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The Second Space Race

September 11, 2001 was a day that changed America in many ways; some being psychological while others being physical. Among the ideals that changed in America following the attacks on this horrible day, was the dramatic change in the field of physics and engineering. 9/11 motivated scientists and engineers to design superior technology just as in the 60's during the Space Race.

Before 9/11 the thought of a major terrorist attack wasn't even entertained. No sane individual could fathom the idea of two planes intentionally crashing into the Twin Towers. This was shown in the lack of security measures taken in places such as airports, planes, surveillance, and building design in pre-9/11 culture. Before 9/11 only a handful of bags were checked before being loaded onto planes due to the lack of technology. It would take too much time to manually check each and every bag. Due to the attacks on 9/11, X-Ray and metal detection technology was improved and refined to be placed inside of airports. Now everyone is mandated to be searched before boarding a plane in a timely fashion (Peterson, 2016). Most metal detectors are based on an idea called Pulse Induction. As we know, metal detectors have two sides on them. Pulse Induction works by sending short bursts or pulses of electric current through coils of wire on each side of the metal detector. Since these wires are able to conduct electricity extremely well, they create short lasting magnetic fields in between them. When the pulse ends of course, the magnetic field that it creates does too. This results in a short lasting electrical spike that runs back through the coils and restarts the cycle. Depending on the make and model of the machine, it can send anywhere from 25 electric pulses per second to over a thousand. As the amount of electric pulses per second a machine can send out increases, so does its accuracy. As accuracy increases, the room for error decreases making it easier for the metal detector to detect smaller objects and more potential threats. When a metal object passes through this magnetic field it will create an opposite but equal magnetic field inside of the object which delays sending the electricity back through the coils. The machine detects this by using what is called a sampling circuit. This is what tells the metal detector whether to go off or not. It can tell if a metal object caused the delay in the cycle or another magnetic field depending on how long the cycle was delayed. The sampling circuit sends this data to an integrator which converts these signals from the sampling circuit into DC current. This produces the noise you hear when a metal detector goes off. Some metal detectors have multiple coils located at different heights in the machine (Grabianowski). Werner in *All the Light We Cannot See* would be very familiar with the terms AC and DC. He loved to repair radios by tracing the path electrons would take with his finger (Doerr, 2014). The main difference between AC and DC current is the way the electrons move. In AC (alternating current) the electrons move in oscillatory motion while in DC (direct current) the electrons flow in a straight flatline motion. Just as the integrator converts AC current to DC, the charging block that we use to charge most smartphones does the same thing. Our houses are run using AC current due to the fact that it is able to efficiently distribute power using relatively low voltages. Moreover, what we think of as a cell phone “charger” isn’t even a charger itself. It simply converts AC current to DC current because smartphones have a built in charging circuit that only requires a DC power supply (Earley, 2013).

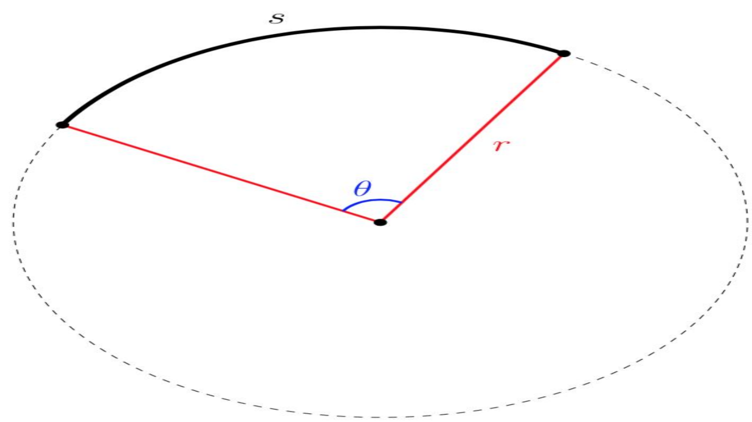
Along with metal detectors, CT scanners became popularized after 9/11. These are the machines that you let your baggage run through on a conveyor belt. CT or a computer-tomography scanner use X-ray technology to inspect the contents in your bags without actually having to open up your bags. An X-ray apparatus rotates around the bag, sending copious amounts of X-rays directed at the bag thus creating an image of the objects inside. Depending on how the object interacts with the X-rays, the scanner can determine the density of the object. If the object's mass to density ratio is similar to that of a hazardous material, then the scanner warns airport security. Due to the fact that these machines take longer to inspect baggage, they aren't always used to check every single bag. Biometrics are also used to confirm the identities of passengers. Instead of just using photo ID or passport information, biometrics uses fingerprint data as well as retinal scans to confirm the identity of the passenger (Grabianowski).

The X-ray system works in a similar way to the CT scanner as in it also uses X-rays and a belt system to move the bags or a *valise* as it was referred to in *American Widow* (Torres, 2008). X-rays are a special high energy type of electromagnetic radiation. Visible light is also a form of electromagnetic radiation. When we go to the doctor to get an X-ray on an injury, the reason we can see our bones and not our flesh is because of the difference in densities. Soft tissue such as skin and some organs aren't dense enough to absorb the high energy X-rays. Dense objects in our bodies like bones can easily absorb the rays which is why they show up on the film. The reason why we have to wear a lead apron when getting an xray is to protect our vital organs. The lead apron acts as a shield, not allowing hardly any X-rays to get through and damage our essential organs. This concept can be applied the same way for X-ray machines in the airport except for a few minor modifications. After 9/11, airport X-ray machines began using what is called a dual-energy X-ray system. This allows the machine to send more powerful X-rays that can penetrate more objects. This type of X-ray machine sends out two X-rays; one of high energy and one of low energy, each one able to target different materials. Once the rays get through the contents of the luggage, they hit another detector. This detector filters out the stronger energy rays from the weaker ones and allows the stronger rays to pass and hit a second detector. Using two detectors instead of only one allows for the machine to better pick up on objects especially those made from organic material. Different materials absorb X-rays at different rates. This is what causes certain objects to appear certain colors on the computer monitor. Many airport X-ray machines use the color orange to represent organic materials. A lot of explosive devices are created using organic materials. Terrorists build a bomb called an IED or improvised explosive device to sneak onto planes. There are many ways in which this can be done. For example, terrorists have been known to hide pipe bombs in other people's luggage or give someone a stuffed animal with an explosive inside of it right before they board the plane. Some even go as far as creating electronic bombs inside of laptops which can be remotely detonated. This is why TSA agents require you to turn on your laptop. If a laptop is unable to turn on, some circuit elements may have been removed in order to place an explosive device inside. Although some skilled bomb makers may still be able hide an explosive inside of a laptop while still allowing the laptop to be fully functioning. If there is a suspicion that a person may have an explosive hidden inside of a computer. TSA uses what is called a chemical sniffer. This is a concept in chemistry that I am not too familiar with. It uses a cloth laced with certain chemicals that when wiped over the surface of the laptop can tell if any residue used to make bombs is present. Before your luggage is loaded onto the plane, they are X-rayed again. Some airports have X-ray machines that take up the size of an entire building. The truck that loads the baggage onto the plane pulls into this building and all the baggage is scanned at once. Other airports have mobile X-ray systems. A truck that has a built in X-ray system drives alongside the truck that carries luggage right before the bags are loaded onto the plane (Grabianowski).

Language is a form of expression and power that we value so greatly in English 210-50. In *All the Light We Cannot See,* Marie-Laure and Werner both have lost senses that contribute to their perception of language (Doerr, 2014). 9/11 has also led to the limitation of our language. The mention of any words that can be considered threatening can result in removal from the flight and maybe even your arrest (Grabianowski). Some of these words include “hijack,” “box cutter,” or “explosive.”

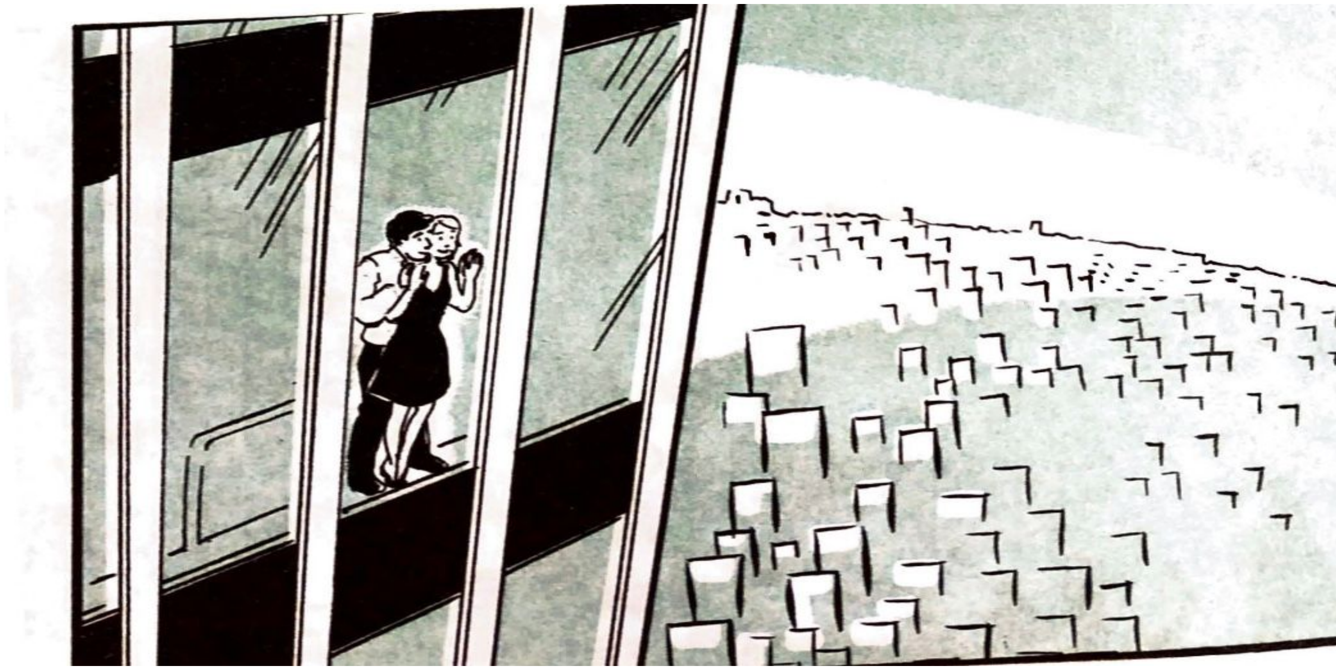
Another item that airlines restrict people from taking on planes is bottled water. Other liquids are restricted too, such as shampoo. The physics behind why bottled liquids are not allowed on planes is because the high altitude decreases the air pressure around the bottle of fluid while the pressure inside of the bottle remains almost constant. This imbalance of pressures causes the fluid to burst out or sometimes even explode. Think of it this way, the bottle wants to stabilize and equal the pressure outside of the bottle. It wants to be equilibrium, which is the natural state of many things. TSA also won’t allow any amount of liquid over 3.4 ounces on board. This is to prevent the amount of liquid brought on the plane from reaching a volume that can cause substantial damage if blown up.

Terrorist surveillance technology also improved and increased after 9/11. More specifically in telescopes, the resolvability drastically got better. The resolvability of a telescope is a property of a telescope that allows it to distinguish two separate objects from one another at extremely long distances. In physics we call this concept Rayleigh's Criterion. There are two equations that can be used to calculate the resolvability of a certain telescope given its aperture and wavelength of light used. $S=r\,\theta$ and $\theta_{min}= 1.22\,(\lambda/D)$ where S is arc length (or the distance between the two objects in which you are trying to resolve), λ is the wavelength of light used, r is the distance in between the object and the telescope, and D is the aperture of the telescope. A telescope's aperture is the diameter of the optical element (which is most cases is the reflecting mirror) and it's resolvability is highly influenced by this. As the aperture increases, the resolvability (which is measured in radians) gets smaller. The resolvability is an angle so the smaller the value is the better. The resolvability is also affected by the wavelength of light through which the object is being looked at. Radio telescopes such as Arecibo in Puerto Rico use radio waves to resolve objects instead that of visible light. Visible light has an average wavelength of 500 nanometers while radio waves have wavelengths longer than infrared light which in turn is larger than visible light. The aperture and wavelength is measured in meters. The wavelength is so small we typically use nanometers but we have to convert that value to meters to calculate the resolvability. For example, the Hubble Space Telescope which was launched in 1990 can resolve a dime from roughly 39,000 meters away. This means that Hubble can tell that there are two dimes side by side from as far away as 24 miles. Any distance past that the dimes become blurry and appear to be one object. Considering that Hubble was built and launched in 1990, it is safe to say that telescope technology has greatly improved since then. I can say beyond a reasonable doubt that satellites put up by the U.S. Government can easily resolve individual people on the ground. For this reason, physicists design telescopes to run surveillance on terrorist safe houses and missile silos. We use these telescopes to determine if a terrorist group is making missiles and how many they are making. As I said before, the resolvability is greatly influenced by the wavelength of light used. Therefore the weather conditions can have an impact on the resolvability. On a cloudy day, a telescope may have difficulty seeing individual people but on a sunny day it isn't even a challenge. This is an image showing how physicists use Rayleigh's Criterion and arc length to calculate resolvability. As I stated earlier, arc length is $S=r\theta$ and $\theta = 1.22(\lambda/D)$. This can be used by engineers to determine how large

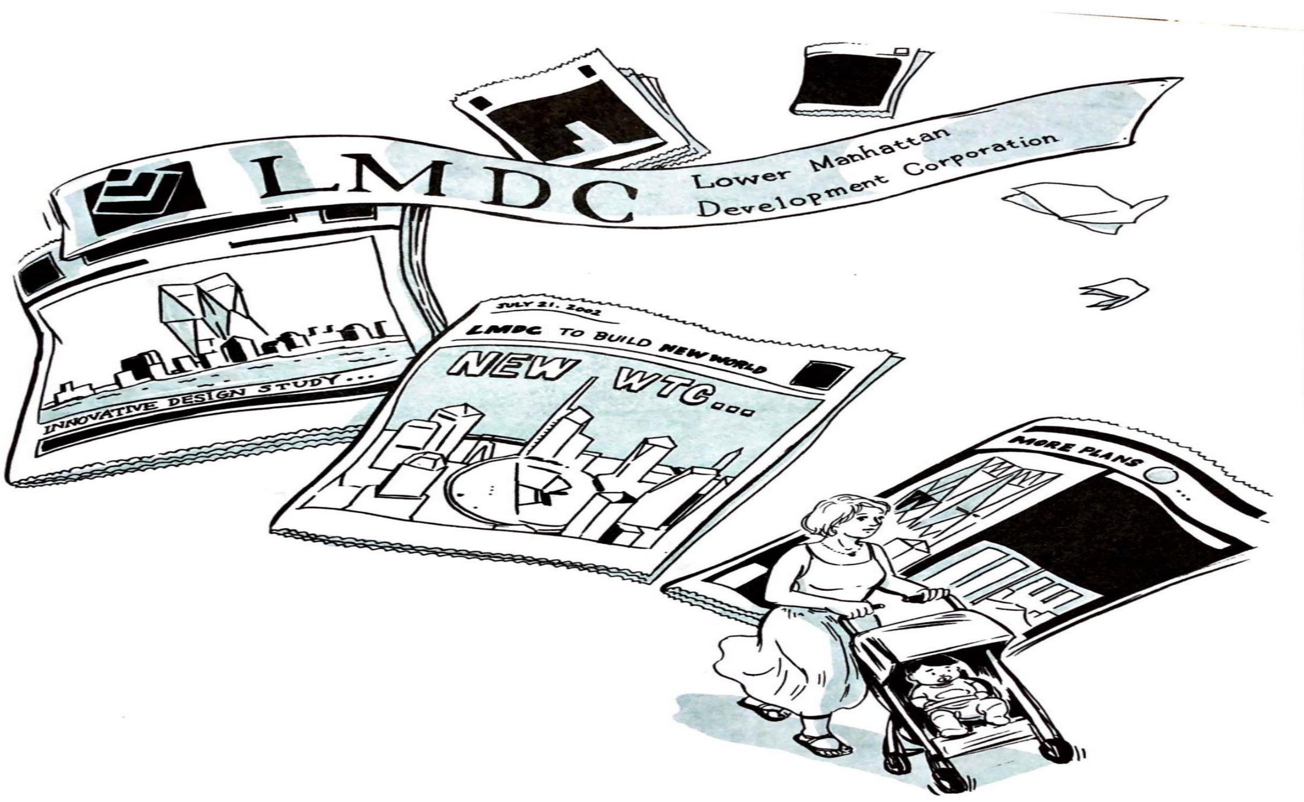


they need to make a telescope to be able to accurately see terrorist camps. Let's say the U.S Government wants to put a telescope in near space to spy on terrorists. They need to know how large of an aperture their telescope needs to have in order to accurately run surveillance on the terrorists. Since we are working with extremely small angles, we can assume $\sin(\theta) \approx \tan(\theta) \approx \theta$. Physicists are allowed to make this assumption when dealing with tiny angles like these to make our calculations easier. This approximation is extremely accurate up until about 10 degrees. Let's assume the government thinks there are at least two missiles silos on a terrorist base approximately 30m (100 feet) apart. How could we find the aperture (D) knowing what we know? Since the telescope is in near space, we can use the wavelength of visible light for λ. This is equal to 550 nanometers and we can say the satellite is going to be 36000 km (22,000 miles) high. This altitude is where most Medium Earth Orbit (MEO) satellites orbit (Brown, 2000). We can find our θ to be about 8.3 x 10^(-7) radians (really small) and use that value to solve for our aperture (D). For this case, the government needs to make the telescope's aperture to be about .81 meters (2.7 feet). This is relatively large but reasonable for a telescope in this manner.

9/11 caused the field of civil and structural engineering to change dramatically. They had to rethink how to build structures to withstand such terrorists attacks. Engineers have to learn to design a building to protect it from experiencing progressive collapse. This is when a building collapses due to only a few columns being damaged. Civil engineers learned about this concept in 1995 when a truck filled with explosives bombed the Murrah building in Oklahoma causing "progressive collapse." This results in total collapse because the undamaged support beams are left to hold up all the weight the damaged support beams can no longer hold up. Progressive collapse is essentially what happened to the Twin Towers on 9/11. The high temperature caused by the burning jet fuel caused the steel support beams to weaken and become malleable. This made them unable to hold the weight of the floors above them and eventually collapse. Before 9/11 progressive collapse was not fully understood and was usually not accounted for by engineers when designing buildings. Engineers now use what is called ductility to prevent buildings from experiencing progressive collapse. Ductility allows support beams to remain sturdy even when they are bowed and stressed. Since 9/11 the American Society of Civil Engineers has required buildings to have structural supports designed to hold up in massive earthquakes. Even though earthquakes and terrorist attacks have two very different effects on buildings, it is impossible to construct a building that is terrorist-proof. Civil Engineers also have to account for another concept called redundancy. Redundancy uses the concept of progressive collapse but for exterior support beams. It ensures that due to an outside support beam being damaged the building won't result in total collapse of the structure (Chao, 2016). The material used to create support structures in buildings was also researched following 9/11. Researchers concluded that in a future attack similar to 9/11, steel support beams aren't the best option. The steel beams when rapidly heated suffered many physical changes such as bending. Concrete however would have been a better option ("Fire Resistance"). This is due to the fact that when heated to the temperatures that the steel beams were heated to, concrete would not have melted. Concrete is essentially fireproof because of its non-combustible material and slow rate of heat transfer. Because of its slow rate of heat transfer, concrete acts as a great fire and heat shield. It also can protect itself from heat damage. The rebuilt World Trade Center uses this concept to its advantage. Along the side of the building are three foot thick concrete walls. Normal concrete can handle around 5,000 pounds per square inch of pressure. The concrete used on the new World Trade Center was specifically engineered to withstand up to 12,000 pounds per square inch of pressure. Miniscule steel fibers have been mixed in with concrete to increase its blast resistance and strength. They accomplish this by minimizing cracking and the spreading of cracks in the concrete. This idea is being used by scientists and engineers to construct buildings to better withstand terrorist attacks.



This image from page 116 in *American Widow* shows the rather weak support systems on one of the Twin Towers. The metal beams shown here will not be able to withstand the extreme temperature given off by the flaming jet fuel. The vertical and horizontal steel supports will become malleable and weaken due to the intense heat and give way to the weight bearing down from on top of it.



This image from page 171 in *American Widow* displays the plans to construct a new World Trade center after attacks on 9/11. The Lower Manhattan Development Company is in fact a real company and facilitated the rebuilding of the World Trade Center. They also had influence in constructing the World Trade Center Memorial. In the leftmost newspaper from the picture, the words read “innovative design study.” This newspaper most likely had the results from the research civil and structural engineers did to improve building design and safety. It housed information on how the new tower would use thicker concrete support beams and be made of a mix of concrete with microfibers of steel for extra stability and strength. In the newspaper above the banner, there is a single building. Architecturally this looks like the new World Trade Center which stands out among the rest of the buildings at 1,776 feet. The newspaper in the bottom right reads “more plans…” This is entailing the new design structure of the new building which accounts for progressive collapse as well as the malleability of the support structure.

Although the main focus of this paper was on the changes in technology due to 9/11, there were many other ways it affected the lives of Americans. 9/11 has impacted the American way of life tremendously, not only through advancements to our technology and building structures, but through the way we view ourselves. Prior to that event we went about our lives assuming that we were safe in our country, that day rocked our American sense of security. We were no longer safe from the acts of terrorism that were occurring in other countries. That day brought Americans together in solidarity to honor the victims and their families. In other ways that day also tore us apart; Americans became skeptical of Islamic citizens and our view on Muslims changed. This event began a wave of deportation and immigration laws. In addition we launched a war against the terrorist cell of Al Qaeda that is still ongoing 17 years later. A war that will have lasting impacts on Americans for years to come. 9/11 has impacted travel by creating a more thorough screening process in our airports. Web and phone surveillance has also been increased due to 9/11. The advancements of telescopes has also helped to collect information on terrorist cell groups. All of these advancements, technologies and ideals are also intertwined in post 9/11 in works of literature. These works demonstrate how Americans have evolved in the wave of political and social changes since this event. The new laws, procedures and technologies have been created in the hope of preventing another major terrorist attack on U.S. soil.

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