According to IoT Agenda, a microcontroller is “…a compact integrated circuit designed to govern a specific operation in an embedded system”1. As parts of embedded systems that comprise the electronic and mechanical functionality of a device, microcontrollers are often found in applications that have multiple separate stand-alone functionalities or work together with other embedded systems as integrated systems; these devices include cars, space shuttles, coffee pots, transceivers, and a host of others.

For the purposes of this paper, I will be examining the technical specifications and functionality of 3 microcontrollers I have worked with or am at least somewhat familiar with: the Raspberry Pi RP2040 (Pico W), Adafruit Industries LLC 4300 (Hallowing M4 Express), and BeagleBone Black. All three of these microcontrollers are smaller in form-factor, consume less power than some other microcontrollers, and work with fewer resources than larger microcontrollers like the Raspberry Pi 4 Model B.

All three of these microcontrollers are consumer-grade, and they are frequently used in projects that involve things like home automation and LED light shows. The Adafruit Hallowing Express has a 32-bit Arm Cortex processor that accommodates 3.3v logic and power and has 512KB of flash on-chip along with 192kb of ram; it has a 3-axis accelerometer for orientation, a light sensor, speaker driver, battery port of lithium polymer batteries, a usb port to charge/program/debug, two header strips to extend its functionality with other microcontrollers, JST ports, a reset button, and an on/off switch.2 The BeagleBone Black also has an Arm Cortex processor, but it is the AM335x and runs at 1GHz. The BeagleBone Black has 512MB of DDR3 Ram, 4GB of on-board flash storage, a 3D Graphics Accelerator, 2 on-board PRU microcontrollers for real-time processing, a USB port for power, a USB port for connecting to other devices, an ethernet port, an HDMI port, and 2 46 pin headers that offer I/O capabilities among other things.3 The Raspberri Pi Pico W has a dual-core Arm Cortex processor that runs at 133MHz, 264kB of SRAM, 2MB of QSPI flash (for fast loading of things like images), a 2.4GHz 802.11n wireless LAN chipset, 40 pins with 26 GPIO pins (it can come with or without headers), a USB port for power and data, 2xI2C interfaces, 2xSPI interfaces, 2xUART interfaces, and a serial wire debut interface.4

There are a myriad of security issues that a microcontroller could present to a network, but the three general areas of concern are network, software, and physical access. Many microcontrollers are programmed to be remotely accessible or are part of larger systems that have remotely accessible components. This being the case, it is extremely important that any remotely accessible microcontroller endpoints are secure from a network perspective (i.e. encryption and enforced authentication) and that any remotely accessible API and it’s underlying application accessible through the microcontroller be securely coded. The prevalence of microcontrollers in everything from our industrial processes to our coffee pots means they are also highly accessible in ways that traditional computers and servers generally are not; this requires that we engineer the hardware to be secure as well.

In addition to the types of vulnerabilities microcontrollers might introduce, it is also important to look at the severity of the vulnerabilities; because we run things like gas pumps, electrical grids, and pacemakers on the backs of microcontrollers, the compromise of these devices can have serious implications, up to and including loss of human life.

1 *Lutkevich, B. (2019, November 7). What is a microcontroller and how does it work? IoT Agenda. Retrieved April 18, 2023, from* [*https://www.techtarget.com/iotagenda/definition/microcontroller*](https://www.techtarget.com/iotagenda/definition/microcontroller)

2 *Industries, A. (n.d.). Adafruit hallowing M4 Express - goth Adafruit Black Edition. adafruit industries blog RSS. Retrieved April 19, 2023, from* [*https://www.adafruit.com/product/4300*](https://www.adafruit.com/product/4300)

3 *Beaglebone Black. Beagle Board - beagleboard.org. (n.d.). Retrieved April 19, 2023, from* [*https://beagleboard.org/black*](https://beagleboard.org/black)

4 *King, P. (2022, July 2). What is a raspberry pi pico W and what can you use it for? MUO. Retrieved April 19, 2023, from https://www.makeuseof.com/raspberry-pi-pico-w-what-you-can-use-it-for/*