# Background and Problem breakdown

## Prior Art

Exoskeleton technology began in 1890 kt, with Nicholas Yagin, with the development of a passive device that used compressed gas to assist in human movement. However, it was not until the 1960s that the first attempt at a practical power exoskeleton was developed. The Hardiman kt, created by General Electric, was ground-breaking but non-viable due to its extreme weight (double its maximum load) and control problems. The suit, when used as a complete system instead of in parts, was subject to dangerous violent uncontrolled movements and the master-slave control system suffered debilitating lag.

Prospective uses for exoskeletons usually involve a scenario where a human user may require the strength and endurance of a machine, but circumstances result in wheeled vehicles are undesirable. Examples of possible applications include:

* Military Operations: operators are required to carry head loads over longs distances, lift large weights, and operate in dynamic and unruly conditions. Difficult terrain, heterodox environments, and general disarray result in heavy machinery often being unsuitable for certain circumstances. From urban to jungle operation exoskeletons provide possible utility.
* Rescue and evacuation missions: Rescue operations feature similar constraints to military operation with the additional concern of environmental hazards and structural collapse. In the event of a fire or chemical incident, the safety equipment and tools can be large, heavy, and cumbersome; exoskeletons can alleviate some of this burden. Where structures are damaged or collapsed an exoskeleton can provide the extra strength required to save a life,
* Medical Systems: When amputation, age, or illness results in an individual suffering from reduced mobility and strength exoskeletons present exciting opportunities to compensate for their pilot’s impediments.
* Construction & Physical Labour:

These applications represent some of the broader more immediately uses for exoskeletons, neglecting the role of specifically designed exoskeletons for niche tasks: shock absorbing legs for parachutes/paratroopers, self-propelled underwater diving suits, etc.

Since the Hardiman, exoskeletons have been plagued by the same two major problems that have prevented their use in real world applications: power to weight ratio/power supply and control. The following outlines current developments in exoskeleton technologies.

### HULC kt

The Human Universal Load Carrier (HULC) is battery-powered lower extremity exoskeleton initially developed by Berkeley Robotics and Human Engineering Laboratory, before entering an exclusive licensing agreement with Lockheed Martin in 2009. The system uses hydraulics to amplify the pilot’s knees and hips while supporting a load of 90kg. Designed for military applications it claims six hours of battery and uses force-based sensors for control.

The HULC was abandoned as” it proved impractical, exhausting users instead of supercharging them” kt and has been succeeded by the TALOS project kt.

### EskoGT kt

In 2010 the original developer of the HULC, Esko Bionics revealed the Exoskeleton Lower Extremity Gait System (eLEGS). With a maximum battery life of 6 hours and maximum gait of 3.2m/s kt, the system uses pushbuttons and force-motion sensors for control. Specially design for medical applications, the exoskeleton uses preprogramed movements to aid the mobility of stroke and spinal injury patients.

The suit is ill suited for dynamic environments, with its finite range of movements prohibiting stairs and uneven surfaces. While the suit may assist those with “upper extremity motor function of at least 4/5 in at least one arm”, the suit is slower than a wheelchair and is not an improvement on standard human movement

### Raytheon XOS Exoskeleton

The 2008 Raytheon XOS Exoskeleton developed by Raytheon is a full body exoskeleton that can support up to 23kg on each arm kt. The suit uses force-based sensors for control. Despite claims that the exoskeleton would be ready for production by 2016, they have made no public comments on progress since 2011.

### Warrior Web

The Warrior Web non-rigid exoskeleton was first demonstrated at the 2016 DARPA Demo Day. Developed by DARPA, it used preprogramed commands to assist with the user’s ankle motions. However, it was unpredictable in uneven terrain, malfunctioned, and could not transition readily between a walking and running state. kt (Cornwall, 2015).

### Hybrid Assistive Limb (HAL)

In 1997 Cyberdine unveiled the Hybrid Assistive Limb (HAL). The HAL’s iterations include a battery-powered lower extremity exoskeleton and a full body exoskeleton. Through a combination of bioelectrical sensors and force sensors the HAL measured muscle contracts to trigger preprogramed movements.

The system has had mixed success, and despite applying for USA FDA approval in 2014, the HAL is yet to be permitted for use in the US kt

## Preprogramed Control

Preprogramed control methods consist of a set of specific movements that are triggered in one way or another. HAL measures contractions in the arms of patients to trigger as the swing them back and forth to trigger left-foot right-foot walking motions. Warrior Web applies torque to the ankle of the user (assisting them walk) when movement is detected.

These systems are inherently limited in their utility. By having a finite or procedurally generated set of movements there will always be scenarios or circumstances where the set of movements is not applicable. In real dynamic environments (e.g. military, rescue & evacuation, and physical labour) dynamic controls are required.

As noted by Dunietz (2017) kt when using an exoskeleton with preprogramed controls, the ”human does try to join in the motion, the two get in each other’s way, cancelling out the gains for all but the most extreme disabilities.” Though this we seem the limited applicability of preprogramed movements; in circumstances where the movement of the pilot is so limited and restricted (e.g. via disability) that any system is an improvement. For an able-bodied pilot preprogramed movements are ”a bit like being a marionette with four wires controlling my legs” (Cornwall, 2015) kt and inadequate.

## Force Based Control

Force based control systems use force applied to the internals of a suit to determine the users desired position. The force applied indicates the direction and magnitude of movement. Force based systems are often inadequate for practical applications due to the sensitivity of force input. Systems which are too sensitive may develop jitter, and lags between sensing and movement combines with physical inertia may result in the system applying force to the user, creating an unstable feedback loop. Systems with are insensitive are slugging and require the pilot to push and move against the suit. Using these systems can be sluggish, cumbersome, and exhausting to use.

As the only mechanism for detecting position for a force-based system is the user making contact with the suit misalignments in sizing can result physical dead bands when users are unable to touch the suit and the control system is effectively blind. Additionally, suits which maintain constant contact with asymmetrical body parts may interpret asymmetry as force input and therefore require constant active resistance from the user to control.

Finally, force-based systems do not distinguish between the force output of the system and the speed desired. If a user wishes to move quickly they must apply a large amount force to the system, if the suit encounters and obstacle this movement is then interpreted as a large amount of force applied to the object. There is no mechanism for quick safe movements.

For exoskeletons in dynamic real-world environments to be viable, responsive, and safe improvement on the existing force-based sensing methods are required.

# Thesis definition and scope

# Background

# Approach and execution

# Conclusion