Pain Alleviation in Carpometacarpal (CMC) Arthritis

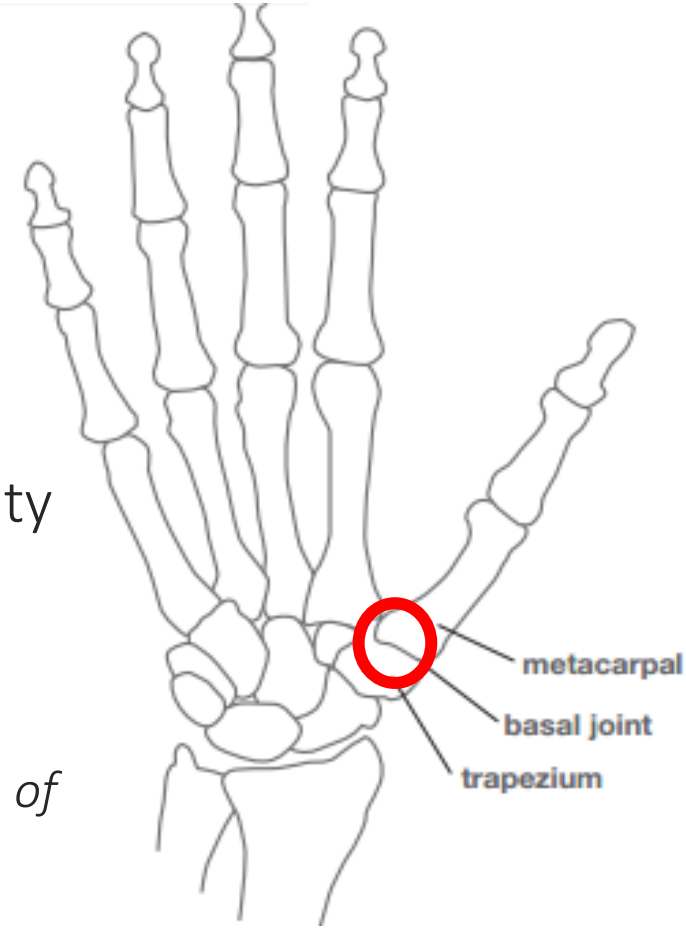
Puneet Kumar, Reith Sarkar, Keshav Kohli

Client: Tiffany Harmon, OT

10/30/13

CMC Arthritis

- Osteoarthritis (OA) of Carpometacarpal (CMC) joint
  - Degradation of cartilage layer
  - Direct contact between bones
    - *Pain*
    - *Deformity*
  - Affects range of motion and ability to pinch
  - Patient Population largely Post-menopausal Women
    - *¼ Women will experience some form of CMC arthritis*



Overview of Need

"I have been working with patients for over ten years that have expressed frustration with the lack of conservative options for the pain that they experience with [CMC arthritis]."

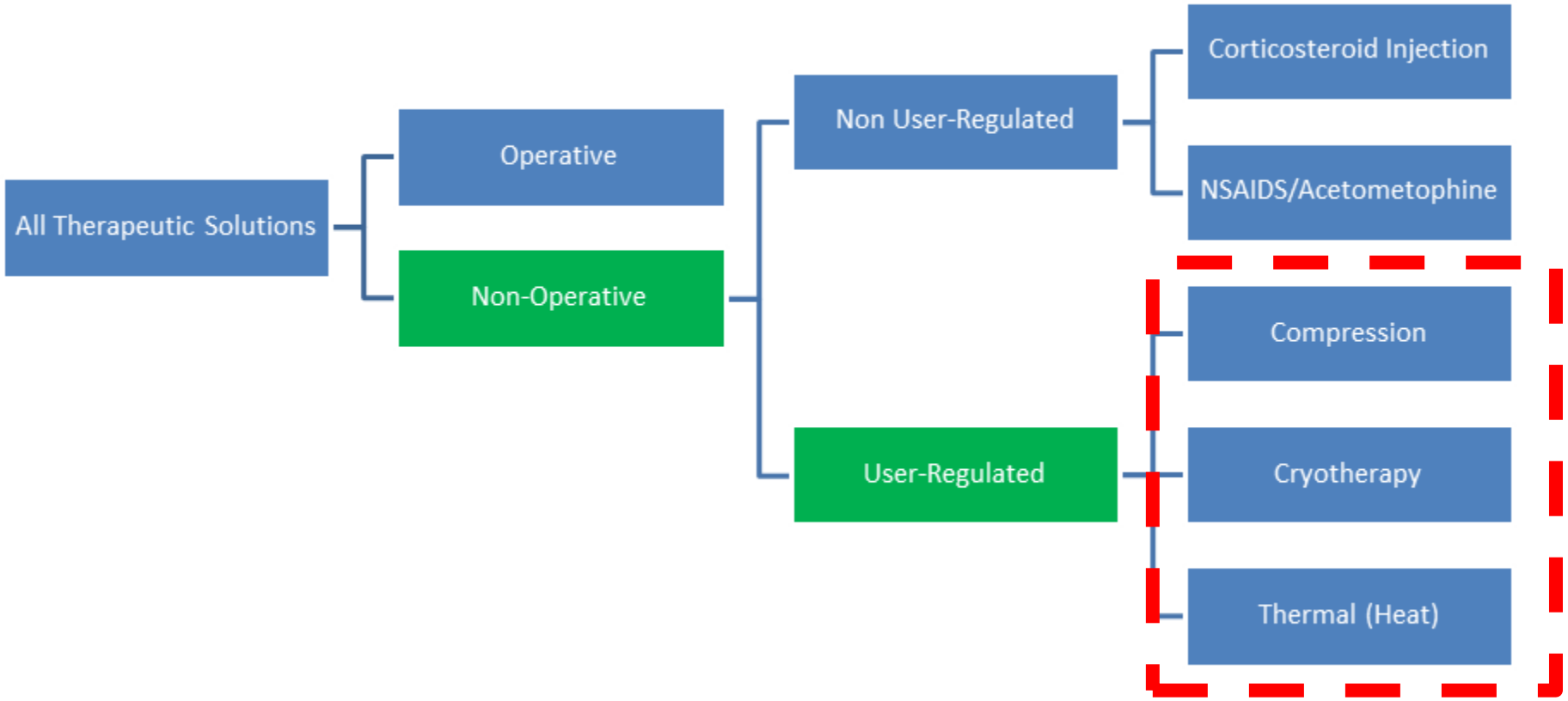
- Need for user-controlled pain alleviation system which can be easily used with existing CMC arthritis splints.

General Design Requirements

General metrics

1. Durability
2. Cost
   a. <$250
3. Safety
4. Active/passive adjustment
5. Feedback possible
6. General Methods of Pain Alleviation
   a. inflammation reduction
   b. joint stabilization
   c. increase of circulation

Selection Tree for Type of Therapy



Compressional

- Pain relief through mechanical means
- Compression can:
  - reduce inflammation
  - increase circulation
  - suppress fluid retention
- Potential risks
  - if compression (static) is too prolonged circulation can be hindered
  - possible electrocution if insulation damaged

Examples of Compressional Therapy

Static Compression

Dynamic Compression

Cryotherapy

- Lowering of temperature at local affected region
  - Decreases cellular inflammation processes
  - Promotes vasoconstriction
  - Nerve signal transduction slowed
  - Norepineprhine (Stress hormone) levels increased
    - *reduces pain sensitivity*

- Reduction of inflammation reduces pain intensity and frequency

- Potential Risks:
  - tissue damage if cold temperature applied to affected area for too long
  - if electrical system involved: potential electrocution risks if wire insulation damaged

Examples of Cryotherapy

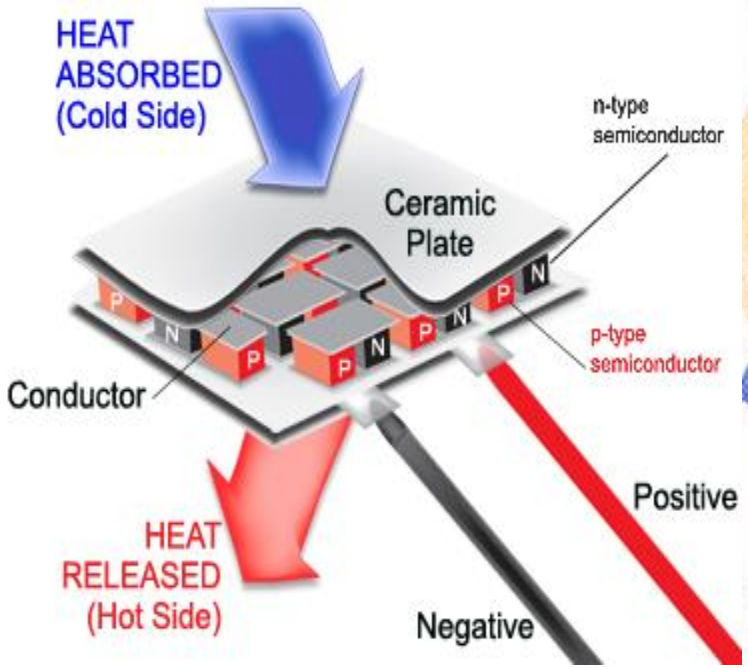
Hilotherapy

Ice Pack

Thermal Therapy

- Increasing of temperature at local affected region
  - Direct application of heat to the body
- Reduction of Pain:
  - Vasodilation flushes out fluid from site, lowering inflammation
  - Increases oxygen supply to tissue
  - Eliminates CO2 and metabolic waste
- Potential Risk:
  - Mild burning of skin if mishandled

Example of Thermal Therapies



Infrared

Peltier

Resistive

Pugh Chart of Therapy options

	Weight	Compression	Cryotherapy	Thermal
Safety	10	8	5	7
Cost	5	8	5	5
Ease of Use	6	9	8	8
Client's Opinion	7	7	10	10
Therapeutic Value	8	6	8	10
Totals	N/A	271	257	293

Specific (Thermal) Design Requirements

Temperature

- max/min: > 45–50°C (113–122 °F) or < 0°C (32°F) can INJURE tissue and local nerves
- heat application:
  - 15-30 min duration, 4 times/day
- cold application:
  - 10 min duration, 6 times/day

Sensor

- sensory frequency <1Hz

Heat Sink

- necessary for certain technologies

Resistive Heating

- Passes electric current through a resistor to release conductive heat

- Electrical energy is converted to heat
  - Heat released is proportional to resistance

- Examples: electric blanket, heated gloves

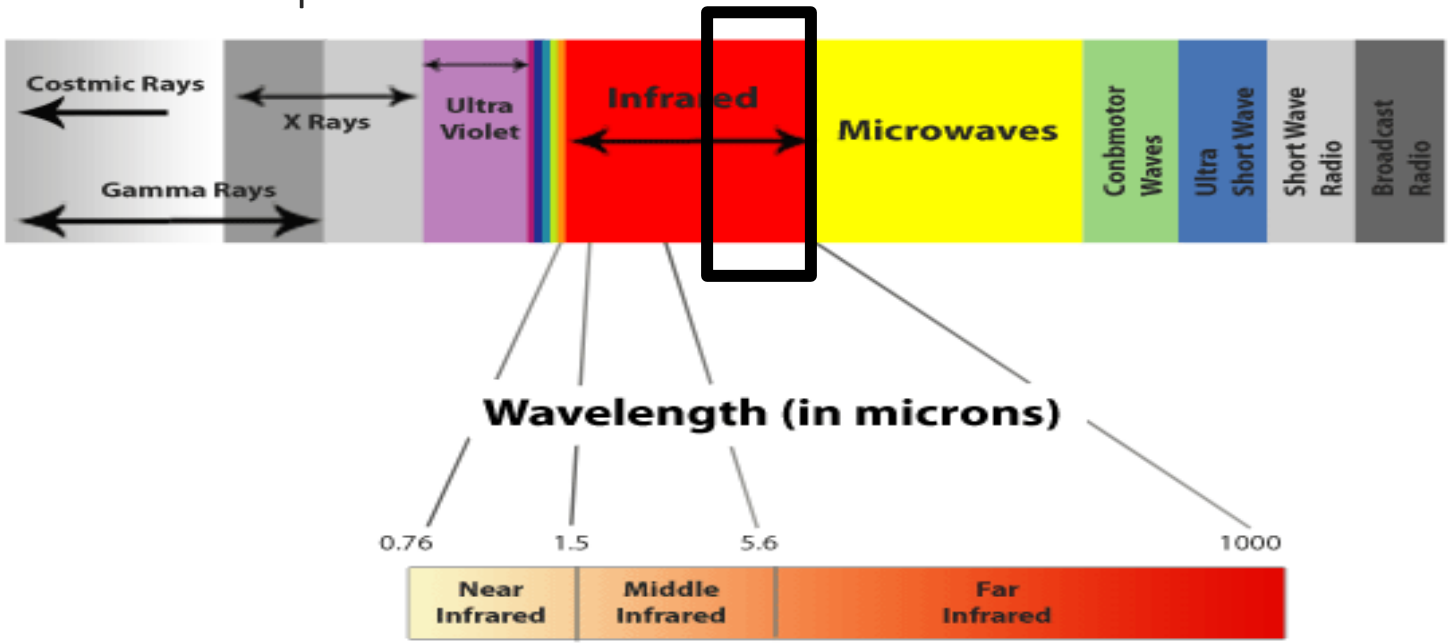
Resistive Heating

Major Pros: Simple, Durable, Effective

Major Cons: No cold capabilities

Far Infrared Heating

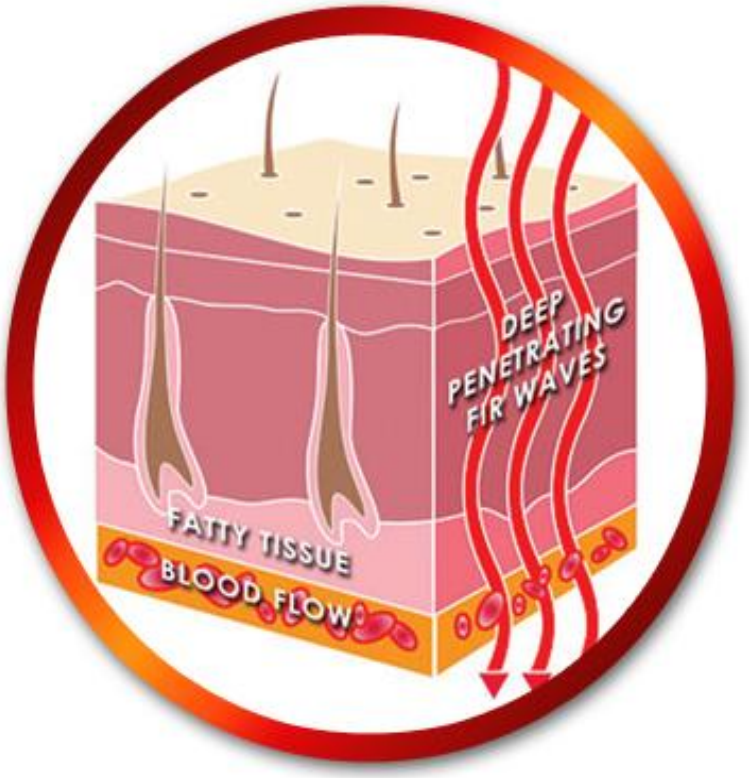
- Electromagnetic radiation
  - Frequency 20 THz to 300 GHz
- 50% energy generated by body is FIR
  - FIR heating increases cellular metabolism
- Heats tissue up to 4-6 cm below skin



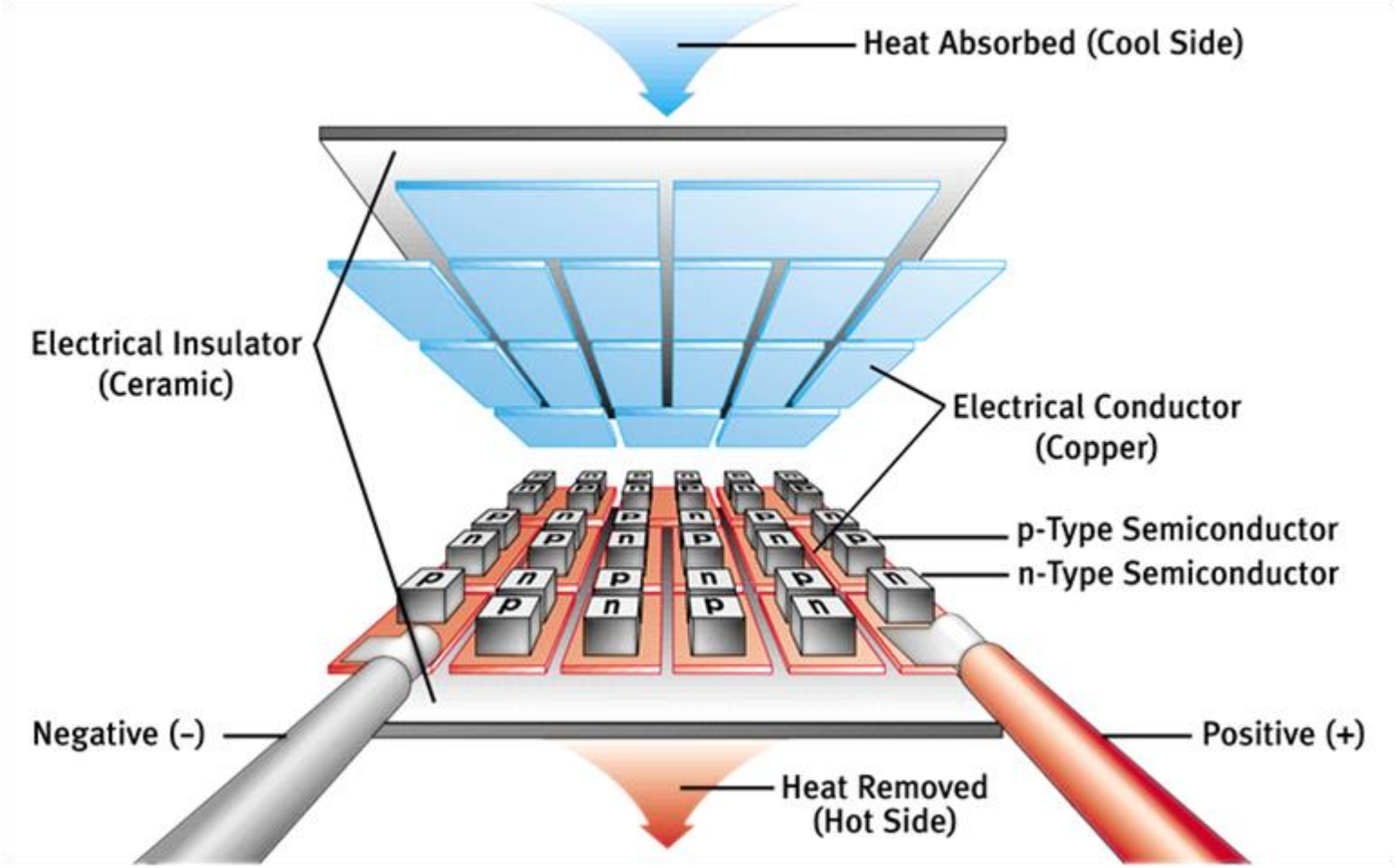
Far Infrared Heating

Major Pros: Deep tissue penetration, very safe

Major Cons: No cold capabilities



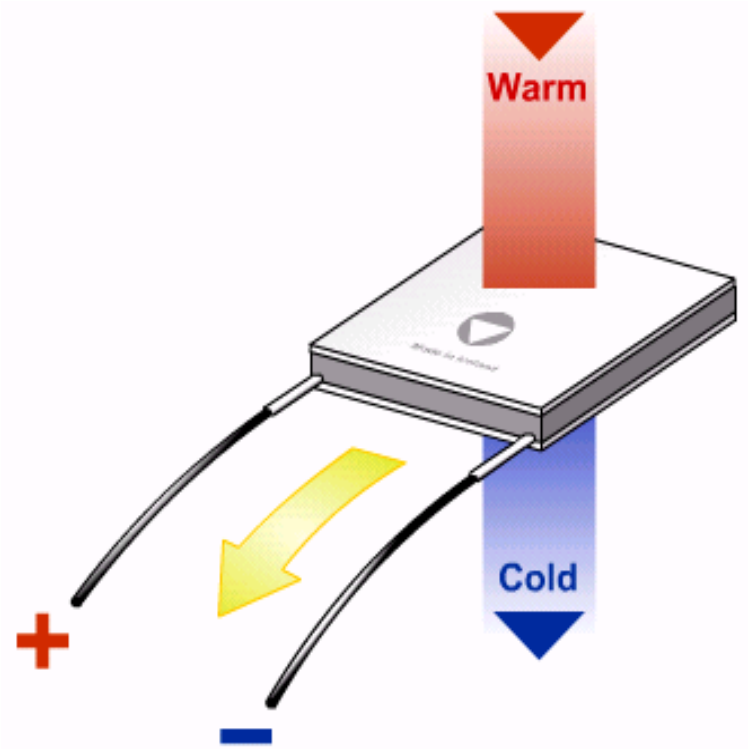
Peltier Heating

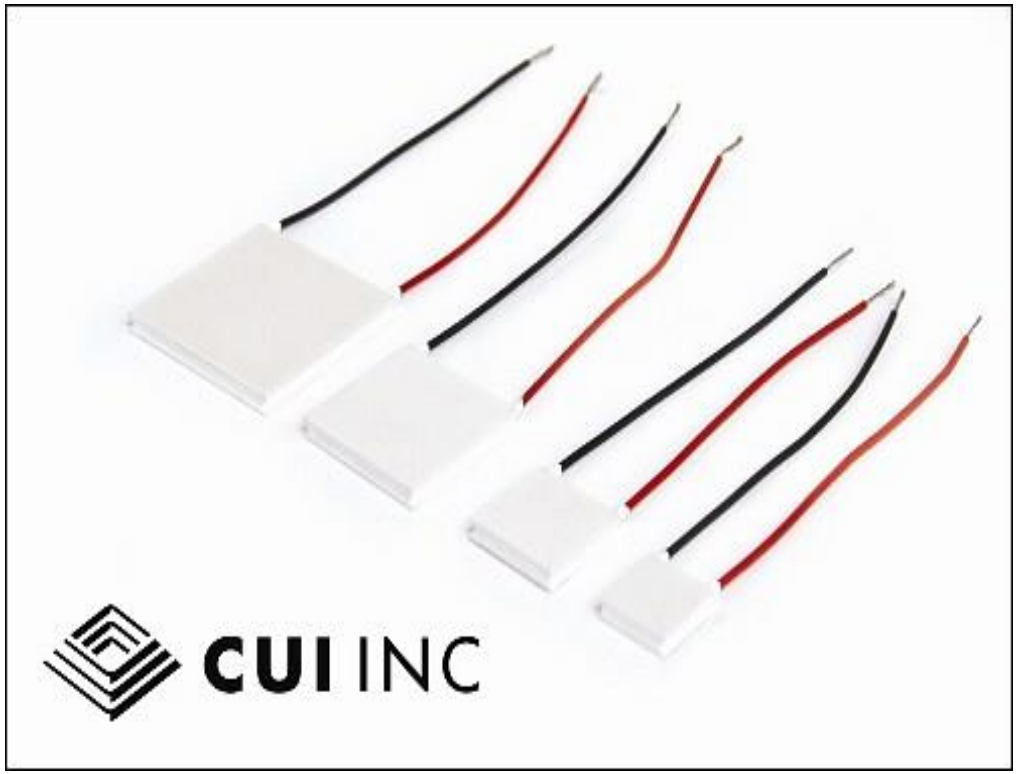


Peltier Heating

Major Pros: Heat and cold capabilities

Major Cons: Poor durability





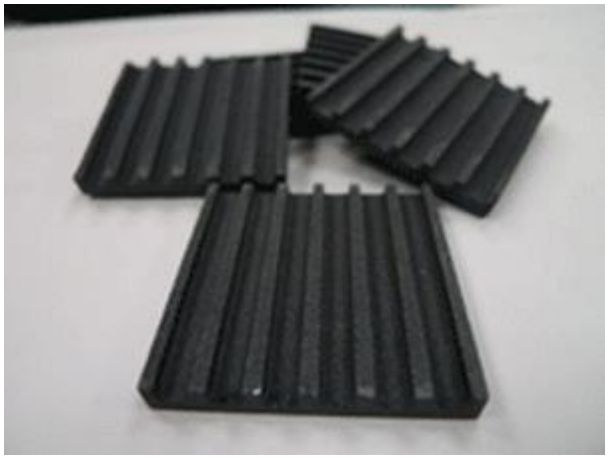
Pugh Chart of various “most ideal” therapy options

	Weight	Infrared	Peltier	Restitive
Safety	10	9	7	8
Cost	6	6	5	7
Ease of Use	5	8	8	8
Weight	5	7	10	9
Durability	7	7	4	10
Cold Capabilities	7	0	10	0
Totals	N/A	251	295	283

Material Considerations

Heat Sink

- Metals
- Ceramics/Non-Metals
- Plastics



Protection/Safety

- Thermally/electrically/mechanically Insulation

Heat Conducting Material

- Thermally conducting metal
  - Spreads heat from peltier device to surrounding skin surface

Material Considerations

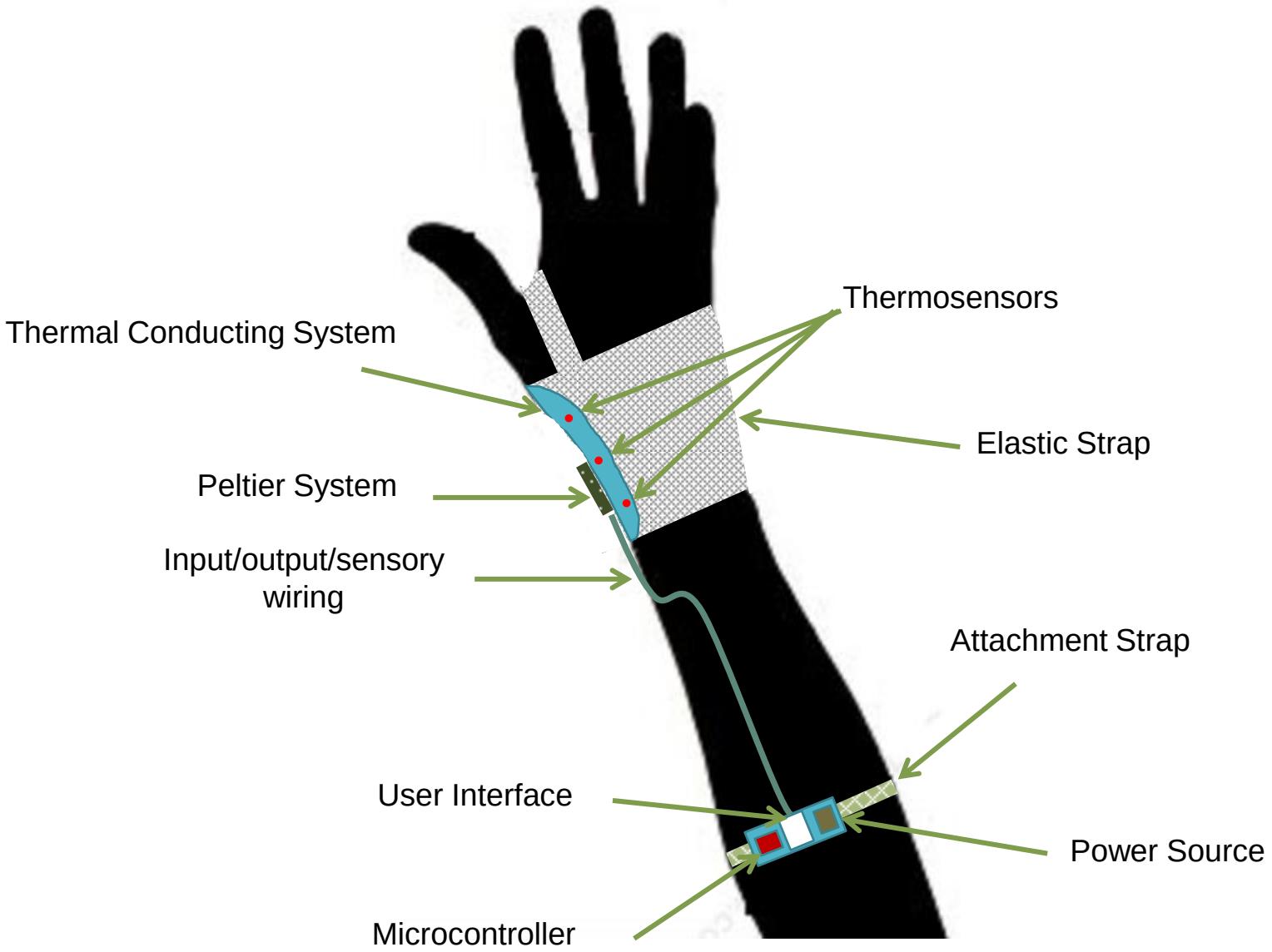
Thermal Sensor

- Thermistor
- Resistance Temperature Detectors (RTD)
- Thermocouples

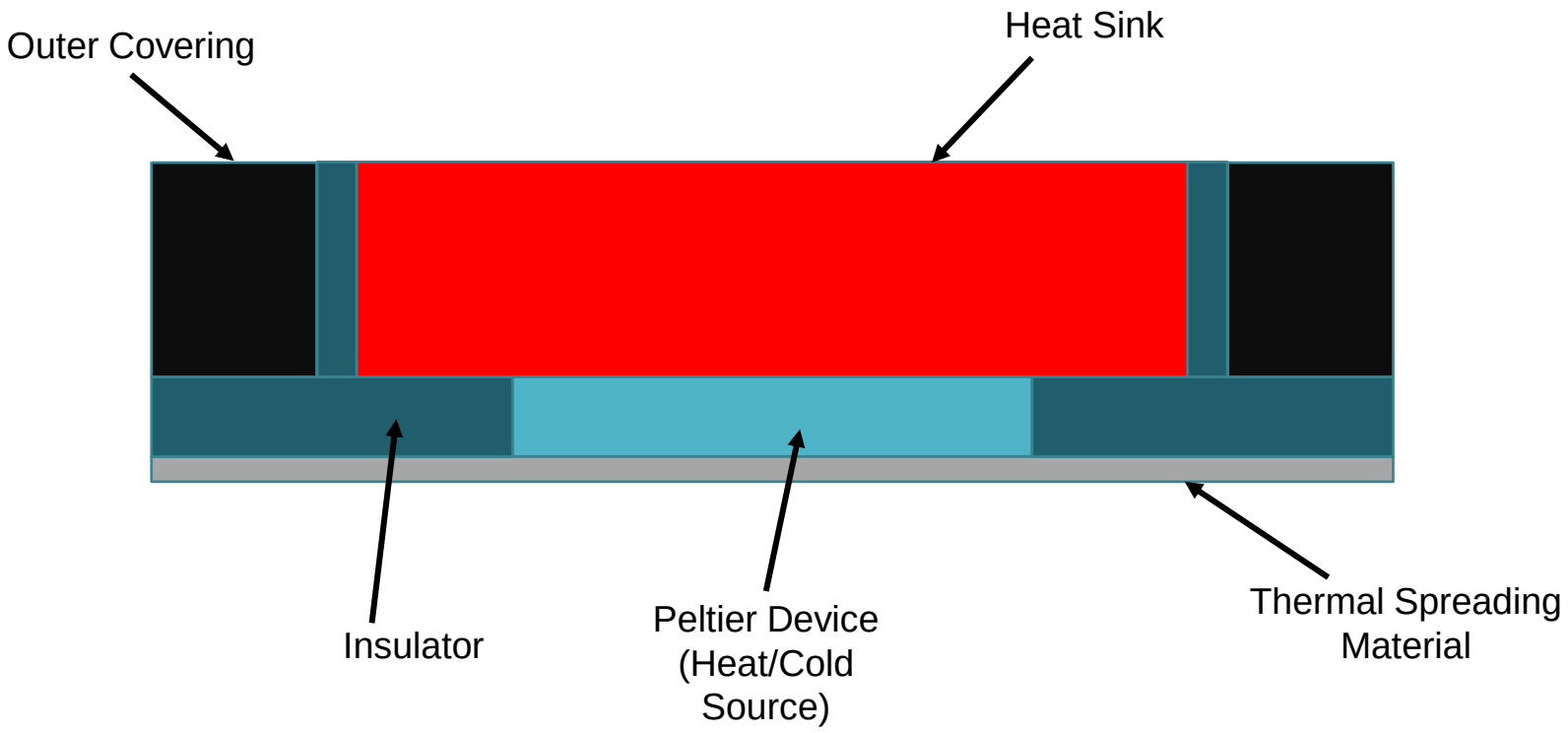
Feedback Control

- Digital
  - *Microcontroller*
- Analog

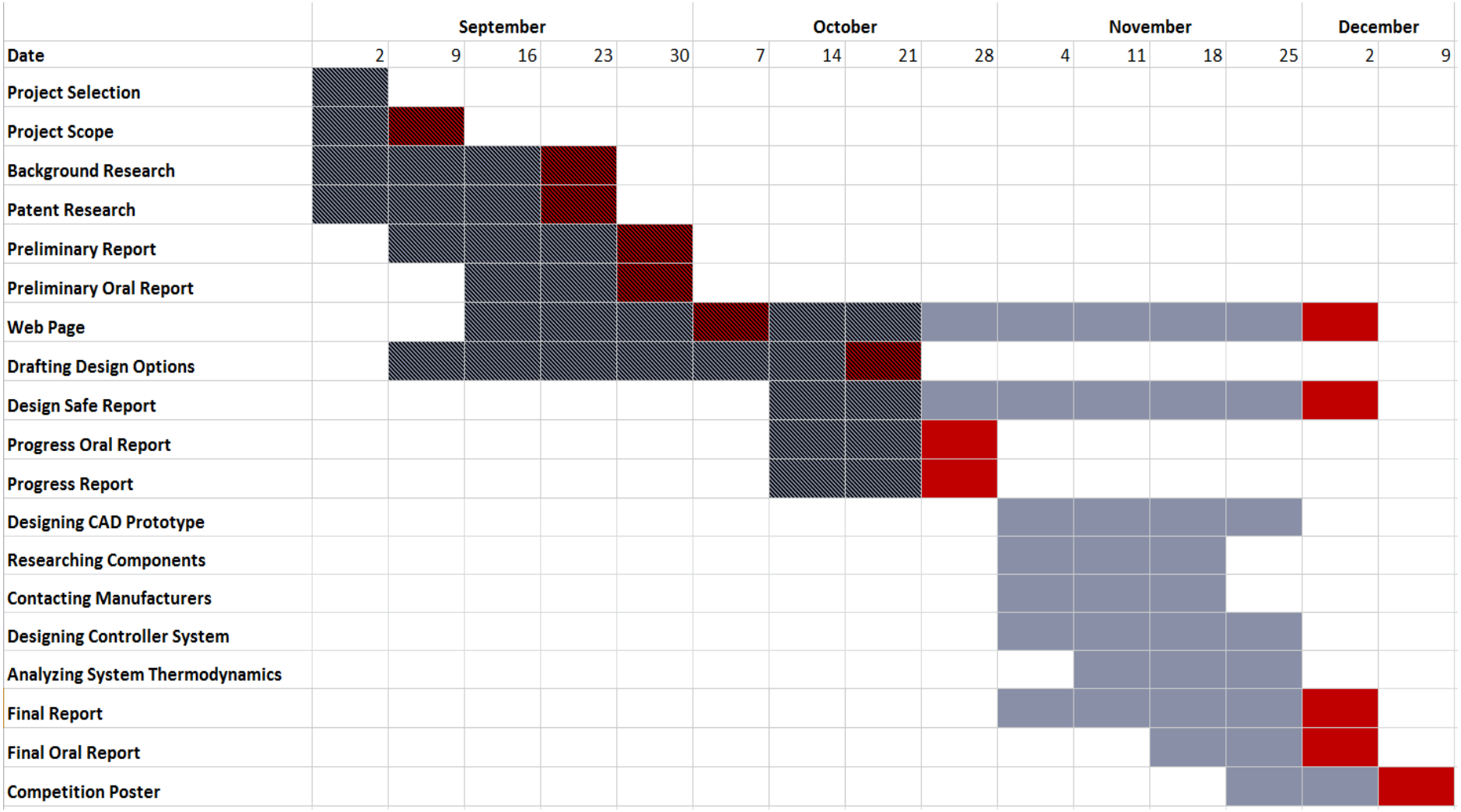
Final Chosen Design



Peltier Component Design



Updated Design Schedule



Updated Duties

Keshav Kohli

- Written Document Quality Control
- DesignSafe Analysis
- Lead Contact
- Manufacturing

Reith Sarkar

- CAD Design
- Materials Evaluation
- Sensor Options

Puneet Kumar

- Microcontroller Design
- Submits Weekly Reports
- Heat Sink Options

References

Van Manen, MD; Nace, J; Mont, MA (November 2012). "Management of primary knee osteoarthritis and indications for total knee arthroplasty for general practitioners." *The Journal of the American Osteopathic Association* **112** (11): 709–715.

Conaghan, Phillip. "Osteoarthritis — National clinical guideline for care and management in adults" (PDF). Retrieved 2008-04-29.

Samuel, Leslie. "Interactive Biology, by Leslie Samuel." *Interactive Biology by Leslie Samuel*. N.p., n.d. Web. 01 Oct. 2013.

Dawson-Hughes, B., Ge Dallal, Ea Krall, L. Sadowski, N. Sahyoun, and S. Tannenbaum. "A Controlled Trial of the Effect of Calcium Supplementation on Bone Density in Postmenopausal Women." *International Journal of Gynecology & Obstetrics* 35.3 (1991): 284. Print.

Spector, T. "Risk Factors for Osteoarthritis: Genetics." *Osteoarthritis and Cartilage* 12 (2004): 39-44. Print.

Hart, Deborah J., David V. Doyle, and Tim D. Spector. "Incidence and Risk Factors for Radiographic Knee Osteoarthritis in Middle-aged Women: The Chingford Study."*Arthritis & Rheumatism* 42.1 (1999): 17-24. Print.

Matullo, Kristofer S., Asif Ilyas, and Joseph J. Thoder. "CMC Arthroplasty of the Thumb: A Review." *Hand* 2.4 (2007): 232-39. Print.

"Definition: Subluxation." *About.com Orthopedics*. N.p., n.d. Web. 01 Oct. 2013.

Kumar, Puneet, Reith Sarkar, and Keshav Kohli. *Pain Alleviation in Carpometacarpal (CMC) Arthritis Splint: Preliminary Report*. N.p., n.d. Web. 26 Oct. 2013.

Tepperman, PS, and M. Devlin. "The Therapeutic Use of Local Heat and Cold."*Canadian Family Physician* 32 (1986): 1110-114. Print.

Denegar, CR, DR Dougherty, JR Friedman, ME Schimizzi, JE Clark, BA Comstock, and WJ Kraemer. "Preferences for Heat, Cold, or Contrast in Patients with Knee Osteoarthritis Affect Treatment Response." *Clinical Interventions in Aging* 5 (2010): 199-206. Print.

Bellman, S., and J. Adams-Ray. "Vascular Reactions After Experimental Cold Injury: A Microangiographic Study on Rabbit Ears." *Angiology* 7.4 (1956): 339-67. Print.

Belli, Evaristo, Guido Rendine, and Noemi Mazzone. "Cold Therapy in Maxillofacial Surgery."*Journal of Craniofacial Surgery* 20.3 (2009): 878-80. Print.

"Thermoelectric Cooler Basics." *TEC Microsystems*. TEC Microsystems, n.d. Web. 27 Oct. 2013.

"Do Arthritis Gloves Help?" *HubPages*. N.p., 6 Dec. 2010. Web. 19 Oct. 2013.

"DIABETES CAUSES, SYMPTOMS AND EFFECTS." *Diabetes Symptoms*. 2012 Diabetes Prevention and Control Alliance, n.d. Web. 26 Oct. 2013.

Chen, AH, SG Frangos, S. Kilaru, and BE Sumpio. "Intermittent Pneumatic Compression Devices -- Physiological Mechanisms of Action." *NCBI*. U.S. National Library of Medicine, n.d. Web. 29 Oct. 2013.

"Breo IPalm520 Hand Massager." *Breo USA*. N.p., n.d. Web. 29 Oct. 2013.

Callister, William D., and David G. Rethwisch. *Materials Science and Engineering: An Introduction*. Hoboken, NJ: John Wiley & Sons, 2010. Print.

Questions?