Updated: 1/27/2017 R Bostelman

ID#	Unique Aspect Characterization	User Community		
		Military (MIL)	Industrial (IND)	Medical (MED)
1	Terminology	Augmentation	industrial robots	Physical assistance robots
2		Exoskeleton	response robots	Exoskeletons
3		Exosuit / soft exoskeleton	amplified human	Motorized orthosis
4		Robot	exoskeleton	Human augmentation
5		Collaborative Robots	augmentation	Physical augmentation
6		Wearable Robotics	wearable robots	Wearable robotics
7		Mobility	Safety/Risk/Benefit	Passive orthosis
8		Load Distribution / Redistribution		Orthosis vs Exoskeleton
9		Powered / Active:		Patient Capability
10		-Electromechanical		Safety/Risk/Benefit
11		-Hydraulic		Efficacy
12		-Pneumatic		Rehabilitation
13		Unpowered / Passive		Robotic Prosthesis
14		Quasi Active		Use cases (ambulation vs rehab)
15		Quasi Passive		Wellness vs medical
16		Joint Actuation		Quality of Life (existing standards)
17		Multi-joint actuation		cleaning and dissenfection
18		Baseline		Personal mobility device and strength
19		Training		Assistance vs resistance
20		Modeling & Simulation		Exercise
21		Controls		Assessment
22		Human Machine Interface		User population (clinician vs patient)
23		Field Test (i.e. vs. Lab test)		Staff support
24		Prosthetic		
25		Energetic autonomy vs tethered		
26		Intuitive		
27		Load transfer path		
28		Ergonomics		
29		Extensibility		
30		psychological		
31		adaptability		
32		industrial human augmentation system (iHAS)		
33		anthropomorphic/ non		
34		modularity		
35		manufacturability / material properties		
36		additive manufacturing		
37		backdriveability		
38		dexterity		
39		human efficiency		
40		hybrid (soft/hard)		
41		portability		
42		remote destructability		
43		repairability/maintenance		
44		user acceptance		
45		ruggedization		
46		reliability		
47		comfort		
48		safety		
49		degree of actuation		
50		degree of freedom		
51		hard stop		
52		graceful degradation		
53		failed state		
54		standoff		
55		predictive movement		
56		encapsulated (mech)		
57		Durability		
58		Intent (perf enhance.; safety enhance.)		
59		variabile assistance		
60		reference frame		
61		Safety/Risk/Benefit		
1		Anatomical Classification:	Anatomy based	Anatomy based
2		- Legs/Lower Body	-Upper extremity	Neck

3		- Hip	-Lower extremity	-Upper extremity
4		- Knee	-Full body	Spine (C, T, L)
5		- Ankle		Further anatomy break down
6		- Combination		Trunk
7		- Arms/Upper Body		-Lower extremity
8		- Shoulder		End-goal based
9		- Elbow		-Rehabiliation
10		- Combination		-Augmentation
11		lower back		System mobility based
12		neck		-Stationary
13		shank		-Mobile/untethered
14				-Mobile/tethered
15		- Helmet Load Re-distribution		QOL
16		- Torso Load Re-distribution		Powered vs Unpowered
17		- Full body		Interoperability
18		- Center of Mass		Energy storing vs powered
19		offloading		Functional Mobility
20				Sitting
21		Mechanical Actuation:		Standing
22		- Hydraulic		Safety features
23		- Electromechanical (including cable)		mobility aids
24		- Pneumatic		Labeling (e.g. warnings)
25		- Spring		Integration with other systems (e.g. FES)
26		user interface for actuation		
27		controls	controls:	
28			- sensory interactive	
29		Power Classification:	- human only	
30		- Powered/Active	- hybrid human + sensors	
31			- haptics	
32			- remote, teleoperation	
33	**Taxonomy**		- autonomous	
34		- Quasi Active		
35		hybrid	System mobility based	
36		- Unpowered/Passive	-Stationary	
37		- Tethered	-Mobile/untethered	
38		- Untethered	-Mobile/tethered	
39		Energy harvesting		
40				
41				
42		End-goal based - task specific	End-goal based - task specific	
43		-Mobility / Agility Augmentation (with worn and carried loads)	-task performed by human	
44		-Increase endurance	-improved performance	
45		decrease fatigue	-increased task longevity	
46		-Increase worn capabilities		
47		-Improve mission outcomes		
48		-Improve Soldier readiness		
49		-Mission Support/Lift/Move augmentation		
50		-Increased task endurance/ productivity		
51		-Improve strength capacity		
52		-Improve Soldier readiness		
53		resilience		
54		accuracy		
55		repeatability		
56		injury prevention		
57		increasing SA / reduce cog overload		
58		-Kinetic Energy Harvesting (via oscillating mass, relative human joint motion, or otherwise)		
59		fuel source		
1		Extreme temperatures:	indoor and outdoor use	Clinics/Rehabilitation Institutes
2		-Hot (quantify)	- warehouses	Home (e.g. bathroom)
3		-Cold (quantify)	- mines	Clothing management

4		-Variations in temperatures throughout course of a single mission	- building construction sites	TSA Compliant
5		Settings / Climates:	- assembly lines	Community (indoor and outdoor use)
6		-Arctic	- forests/farms	-Recreational activities (e.g. sports, gardening,
7		-Jungle	- ports	-Different surfaces/elevation
8		-Tropical	- driving	-Driving
9		-Desert	- airports	Different weather conditions
10		-Urban	- Emergency situations, intrinsically safe	Surfaces
11		space	- p[ainting, chemical handling, welding	Exoskeleton for stability
12		-High Altitude	- explosive, hazmat	Workplace
13		underwater	- rubble, USAR	School
14		hazardous environment (CBRNE, fire)	- nuclear, radioactive, EMI	Disability accomondation
15		confined space		Wheelchair compatability
16		microclimate conditioning		stair climbing and descending
17		vibration (e.g. HSV)	-Indoor clean	Sit to stand
18		-Variations in settings/climate throughout course of a single mission	-Indoor dirty	transportation (public and private)
19		Weather:	-Outdoor (dirty, dry/wet, extremes)	Activities of daily living
20		-Rain		Day and Night
21		-Snow		Accessability to controls
22		-Variations in weather throughout course of a single mission		Special ceremonies (e.g. religious, noise, accesability)
23		Time of Day:		Turning
24		-Night		
25		-Day (with varying solar load and cloud coverage)		
26		Visible Light Levels:		
27		-Full		
28		-Low		
29		-Near zero		
30	**Environments**	Obscurants:		
31		-Fine Dirt/ Dust / Sand		
32		-Smoke		
33		Noise		
34		EMI		
35		Terrain:		
36		-Course Dirt / Dust / Sand		
37		-Mud		
38		-Fine Dirt / Dust / Sand		
39		-Ice		
40		-Flat / Level		
41		-Uphill		
42		-Downhill		
43		turbulence during transport		
44		-Stairs		
45		-Obstacles (natural and man-made)		
46		-Variations in terrain throughout course of a single mission		
47		Varying access to power		
48		-Ample, reliable power supply		
49		-Remote / Off-grid		
50		Remote / Off-grid - Power, maintenance, and in case inoperable		
51		Variations in environmental conditions within course of a single missions (outdoors, inside vehicle, indoors, back to outdoors)		
52		Water (shallow immersion)		
53		camouflage / signatures (noise, light, etc)		
54		Adversarial Threat Level:		
55		-Safe		
56		-Potentially Hostile		
57		-Hostile		
1		Physically demanding	Material handling	Rehabilitation
2		Varying Durations:	-heavy loads pick and place	Strength augmentation

3		-Long Duration	-currently incapable tool control (e.g., grind above head)	Mobility augmentation
4		-Short Duration	-single worker (vs. current multi-worker)	Stability
5		Mobility Augmentation (Dismounted infantry:	- warehouse load handling	Support (e.g. head drop)
6		-Highly Dynamic, High Mobility, Agility	- mining	dexterity
7		-Long Duration	- building construction	maintaining early recovery
8		-Short Duration	- assembly line	ADLs
9		-Armor	- forestry/farming, agriculture	use with other rehab interventions
10		-Carrying /enabling other capabilities	- port	Hybrid devices (e.g. exerciser and personal mobility
11		Load Distribution / Redistribution	- driving	Neural component (e.g. neural learning, plasticity)
12		Upper Body Lift Augmentation	- airport baggage handling	Weight distribution
13		-Low repetitions, High loads	- EMS	Bowel and bladder
14		-High repetitions, Light loads	- firefighters	Sexual function
15		-Varying load types and frequencies	- movers	Neurapathy pain
16	**Use Cases/ Applications**	Tool Holding Augmentation	- parts handling, picking	Seizures
17		transport	- patient handling	
18		operate in hazardous environment (CBRNE, fire)	- hotel indoor security teams	
19		communications with other devices	- travel - maintenance, cleaners	
20		urban operations / homeland defense	- highway construction	
21		weapons handling	- climbing ladders, heights	
22		haptic devices for virtual training	- dirty jobs	
23			- CBP, lawenforcement, TSA	
24			- building demolition	
25			- office workers	
26			- holding heavy objects/tools	
27			amplification	
28			(ONET)	
29			- drop prevention - gloves	
30			- postal workers, package delivery	
31			- ships, tanks, aircraft, car - maintenance, repair	
32			- recreation, exercise, sports	
33			- decommitioining	
1		System specific	Navigation	**Clinical:**
2		Task specific	Perception	-Human Factors
3		Biomechanics:	Management of tasks	-Functional assessments
4		-Postural Stability	Manipulation	-Kinematic/kinetic
5		-Spatiotemporal Gait	Duration of performance	-Metabolic Metrics (inc. vital changes)
6		-Kinematic	Speed	-QOL Assessments
7		-Kinetic	Pose uncertainty	-Cognitive demand
8		-Physiological (Metabolic, Muscle function,	Back-drivability	-SCI: Bowel and bladder
9		Heart Rate, etc.)	Control force	-Psychological Assessments
10		-Muscle Strength and Endurance (Pre and Post task)	Vertical maneuvering	-Stability and Maneuverability
11		-Subjective - comfort	Horizontal maneuvering	- back to work
12		-Simulated Marksmanship	Ergonomics	dynamometry
13		-IMU Performance Metrics (task dependent)	Ingress/Egress complexity	minimum walking speed
14		Human Factors:	Ease of use	Stability
15		-Ease of Use	Battery life	Alignment to natural function
16		-Fit & Adjustability	Environmental range of use	Labeling (e.g. warnings)
17		-Compatibility	Portability	Functional mobility assessment
18		-Mobility	fit and adjustability	ADL tool
19	**Metrics**	-Comfort, Safety, Health Hazards	- ability to rest	Neural plasticity
20		-Survivability	eletrical considerations for various environments	Validated clinical scales
21		Operational:	- efficiency, productivity relative to baseline	Registry
22		-Training	- expanding or fitness to duties, expanding operator envelope	Patient preferance (patient outcome measures)
23		-Storage	- storage and maintainability	Self reported outcomes

24		-Ruggedization	- ability to be decontaminated, expendability,	economic and health outcomes for reimbursement
25		-Mission Suitability	- task repeatability	Exoskeleton specific outcome measure
26		-Mission/Task Performance	- compatibility with breaks - don/doff	
27		Engineering:	e-stop	
28		-Power	fire, smoke, toxicity	
29		-Reliability	- user feedback - fatigue,, exertion, pain	
30		Cognitive:	- thermal comfort	
31		-Situation Awareness	- safety, worst case scenario,	
32		-Recall	- body conformance, footprint	
33			- metabolic benefits - with and without exo	
34			- engine driven - contaminants	
35			- snag points,	
1	**Tools**	IMUs	Body sensors (body reaction to exo use)	**Clinical tools:**
2		Obstacle courses (e.g. LEAP)	IMUs	-IMUs
3		Cardiopulmonary Exercise Testing Equipment (e.g., COSMED)	Skin/core temperature	-3D motion capture
4		HR monitors	HR monitors	-force plates
5		Isokinetic/Isometric Measurement Systems (Biodex, Cybex, etc.)	Isokinetic/Isometric Measurement Systems (Biodex, Cybex, etc.)	-EMG
6		EMG	EMG	-self-report surveys
7		Optogait	Optogait	-Physio measurements (e.g. EDA, HR, BP)
8		Motion Capture Systems and associated processing software	Motion Capture Systems and associated processing software	-Standardized functional assessment scales
9		Timing gates	Skin/core temperature	Test dummy
10		Force Plate	Timing gates	Validated tools (e.g. TUG, 10 MWT, 6 MWT)
11		Force Plate Treadmills	Exoskeleton sensors (system performance and safety):	Metabolic
12		Pressure Sensors (e.g., Novel, Tekscan)	black box software/hardware	Neural assessments (e.g. cortical arrays, EEG)
13		Questionnaires (e.g. BORG, PSD)		Mobile application tools
14		Activity Monitors	artifacts - generic representation of tasks	Home monitoring (e.g. blood pressure)
15		Skin/core temperature	physical/virtual	Clinician feedback
16		Blood lactate		Caregiver feedback and involvement
17		Marksmanship (e.g. simulator or live fire)	test equipment:	Machine learning of existing data to analyze use cases
18		Monitor in front of treadmill to test cognitive performance (e.g. situational awareness and recall tasks)	optical tracking system	Sensor data and motor data
19			force plates	Time of use (e.g. fatigue)
20			EEG	standardized data logging
21			sweat production	Measurement of reach
22			load cells / pressure, shear sensing	Standardized data analysis
23			accelerometers	
24			strain gages	
25			thermocouples - on machine or individual	
26			FEA	
27			torque sensing	
28			GPS, SLAM	
29			stereotactic	
30			communication systems - bluetooth	
31			sound sensing, beeping	
32			lights	
33			rechargability	
1		Participants:	ISO 13482:2014(3) safety concerns	**Nonclinical testing:**
2		-Soldiers with load carriage experience		-EMC; electrical/thermal safety
3		-Military Occupational Speciality (MOS)	Load carry	-Battery testing
4		-Physical Strength Demands/OPAT	Load position	-Durability/stability
5			Load orientation	-Mechanical testing
6		Conditions:	Peg-in-hole	-Flammability
7		-Baseline (Soldier wearing standard equipment/load)	tool force	-Software testing
8		-Technology ON (in active state, worn in addition to Baseline configuration)	navigation	-Biocompatibility

9	Test Methods	-Technology OFF (in passive/inactive state, worn in addition to Baseline configuration)	single operator don and doff	-Water/particle ingress
10			static load holding	Safety features (e.g. falls)
11		Worn/carried Equipment:	varied height, orientation load/tool handling	safe degredation (e.g. safe falls)
12		-Standard issue uniform (ACUs, boots)	physical therapy - FCE (literature)	application of prosthetic and orthotic test methods
13		-Standard issue uniform (ACUs, boots)	equilibrium	Testing for software update
14		-Standard issue uniform (ACUs, boots)	diagnostics,	MIL 882 Software testing
15		-Dummy weapon	human system interface - indicators	impact testing
16			tactile, visual, audible feedback	joint cycle testing
17		Tasks:	baseline vs use - single vs circuit tests, recovery	
18		-Static balance (effect on postural stability, indicator of fatigue)	vibration attenuation - whole system, segments	
19		-Functional range of motion (mobility restrictions)	transitions between fast, slow	
20		-Basic motions (mobility restrictions, effects on task performance)	fail safe condition	
21		- Sitting, crawling, squatting, side-stepping, taking a knee, stairs, ladder climb, bend and pick up object, etc	lab vs field	
22		-Dynamic motions (mobility restrictions, effects on task performance)	pinching hazards	
23		- Drop landing, run and cut	device fit - no flip, flop, fit to user population	
24		-Movement between firing positions (equipment compatibility, effects on task performance)	speed of emergency doffing	
25		-Treadmill walking/jogging (effects on gait under controlled conditions)	end user validation	
26		-Road march/ cross-country walking (effects on gait over natural terrain)	endurance	
27		-Stepping up/down and over (effects on obstacle negotiation in controlled environment)	warning label presence, visibility	
28		-Obstacle course (effects on obstacle negotiation under operational conditions)		
29		-Vertical jump (effects on dynamic movement, indicator of fatigue)		
30		-Marksmanship (effect on operational task)		
1	Stakeholders	Army:	OSHA	FDA
2		-NSRDEC	NIOSH	Industry
3		-ARL-HRED	Commerce Department:	Patients
4		-PEO-Soldier	- NIST	Standards Development Organizations
5		-US Army MCoE	- ITA	Other government agencies
6		-US Army MSCoE	- NTIA	Patient Advocacy Groups
7		-US Army SCoE	- BIS	Clinicians
8		-MEDCOM	DHS	Payers
9		Navy	DOJ	
10		USMC	DOE	
11		Air Force	Standards Development Organizations	
12		USSOCOM	Industry Associations and Unions	
13		DARPA	- MHIA	
14		Industry	Academia	
15		Academia	Manufacturers	
16		Standards Development Organizations	International	
17		International	Insurance Industry	
18			SAE standards	