feature example	Product Example
Automated driving system provides user health and wellness data collection capabilities					
	Connection to sensors and/or wearables to monitor driver health data	System has the ability to connect to sensors and/or wearables to monitor, record, and report medical data	Driver or caregivers can view data on a smartphone	System can be programmed to share health data.	LUCI -heart rate tracking and notification of elevated heart rate -Apple Health and Google Fit compatible heart rate monitoring -other features pending

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Connectivity to Integrate with the Connected World

- All Complex Rehab power wheelchairs offer Bluetooth (BT) which can provide switch access or mouse emulation to external devices

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Connectivity to Integrate with the Connected World

- Permobil
- MyPermobil App
  - Tracks battery status, distance traveled, and seating activity
  - Integrated map

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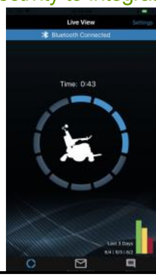
Connectivity to Integrate with the Connected World



- Quickie
- Switch-It Remote Seating App
  - On Sedeo PWC
  - Measures and tracks duration of seating angles

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Connectivity to Integrate with the Connected World

- LUCI
  - BT, Bluetooth Low Energy (BLE), Wi-Fi, Cellular
- Notifications:
  - Obstacle avoidance occurrences
  - Tip alerts
  - Notifications can be received on Tablet, Smartphone, or Intelligent Virtual Assistants (i.e. Alexa)
- Driver location (using GPS)
- Power Seating reminders

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Health and Wellness Data Capabilities

- LUCI
  - Heart rate tracking and notification of elevated heart rate
  - Apple Health and Google Fit compatible heart rate monitoring
  - Other features pending

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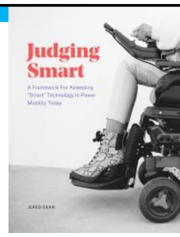
Continuum Summary

- Smart Wheelchair technologies fall on a continuum
- Some categories are not represented by a commercially available product at this point
- Definitions and recognizing where product options fall within a hierarchy is critical and worthy of discussion
- Great Resource:
  - Judging Smart: a Framewook for Assessing "Smart" Technology in Power Mobility Today by Jered Dean
  - Available at no cost from LUCI
    - LUCI.com



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Questions?

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Clinical Applications

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Clinical Applications

- Accessibility
  - Maneuvering around tight spaces is very difficult
  - Examples: within a van to line up with tie downs, a crowded classroom

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Clinical Applications

- Obstacles
  - To avoid obstacles, the driver must see them
  - Hard to see areas: behind and low
  - Also need to gauge distance and response time

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Clinical Applications

- Distractions…squirrel!
  - We all get distracted
  - I tend to trip and walk into things… but consequences are more severe in a PWC

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Clinical Applications

- Motor, visual, and cognitive requirements
  - **Motor limitations** may limit driving precision and reaction time
  - **Visual limitations** may make driving more difficult, specifically lack of acuity and visual spatial concerns (i.e. depth perception)
  - **Cognitive limitations** may lead to a reduced understanding of the implications of certain driving maneuvers, such as driving off of a curb and a collision
  - Many clients have **more than one area** of involvement

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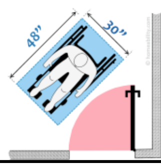
Clinical Applications

- People who use **alternative driving methods** have limited motor skills and may also have visual and/or cognitive limitations
- This impacts driving precision, gauging distances, changes in height (i.e. curb vs. sidewalk, ramps), and visual field (especially behind the driver and down low)
- These factors can also impact:
  - Functional mobility
  - Independence
  - Confidence
  - Safety!



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Alternative Driving Methods and Smart Wheelchairs

- *Smart Wheelchairs can make driving a power wheelchair more **efficient and safer**, opening up independent driving to more people and improving driving for many current drivers
- Ensure system is **compatible** with a full range of alternative driving methods

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Clinical Applications Summary

- So, who can benefit from Smart Wheelchair technologies?
- Anyone who is not driving efficiently and safely, to their full potential
- Important to match client needs with specific product parameters

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Take Home Message:

- Complex Rehab Power Wheelchairs provide a means of mobility and much more
- However, limitations in efficiency and safety remain
- Smart Wheelchair technology is addressing these issues along a continuum of need and offering even more capability including connectivity and health and wellness features!
- This new technology helps drivers to do what they do Better and Safer!

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Questions?

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Thanks!

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Contact Information:

LUCI
1-800-621-LUCI (5824)
info@luci.com
www.luci.com

LUCI

Michelle Lange
MichelleLange1@outlook.com

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Smart Wheelchair (SWC) Automation Levels

A Smart Wheelchair is integrated or retrofitted self-monitoring technology for a power wheelchair that provides enhanced, independent **mobility** to a wheelchair user, is able to collect and report **user health and wellness data**, and provides **connectivity** to integrate with the connected world.

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