Comments on Ian's Writeup of what The REU Students Did This Summer

I have my comments in sections to mirror the sections of the document.

1 Introduction

1. Page 2. You have

   ... whether there is a killer application that an alternative substrate was uniquely suited to ...

   This is perhaps to much to ask. I think just finding an application, which need not be killer, would be interesting.

   So I would suggest

   ... whether there is an application that an alternative substrate can do better (for some notion of better) than a classical computer.

   If you do keep the terminology, I think *Killer app* is what one usually hears.

   QUESTION FOR BILL R AND WARREN- does the full document use the term *unconventional computing* instead of *alterntive computing*?

   IAN- My corrections have used *alternative computing*. If the full document is using *unconventinonal computing* then you should also (I think you already do).

2. Page 2. The last paragraph before Section 1.1, and the first paragraph of Section 1.1 are almost identical. I think you can delete the last paragraph before Section 1.1.

1.1 Executive Summary

1. The Exec Summary should be its own section.

2. General. In the abstract and the first paragraph of the exec summary you say how bad the simulators are. Most of the tech we want to use is not publicly available and hard to simulate. But throughout the paper you have tables of numbers. You should make sure you say how we got those numbers.

3. You should have a paragraph on each model.

4. The paragraph should be less technical than what you have here.

5. The order of the paragraphs should be the same as the order the models are discussed in the rest of the paper, which is

   Neuromorphic

   Reservoir

   Cellular Aut

   Ising

   Alternatively, you could change the order of the topics in the paper.

   In the exec summary you should give each topic its own subsection.

6. You should not say that the poly VDW stuff is the most exciting since (a) poly VDW numbers are not a hot topic, and (b) in the context of this report *exciting* would mean that some *alternative computing* did something better than classical. Instead you have alt comp inspiring classical, which is still good. But see next comment.

7. (I added this last when proofreading my suggestions.) The last suggestions and later suggestions assume that Ishan's work is classical. YOU have worked on the Ising Model, so you know more about this than I do.

   Question for Ian: Is Ishan's work actually classical?

   Question for Bill R and Warren: I noticed that Ian's document uses the term *uncovnetial computing* rather than *alternative computing*. Whichever term we use, we should make it uniform through the final big docuent.

   Question for Ian: If the final big document will use the term *unconventional computing* then is Ishan's work unconvential?

   If Ishan's work is either alt or unconvetial then some of my suggestions that assume otherwise are incorrect and should not be acted on. I will note those suggestions.

8. Phrasing of the poly VDW stuff is not quite right. Here is what you should say

   Prior work on quantum annealing inspired a new method to obtain, by computation, lower bounds on some polynomial van der warden numbers (a concept from Ramsey Theory which we will define later). Those

computations in turn inspired a new analytical methodology to obtain such lower bounds. We note that in this case alternative computing was not directly used to obtain the result; however, it inspired techniques that were.

(NOTE- I could be wrong about this.)

9. In your later section on Neuromorphic you mention vision, drones, bio signal classification, and ML. Mention those in the executive section. Be honest but brief about how well they did.

10. In your later section on Reservoir Computing you mention tracking the boundary between dynamical systems as an application. Mention that here. Be honest but brief about how well they did. Both here and later you should use the term *tipping point* as it is a common term.

11. The paragraph on cell aut is fine.

12. The paragraph *As discussed* can be deleted since this is an executive summary and you will go into details later.

2 Neuromorphic, Spike-based Computing

1. Page 3. The word *based* in the section heading should be *Based*.

2. Page 4. You use the term *steering-angle dataset*. What is that?

3. Page 4. The last paragraph seems to say that spiking NN are already flying real drones. I am sure there is a catch here- likely that these were short-range drones, or toy drones. You later say *These are promising results* ... which indicates that they POINT TOWARDS real applications but are not there yet.

4. Page 5. First two paragraphs seem to optimistic.

3 Reservoir Computing

1. Page 9. *The most famous of these is a water bucket*

I think the water bucket approach was more of a joke- I don't think it really worked at all. It is famous, but perhaps not for the right reasons. Omit the mention of it or at least don't highlight it.

2. Page 9. *Res computing currently has the easiest experimental pathway of any class of unconventional computing devices discussed in this report.* Is this an exception to what you said earlier about the models in this report being hard to simulate?

4 Alternative Substrates for Cellular Automata

1. Page 10. Minor point here:

   Within computer science, cellular automata has been applied to fundamental problems, including psuedorandom number generation, where a chaotic, nonlinear PRNG was created ...

   Should be

   Within computer science, cellular automata have been applied to fundamental problems, including psuedorandom number generation (PRNG), where a chaotic, nonlinear PRNG was created ...

2. Page 10. Emphasize that Cell Aut are NOT an alternative computing device. We hope to use alt computing to simulate it fast.

3. Page 11. In the first paragraph you have

   As shown, excluding conversion overhead, there is a roughly six to seven orders of magnitude between the two devices.

   There are two things wrong with this sentence

   a) six or seven orders of magnitude between the two devices. I don't know what direction you are going in.

   b) *excluding conversion overhead* seems like if the alt computing device is doing better excluding the conversion, its not really doing better.

5 Ising Model-Based Computing

1. Reminder of prior comment: This is stuff YOU (Ian) works on so I may be incorrect in my thoughts. I THOUGHT that Ishan ended up

using classical computing to get lower bounds no poly VDW numbers. However, you talk about it as if he used unconvential computing. So note that my comments will say that he used classical techniques but if you think he was using unconvential computing then my comments are incorrect.

2. Page 13. Here is a better and correct rewriting of the first paragraph of section 5.2.

   The team considered using the Ising model to find lower bounds on some polynomial van der Waerden numbers (which we will define later). This did not work; however, it inspired a classical approach that did work.

   We give some examples of the polynomial van der Warden Theorem before stating it formally.

   Imagine that you want to 3-color $\{1, 2, 3, 4, 5, 6, 7, 8\}$ such that if x, y are a square apart (i.e., $x - y \in \{1, 4\}$) then they are different colors. Figure 2 shows two attempts at such a coloring. The coloring labeled Valid achieves the goal. The coloring labeled Invalid does not achieves the goal. Is it possible to color $\{1, \ldots, 100\}$ such that if x, y are a square apart then x, y are different colors? No. What about other polynomials?

   The polynomial van der warden settles most of these cases:

   Theorem: Let $p(x)$ be a polynomial with integer coefficients such that $p(0) = 0$ (so the constant term is 0). Let $r \geq 2$. There exists $W(p, r)$ such that, for all c-colorings of $\{1, \ldots, W(p, r)\}$ there exists x, y such that

   a) x, y are the same color

   b) there exists d such that $x - y = p(d)$.

   Notation: We will take $W(p, r)$ to be the least such number.

   Note: In our example we had $p(x) = x^2$ and $r = 3$. The theorem says that there is some number $W(x^2, 3)$ such that for every 3-coloring of $\{1, \ldots, W(x^2, 3)\}$ there are two numbers, a square apart, that are the same color.

   The problem of finding $W(x^2, 3)$ is easy to represent in energy-minimization terms.

THE REST IS FINE.

3. Page 14. What is a QUBO? Quadratic Something?

4. Page 14. Table 6 comes to soon in the paper since when I come across it I do not know what Potts, Kissat are yet.

5. Page 14. You say that a Potts Annealer is a type of simulated annealing method. You should point out that its classical. NOTE- This is one of those suggestions where I might be wrong.

6. Page 14. The table should have a * on the new results.

7. Page 14. You give WALKSAT a mention- are there any numbers for that?

8. Page 14. ... *however the team is hopeful that unique-to-quantum features (quantum tunneling) will still allow a quantum Annealer to find additional new solutions.*

   This is not true. Ishan does not think quantum annealers will ever work and neither do I.

   Better:

   ... *however, the team wonders if that unique-to-quantum features, such as quantum tunneling, might allow a quantum Annealer to find additional new solutions.*

9. Page 14. WALKSAT is faster but only gives one solution, whereas Potts annealing gave several.

10. Page 14. WALKSAT also does not give a guarantee of non-solution.

11. Page 15. *As proposed by Mohseni, this is a known benefit of quantum annealing and annealing more broadly.*

    I do not know what *this* is.

12. Page 15. We submitted an application to D-Wave but they have not gotten back to us and we are not at all confident that they will.

13. Page 15

    Therefore, the team is confident that this form of unconventional computing will continue to be valuable and improve over time.

    We are not confident. Here is how we see it

    Quantum Annealing inspired a classical approach that worked well. Great!

    (NOTE- this last line is one of those that perhaps I am wrong about.)

    That does not mean that a quantum Annealer will be any good.

    And (I think this is on Ishan's slides) the Boolean formulas that D-Wave has managed to find satisfying assignments for with their quantum Annealer have a pathetically small number of variables.

6 Conclusions

1. Page 15. You mention the Analog-to-Digital and Digital-to-Analog problem in the conclusion, which is good, but you should also mention it when it comes up in the sections it comes up. And it does not always come up- I think the Neuromorphic computation was analog-to-analog.

2. Page 16. Your description of the Ising model that Ishan used as unconventional seems odd. I thought that in the end Ishan's work was classical. (NOTE- This is a suggestion that might be incorrect.)