Preliminary Analysis of Energy Harvesting Assault Pack

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APPROVED FOR PUBLIC RELEASE

Introduction

- Advanced Technology & Increased Power

The problem:

- Increased quantities of batteries are carried by the Soldier.
  - Weight, volume, energy, cost, logistics

One possible solution: Soldier Wearable Energy Harvesting

- Recharge one central battery on-the-move using kinetic energy harvested from the Soldier's motion.
- One promising technology is an energy harvesting assault pack (EHAP)
- Converts vertical kinetic energy from a Soldier's walking and running gait into electrical energy using a double frame load suspension system.

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Why Energy Harvesting?

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What it offers

- Interoperable power solutions that maximize mission duration and effectiveness
- On-the-move power generation and battery charging
- Enables Net Zero Soldier
- Reduced logistics and Warfighter physical burden by generating power and the point of need
- Reduced tactical sustainment costs

Pay offs

- Extend mission runtimes by trickle charging the centralized power source (>72 hrs)
- Generate power on the move (>10 W)
- Reduce carried replacement battery weight (>2 lb)
- Significantly reduce joint impact forces and perceived weight burden

Materials & Methods

Early experiments conducted in-house

- Walking and running on a treadmill
- Measuring voltage, current, & power with an Agilent 34970A
- Electronic load: <30% charged conformal wearable battery.

On going testing:

- Joint biomechanics and power study
  - CERDEC CP&ID Power Division and ARL HRED at the SPEAR facility
  - Compare the EHAP to standard issue Army assault pack.
  - Test conditions include
    - 17.5 and 35 lb. pack payload;
    - 3 mph and a self-selected faster pace;
    - Level ground, 5% incline and 5% decline.

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Experimental Considerations

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- Experimental design is critical for KEH testing
- Human motion powers these devices
  - Every human is different
  - Test conditions alone aren’t enough to attain accurate, reliable, and reproducible results when humans are involved
  - Human factors
    - System integration with soldiers/test subjects
    - The human motions vary
- Consistency & Repeatability

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Future Testing

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Future experimental designs

- Continue in-house treadmill testing with NI cDAQ & LabVIEW
- Warrior Torso Test Stand (WATTS)
  - Utilize results of joint power & biomechanics study to build 2 laboratory test beds capable of roughly simulating human torso motion during walking and running
  - Some WATTS Capabilities:
    - 15 – 135 lbs. payload
    - Variable speed control of actuation cycle: 0 to 2 Hz
    - Adjustable stroke length: 0 to 6 in.; 0.5 in. increments
    - Adjustable torso angle: 0° to 30° relative to gravity, in 5° increments
    - Operating temperature of test stand ranges from -20 to 55 °C

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Results

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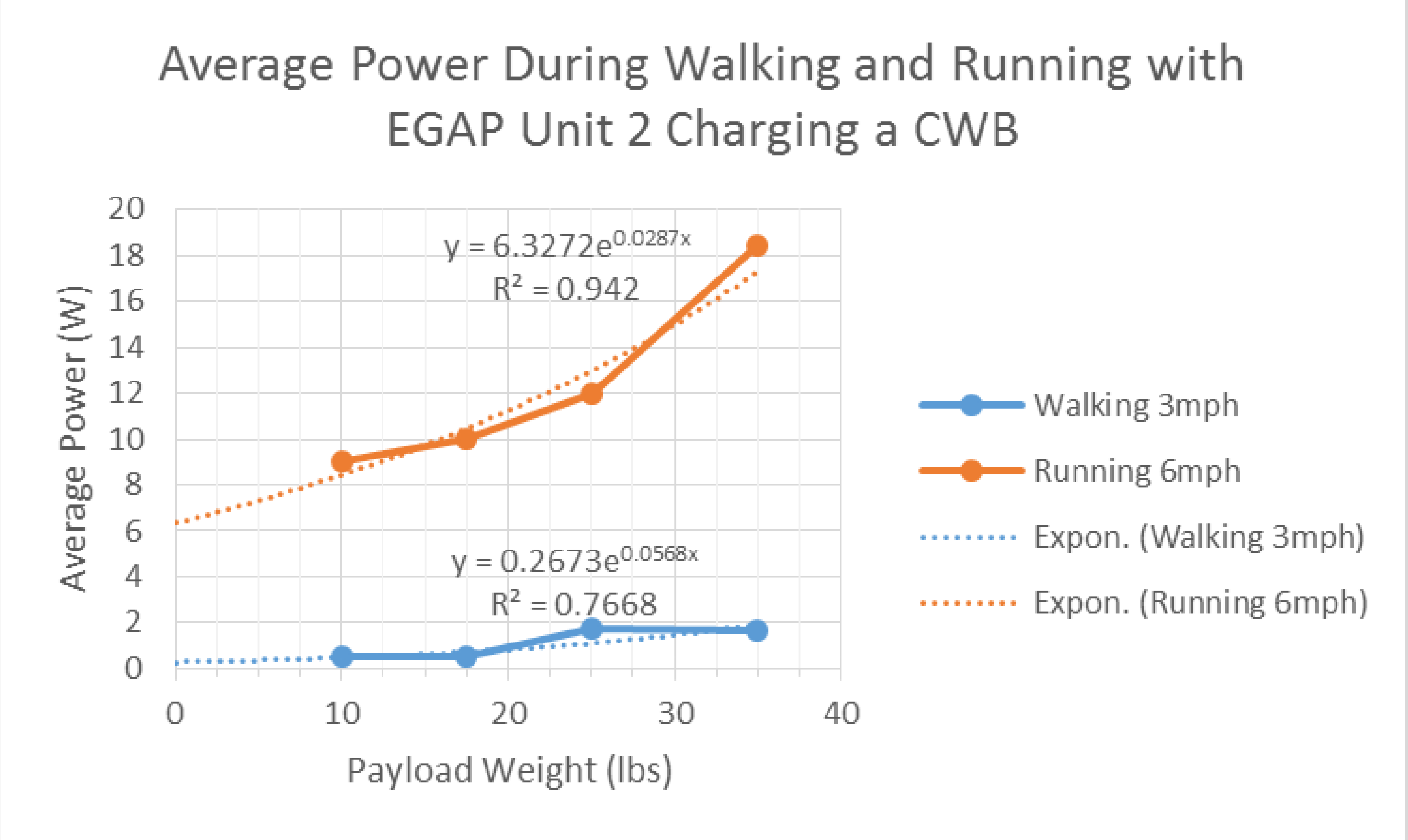
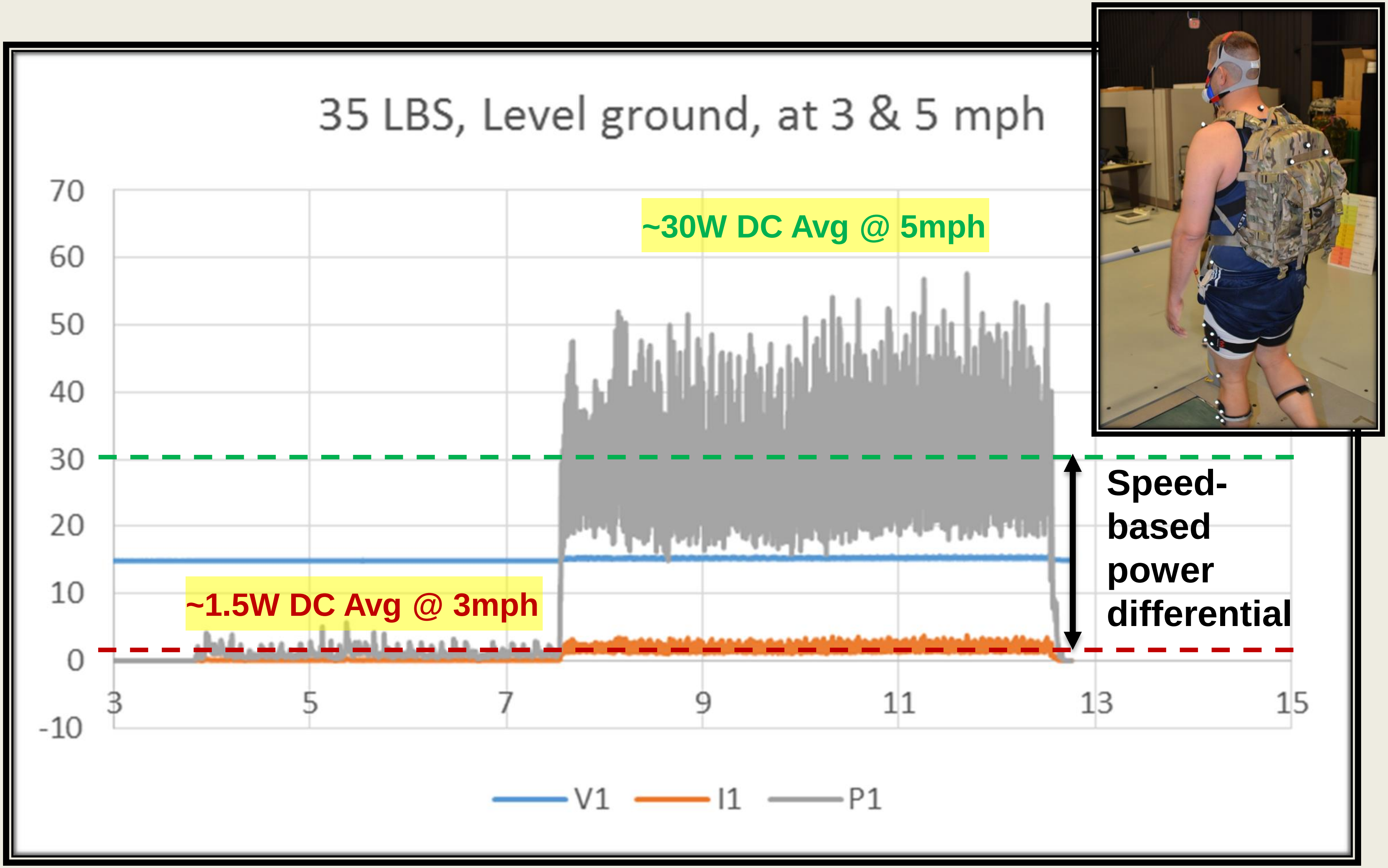


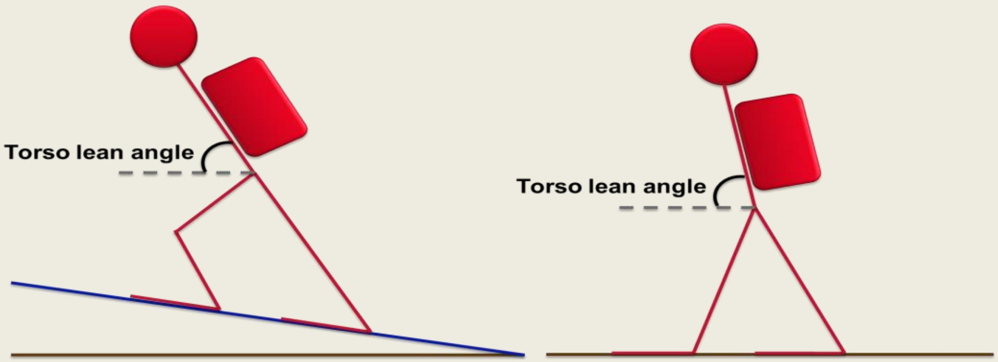
Results


35 LBS, Level ground, at 3 & 5 mph
~30W DC Avg @ 5mph
~1.5W DC Avg @ 3mph
Speed-based power differential
70
60
50
40
30
20
10
0
-10
3
5
7
9
11
13
15
V1
I1
P1

Results


Power VS. Speed (all grades)
Avg Power Output (W)
Speed (mph)
25
20
15
10
5
0
-5
2.5
3
3.5
4
4.5
5
5.5
6
6.5
17.5 LBS DEC
17.5 LBS LVL
17.5 LBS INC
35 LBS DEC
35 LBS LVL
35 LBS INC

Results



- Possible decreased torso lean angle on incline vs. level may contribute to lower power outputs (no conclusive results yet)

Preliminary biomechanics results from ARL HRED

- Treadmill speed & estimated vertical COM freq. correlation ≈1.8 Hz at 3 mph on level ground for both 17.5 & 35 lb. loads.
- Initial analysis indicates that COM frequency correlates strongly with speed and not with physical load.
- COM vertical motion doesn’t appear to change between speeds, maybe due to tradeoffs between cadence and stride length.

Conclusion

- Analysis of test results & feedback from soldier and civilian surveys clearly indicate a need for EHAP prototype improvement before it could be ready for deployment.
- Significant improvements to system weight, ergonomics and ruggedness are planned for the future.
- Optimization of the electronics and power generation components to better tune the output to slower speeds and different payloads.

Future Work

- Primary emphasis will be placed on reducing system weight by half.
- Improve the ergonomics
- Durability and ruggedness.
- In addition, an alternative design utilizing an electromagnet layout will be simulated and compared to the experimental results of the current design.

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Programmatics & Schedule

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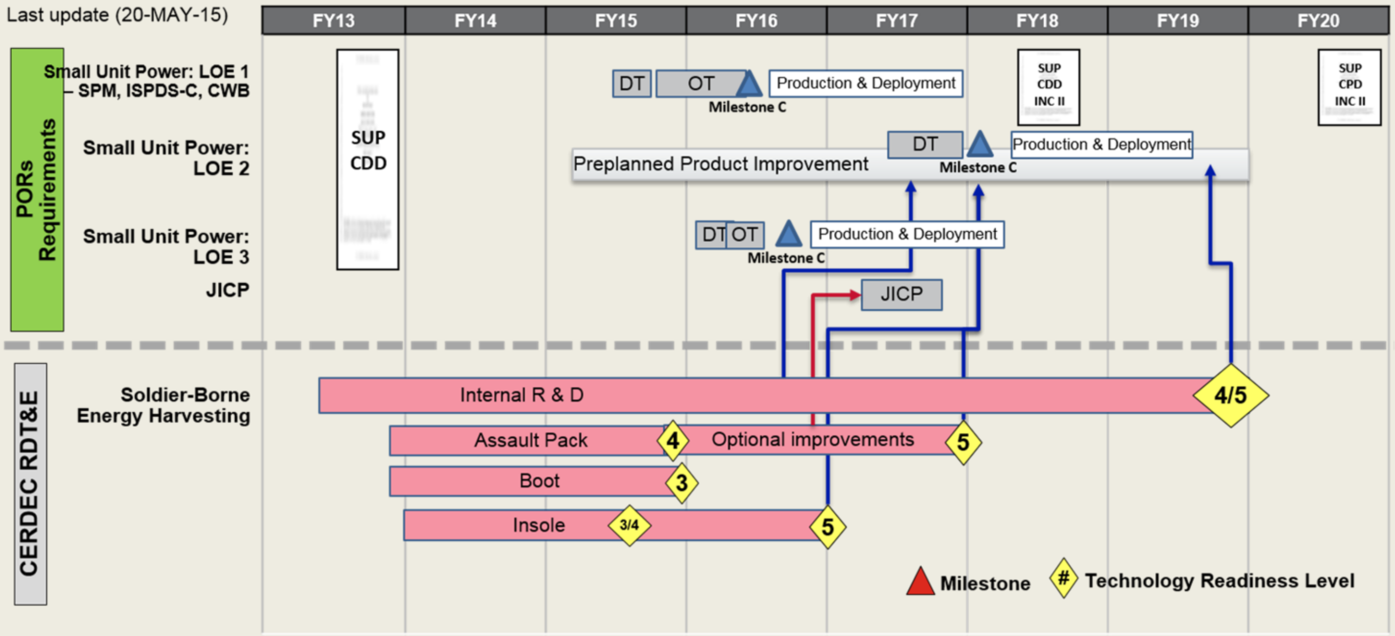
Current Efforts

- System & component lab testing
- Internal component level R&D
- Assault Pack
- Boot
- Insole

Partners

- Army: ARL HRED & SEDD, CERDEC CP&I PIT, NSRDEC
- USN NSWC
- Industry



Questions

- Questions?