



Project “Socket Steward”

ELECOMP Capstone Design Project 2022-2023

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Sponsoring Company and Technical Director:

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Company Overview:

South County Gadgets is a contrived company name I made up last night. I will serve this team as an experienced product designer, independent technologist, and mentor now starting on an entrepreneurial path.

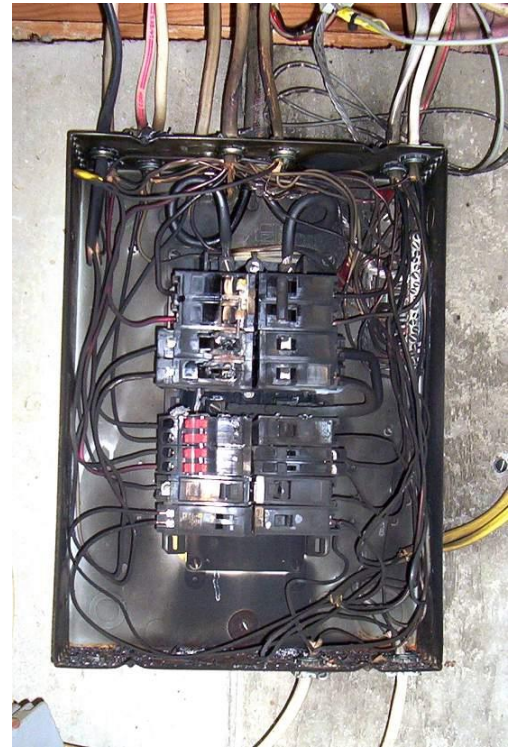
Over the years, I have served as Sponsor and Capstone Technical Director for 3 URI and 4 UMASS Dartmouth yearlong Capstone projects. I typically follow a product development lifecycle that will be tailored for this team and project, to make room for course deliverables and the needs of the proposed product. Here is [my resume](#) and [LinkedIn profile](#).

My past URI Capstone Projects are:

- [Smart Valve Actuator Proposal](#), [Smart Water Valve Actuator Outcome](#) ([1st Prize Team for 2017](#))
- [Project Falcon: Wireless pool-side multi-sensor system proposal](#) (5th prize award 2018)
- Project Rabbit: [A fast, portable chlorine generator cell tester](#) and [Poster](#) (I’m sure it won something in 2018)

Project Motivation:

To design a Consumer plug-in Smart Power Disconnect
prevent these things from happening, no matter what:



... and also to allow people to use products like this heater **SAFELY** without knowing or heeding the pretty dramatic safety requirements:

350-Watt Wall Outlet Handy Heater \$22.97

"Handy heater is the personal plug in heater that allows you to have warmth and comfort anywhere you want to relax. Simply plug Handy heater into any outlet and set the digital control to your ideal temperature. You will keep you spot warm and constant by using the built in timer."



- Quick and easy heat instantly
- Digital temperature display
- Heats up to a 250 sq. ft. area
- Great for any room in the house where heat is needed"

WHAT THE
PRODUCT'S
PACKAGING SAYS...

<https://www.homedepot.com/p/350-Watt-Wall-Outlet-Handy-Heater-HEAT-PD36/303667302#overlay>

IMPORTANT SAFETY INSTRUCTIONS

Read all instructions before using this heater.

- This heater must be plugged into a 120 V, 15 amp (or more) circuit of its own. Do not plug anything else into the same circuit. If unsure if your home meets this specification, consult a certified electrician prior to use. Risk of fire, overheating, malfunction, property damage, injury, or even death may result if not adhered to!
- Connect to a properly grounded, 3-prong outlet only. Do not connect the heater to extension cords, surge protectors, timers, direct breakers, or an outlet with other appliances connected to the same outlet. Risk of fire, overheating, malfunction, property damage, injury, or even death may result if not adhered to!

WARNING: This heater has a voltage rating of 120 volts. It has a threeblade, grounding-type plug. An adapter should not be used if a three-slot grounded receptacle is not available. **DO NOT DEFEAT THE SAFETY PURPOSE OF THE GROUNDED PLUG.**

... vs what lurks as *fine print* inside the box, saying **HOW YOU MIGHT DIE OR BURN YOUR HOUSE DOWN IF YOU PLUG IT IN WITHOUT HIRING AN ELECTRICIAN!**

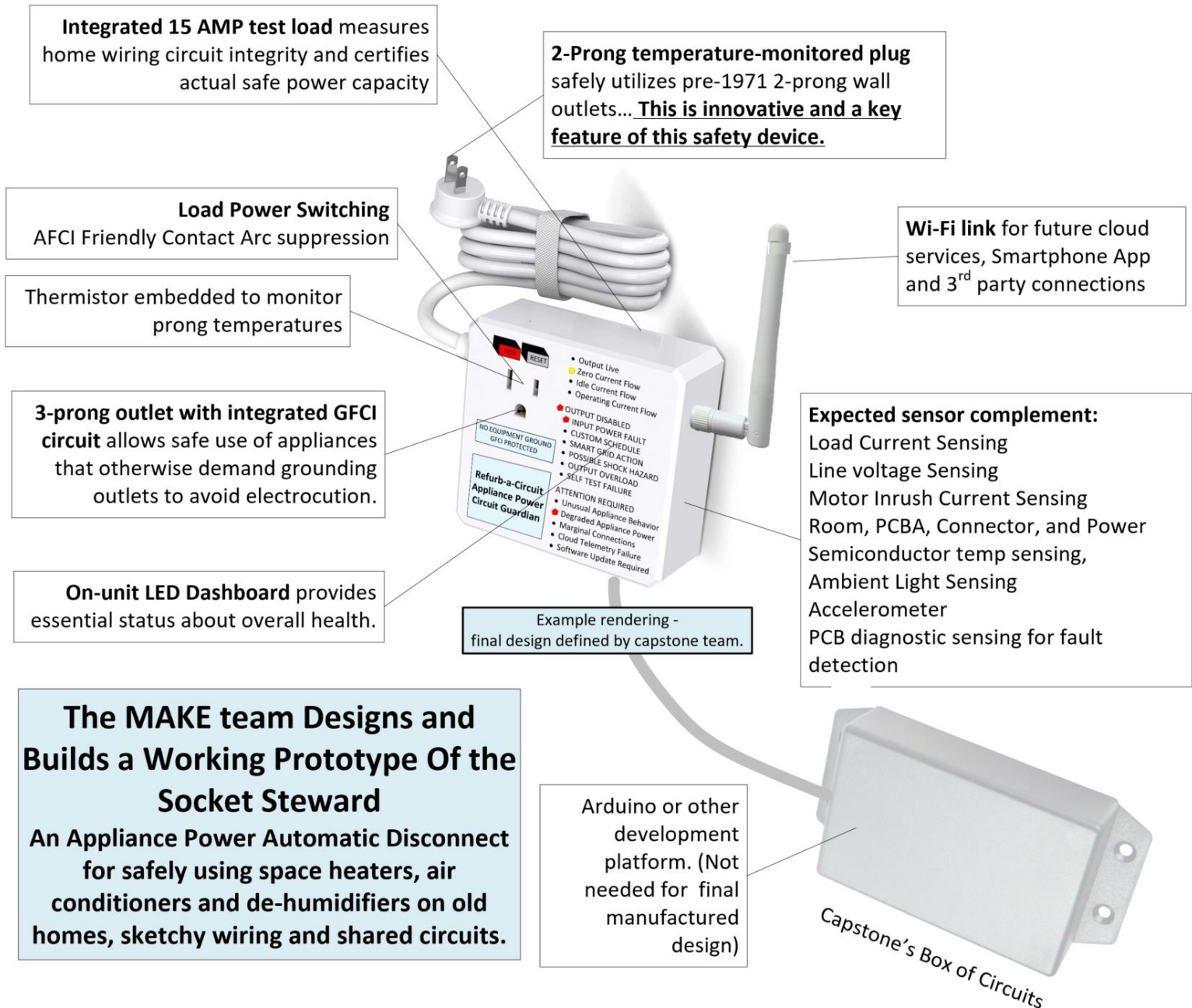
Is this really "Plug in... and relax"?? "Quick and easy"??

After a lifetime of having my own fuse box catch fire, finding burnt wiring in attics, breaker panels, and finding my mother's space heater plug to hot to touch on a chance encounter, **our team's mission will to be to enable modern appliances to work with old, uncertain, possibly dangerous home wiring without "consulting an electrician"**, the standard and prevalent demands seen in user manuals, media articles, and the insurance industry.

Anticipated Best Outcome:

TWO teams will make this a widget a masterpiece! A “MAKE TEAM” and a “BREAK TEAM”

Our “Make Team” will create a working prototype of an Automatic Power monitoring and disconnect System. It will be used to demonstrate the first useful power extension cord that prevents fires.



Our “Break Team” serves as the Fault Study and Product Validation authority using their Arcs & Sparks Bench!

First tasked with researching, measuring and documenting thermal runaway scenarios, this team informs the product team of thermal runaway behaviors that must be detected and what normal behaviors must be ignored. The team will study various melting and burning disasters replicated in this lab. The final task of this team will be to hunt for any performance and reliability gaps the design team will undoubtedly deliver! (Fireproof test chamber required!)



Project Details:

Still reading? First the Make Team and the Break Teams collaborate with the Technical Director to immerse us in the problem to be solved, all of it's various flavors. There is abundant data available from the National Fire Protection Association and the Consumer Product Safety Commission.

Collaborative Make and Break Team Activities. Early on we want to answer:

- What are the various failure modes that burn down houses and electrocute people? How can sensing and control detect and stop them by powering down the appliance?
- How can our own circuit fail to protect, via a fault and how can we “fail safely” so that malfunction never decreases protection, but instead drives appropriate user responses. (A DFMEA Analysis and remedy plan)
- Can this ultimately be made so affordable that people actually buy and use it? Can it be sold alongside the products that cause fires when “consult an electrician” isn't done?



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- What support can we leverage from those who study the problem, like authors of the National Electric Code, the UL safety standards, and the Consumer Product Safety Commission? I will show you how to engage such people.
- What real scenarios should the Break Team replicate and characterize on their test bench?
- What interactions would this have with installed modern AFCI / CAFCI / GFCI breakers?

Once this discovery period is complete, the teams collaborate on a Product Requirements Document. Then Make and Break teams get to work!

Make Team's Anticipated Activities during the build phase:

- Choose a GFCI solution and acquire a demo board
- Choose methods for measuring peak and average load currents
- Choose methods for measuring supply voltage impairments
- Design a 15 amp switchable AC dummy load that is tiny, can load the source voltage for the needed fractions of a second we decide, and will ALWAYS release before it creates it's own fire! At 15A x 117.5V this is a 1764 Watt dummy load that we want to switch in and out real quick!
- Design data acquisition front end to deliver high reliability digital signals for our signal analysis and simple machine learning tasks
- Design and assemble a custom PCBA for our prototype
- Code the outboard proto development platform to detect the signature of hazardous power impairments

Break Team's Anticipated Activities:

- Research and inventory the wiring and electrocution faults known to safety experts.
- Replicate faults and characterize the signal behaviors our chosen sensing methods need to identify.
- Characterize the normal operating behaviors of common appliances Space Heater, Window Air Conditioner, for example. These must not trigger false positives and nuisance disconnects.
- Work with the Make Team to test candidates for various product circuits for selection and performance.
- Build the Arcs and Sparks workbench under the watchful eye of URI Safety engineers (or offsite if needless bureaucracy becomes evident), then Intentionally accelerate the wear of normal usage for some example power strips, extension cords, cheap, good and medical grade wall outlets, possibly with support of external test labs. Then burn these things up, instrumented with thermocouples and dataloggers. The data and videos of these recreated house fire ignition sources will be contrasted with the FAILURE to burn when the Socket Steward is then used.



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Composition of Team:

2 – 3 Electrical Engineers and 1 Computer Engineer on the “Make Team”

2 Electrical Engineers on the “Break Team”

What practices we could or likely will follow:

(This list sounds like a lot and some might be addressed only if needed or as interest appears)

- **The phases and steps of a product development** life cycle as tailored to needs and constraints of this program, ideally a blend of “waterfall” and “agile” principles.
- **Leveraging resources:** how to make contact and ask for guidance when we know we need to learn something fast or deeply, or do something with mastery that we don’t have time to (or care to) personally attain.
- **Making decisions without enough time** and the data we are missing
- **Using design reviews to catch errors**, collect ideas, and validate choices
- **Assessing Project Risk** and identifying what mitigation steps must be taken now or just documented for others or revisiting in the future
- **Reliability in design** via use of component safety margins, stress assessment and validation principles
- **Safety engineering principles** especially DFMEA – Analyzing our Design by mentally simulating various Faults and their Effects on function, life, safety and user experience. Ideally this catches important “single points of failure” that would be unacceptable. (This is a mindset best employed continuously yet typically done in an arduous team meeting ...)
- **Using human emotions as a compass and signal for acting.** How to measure ourselves – set personal metrics – set expectations and hold ourselves accountable – communicate setbacks - invite feedback – sound “the alarm” – let others hold you accountable. Finding personal power and authenticity for mentoring self and others by words or by example as you build team trust, emotional safety, and a culture that delivers the best results. How to find bravery for the “radical candor” that is sometimes needed even with some insecure bosses, professors, friends, mates and parents you worry about making uncomfortable and reactive... and how to find the right words if radical candor is terrifying but staying silent or working around someone is worse. How to turn moments of feeling scared or angry into energy and immediate action to avoid depression and resentment.



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Skills Required:

Some “Make Team” Electrical Engineering Skills used and developed:

- Analog and Digital sensor selection and processor interface design
- Power circuit design for test load
- Some Spice Simulation
- Regulatory and Fire Risk research
- Team Project and time management

Some “Break Team” Electrical Engineering Skills used and developed:

- Mechanically inclined and interested in hands-on design and build of the various test fixtures to create the Arcs and Sparks workbench.
- Electronic Design Verification test development, Unit test and System test development
- Spice simulation of test scenarios
- Curiosity and tenacity

Computer Engineering Skills used and needed:

- Adept at coding various functions and UI on team-member’s preferred development platform
- DSP routine sourcing and application on streaming data for detecting signatures of faults and normal load behavior
- UI design and coding
- Creating “unit tests” before coding
- Writing user stories and epochs to measure workload and catch overloading in the plan before it becomes the experience

Anticipated Best Outcome’s Impact on Company’s Business, and Economic Impact

This is a serious problem that regulations on manufacturers and messaging to users haven’t solved.

The [National Fire Protection Association](#) Author of our National Electric Code and 300 other safety standards, says **that Outlets, Extension Cords, Branch Circuit wiring and other electrical wiring faults amount wiring amount to 270 average annual deaths, 18,450 average annual fires, and \$691M average annual Direct Property Damage.** As seen in the table below, degraded and improper electrical connections cause a lot of pain for many people.

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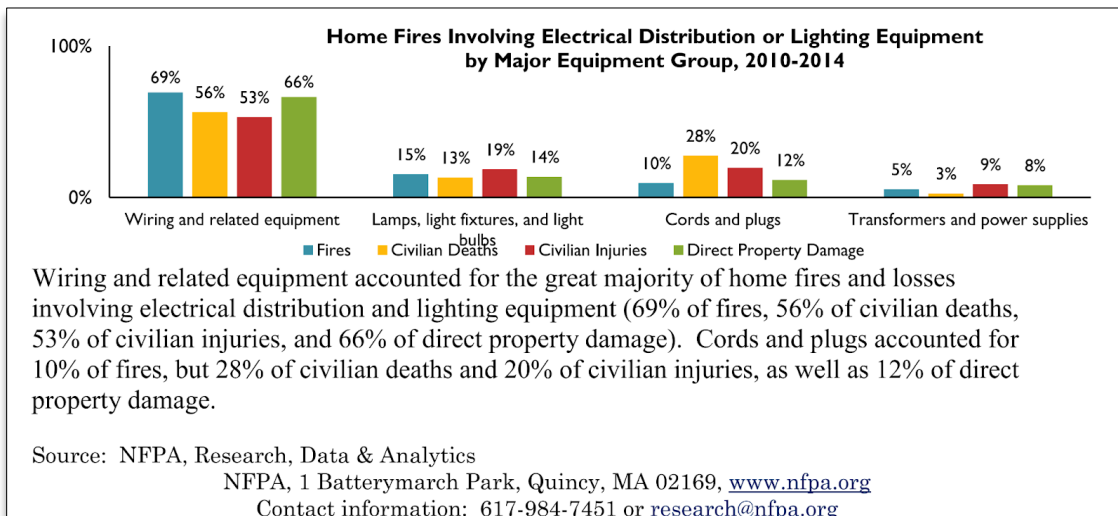


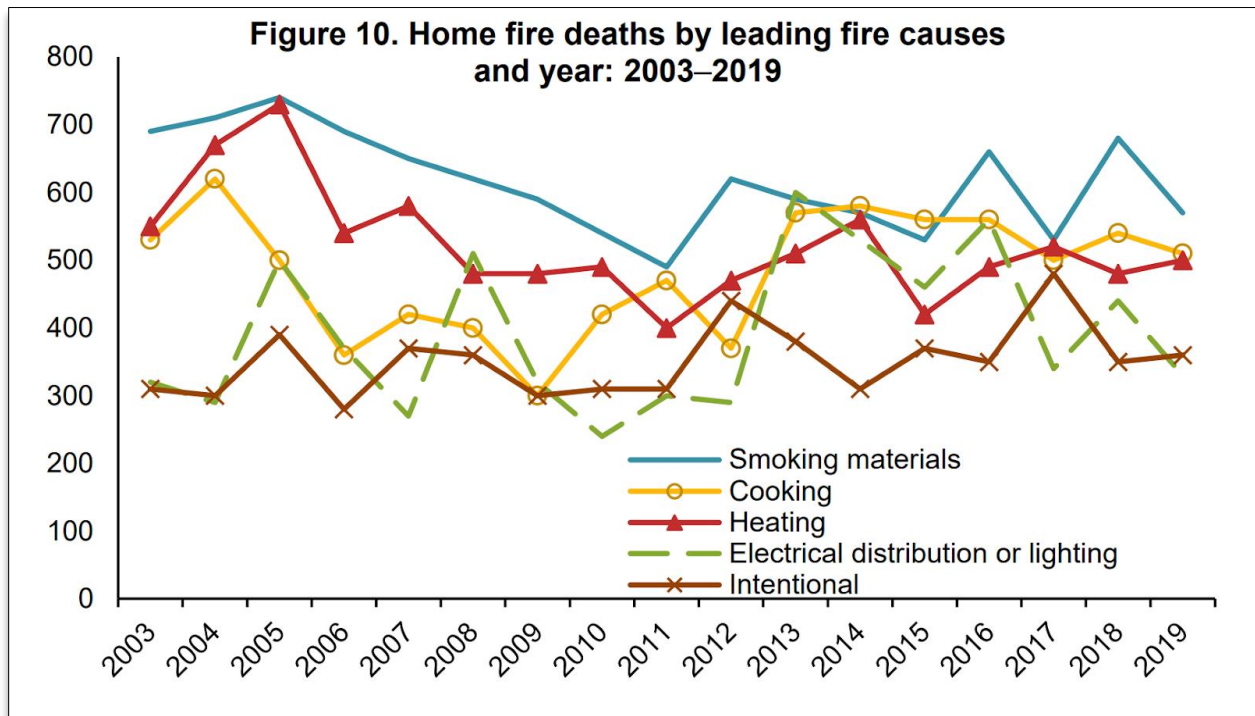
Table 5. Home Fires Involving Electrical Distribution and Lighting Equipment by Equipment Involved in Ignition: 2015–2019 Annual Averages

Type of Equipment	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Wiring and related equipment	22,210	(68%)	180	(42%)	560	(53%)	\$802	(60%)
Outlet, receptacle	4,210	(13%)	40	(9%)	130	(12%)	\$120	(9%)
Electrical branch circuit	2,410	(7%)	20	(5%)	50	(5%)	\$108	(8%)
Panelboard, switchboard, circuit breaker board	1,360	(4%)	10	(3%)	20	(2%)	\$51	(4%)
Ground fault interrupter, GFI	100	(0%)	0	(0%)	0	(0%)	\$3	(0%)
Unclassified electrical wiring	10,050	(31%)	100	(22%)	280	(27%)	\$385	(29%)
Unclassified lamp, lighting	1,470	(5%)	10	(3%)	50	(4%)	\$56	(4%)
Cord or plug	3,210	(10%)	180	(41%)	190	(18%)	\$130	(10%)
Extension cord	1,780	(5%)	110	(26%)	110	(10%)	\$78	(6%)
Power cord, plug, detachable from								

Home Fires Caused by Electrical Distribution and Lighting Equipment, February 2022 7 NFPA Research, Quincy, MA

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Product Safety standards have forced manufacturers to make much safer products and Building Codes have forced new homes and new wiring to have more inherent safety. Why isn't this moving the needle?



The dashed line for Electrical Distribution or lighting is bouncing between 300 and 600 annual deaths, even over 15 years of new home construction and new appliance safety requirements. No downward trend shows up.

I intend to take this product to market in a form that actually delivers on it's promise and in a form and cost that people will actually buy. This is a hard endeavor yet worth doing.

Broader Implications of the Best Outcome on the Company's Industry:

This abandons the dysfunctional approach of allowing consumers to operate modern appliances in their homes with wiring they don't understand, risk that is not assessed, and instructions everywhere to "consult an electrician"; replacing it with a device they can buy and plug in as easy as buying a power strip, but automatically prevents fires by disallowing more current to flow than the old, worn, poorly wired, corroded, wiring can support. If successful, this truly meets a very unsupported market need.