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A Paper on the different types of stealth technologies.

You may never have heard about stealth, or you may think it is just another conspiracy, in this paper I will briefly introduce many of the different concepts of stealth technologies and prove the that stealth is a real technology. There is a large focus on the B-2 and the F-117 in the paper. Stealth started before radar existed. In WWI, radar was not used on planes so the only way to be detected was either by sound or sight. One early way to detect planes before radar existed was using an acoustic location device. These tried to detect the sound of the plane engines. The other way that people could detect planes would be visual. The Linke-Hofmann R.I, was a plane that was built out of a cellulose material so it would be transparent therefore invisible to the eye. On paper, this was a great idea except that instead of being transparent it reflected all of the light having the opposite effect. This is expected as stealth technology was in its infancy back then. The Ho 229 was built in 1944 and was the next stepping stone in stealth technology using radar absorbing materials to absorb radar. The only reason for this improvement was because of the fact that radar had been a growing problem for the Nazis. For a long period of time after the Ho 229, there were no advancements in stealth technology until the 1980s where the F-117 and B-2 were introduced. As mentioned before we will go into further into depth with these two planes and their revolutionary leaps in technology.

Stealth technology date back to WWI but maybe not in the way that you imagined it. The Linke-Hofmann R.I used a cellulose covered body so that it would become invisible to enemy planes.. The Linke-Hofmanns were constructed by Linke-Hofmann and designed by a Paul Stumpf. His transparent cellulose plane suffered from not being able to land properly because of the high vantage point of the pilot. This was not the only downside to the R.I, it also suffered from the cellulose, the one thing about this plane that made it so different. Cellulose, instead of keeping its transparency it turned yellow and reflected all of the light back. This basically made the plane a giant lighthouse in the sky that would tell the enemy planes exactly where the Linke-hofmann was. Another problem with using cellulose is that because of its properties it bent and became deformed when heated up by sunlight. The Linke-Hofmann R.I was the extent of stealth technology in WWI, nothing in the realm of stealth was visited again for a while until WWII.

This next technology definitely the reason that there was such a rise in stealth technologies in the later half of the 20th century. Introduce RAdio Detection And Ranging (Radar). The first workable version of a radar system was constructed by the British in 1935. Radar works by shooting off a beam of radar waves, next the waves will travel outwards until an obstacle is detected. If an obstacle is detected, then the radar beam will bounce back towards the radar source. During WWII, to get a specific location of a plane or a boat you had to use multiple radars to triangulate the position. One radar is enough to tell you only that there is something in the air and what general direction it is in. Two radars are enough to tell you the velocity and altitude. Three radars can, in addition, give you all three axes (x, y, z). The British were the first to use radar in military purposes creating ,Chain Home, in 1939. This is a very remarkable and important advance as it is the first one in the world and gives them a giant upper hand. Once WWII broke out in September of 1939, Britain had the leading edge in radar

technology. The runner-up to Britain is most likely America as they had somewhat reliable radar systems on land, sea, and air. America was, in fact, able to detect the Pearl Harbor attack one hour before it happened. The only reason it was not able to get planes into the air was because a B-17 squadron was due at the same time and the radar system confused the Japanese for the B-17s. Germany is probably the third as they did not have very good radar until about 1943. In fact, in 1943 the Nazis grip on Europe increased dramatically, this was likely a byproduct of using radar.

The counter to radar was the Ho-229. This plane ignited a large leap in stealth technology as it used wood glue mixed with charcoal dust to absorb the radar waves from Chain Home. Many people believe that the so-called stealth on the Ho-229 was, in fact, the engines charring the wood at the back of the plane which then was the charcoal found on the plane. There have been studies done on the Ho-229 to find the wood glue mixture and they were successful and with the evidence from one of the Horten brothers himself it has discarded many of the mentioned theories. In other terms than stealth alone it held two 30mm Mk 108 cannons, in addition to that, it had the capability to hold R4M rockets and two five-hundred kilogram bombs.This jet was intended to be part of the “3 x 1000” requirement for many light german bombers of the time. The first “1000” is for the capability to carry 1000lbs of bombs, the second is for a range of 1000 km and the last is for a speed of 1000 km/h. The only way to achieve this velocity was to use jets, at the time jet engines consumed enormous amounts of fuel for short distances. The largest challenge for this plane was easily the 1000 km requirement. The final product of this plane was finished by Gothaer Waggonfabrik but was originally designed by the Horten brothers. The Horten design was a glider but Gothaer turned it into a jet aircraft.

The Ho-229 for many years was the plane with the best stealth equipment until the 80s. During the Korean and Vietnam wars stealth technology were not looked at heavily even though

Surface to Air Missiles (SAMs) were on the rise. The next time that stealth would be looked at was in the 80s in the Gulf War. The plane was the F-117 Nighthawk. The advancements that were made were gargantuan. First of all, it used breakthrough angular surfaces to deflect the radar beams, not to absorb. The plane was so breakthrough and stealthy that the Skunk Works advanced development team at Lockheed had to redesign the pole of which the plane was sitting on to test the RCS footprint. This was one of the first stealthy planes that used more than just jammers and radar absorbing paint. There were other planes that were hard to detect by radar or simply impossible to shoot down. The Sr-71 shot through the sky at Mach 3.2 and the missiles at the time traveled at Mach 3.5. Added with the altitude it traveled at it was extremely hard to shoot down. The U-2, on the other hand, flew at an altitude of 70,000 feet while the missiles flew at 82,000 feet but again, the U-2 would be out of the area by the time the missile got to them. The F-117 was a true stealth plane, combining radar absorbing paint, and angular surfaces this was an amazing plane. The second plane that is in the American Air Force and stealthy is the B-2. This plane was built by Northrop Grumman and they went the opposite way than what the F-117 did. The F-117 using angular surfaces to bounce radar in different locations other than the way it came has its disadvantages. First of all, if the enemy has a large enough radar network one of those stray pulses that bounce off the F-117 can be picked up from one of those other radar stations. The B-2 uses smooth surfaces so that the radar flows around the plane instead of bouncing everywhere. One of the inspirations for this plane did come from the Ho-229 as the design characteristics are very similar. The next plane on the list is the newest addition to the US Air Force, the F-35. This plane is still very secretive, even more so than the other planes mentioned. There are some design characteristics out for the public, for instance, it is the first stealth plane to have a machine gun in one version. It is also the first stealth plane to be Vertical Take Off Landing (VTOL). The F-35 is not the first plane to have these features

although it is the first to have them and be stealthy. Because acquiring a stealthy status is already so hard adding VTOL and armament doubles the challenge. This plane achieves that VTOL through having compartments for each appliance so that it is still stealthy. Each of these compartments can open and close depending what it is currently doing.

RAM is a very valuable asset to any stealth plane and because of how easy it is to add onto a We have talked about the different types of planes that use stealth technology, here we will describe how they work.As mentioned before, the first time that radar was trying to be blocked was with the Ho-229. This plane used a mixture of wood glue and charcoal dust in an attempt to absorb radar. The way that Radar Absorbing Materials (RAM) work is they greatly decrease the amount of energy that is in the radar beam. One mixture of RAM is specifically for one or few types of radar frequencies. Because radars only use a certain range (1.2 m to 3 mm) and so depending on the technology of the enemy you can coat the plane with the correct type of RAM.The Ho-229s RAM was a very trial and error method to find the right RAM, or in this case wood glue and charcoal. There are several types of RAM but the most common on aircraft is Iron ball paint. This paint works by having several microscopic balls of carbonyl iron arranged in liquid silicon, next a magnet at a certain power and distance which arranges the balls in a pattern. If done properly and the balls are evenly spaced and electrically isolated than it will be the most effective. There are many other methods that work better but are not reasonable to apply to a plane. One such example would be the Foam absorber method which is mounted on pyramids and would ruin and planes aerodynamics. There are also types of RAM that help existing types such as the split-ring resonator. This method can be tuned to different frequencies. One its own it does not work very well as it loses some radar absorbing capability.

The way that RAM works is it transfers the radar wave energy into heat energy. There is of course the problem of infrared missiles. This is not a problem however because the amount of energy in a radar wave is negligible so when transferred to heat energy it is almost impossible to detect by infrared camera. The exact process in which it does it is classified. The individual particulars of RAM are vibrating at the same frequency of the radar waves and so turn the radar energy into heat energy. Above I mentioned the split-ring resonator, this type of RAM is a large but thin copper plate that can vary frequency until it finds the correct frequency. Unfortunately because it is variable RAM it loses some of its absorbing capacity. RAM is very effective for a certain range of radar frequencies. RAM is usually not used on its own without help from a stealthy body.

plane can make a entirely non stealthy plane somewhat stealthy. The first example of stealth ever recorded was on the Ho-229, a Nazi flying wing. It used several layers of wood glue, wood and charcoal dust. This was meant to absorb the radar waves from chain home. Its effectiveness remains up to debate. There are several types of RAM, the simplest is the sandwich of different materials that were on the Ho-229. Iron ball paint, on the other hand, is rather more complex. It vibrates at the same frequency as the radar waves which results in the radar energy being converted into undetectable heat energy. Undetectable is used because without being very close away from the craft it is extremely hard to detect. Overall RAM is a valuable but limited asset to a stealth plane.

Changing the geometry of a planes body and wings to counteract stealth is a relatively new idea. It was first thought of and implemented on a plane in the 80s on the F-117. The F-117 is labeled as a fighter but does not have any of the capabilities of a normal fighter. It does not have any cannons or the capability to carry air-to-air missiles. The only weapons it can carry are laser guided bombs and missiles. Angular surfaces have the problem of aerodynamics. Most planes are very smooth and do not have irregular geometric shapes. While RAM can simply absorb and transform radar energy, angular surfaces must deflect the radar in other directions than the original direction it came in. This principle is basic physics, because angle of incidence equals angle of reflection, and since you can't control the angle of incidence you change the angle at which it reflects. That is achieved by changing the the angle of the surface.

The general equation for RCS is $\sigma_B = (\theta, \beta)$. The sigma ($\sigma$) is the average RCS of an object or objects. The theta (θ) is the polarization of the material. Lastly is the beta (β) which is the frequency of the material. Polarization of a material means the orientation of the waves that the material is at. This means that is the frequency of a wave is 5 Hz could have a certain angle which is the orientation of the material. This will give you how large or small your object will appear on radar. If you want to find out where the radar will deflect you use the angle of reflection equals the angle of incidence. This is all relative to the normal which is at a 90^O to the surface. As mentioned before you can not control the angle of incidence so you need to make a educated guess as to where the radar waves are coming from. It all depends on what type of mission you are flying, how high or low you are, and how close you get to the target.

Overall angular surfaces are extremely effective and are also adaptable to all frequencies of radar. The F-117, F-35, Su PAK FA and the Chengdu J-20 all use this type of stealth technology, angular surfaces. This method of stealth does have its disadvantages, aerodynamics. When you are changing the normal to deflect the radar it ends up with very strange geometric shapes. A great example of this is the F-117, the designers of the F-117 did not only have problems with getting the plane to become stealthy but also to have the plane fly. Especially on the wings. Because wings require very smooth surfaces(if not designed properly smooth surfaces can very easily reflect radar back to the source) to have the proper pressures on the top and bottom of the wing. The result of this is a slow flying aircraft because of terrible aerodynamics. This is all counteracted by the fact that it is stealthy and does not require speed to run away from SAMs. In the recent advancement of technology in both stealth and propulsion stealth planes are now able to go super sonic.

Contrary to the above smooth surfaces can also provide equal or superior amount of stealth protection. The first example of this is on the Ho-229, originally the plane was built as a glider and so a flying wing body shape was the best solution. Later when dual jet engines were added on and a mixture of charcoal and wood glue to prevent radar detection. Originally the body was not meant to deflect radar but just by chance this body has been claimed to flow around radar. This means that radar would flow around the body of the plane and would continue in a straight line. There never has been any test on the Ho-229s body as there are no whole surviving replicas. Northrop Grumman did attempt to build a modern version called the V3 but this model is only on predictions of what the real version was like. The next time a stealthy flying wing would be built is by Northrop in the late 90s. The B-2 was very similar to the Ho-229 and

Northrop even admitted to using ideas from the Ho-229. The B-2 was a flying wing had dual jet engines and was meant as a stealth aircraft. After half a century of technology improvement the B-2 was a much more superior aircraft. The B-2 can be thought of as a major improvement to the Ho-229.

Most stealth plane designs have the radar bounce off into random directions other that the direction it came in from. This can be a disadvantage as if there is another radar station nearby it can detect the radar pulse that bounced off of that plane. With the B-2 the radar flows around the body of the plane instead of bouncing off of it. This happens because the B-2 is shaped like a stretched out sphere. Spheres have a property that allow radar to bend around it instead of bouncing off. The front of the B-2 has enough properties that are similar to spheres, the one major thing is that the end of the B-2 is a flat plane so that the radar flows off the back. Spheres are not the only one to have this property, any shape that has a rounded outer edge, such as a cylinder, can have radar bend around it. The exact way that a sphere bends light, or radar, is not available to the public. The B-2 is currently the only plane to use this type of stealth. The FB-22 which was designed but never built by Lockheed Martin used this type of stealth but because it was not built we don't know if it would have worked. A plane that will soon be built in the future, the B-21 raider, this plane is very similar to the B-2 but will incorporate many modifications.

The bending of radar using smooth surfaces is several times more effective than traditional radar. The main reason is that once the radar has slid off the back of the plane it will not be picked up by another radar. This technology comes from the Ho-229 which is a WWII era plane. The Ho-229 started off as a glider transport plane but was then transformed into a stealth

fighter. This plane was then the inspiration for several american built planes, the B-2, B-21, and the X-47B. The one main similarity is that all of these planes are built by Northrop Grumman. The other type of stealth, angular surfaces, are almost all built by Lockheed Martin. This will prove in the near future what type of stealth is more reliable and safe to the pilot.

There are many different routes we could take with fighter jet aircraft. One method is to keep the pilot and have the plane stealthy so that it will not be shot down. There are several upsides to this, for instance if there is a random occurrence than the pilot does not need lengthy instruction of how to keep on flying. The other option is take the pilot away and create a cheap disposable UAV. These UAVs don't need a pilot but are also not stealthy. Because they are not stealthy the possibility that they are shot down increase dramatically. They do have the advantage that they are much smaller because there is no pilot onboard. A smaller size also decreases your chance of being seen on radar. With the gradual development of SAMs the UAVs will become obsolete as the SAMs will be overpowering.

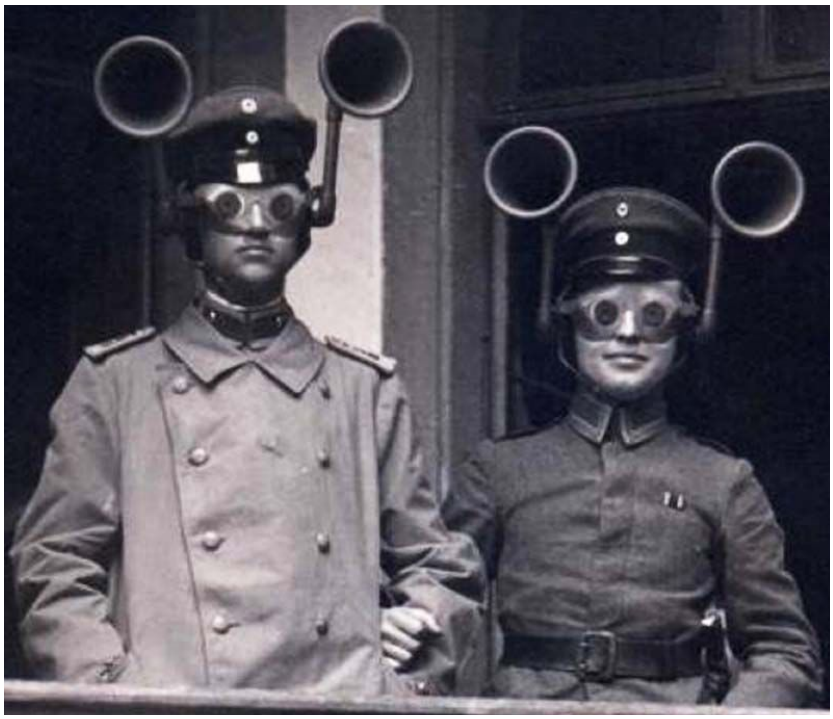

Figure 1, an acoustic sound locating device used in WWI.

THE LINKE-HOFMANN R.I: View of the cabin and airscrew mounting.

Figure 2, a Linke-Hofmann R.I was a WWI plane that was built mostly out of cellulose so as to not be detected by an observer's eye.

Figure 3, a Ho-229 the first fighter to be slightly stealthy against radar.

Figure 4, the F-117 was an extremely advanced plane and used many new technologies.

Figure 5, the B-2 was the next jump in stealth technology as it used smooth instead of angular surfaces.

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