

**Present Technology:** The present form of the Constellation technology are everyday solar panels and the process of a satellite taken to space. Solar panels consist of tempered glass, aluminum frames, encapsulants, and photovoltaic cells(Richardson, 2019). The photovoltaic cells are the most essential aspect of a solar panel, as it transfers photons into electrical energy, through the usage of semi-conducting material(Richardson, 2019). To add on the photovoltaic cells collectively function, to generate electricity by creating electrical currents, due to a phenomenon known as the photovoltaic effect(Science-Direct, 2021). The photovoltaic effect causes photovoltaic cells to work because it finds specific materials that can absorb photons and release electrons. As a result of electrons being excited after speeding photons are absorbed, it causes a build-up of electrical current, which generates electricity (Science-Direct, 2021).

Another essential aspect of our technology is on satellites and their procedure to space. Every satellite is launched into space using rockets, where they are put in a cargo bay and are placed in a vertical position before launching (NASA, 2020). As for the rocket, they have fuel and propellant stored in a cylinder, which is responsible for blasting them off to space. The rockets also have a nozzle that directs the rocket in a singular direction(NASA, 2020). According to the NESDIS, satellites maintain and balance their orbit because of the satellite's velocity and the Earth's Gravitational pull (NESDIS, 2017). The velocity of the satellites must be fast enough to go against the force of gravity on Earth, to overall maintain its orbit (NESDIS, 2017). Another concept that is essential for our invention, the Constellation is energy transfers. Energy can easily be changed from electrical energy to microwaves through a microwave transmitter. A transmitter radiates microwave beams and transmits energy through electrical energy. The approach to turning microwaves into electrical energy is through microwave radio transmitters, in which there is a ground rectifying antenna that would convert microwaves into direct current

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electricity(Reynaud et al., 2020). The rectifying antenna is made up of a dipole antenna consistent with RF diodes. To generate DC electricity, the diode fixes the AC caused by the microwaves in the antenna, which powers a load attached throughout the diode (Reynaud et al., 2020). An essential aspect of building this technology is understanding the concept of energy transfer. The law of thermodynamics is essential for establishing this invention.

The main focus of our space-based solar cells is on the first law and second law of thermodynamics. The first law states that energy can't be created or destroyed, but can be transferred or changed (Mott, 2021). Our focus is on turning photons into electrical energy, to microwaves, and back to electrical energy. In doing so, we will lose energy in the given system according to the second law of thermodynamics. The second law of thermodynamics states that the entropy of a system that is isolated will always increase (Mott, 2021). In our invention, converting energy causes an increase in entropy, which means there is a loss in usable energy. As a result, the second law of thermodynamics is our limitation, as there is a decrease in electrical energy, because of an increase in entropy, due to a loss of energy in our given system. As we change from solar energy to microwaves into electrical energy, we have lost more energy than we can account for. In conclusion, we will need to improve on a source of energy production, to account for the lost energy in the system caused by the second law of thermodynamics.

**History:** The history of our invention begins with the photovoltaic cell and its effect. The photovoltaic effect was found by French physicist Edmond Becquerel in 1839 (Vivint-Solar, 2021). He found this through experimentation, as a cell made of metal electrodes could produce electricity after it was revealed in light (Vivint-Solar, 2021). By 1873, Willoughby Smith found that Selenium could be used as a photoconductor (Vivint-Solar, 2021). Finally, by 1883, the inventor Charles Fritz created the initial functional selenium solar cell, which has developed the

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foundations of solar technology today (Vivint-Solar, 2021). Another essential aspect of our invention is satellites and rockets. Satellites were essential in the 1950s as a space race against the Soviet Union (Science-Learn, 2021). They were launched using rockets in 1957, allowing further advances in science and weather through infrared imaging (Science-Learn, 2021).

The satellites and rockets built created the foundation for space technology and developed pathways for further technological development. An additional historical invention that will help develop our technology is microwave transmitters. This invention was used and created in World War II, in the form of radar for communication (Cable-Free, 2018). The microwave radio waves were created in 1931, through telecommunication links for microwave communications (Cable-Free, 2018). Microwave transmitters improved further by the 1950s, as it was used for microwave relay networks in telephones, and by 1960, they were implemented in satellite communications. The last concept that is essential for our technology is the law of thermodynamics. This ideology in chemistry was developed by Rudolf Clausius and William Thomson, after proving Sadi Carnot's book "Reflections on the Motive Power of Fire" on thermodynamics to be true (Wolfram-Science, 2021).

**Future Technology:** Our vision for our future technology is to create an army of versatile nanoscale photovoltaic cells that bind together to form a larger solar array. The cells will collect energy from the sun and transfer it to the "core" of the solar array which consists of a module that's capable of beaming vast amounts of energy back to earth in the form of "microwaves". The nanoscale photovoltaic cells within the larger solar array can attain a higher degree of energy by maximizing efficiency. A photovoltaic cell is responsible for absorbing sunlight and turning light energy into electrical currents which can then produce electricity. The electrical currents are created by "excited" electrons by using photons from the light source of the sun. These cells are

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found in existing solar panels, yet they are only capable of absorbing up to 40% of the sun's energy. We would like to maximize the potential of photovoltaic cells to absorb up to 90% of the sun's energy.

To accomplish this, we could capture more photons by making smaller, more efficient photovoltaic cells that use less energy while making better use of the sunlight captured. One method would be to replace the semiconductors within the photovoltaic cells with a conductor like copper, to capture more energy. The issue with this is that semiconductors have one electron flow, so electricity flows one way. Using a conductor means we have to create a new method of capturing energy from multiple electron flows.

The photovoltaic cells will be created at the nanoscale to allow for faster electron travel through the two-electron layers of the photovoltaic cell. This occurs because of a P-N junction, which is a boundary between two semiconductor materials, which allows electrical current to pass in one single direction. This means it's more efficient since more energy is being produced due to the electrons being able to go faster from one side of the photovoltaic cell to the other. In contrast to existing photovoltaic cells which are larger, the electrons take longer to travel from one side to the other, meaning there is less electrical energy because the energy is produced at a much slower rate. Since this device will be in space, it will take the form of a satellite. The device will convert solar energy into electrical energy. The energy will be beamed as a microwave to a receiving station on earth that will turn the wave into electrical energy. The microwave will be transferred to a semiconductor in the station to allow one-directional movement of electron flow. The receiving station will be connected to power lines, which will lead to cities. The structure and technology of the solar satellite will be built using stainless steel, with stainless alloys, which is immune to corrosion, has elevated ductile strength, very durable,

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resistant to temperature, has a simple structure and manufacturing process, with low maintenance facility (long-lasting), and is environmentally friendly (renewable).

We plan to place this army of solar panel satellites in low Earth orbit. This allows us to have a constant supply of sunlight and eliminate the loss of energy from the sun due to Earth's atmosphere. The technology will be programmable, and if the initial stages of this energy source is a success, we can update and improve its applications, by adding it to rocketships, so energy can be transmitted through long distances. This means that we can further expand our journey through space, while also improving a renewable energy source by making it more efficient.

**Breakthrough:** There are multiple breakthroughs required to successfully create this technology. One essential breakthrough is a rocket required to push the technology into space. To launch thousands of small photovoltaic cell satellites into space, we will need a rocket that's capable of launching vast amounts of payload to low earth orbit while being cheap and efficient. The reason this has not occurred yet is that the technology has not been created. Current rocket technology is highly inefficient because it requires large amounts of fuel to lift a small payload while barely being reusable. This means that launching any significant amount of payload into space would be very expensive. However, with private rocket companies such as SpaceX and Blue Origin, whose goals are to develop highly efficient rockets that are rapidly reusable and efficient, we should be able to lift vast amounts of payload for cheap into space in 10-20 years. We've already seen rapid progress with SpaceX who has developed the Falcon 9 rocket which is reusable and cheaper than most rockets. They're currently working on the "Starship" which aims to be 100% reusable while being very cheap and efficient to operate.

Another prominent and realistic breakthrough would be making more effective photovoltaic cells at a smaller scale. The smaller a photovoltaic cell is, the shorter the distance is

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for electrons to travel, which means lower resistance. This allows the photovoltaic cells to be more efficient since less energy will go to waste as a result. This means that we could harness energy faster, allowing us to harness more than the 40% of energy converted from sunlight compared to what we have in our modern-day solar panels. We need a breakthrough in the amount of energy harnessed by solar cells, and we will have to change particular mechanisms to allow the photovoltaic cells to capture more photons.

Furthermore, we need a fundamental breakthrough in achieving long-distance energy transport. To harness solar energy and send it in the form of microwaves/laser beams back to Earth efficiently is very difficult. We need a breakthrough in both sending and receiving energy in long distances, in which one mechanism releases the energy, and the other mechanism captures the energy. The most plausible method so far would be creating a high-frequency microwave or concentrated laser beam using harnessed electrons to emit photons using special glasses. The energy would be beamed down to a receiving station. A necessary breakthrough in this circumstance would be creating a receiving station that can convert the laser or microwave into electrical energy, which would run a city. Currently, internet providers can convert microwaves to transfer data, but no one has been able to beam microwaves down from space to provide energy at such a large scale before. For our vision to work out, there will need to be receiving stations all over the world connected to power grids that provide constant power to all areas around the world.

Another necessary breakthrough for this technology would be making photovoltaic cells last longer, so it can withstand space. There need to be tests done to understand the efficiency of the mechanism of using lasers to create energy, and testing photovoltaic cells to be more efficient and programmable. The last breakthrough required is harnessing energy through conductors and

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controlling their electron flow. This is necessary because using conductors allows us to harness more energy, however, controlling electron flow becomes a large issue. The reason this invention was not created is that it requires controlling electron flow in a conductor, turning lasers into energy through a receiving station, creating better and smaller photovoltaic cells that capture more energy, and creating nanobots to program the photovoltaic cells for futuristic applications. We hope to revolutionize energy by first improving photovoltaic cells, in which we need to test increases in energy absorption from the sun.

The last breakthrough required is harnessing energy through conductors and controlling their electron flow. This is necessary because using conductors allows us to harness more energy, however, controlling electron flow becomes a large issue. The reason this invention was not created is that it requires controlling electron flow in a conductor, turning microwaves into energy through a receiving station, and creating better and smaller photovoltaic cells that capture more energy. We hope to revolutionize energy by first improving photovoltaic cells, in which we need to test increases in energy absorption from the sun.

**(Research Project to test the photovoltaic cells):** For our research plan, we would test photovoltaic cells, making them more effective in the nanoscale, while also replacing its semiconductivity with conductive materials to intake more solar energy and photons, while also creating a different mechanism that can withstand high electrical energy from large quantities of excited electrons. We will be calculating SI(solar irradiance) increases for watts per square meter, to determine the effectiveness of photovoltaic cells.

**Question:** How do different materials affect the energy acquired by the photovoltaic cells?

**Hypothesis:** We can increase the amount of solar energy acquired and increase the amount of electricity by decreasing the size of photovoltaic cells, and creating a new

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A mechanism that can withstand high electrical energy, using different conductors and semiconductors.

**IV:** Creating small-sized photovoltaic cells with different conductors and semiconductors.

**DV:** The amount of energy produced in watts per photovoltaic solar panels with different conductors and semiconductors.

**Design Process:** There were multiple alternative design concepts and features that were rejected from our ideal invention. One prominent alternative that was rejected was converting electrical energy into laser beams and using laser beams as a transfer of energy, which would be converted back to electrical energy. At first, this seemed like a sufficient solution because the laser could be easily converted into electrical energy through a photovoltaic receiver, after being beamed down to Earth. Also, laser beams seemed plausible because it was easily capable of converting into different forms of energy because of our current technology, as opposed to microwaves which were more difficult to convert to electrical energy. Overall, the laser beams seemed like a better alternative to beaming down energy in comparison to microwaves, except when we take into account safety and atmospheric refraction. First, using lasers as a form of energy transport and beam could potentially harm a person near the receiving station. Also, a small technical error in the overall satellite could cause potential harm to civilians, because of small inaccuracies. In comparison to microwaves, which are used every day to transmit data with minimal health concerns, using lasers as an alternative would cause more harm than good. Another issue with lasers is atmospheric refraction. Atmospheric refraction is the departure of energy or light away from its course because of air density, which refracts beams in the air due to height. This indicates that there would be a significant loss in power conversions, and a lack of efficiency

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because lasers are not being directed to a receiving station, because of atmospheric refraction. To add on. This would only further cause safety concerns, as now lasers are being directed all over the place because of these refractions. Our usage of microwaves instead is safer, and as it uses waves, which is a more practical way of beaming energy. Another alternative design that was rejected was using nanotechnology incorporated in photovoltaic cells for management and construction. Adding Nanotechnology using nanobots would mean creating a new invention that doesn't currently exist. Our main reason for initially adding nanotechnology was to help maintain the Constellation in space, without damage to its exterior or interior from space debris. Also, we wanted to make the nanobots programmable and movable, while also capable of attaching to photovoltaic cells to achieve specific movements and angles in space, to further increase energy efficiency and production. Additionally, adding nanobots would also allow construction to the invention at a molecular level, so future damages could be prevented. The main reason this idea and feature was rejected was mainly that it was not feasible.

To create nanobots, attach them to photovoltaic cells for movement, and programming them for construction would obstruct us from our main objective of finding a new form of renewable energy that can be transferred and converted in space. Creating nanobots itself is a new invention that would only hinder the current objectives this invention proposes only to achieve maintenance. As of currently, we plan to maintain our technology through traditional and standard ways, which is by clearing away as much debris and space junk as possible, to maintain our invention. The last design process that we rejected was sending microwaves back into space to maintain the energy in the Constellation. There are multiple issues with this feature. First off, it's counterintuitive, as microwaves being sent as beams to be used as electrical energy, would also be sent back to maintain the invention. This means this idea is impractical, because

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microwave beams are no longer being used as an energy source, but just for maintenance of a device with no essential usage. Also, there seemed to be no point in sending back microwaves to maintain the device. So, instead, we focused on using the sunlight as a source of energy to maintain the device, while beaming down microwaves to create a sufficient energy source. What we realized was that our design was based on creating a satellite that used sunlight to function, and used the sunlight to turn photons into electrical energy, into microwaves, and back to electrical energy on the receiving station. This effective idea helped us take out nanotechnology, lasers, and microwaves as an energy source for the invention's functionality as features because they overcomplicate the design and the process in which renewable energy is transferred.

### **Consequences:**

Possible positive consequences of using space-based solar-based solar power are renewable energy with minimal environmental effects while being able to provide power reliably. This is due to the use of solar panel satellites in space which are exposed to the sun 24/7. Solar panels in space allow us to convert solar energy into electricity which can be beamed down to earth as microwaves. The microwaves can be collected back down at earth and transferred into electricity. As a result, we're getting clean energy harvested from the sun while having a reliable source of energy. Furthermore, satellites with solar panels in space don't require high maintenance unlike solar arrays down at the earth, allowing low costs and management (Mrusek, 2019).

Our vision for the future comes with many benefits such as effective renewable energy with minimal flaws, however, along with those benefits, they also present many consequences. Such of these include radiation caused by beaming the energy down from space. If we miss the timing of the beam of energy back down to earth, the electromagnetic radiation or microwaves

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could harm organisms that are highly sensitive to microwaves. Although this radiation isn't a big concern towards humans since the frequency of the microwave (5.8 GHz) is well within the safety limit of 30-300 GHz, it is a big concern towards small life forms such as insects which could be harmed by the radiation caused by the microwaves (FDA, 2017). Furthermore, these microwaves could interfere with communication onboard planes which are highly sensitive to radio waves and microwaves.

Another consequence of launching thousands of solar panel satellites into space is space debris. As satellites get older and go past their designated lifespan, they will break down and become space debris. This poses a huge threat to future space flight because these satellites travel at thousands of miles per hour. Space junk caused by old satellites that are out of use could slam into spacecraft and space stations at hundreds & thousands of miles per hour. This can cause catastrophic amounts of damage and endanger lives on board those spacecraft (Mrusek, 2019). Furthermore, a buildup of space junk can result in us being cut off from space due to it being too dangerous to get to space.

Lastly, our future technology allows us to produce large and reliable amounts of energy while not releasing any pollutants. Using solar panels in space allows us to harvest the sun's energy and turn that into energy. Compared to other future forms of energy such as nuclear fusion which produces nuclear waste as a byproduct, our future tech will produce little to no pollutants once fully functional (EIA, 2020). As a result, our future technology will help solve global warming by producing clean energy that releases no pollutants or toxic byproducts that have adverse effects on the environment. This will shape society into a world where clean energy is accessible to everyone and little to no pollution caused by energy production.

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