SOCIETY OF PHYSICS STUDENTS
An organization of the American Institute of Physics

SPS Chapter Research Award Final Report

Project Title	SPS @ UCA: Small Parallel Supercomputer at UCA
Name of School	University of Central Arkansas
SPS Chapter Number	Zone 10, Chapter 1059
Total Amount Awarded	$1997.73
Total Amount Expended	$2212.96
Project Leader	John Singel

Abstract

The Society of Physics Students at the University of Central Arkansas plans to build a small parallel supercomputer. We will use it to get hands-on experience with the tools and techniques of computational physics research. We will expand our astrophysics research, attract new SPS student research, and foster educational outreach.

Statement of Activity

Overview of Award Activity

This project sprouted from two students' independent research with university physics faculty in both parallel computing and astrophysics. With additional SPS volunteers, the project developed into two main focal points. Firstly, we planned to research, build, and deploy an operational small parallel supercomputer and simultaneously develop a Python control program to maximize parallel processing. Secondly, we intended to use this computer to process the tremendous amounts of data necessary to model the lightcurves of supernovae and calculate their bolometric luminosities.

College campuses, generally, lack a dedicated supercomputer server (Adams, 2015). Our team concluded that the use of a locally-built supercomputer would significantly aid data processing to create lightcurve simulations with a program known as SuperBoL. Telescopes cannot directly observe the bolometric luminosity of a supernova, since much of the emitted radiation falls outside of observable wavelength range (Lusk & Baron 2017). Using SuperBoL we can simulate the luminosity of supernovae across the electromagnetic spectrum.

As we constructed the supercomputer, we realized that our project held significant potential as an educational tool. Our design for the supercomputer's protective case includes modifications that allow it to be transported relatively easily. As we refine and develop our project, we plan to display it at events and local schools in educational demonstrations.

We initially planned to launch into modeling supernovae within the time frame of this project, but our progress was delayed by unexpected complications in the construction of the supercomputer, including technical issues with the memory units and complications linking the nodes into a productive parallel supercomputer. The memory units initially received were proven, after copious confusion and research, to be incompatible with the nodes. After fresh memory units were ordered, received, and installed, a few weeks of experimentation and trial-and-error were required to arm the nodes with the correct authorizations to operate in parallel. The supercomputer was modelled after Little Fe, an educational parallel computing project (Peck, 2010), but our model deviated somewhat to fit our purpose and materials; consequently, solutions to our roadblocks were either organic or deeply searched for. Although several challenges slowed our progress, modelling supernovae luminosity and demonstrating the scientific process for aspiring physics students remain our ultimate goals.

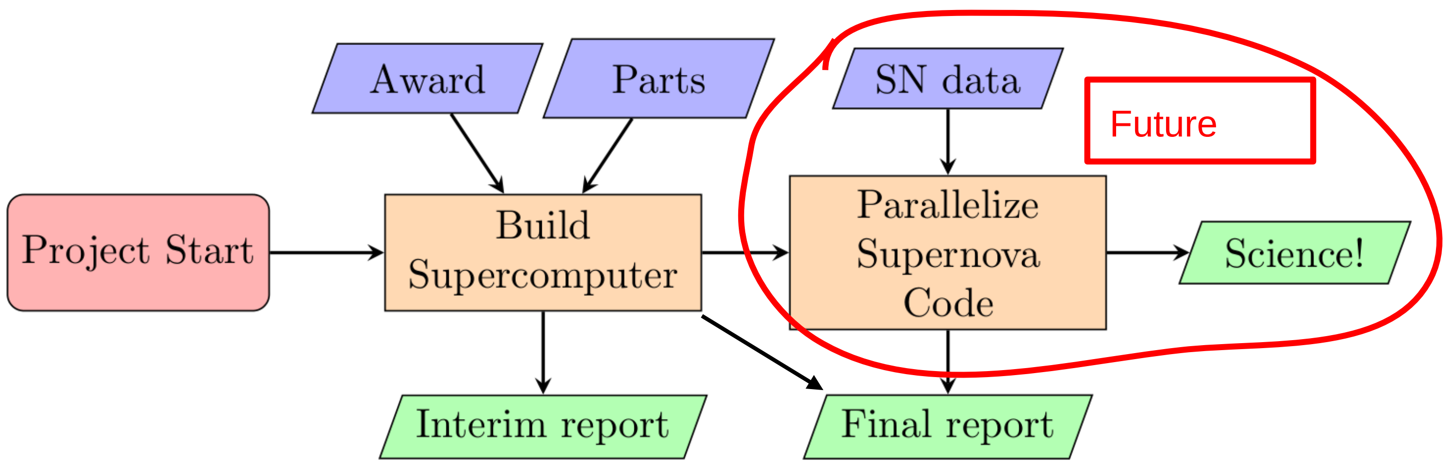

Figure 1. Overview of our chapter's goals and steps to reach them.

Four students played large roles in the completion of this project - John Singel, Shane Doolabh, Hannah Barry, and Christopher Geske. All four are members of the local UCA chapter of SPS, and John is a member of SPS National. Shane and John worked together to write the initial proposal, and both have worked on all aspects of the cluster. Hannah and Christopher began working on the project in the Fall of 2019, and both students immediately joined in the assembly, troubleshooting, and configuration of the cluster. John and Hannah collaborated on designing an enclosure to hold the motherboards and other components in a compact, portable package. That work continues, and we hope to begin prototyping when classes resume in the Spring semester. Hannah and Christopher assembled and tested the 12-volt wiring harness which powers the motherboards and the ethernet switch. All four students spent many hours working their way through possible solutions to the many problems we faced during the troubleshooting phase of the project. In the end, it was their curiosity and determination which brought the cluster to its current working state.

Description of Research - Methods, Design, and Procedures

The first step was to familiarize ourselves with the environment of the computers and install the operating system for our command and control or "head" node. The initial attempts at installation required a fair amount of troubleshooting, but the complications also led to an enhanced understanding of how the operating system installs and boots itself. Up to this point the motherboard had been powered by a connection to an AC battery charger, so the next step was to construct a wiring harness that would allow us to power all 6 of the nodes simultaneously. The wiring harness ended up being a parallel circuit constructed from wire, barrel jacks, and heat shrink tubing, which was simple but effective. Once the nodes were powered, they were networked together with an ethernet switch and configured to boot and install over the network using the tools provided in the ROCKS Linux distribution. Our initial thought was to try and run the nodes from a single hard drive, but due to the limitations of the ROCKS distribution, this proved problematic. Instead, each node was outfitted with a small SSD to boot from, and an HDD connected to the head node was used as a shared data drive.

Discussion of Results

In total, our supercomputer has six motherboard units, one acting a head node and the others processing tasks delegated by the head node. Each node connects to an ethernet hub, and a common power source. Together, the cluster has 24 cores running at 1.1GHz, capable of boosting to 2.5GHz during heavy computation. Each node has 8GB of RAM, for a total of 48GB of memory. In order to hold the operating system and file system, each node has 120GB of storage on a solid-state drive.

After installing the ROCKS Linux distribution across the cluster, we began testing the parallel processing capabilities of the system. To perform computation across multiple computers, we used the OpenMPI - the Open Message Passing Interface. This software library allows us to run properly prepared code in parallel across the cluster, and handles the details of passing information back-and-forth over the ethernet network.

Once we installed OpenMPI on the cluster, we ran a simple test - launching 20 processes on the 5 compute nodes (one process per physical CPU core.) the test code passes a message from one core to another in series, so that each core has sent and received a message to a different core on a different node by the end of the test. Thankfully, the test passed with no complications, and we had confirmation that our computers were working together as a cluster.

As a more intensive computational task, we have begun evaluating the performance of the cluster using HPL - A widely-used benchmark for testing the performance of parallel computers (Petitet et. al.) The HPL algorithm uses a multitude of techniques to solve a dense linear system, and the underlying linpack algorithm is used to rank the top 500 supercomputers in the world (https://www.top500.org/)

Out initial results on 20 cores show a rather disappointing 4 GFlop/s - but more time is required to fine-tune the test parameters. It is also possible that the heat generated by the high utilization of the CPUs is leading the thermal throttling - when the processors lower their clock speed to prevent overheating. We will experiment with the test parameters and the system cooling to try and increase the overall performance.

Dissemination of Results

Our work building the cluster has been accepted to the Arkansas STEM Posters at the Capitol session (https://faculty.uca.edu/wvslaton/ARposters/). This poster session is held annually in the rotunda of the Arkansas State Capitol, and gives student researchers at Arkansas colleges and universities a venue for presenting their work to fellow students, professors, legislators, and members of the public.   Because we were unable to complete the scientific exploration we intended, we have not yet disseminated the results of our efforts beyond discussions within the department.

Bibliography

Adams, J. C., Caswell, J., Matthews, S. J., Peck, C., Shoop, E., & Toth, D. (2015). Budget Beowulfs: A Showcase of Inexpensive Clusters for Teaching PDC. In Proceedings of the 46th ACM Technical Symposium on Computer Science Education (pp. 344–345). New York, NY, USA: ACM. https://doi.org/10.1145/2676723.2677317

Lusk, J. A., & Baron, E. (2017). Bolometric Light Curves of Peculiar Type II-P Supernovae. Publications of the Astronomical Society of the Pacific, 129(974), 044202. https://doi.org/10.1088/1538-3873/aa5e49

Peck, C. (2010). LittleFe: Parallel and Distributed Computing Education on the Move. J. Comput. Sci. Coll., 26(1), 16–22.

A. Petitet, R. C. Whaley, J. Dongarra, A. Cleary. HPL - A Portable Implementation of the High-Performance Linpack Benchmark for Distributed-Memory Computers, version 2.3 http://www.netlib.org/benchmark/hpl/

Impact Assessment:

How the Project Influenced your Chapter

Our work in parallel supercomputing gave our SPS team a healthy appreciation for the requirements upon the experimental physicist to build and conduct experiments to prove the validity of the theoretical physics. Although the roadblocks we encountered slowed our progress, it reinforced the importance of both expecting the unexpected and balancing flexibility and focus on long-term research. Challenges in working with the code and designing the physical aspects of the supercomputer provided constructive hands-on experience in solving practical challenges creatively and organically. The cross-field experience this project offers served as a superb launching pad for members of our chapter as they develop as physicists and explore intriguing questions in parallel computing and astrophysics.

On an individual level, the project strengthened our SPS team by giving first year members a vector for their enthusiasm. Particularly, the project connected them to intriguing research in their field of specialty. Constructing the small parallel supercomputer and working with SuperBol catalyzed both our team's growth and the expansion of STEM research at the University of Central Arkansas.

Lesson learned for future Chapter Research Awards: delays, unexpected challenges, and trial-and-error problem solving are okay, but giving up is not! It's vitally important to stay focused on the goal, even if the path takes unforeseen turns.

Key Metrics and Reflection

How many students from your SPS chapter were involved in the research, and in what capacity?	Four students were heavily involved in the project - and all four worked on both the hardware assembly/testing/troubleshooting process and the software installation and configuration process.
Was the amount of money you received from SPS sufficient to carry out the activities outlined in your proposal? Could you have used additional funding? If yes, how much would you have liked? How would the additional funding have augmented your activity?	Although our initial estimation would have been comfortable had nothing major gone awry, reordering the necessary memory units after discovering their incompatibility hefted our amount spent to $215.23 above our received funding. Additional funding for challenges like these would have helped immensely.
Do you anticipate continuing or expanding on this research project in the future? If yes, please explain.	Absolutely! We plan to continue refining the supercomputer and work with SuperBol to produce the bolometric lightcurve models we initially set out to create. We would also like to create a portable case for the supercomputer so that we can bring it to schools in our area for demonstrations and learning opportunities.
If you were to do your project again, what would you do differently?	Prepare for hiccups, both monetarily and temporally!

Expenditures

Expenditure Table

Item	Please explain how this expense relates to your project as outlined in your proposal.	Cost
Motherboards	Parts	1195.70
Crucial memory	Parts (incompatible)	329.28
HyperX memory	Replacement parts	269.01
Ethernet switch	Network equipment	49.99
Hard drive	Parts	33.39
SSD drives	Parts	184.44
WiFi adapter	Parts	21.49
WiFi Antenna	Parts	10.99
Ethernet cables	Parts	5.95
Power cable	Parts	3.39
SATA cable	Parts	5.80
Power supply	Equipment	103.53
	Total Expenses	2212.96
	Total of Expenses Covered by SPS Funding	1997.73
	Expenses Covered by Outside Funding	215.23

Activity Photos

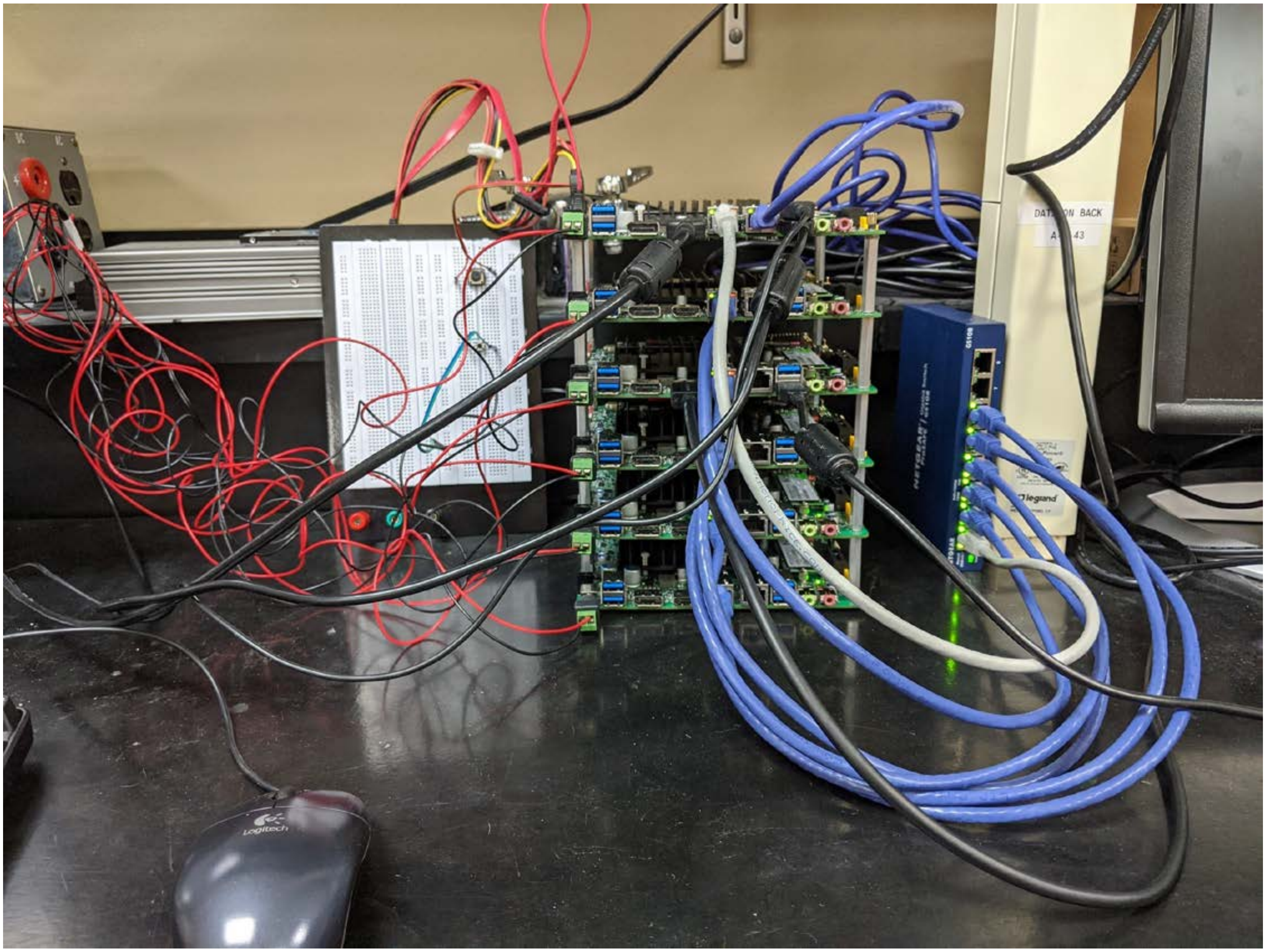

Figure 2. The supercomputer’s most recent stage, complete with six nodes and power, Ethernet, and internal connections. Credit: Jeremy A. Lusk

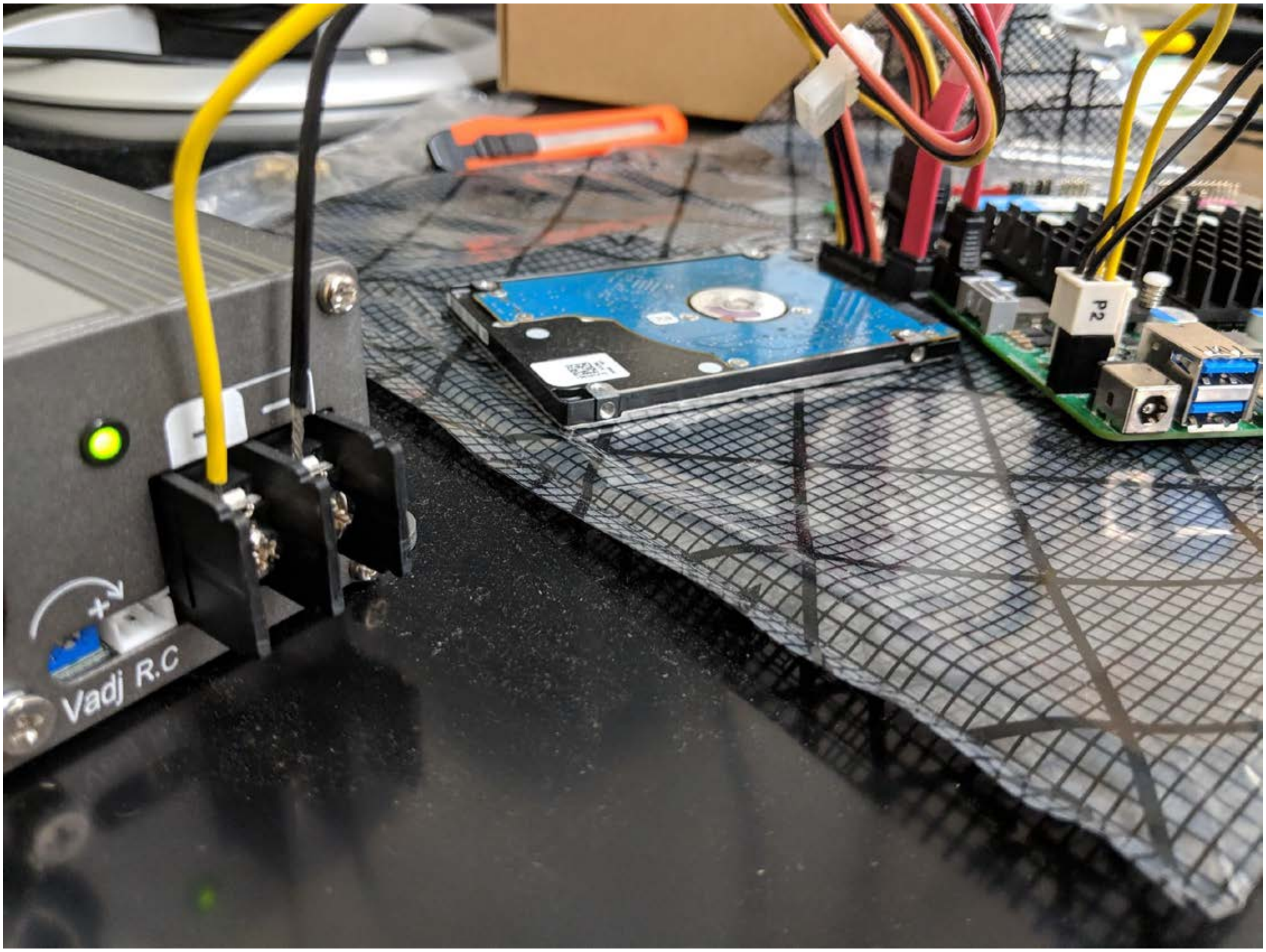

Figure 3. Powering the first motherboard, the head node. From left: 12-volt power supply, hard disk drive and motherboard on anti-static mat. Credit: Jeremy A. Lusk

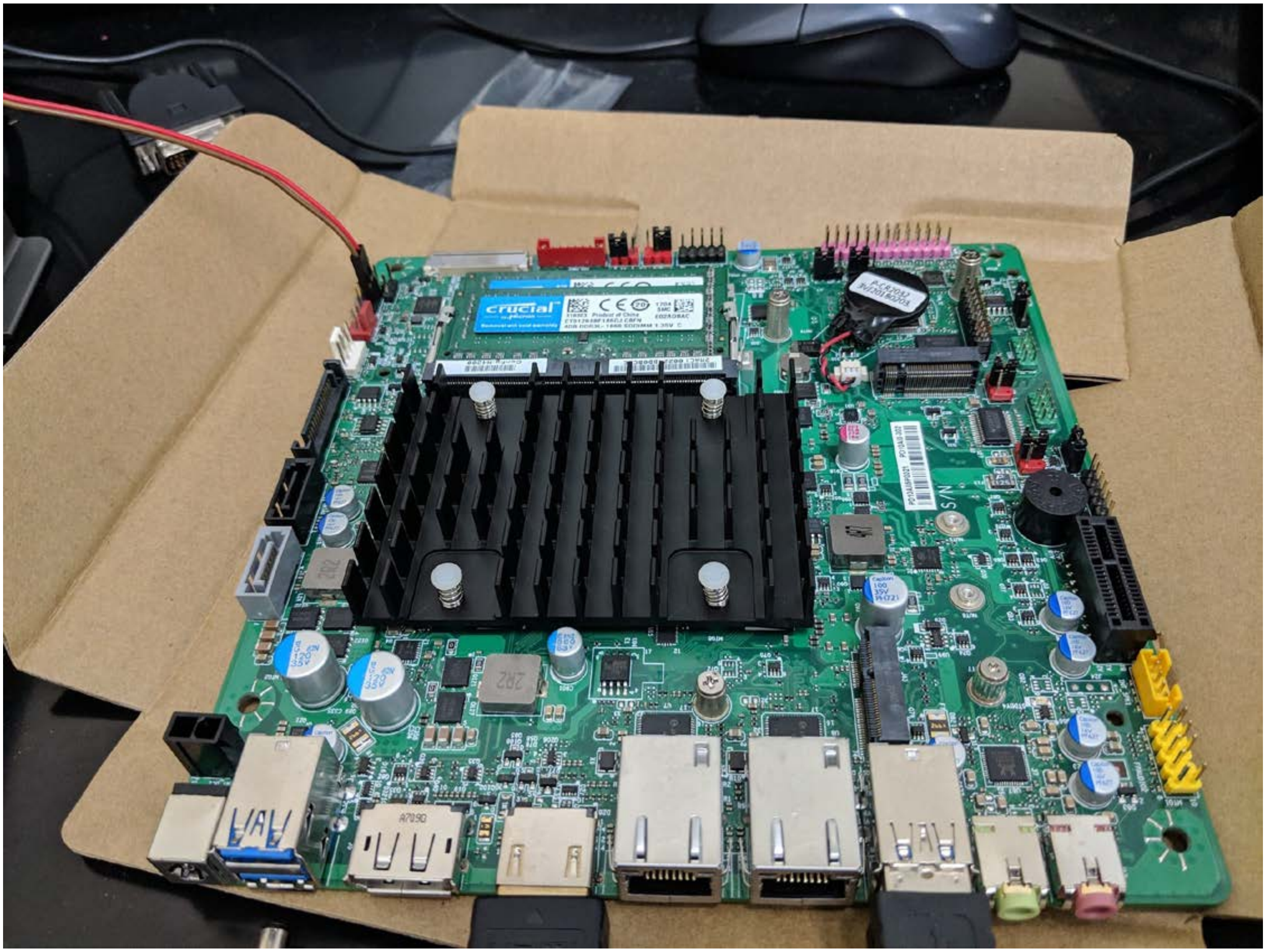

Figure 4. Our MiTAC PD10AI MT motherboard. Our configuration includes the faster 4-core Intel N4200 CPU. Credit: Jeremy A. Lusk