E=mc^2 Journal Submission:

Space Based Solar Power: Examining Optimal Configurations for Interplanetary, Near-Sol SBSP Satellites to Maximize Returns on Investments through Power Generation

(Because long titles look impressive)

John C. Wilkins

Part the First: ***The Original:*** the personal bit

So, space is cool, right guys? I mean, who can't help but marvel at the sight of thirty-story tall hunk of metal literally exploding its way to the cosmos or ponder with awe the profound and humbling implications of, as Carl Sagan put it, a pale blue dot – Earth as seen from the edges of our tiny solar system? Combine the *natural splendor* of space with the wild imagination of an eleven-year-old and you get the beginnings of a long, ongoing, journey of joyful discovery; indeed, since my first foray into science fair and space "research" (my first few projects were less like actual research projects and more like thought experiments or even fantasies: mostly inapplicable to the real world, but entertaining and encouraging nonetheless) seven years ago, I've been hooked. I'll admit that when I started out, I knew basically nothing and needed excessive amounts of help from my father, and later my mentor, but getting better along the way – the journey of discovery, well, that's the joy of research; the cherry on top is getting to share my findings with the world.

Then finally, after several years of messing around in the theoretical space inside my head, I came across a specific topic where further research could be of legitimate use: space based solar power (SBSP). SBSP is exactly what it sounds like: solar power – but in spaaace! Large solar panels are launched into orbit, specifically geosynchronous Earth orbit, and beam collected energy, via microwaves, back down to Earth for use. It's clean and efficient; considering the existential threat of climate change, it's exactly the kind of energy source we need. I was just in my room, on my computer, moseying around the internet, when I came across the wiki page for SBSP; the first thought that went through my head was, "well, no duh! This is brilliant! Why hasn't this been implemented yet?!" The second thought was, "why is my internet so slow?!" And the third thought was, "whelp, I need a book now."

So, I got a book: *The Case for Space Solar Power*, by John C. Mankins; reading it in my most comfy chair, I immediately got giddy from thinking of ways that I could possibly improve the idea, to take an already fantastic concept and try to make it even more efficient. After I finished chapter one, I could tell I was in for a good year of science fair. So, I got to work; pulling out a pen and some paper, I sketched out convoluted flow charts and incomprehensible diagrams, all accompanied by my illegible handwriting. Nonetheless, a couple weeks later, I opened up eclipse on my computer and began programming my thoughts into a slightly more concrete program.

Now, not entirely sure my idea would work in the first place and not exactly in the best economic situation, I couldn't realistically go to a physical lab or anything of the sort to conduct my research, so I made do with I had at home: pen, paper, computer, and, most importantly, snacks (to be frank, I much more prefer research at home to in-the-lab; it's an environment where I can work in the comfort of my pajamas and have the peace and quiet to really work with the material, to knead and reshape and wrestle with it). Nonetheless, work proceeded as well as it could: as I was starting my junior year and hadn't quite gotten to the necessary calculus, I had to implement a clunky, algebra-based work around, but it worked well all the same. What's really needed in terms of programing, and indeed most experimental design, is a strong grip on logic and the ability to creatively work around obstacles.

Finally, after months and months of tearing my eyes out over maddeningly irritating bugs and errors and exceptions and crashes and of nonstop mental combat with the many-headed hydra that is applied mathematics, my program was finished. And when it began to return data, all of that hard work and anguish was paid off; I imagined that, as my console filled with glorious, glorious data, this is how Frankenstein must've felt, "it's alive!" Well, not exactly, but you get my point. Although the journey itself is worthwhile, the end result is undeniably satisfying.

And so ends the fascinating tale of John versus Java and semi-colons, but before I move onto the nuts and bolts of my research, I suppose I should leave a bit of advice for those of you interested in pursuing research in math and science. My advice is simple: “Don’t let your dreams be dreams! *Just do it!*” I’m one of two people in my school who has done science fair every year and, this past year, one of only four seniors who participated at all. Far too many people were afraid of the workload or of the possibility of failure or of simply being out-competed. But if you think you have an idea, no matter how absurd, just go for it! All you have to do is put your best foot forward and make the most of it. Indeed, to quote the mantra of my favorite Bollywood film, “pursue excellence, and success will follow, pants down.”

Part *Two* **(2):** *Electric* **Boogaloo:** the research half

Now, to get into the actual science of what I did, I’ll reclarify precisely what it was that I was trying to achieve, as all research needs a purpose. SBSP is efficient no doubt, but I wanted to make it even more so; to achieve this I moved the SBSP satellites from Earth orbit down to a near-Sol orbit. This change, facilitated by beaming concentrated light across the solar system, would theoretically result in exponentially higher energy production, via the inverse square law, as well as increased costs of delivery of satellites to their final orbits. To find the ideal sweet spot between the size, number, and positioning of collector and transfer satellites, I created a program in Java through eclipse to handle all of the physics and relevant calculations, as well as a rudimentary cost analysis. By varying the orbital characteristics of the collector satellites, the dimensions of the collector satellites, and the ratio of collector to transfer satellites, 1008 different test configurations were conceived and tested.

In terms of key components to my research, my program handles practically everything, from experimental design, to modelling, and even to data collection, save data analysis. The program tackled the problem in a two-fold manner, at a micro and macro scale: the micro scale code handled all of the interactions on a satellite by satellite basis, from energy collection to heating; the macro scale code handled all of the orbital mechanics as well as energy transmission and efficiency, including the tedious line of sight calculations.

Now in terms of the results, there is simply far too much data to comb through and analyze without simply copying over my entire research paper, so I'll get to the gist and relate the most important data, especially in regards to practical application: the most efficient and productive configuration of the 1008 tested configurations (keep in mind that there are an infinite number of configurations; many of the test configurations can be scaled up for even greater efficiency and productivity) was the one with the shortest semi-major axis, essentially the distance to the Sun; the largest satellite size, in terms of collecting surface area; and the largest collector to transfer satellite ratio, pointing towards a focus on collection over transmission.

Although the data from 1008 configurations feels like a lot to take in and synthesize, it forms the basis of a regression, a regression that, with further research, could eventually lead to an equation for efficiency; with an efficiency equation, the research takes on some value with its practical application in combating climate change with clean energy. To put into perspective the scale of what was estimated, the most efficient tested configuration yielded 5.71E19 joules of energy per year, or roughly four times the energy production of the entire United States; all of this energy would be perfectly clean. Now the research is still very early on; the real values might be nowhere near that, but ultimately the goal of this project was to draw attention to SBSP, to say that this is a field that definitely warrants further investigation.