‘Most people have valuable items that they need to leave securely in a building or public space. Your task is to engineer a device or system to keep buildings or personal belongings secure when left unattended.’

- AQA

There are multiple ways that one can approach this problem. There is the possibility to secure items away from thieves and robbers , where items are fully secured in their own container. This way the valuables are fully protected from any tampering. This method is excellent for securing bikes, watches, phones or vehicles as it protects them fully. For example, a bike’s brakes can be tampered with if a chain lock is used which poses a safety risk to the bike user. However, with an enclosed environment such as a garage the bike cannot be tampered with. Valuables which are kept in a safe are fully secure from any damage also. For example, an expensive watch will kept be kept incredibly safe if stored in a secure container such as a locking safe. The glass of the watch cannot be damaged by an intruder/thief so the user can have the peace of mind that their items are highly secure. Safes are a excellent choice for smaller valuables and a garage is ideal for bikes or cars. However, safes on the whole lack portability and are not ideal for larger objects.

Another solution to the problem is to manufacture a product which will secure the valuable object to fixed/stationary object. This solution is ideal for larger objects which are often too heavy, big or even messy to be put in a safe. However, one major downside to this method of security is that the object being protected is subject to abuse from a thief of intruder since a bike or a car can still be damaged or scratched. It is necessary for maximum security that this method involves connecting the valuable to a large, heavy immovable object such as a lampost. A prime example of this method of security is a car clamp seen on vehicles out in public which are clamped for parking fines. This is an excellent method at securing large moving parts of large objects which makes the valuable imobile. In the case of a car clamp, a metal bar is passed through a wheel on the car and then this locks the wheel in place. For this method of security to be effective, it is necessary for the material of this product to have the following properties: hardness, corrosion resistant and strength. There are only a handful of materials which fit these requirements, one of them being painted or galvanised low carbon steel. High carbon steel would be too brittle and heavy for this clamping application and aluminum would not be strong enough. Other clamping solutions include using a cable lock for a bike, a folding chain for a bike or a simple padlock for luggage.

Sometimes seen on bikes, this next method of security is an interesting choice. It is a method involving the user/owner being notified when an object is being moved or operated when not meant to. This design can be a compact circuit utilising a motion trigger as an input and then a siren buzzer as an output or possible a Wi-Fi/ Text notification to the owner. This design offers no protection against theft of the product, let alone damage to it. For example, a thief can very easily ride a bike away whilst the siren on the bike is sounding. This security method is fully dependant on the user being able to quickly respond to the sound notification and check up on the valuable. What is positive about this security method is the ability to notify the owner of the product when a security breach is detected.

Engineering GCSE

NEA - Containing: Analysis of problem, Research, Design Brief, Specification, CAD Views and Problem Solving

Samuel Packer - 4118 AGS 2019

Problem Statement Analysis

Another opportunity to investigate is the idea of a non contact security system to secure much larger valuables. My idea for this approach is to use a laser tripwire. The main principle involves placing a laser emitter and receiver to more a connected laser line. This method for security is great since it can secure very large objects; this method could be used to secure the car in a garage. A downside to this system is there is not physical mechanical attachment to the object being secured, the security of the object is highly dependant on the use of a sounder or some method of notification to the user as it is them who must deal with the movement of the item. This security system is ideal for securing items which are usually on display and are not wanted to be secured, for example in a museum or home situation there may be precious pictures or diamonds that need to be on display with as little interference with the item as possible.

Simple outline of brief

My aim is to produce a safe using both a keypad and RFID entrance solution to enter the safe. The safe will be made, as a prototype, out of a simple wood board. There will be multiple locking mechanisms including solenoid, servo bolts and a rack and pinion mechanism. The user will be alerted through wifi alerts and sound from the safe itself.

For a full detailed plan, see the pages titled 'Product Design Brief' and also 'Production Plan' (Separate) and 'Drawings and conventions' (Separate)

Safes - solution to problem 1

Anchor/Chain - Solution to problem 2

Alarm system - solution to problem 3

Simple outline of brief + Analysis

My aim is to produce a safe using both a keypad and RFID entrance solution to enter the safe. The safe will be made, as a prototype, out of a simple wood board.

Aesthetics:

The item must appeal to the user since it will be on show to many. A design theme can be incorporated into the product as this can increase the user friendly aspect for the safe. Personally, in my design for a high security safe, I think that the safe should have a Industrial strong appearance. Not only will the product look impressive, but the aesthetics may deter thieves from attempting to enter the safe in the first place. I aim for my product to have a sleek and clean look to be functional and ideal for a variety of users. However, the aesthetics will depend on the item's location. For example, when in a home or office environment the safe should have a user friendly appeal but when used in industry or in a construction environment the safe's aesthetics don't have to be a major priority since the major requirement there is for high security and not looks. Many teenagers may want a contemporary and functional design maybe using a veneer pattern on the safe.

My target audience is primarily at teenagers so I believe that a sleek and functional design with contemporary features is necessary for user satisfaction with this product. The item must appeal to the user since it will be on show to many who pass it. A design theme can be incorporated into the product as this can increase the user friendly aspect for the safe. Personally, in my design for a high security safe, I think that the safe should have a Industrial strong appearance. Not only will the product look impressive, but the aesthetics may deter thieves from attempting to enter the safe in the first place. I aim for my product to have a sleek and clean look to be functional and ideal for a variety of users. However, the aesthetics will depend on the item's location. For example, when in a home or office environment the safe should have a user friendly appeal but when used in industry or in a construction environment the safe's aesthetics don't have to be a major priority since the major requirement there is for high security and not looks. Many teenagers may want a contemporary and functional design maybe using a veneer pattern on the safe. However, using a metal front creates a strong and rugged appearance whilst only using expensive metal for the front door of the safe thus reducing the cost of production.

Cost:

Many safes on the current market are very expensive and lack user friendly aspects to them. Many that I researched with RFID interface were well into £150+. Others with more primitive key or keypad interface were still pricey for their quality at an average of about £50. These costs are excessive for use for a teenager or child but are somewhat justified in an office and business setting. I aim to close the gap between these two extremes of medium quality and high price to low quality and medium price. My safe will cost <£30 in production and has some very significant security aspects that potentially allow it for retail at the top end of the market. The low cost means it is accessible for as many as possible.. The safe aims to be excellent value for money whilst still incorporating a highly sophisticated design.

Analysis

Safety:

The products currently on the market are often made from thin sheet metal and are not ideal for children as there is a trap hazard for fingers. As my product is aimed at teenagers, this trap hazard has to be eliminated for a child friendly product. Low operating voltage will be critical for the product as this will not be harmful to anyone who short circuits the product. Subsequently, I believe that It would be unsafe to use high current and voltage devices beyond 12V as in the event of water damage this could become very dangerous to the user. Sharp edges to the product should be avoided during the manufacturing process to avoid cuts and other injuries during both the manufacturing and usage of the product.

Customer:

The majority of safes can be aimed at anyone, however some are incredibly expensive. It is required that a high security safe can be built for much lower than £600-£1000+ unlike safe C. Many teenagers cannot afford such a safe, but they still require some more advanced security features. Despite this, I do not want to loose advanced features as seen in expensive devices; for example using a keyless RFID entry and possibly Wi-Fi notifications.

Legal Requirement:

From the data sheets that accompanied the existing products which I researched, I realised that safes need to meet certain legal quality standards. For example, safes follow a "Sold Secure Accreditation" which is a UK certification scheme for safes set up by the police. It gives the safe an accreditation the the safe can survive a certain degree of attack including using a pry bar, grinding, drilling, rattling, cutting, hitting an da drop test. The rating is given to a company's device by the Master Locksmiths Association who work closely with the police and insurance companies. In general, the more expensive a safe, the higher a security rating is for that safe. For my product, I am obviously not able to get a security standard ratings however I am able to test the security of my item. To fully test every security aspect of my safe, I would require to perform destructive testing upon my product. I am not willing to perform destructive testing on my product for obvious reasons.

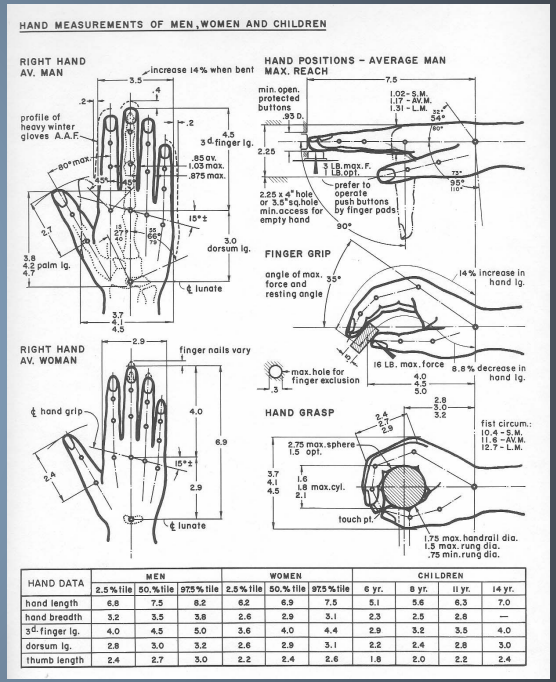
Analysis

Ergonomics and anthropometrics:

Ergonomics will not be the major consideration in my product. The product will not be hand held and grip is not essential when operating the device. However, it is worth considering what could be improved in terms of ergonomics on current safes. Some considerations include: door handle, keypad and buttons, user interface and LCD screens. The door handle to open the safe should be comfortable to operate whilst still being a hard and strong part in the safe. There is the possibility for the handle to be custom molded if there was only ever one user for the item. This handle ideal is ideal if used for a personal use item, it can be made easily through using a 3D printer to produce a handle grip for the hand. This is not ideal for my application in a safe since the handle does not require an ergonomic design. A brushed stainless steel handle can be used since it is strong, stain/scratch resistant and does not corrode. A user screen is almost essential, for me, so that the user can see what the safe is doing, if it is unlocked and other outputs which the user needs to be alerted about. A buzzer can be used as well to allow sound notifications to the user. This can be used to alert the user when the keys on a keypad are pressed.

It would not be in users interest if the safe is the incorrect size. For example, a safe which is only big enough to hold a few coins is not ideal for a user who wishes to secure multiple larger valuables. On the other end of the spectrum, if a safe was so big that it was not suitable for a home environment. From an anthropometrics data sheet of a hand, I have deduced that the handle for the door should be no more than 1.5 inches (3.81 cm) in diameter if a cylinder is used. This means the circumference of the this circle is 13.00 cm (5.12 inches -2dp-). The handle does not have to be made from a cylinder, in fact, if a contemporary design with interesting features is to be achieved, most probably not made of a cylinder. As long as the diameter of the cylinder is no more than 3.81 cm and the maximum diameter/width of the shape is not met the shape of the handle can be a wide variety of objects. It is possible to design a handle made from a piece of aluminum bar as long as it fits in with the anthropometric requirements for the hand of the user.

The handle, keypad buttons and overall size of the product must be in keeping with the users of this product. My product must include a door handle to operate the device, this handle must be of a reasonable and suitable thickness to be used by a variety of users with different hand sizes. To really allow this product to connect with the user, Wi-Fi alerts can be achieved if there are security issues that the user must be notified about. For example, notifications can be sent to the user when access was attempted.



HAND DATA	MEN			WOMEN			CHILDREN			
	2.5% tile	50.% tile	97.5% tile	2.5% tile	50.% tile	97.5% tile	6 yr.	8 yr.	11 yr.	14 yr.
hand length	6.8	7.5	8.2	6.2	6.9	7.5	5.1	5.6	6.3	7.0
hand breadth	3.2	3.5	3.8	2.6	2.9	3.1	2.3	2.5	2.8	—
3d finger lg.	4.0	4.5	5.0	3.6	4.0	4.4	2.9	3.2	3.5	4.0
dorsum lg.	2.8	3.0	3.2	2.6	2.9	3.1	2.2	2.4	2.8	3.0
thumb length	2.4	2.7	3.0	2.2	2.4	2.6	1.8	2.0	2.2	2.4

Analysis

Manufacturing:

There are multiple ways to manufacture this product. If made from sheet metal, there would be a lot of scoring and press forming to produce a metal container used for the safe. It may be necessary to grind, cut and weld sections of metal plate together to produce the container. Using metal to produce the product would take a long time due to the requirement needed in production. For my prototype, I believe that it is a more efficient option to use MDF since the manufacturing process for MDF is arguably a lot easier. However, the fibres when cut are carcinogenic in large quantities. This is why it is essential, for safe manufacture, that I use a P30 mask to protect myself from the dust. A 3d Printer will be used to produce the small technical parts. 3D printed parts are not structural and is not an effective solution to 3D print very large parts but that is not an issue in my product.

Materials:

There are numerous options available to use as the prototyping material for my design. From my research I have deduced that metals such as mild steel sheet or aluminium are a great option for a final product. Mild steel is a hard material so it is not scraped or scratched easily. Likewise, it can be painted, treated or plated to suit the requirements for the users. Mild steel is a conductor of electricity so this must be taken into consideration when manufacturing the electrical components in my product - electrical current must not come in contact with a mild steel casing since the product will have a live casing and, even at ~12V DC, has a potential danger for both the user and the longevity of the product. Mild steel has the ability to be heat treated by annealing to make it even stronger which would be suitable for a security device. Aluminium sheet has a low density and is ideal where portability and low weight is necessary. Similarly, Aluminium is a relatively inexpensive metal in comparison to mild steel. However, aluminium is not an exceptionally hard material so may not be ideal for my idea of a high security device. But, as mentioned, It would be a great design feature to use aluminium sheet on the front drawer face as a resilient section because it is backed behind 18mm MDF.

Both metals (Aluminium and Mild Steel) are desirable as a final product material however as I will be producing a prototype product such materials are not an efficient solution to make the the container of the safe out of.. In terms of economy and efficiency I believe that the best material of choice would be a softwood or man made such as MDF, Plywood or pine. These woods are readily available in the UK and for a relatively low cost. Likewise, these woods can be painted, veneered or stained to suit the aesthetics need of my end product. I believe that MDF is my best choice for the material for my prototype safe; it can be worked and cut easily which is necessary for hand tools. MDF doesn't warp easily like pine or some hardwoods which makes it ideal for this application when precision for length, angles and thicknesses is a high priority. However, when cutting MDF precautions must be taken since the small sawdust and fibres can be harmful in large quantities to lungs. As a result of this research, I will be using a P30 particulate mask which is suitable up to micro particles. When cutting is completed, the wood used will obviously pose no threat to the users since the fibres and saw dust will not be in the vicinity of the user.

Analysis

If this product was to be produced for the masses as an actual solution, I would make my safe out of sheet mild steel as its properties (as mentioned above) are ideal for the safe. However, the design of my safe work of have to change since the MDF that I am using is 18mm thick which is a suitable thickness for this product. The mild steel sheet would be 2mm thick. The obvious difference in thickness in materials would have to be incorporated into the dimensions of the product since the internal volume of the box would be bigger if the external dimensions are kept the same and sheet steel is used. Likewise, the fittings that I use for Ironmongery such as the hinges, handles and door bolts would have to change from screws and dowels into self tapping zinc PZ2 Screws and using pop rivets with a riveting gun.

Function:

Safes are designed to secure and keep objects safe. They allow only a person with a unique entrance method to access the belongings in the safe. Safe are better than say a bag lock as they allow the objects) to be totally secure from any tampering by unwanted people. This is ideal for small valuables such as mobiles or watches since they are dedicated and in some cases fragile. Other considerations are that the safe should protect the contents from external environmental aspects. For example, there could be a situation where there is a house fire and important travel and finance documents must be kept safe from the fire for a minimum amount of time. From my research I discovered that some safes had 'fire times' which states the longest possible time that the safe can be left surrounded in fire before the internal temperatures of the safe is too high and the contents are destroyed. Since my safe will not be made from a high heat resistant metal such as mild steel, my safe will only have a small fire retardancy and low 'fire time'. If my product was to be produced as a final design for sale then ideally a metal casing would obviously protect the mechanisms and contents from the high temperature of the fire.

My safe needs to not only keep the object safe, but the users also. Possible dangers to the owners of the safe may include fire, smoke, CO, weather and burglars. It is possible to convert any simple idea of a safe into a fully functional home security system. A smoke detector and IR Flame module can be added to my system to detect smoke and flames in the home. The smoke detector needs to be positioned low to the ground so that the smoke can be detected by the safe. A high power siren can be triggered to turn on a high pitched and loud alarm to alert users nearby. It is also very easy to alert the users when they are not at home, using Wi-Fi alerts for their phone when out. Using an ESP8266 and/or ESP32 it is possible to alert the user on any security status of the safe such as if the door is open or not. I am only able to add one notification per ESP board so I may just include say motion detection but leave out the IR sensor and smoke detector.

Analysis

A safe should obviously open and close by control of the user. It would be a bad product if the safe would take a long time to open or not even open at all with the correct key/code. This needs to be taken in consideration when choosing how to make my mechanism for the locks of the safe. Fewer moving parts would be ideal since there is less to go wrong when being operated. Likewise the maintenance of the mechanisms and the safe itself must be taken into account. It would not be user friendly if nuts and bolts for the linkages from a servo to a rack and pinion system had to be tightened every week just to make sure that the sfa functions properly. Lubricants such as WD40 and Wzeeel may be necessary for moving parts to prevent degrading pins and linkages in a design. In my design, there will be 4 locking points in total. Two of these mechanisms will be a servo controlled door bolt system which, when commanded, can operate two bolts to go across the door into the door frame. This will be a very effective method at locking the door. There will be two of these mechanisms which I will make myself. They will go at the edge of the door right at the top and bottom of the safe door. The products which I researched used 2 aluminium hollowed poles which slide out of the door and go into a door frame which blocks the door being opened.

These mechanisms are maintenance free and are a heavy duty solution to how to lock the door. In conjunction with the servo controlled door bolts, I will be using 2 standard 12V solenoid lock valves. These solenoids are very reliable and add an excellent security aspect to my design. From my research, I did not see any safes which use these solenoid valves. In sales terms, it shows there is a gap in the market for high efficiency and reliable locking mechanisms for safes. But for me, this shows my unique design and how this locking method, coupled with my custom servo controlled door bolts, is excellent choice for the product. Hinges will be necessary to allow the user to open the safe and close it when required. The hinges have to be sturdy and heavy duty for a high security application. Because of this product requirement, I believe that it is necessary for the product to utilise a set of heavy duty door hinges. They are ideal for my application since they are outdoor suitable and are made from mild steel which then undergoes electrolysis to chrome plate the hinges. The chrome plated aspect to the hinges again re enforces my idea of a sleek, clean and contemporary design. These hinges are aesthetically pleasing to the user as well as functional.

None of the safes I researched had a developed user alert method for when access was attempted or granted. This leaves a major problem with current safes; if someone is at the location of that safe and attempting to enter it but doesn't know the correct key code, the owner of the safe cannot be notified. This is a problem if the safe owner is out and not able to monitor the security of the safe. From my research I believe that it is pivotal that the owner of that safe is notified about the activity of his/her safe. This issue can be fixed by sending alert messages to the user. I plan to achieve this by using a NodeMCU ESP12-E board. This Arduino compatible board can send Wi-Fi alerts to the person when the safe is opened or closed. This extra feature is not seen on any of the safes which I researched and as of which I believe to be an important feature for a modern safe. But, when I investigated the fire safety for safes and their contents I realised that my MDF prototype would not be suitable against high temperatures and fire. This is why it is ideal for the user to be alerted when a fire is active in the surrounding area of the safe. Wi-Fi alerts can be used to alert the user when not in the vicinity but a siren style alarm would be necessary when the user is inside the home. The sensors required for this aspect would be an IR Fire module and a DHT11 temperature sensor with humidity sensor.

Analysis

Adding these advanced Wi-Fi lert features may be beyond what I can do within the time limit allocated for the NEA and may be beyond what I can do currently a my skill level. As the processing centre for the safe, all bar one of the solutions that I investigated used an integrated circuit with SMD components and AT Chips. These circuits are very reliable, custom made for their individual product and are very small. Whilst offering many features, they are not as powerful as an ATMEGA 2560 chip. For the processor of my prototype, I will using an Arduino to make the complex tasks that I wish to perform a lot easier. The Arduino boards are very user friendly to work and modify as they are part of an OS learning platform. They are an ideal solution for when I am using an MFR522 RFID reader with a 4x4 Matrix keypad as well as a NODEMCU board for the wifi alerts and an I2C LCD display for user interface on the product. As a result from my product research into what other safes' use, the use of an Arduino itself seems different to others. However, SMD soldering with AT chips is not a viable option since custom printed circuit boards using GERBER files would be needed for this to work. Arduinos seem the best option to operate the locking mechanisms.

Environment:

Many safes on the market are made using a sheet metal which is then powder coated in a fluid plastic. This method allows the material to corrode a lot slower, its aesthetics to improve and improve the appeal to the user. However, this method uses a lot of plastic to fully coat the sheet metal used for the safe. Likewise, some of the plastic has the possibility to be inhaled by the manufacturer of the product which poses a severe safety problem for the the production company of the safe. As a result of my investigation into this process of plastic coating, I have deduced that it is not a viable method to use for my final product if sheet metal was used as the casing of the product. MDF, the wood which I am using for my product, is made from the sawdust of a variety of other woods. This means that the primary material for my safe is a recycled man made board. This is an excellent choice for the production of my prototype. If on the other hand I was using new pine wood, then my usage of the wood would be a factor contributing to the deforestation of numerous threes in the UK forests. This problem would be even more of an issue if I used hardwoods to make my safe as these take many more years to grow meaning the environmental impact of using say oak would be far greater than pine and obviously MDF.

If I used a plastic based material in the prototype of my product, thee would be numerous environmental consequences because of this. Since plastics are from the drilling of crude oil, the use of say acrylic would be a bad choice. Not only it is a weak material for security processes but if the product was to disposed of after needed then recycling the plastics takes money and time to do so. However, when using wood and metal alternatives the recycling process for the item decreases in cost and time.

Analysis

Size:

From my research I found that a size of 300mmX200mmX200mm was a common design in basic and cheaper safes such as safe-A. That size is suitable for when the user desires to secure multiple small valuables such as a few pens, watches, phones and maybe a medium sized camera. This is a size that I definitely need to take into consideration when designing my product. Some of the more expensive safes such as safe-B had dimensions 453mmX415mmX491mm. In context to safe-A, this safe a much larger solution and in turn takes up more room. Such a size is not ideal for my target group for teens and OAP where masses of spaces in homes are not always available. These bigger safes are better suited for an office or business environment where there is the possibility for many items to be secured at one time. For example, work mobile phones to be secured overnight. From my research I can deduce that there is an optimum spot for amount of valuables to be put in the safe in contrast to a small compact design. As engineers, we have to consider aspects such as the wall thickness of the safe and how this can affect not only the security rating of the safe but the internal volume to external volume ratio which is all dependent upon the thickness of the MDF that I am using and the mechanism sizes.

Weight and portability:

When it comes to a high security safe, weight and portability may not be a high priority if the safe is going to be in a fixed position in an industrial setting. But, since my target audience is teenagers then the weight of the device has to be suitable for the home environment. From my research, Safe-B's weight of over 50KG seems extortionate for a home setting. Issues may arise with this weight of a safe since if the safe is placed on a bookshelf in a bedroom or other living space, over time, the shelf is likely to warp and hence break. There are more severe risks using such a heavy weighted safe, if this safe was to ever fall on the user from any height, it is likely to cause severe injury and possibly death. Such a weight is most definitely not suitable for teenager or anyone for that matter. From this research I have deduced that the weight of my prototype must be a weight which is deemed safe for the user group. When researching safe-A, its weight was a mere 5KG; somewhat incredible compared to safe-B. However, 5KG seems almost too light as the feel to the user may be a low quality product. It is important for my product to be a contrast of advanced product as well as advanced features.

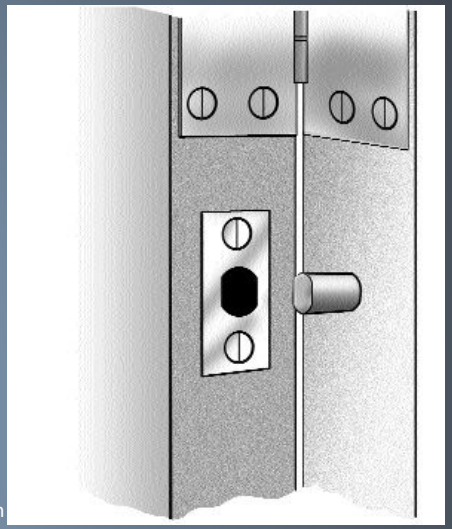
Research of features

Security Lock Bolt:

When researching of extra security methods for my safe, I found the security door bolt which is commonly seen in thick doors for secure buildings such as hotel rooms etc. I decided to implement this into my design since it enabled increased security since anyone attempting to break into the safe would have to cut through this thick 15mm diameter door bolt as well as the 5mm hinges and the solenoids and my designed door lock mechanism. I decided to by a security door bolt since they were finished pieces that had the filleted edge and were made of 15mm thick mild steel - a material that I would not be able to machine at school due to its hardness. The diagrams opposite show how my design will feature in the final product. The smaller image shows that the product that I bought from yale comes with an included plate to protect the door when in operation. My design of using 18mm MDF with the S-1 piece does not allow me to use that piece due to size constraints. So that Is why I decided to design and 3D Print an inserted part into the recessed section of S-1.

Switch Handles:

Whilst researching products to use as a handle for my project door, I found a set of handles that come in a variety of sizes and are ideal for my application since the handle section can fold away on itself when it is not in use (ie: when the door is locked). For installation, the handles require a cut out rectangle as well as 2 5 mm mounting holes for screws. I pan to design a print templates that can be stuck on the main door and also the drawer face which can be stuck on and then the user can drill holes into the given section sand then use a jigsaw cutter as appropriate. This allows repeatability or my product which is very helpful for the production if this was the case.



Research of solutions (Safe-A)

Yale Compact Digital Safe YSV/200/DB1

Price: £34.99

External Size: 200mmX310mmX200mm

Internal Size: 180mmX300mmX180mm

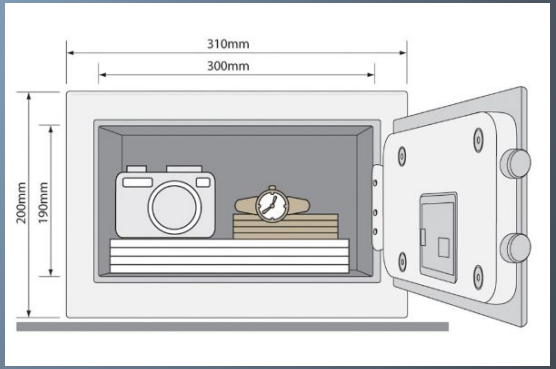
Weight: 5KG

Warranty: 2 Years

Fire Protection Time: 10Mins

Water Protection Time: N/A

User ratings: ***** (5 star approval)

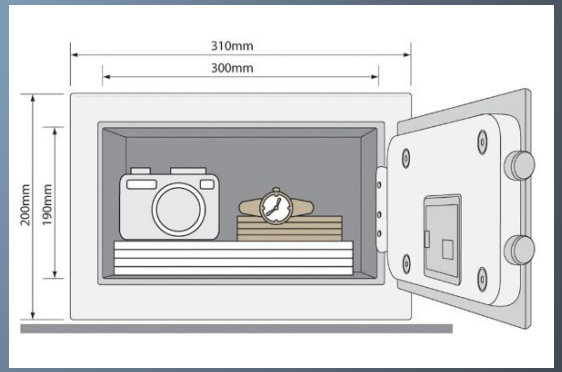


Research of solutions (Safe-A)

Uses 4xAAA batteries to power the system

My deductions:

This a good general safe for some valuables but is not suitable for very expensive items. This is because there is an override key the pin code can be as little as 3 digits which can be cracked using a program swiftly. Moreover, the safe uses off the shelf AAA batteries to power the locking system; to me this is not a viable method to secure items. When the batteries run out the user is forced to use a generic key to open the safe, this is not a high security system. What is good about this safe is the low price point which is excellent for my target audience and its compact size which is again ideal.



Research of solutions (Safe-B)

Master Lock LTW123GTC - Fire and Waterproof Safe

Price: £467.99

External Size: 453mmX415mmX491mm

Internal Size: 349mmX319mmX302mm
Weight: 58.2KG
Fire Protection Time: 120Mins
Water Protection Time: 24hrs
Warranty: 5 Years
User ratings: ***** (5 star approval)

'Combined user programmable 5 digit code digital lock (AAA batteries not included) and key lock'

'4 large locking bolts and pry-resistant hinge bar for additional door protection'

'Features 1 x multi-position shelf, door pocket, key rack and interior lighting'

My Deductions:

The security aspects of this safe are incredible, this is obviously a very high security safe which is reflected in the heavy price. include in my product.

Research of solutions (Safe-B)

For example, this same includes internal lighting which is an excellent addition so the contents of that safe can be seen in any lighting conditions. Similarly, this same includes a door pocket on the inside of the door to hold small documents and passports. I wish to include this feature into my product as it allows critical documents to be kept easily available as soon as the safe is unlocked. The 4 bar mechanism is another aspect to consider for my product since this an excellent security aspect for high end safe. What is not good about this safe is the weight. Being so heavy, it cannot be moved easily from position sin a room and if it were to fall on anyone this could incur severe injury. Similarly with safe-A, the system is operated with 3xAAA batteries; from a high end price safe I think this a bad choice from the company.

Research of solutions (Safe-c)

Phoenix NEXT LS7003 Black Luxury Safe

Price: £1932.50

External Size: 900mmX500mmX950mm

Internal Size: 725mmX375mmX305mm

Weight: 152KG
Fire Protection Time: 60Mins
Water Protection Time: N/A
Warranty: 2 Years
User ratings: **** (4 star approval)
'£3,000 insurance rating with 60 minute fire time'
'Comes with 2x adjustable shelves and 2x carpet lined drawers'
'Door includes 5 32mm door locking bolts'

My deductions:

This is a high security safe whilst giving some luxury design appeal. There are some features that I feel would make an excellent addition to my safe: small integrated drawers, multiple door bolts and a shelf. The price of this product is exceptionally high and I do not feel that it is a value for money item.

Research of solutions- Deductions:

As a result of researching Safe-A:

- I will not be powering my product with one time use batteries; they are bad for the environment and problems will arise when they run out. So, the best power option would be a mains power supply with transformer or a LiPo/NiMH Rechargeable pack.
- I will be making my design compact and a contrast between internal volume and a suitable size for the home. Safe A does this very well be being a good size for shelves or drawers. Because it is made from thinner steel sheet, it does not have an excessive waste which saves on shipping costs for the product as well as being safer for the user to operate.

As a result of researching Safe-B:

- I will be using multiple door lock bolts to secure the door in the locked position since this makes for a very secure system. Using large and more lock bolts means that any robber/intruder would have to cut through many sections of thick steel which would both deter them and take more time to steel the belongings inside.
- My safe will not be as big or as heavy as safe-B since it is not suitable for my target audience of teenagers where safety is key - if safe B was to fall from a shelf then that poses a major safety risk which is unsuitable for teenagers.

As a result of researching Safe-C:

- I will be including some luxury touches to the design such as a locking drawer and possibly an extra shelf. I will also apply a vinyl cover to the front of my design to increase that aesthetics, similar to safe-C. I believe that some of the high end features of safe C offer a better experience for the user so therefore increasing user satisfaction of the product.
- The integrated lighting inside makes it ideal when accessing items during the night and that is an easy and inexpensive feature that i can add to my product using 5050 LED Strip at 12V.

As a result of researching Arduino based electronics:

- As I am competent in the C++ language that Arduino uses, I feel very confident at creating complex features such as my Wi-Fi connectivity and the RC522 scanner in my product. I have experience with Arduino before and find the products and services axcellent for this type of project

Spec. Point	Justification	Test of success...
Aesthetics- Sleek And contemporary	Similar to safe C but with the secure look as safe B. Ideally the safe should not attract unnecessary attention as this would highlight to others that there are valuables in the safe.	Does the product fit the required aesthetics stated by the customer?
Customer - accessible to all but aimed at certain group	Available to all like safe A aimed to teenagers & OAP's. The safe aims to be a suitable design for all customers however the target audience will be at teenagers and OAP's	Appeal to target audience
Cost - accessible to as many as possible.	Much lower ale price than safe B+C but higher than A (*£120). Manufacture for prototype is lower than £40.	Parts and manufacture cost low to sell high as a product.
Environment -made from sustainable materials and recycle	Made from recyclable materials like safe A. Having an environmentally friendly product is ideal as it reduces harmful impacts on the environment.	If it can be recycled
Ergonomics - suitable for the customer of the product.	No sharp edges like safe C. Using certain manufacturing processes can increase the ergonomic appeal of the product to a customer. Necessary so that the product is usable and accessible to target audience.	If the parts which are operated by the user work accordingly.
Size - ideal for a variety of smaller valuables	A contrast between safe A + B (445x350x250). The size must be big enough to facilitate the security of multiple valuables.	Measure up after and see if dimensions fit in with a 1mm tolerance.
Safety - no possible danger to the user of the item	Not like safe A, more like safe C with safety features. No sharp edges, trap spots or even electrical surges to the user.	Is it dangerous? Is tha product safe to be used by a person
Function - to secure valuables and also unlock	Similar to safe B but with more advanced features. Must be able to fully secure the items kept in the safe.	Do features relate to plan

Materials - strong and usitible to secure the valuables from various attacks	Prototype: MDF, Final: Sheet Mild Steel; like safe B. The final manufacturing material must be strong, hard and dense to protect the valuables in the safe.	The materials and product should be to survive some destructive testing to recreate a
Manufacturing - reliable processes with suitable tools	Cutting, unlike metal bending seen in safe A+B. The product must be made suitably to provide a strong system.	Product made from cuts not bends. Do the manufacturing processes allow for a secure system.
Maintenance	Little required; like safes A+B+C. The screws on the mechanisms such as the SRC's and hinges need to be able to left working alone for the full life of the product without any tightening.	Parts work for long time
Door must open with RFID	A high security option which offers a fast method to enter the safe. There can be multiple key cards for multiple people/users and objects	Does the door open with the use of the RFID solution?
Door must open with Keypad	The keypad is really helpful for a memorable method to enter the safe as no key/card can be lost.	Does the door open with the use of the keypad solution?
The safe door must open with a bimetric solution using the keypad and RFID system	Once the system is armed and on, the use of a keypad and RFID solution will be used to allow users to enter the safe. It will function by allowing the card to be read first and then the keypad to be entered. If correct, the door can unlock.	Does the door open when the correct car and keypad are used?
The led ring light must light up green when both security measures are correct.	The 24 LED adafruit ring light enables the safe to have a user friendly appeal. The individually programmable leds can allow for vibrant designs + animations when certain actions occur. In this case, the whole ring light goes green.	Does the ring light switch green when the safe is ready to be opened

The safe will be turned on with a key to arm the system	A key switch will be the master switch to the whole system. This is a switch for the 12v power supply which powers the Arduino(s) and Solenoids etc.	Does the safe use a key to arm the whole system?
The safe case/box will be made from 18mm MDF	18 mm MDF is a contrasting choice between cost and structural strength. MDF is easy to work with, dense and strong against force and a cheap solution. When cut, its' sawdust is harmful to health so a P30 mask is necessary when the material is undergoing cutting process. The full product would be made from 2mm Mild Steel as it has many desirable properties for the manufacture of the safe. It is very hard wearing, strong and tough. The reason that I am not using it in my prototype is due to cost reasons.	Is the safe made from 18mm MDF
The safe should open using a gas hinge that will automatically open the door when unlocked.	I have bought a 120N gas hinge for this application. Before even starting the build I have my doubt sif the hinge is the correct for the open the door as it may be too strong meaning that the user needs to exert a lot of force to open the door.	Does the door open and close with minimal force from the user?
The safe will house a built in drawer for added security for smaller objects.	This is made simply from using 6mm plywood and mounting that onto drawer runners. The front face of the drawer is made from 18mm MDF as this allows me to mount larger objects that are needed such as the lock mechanism and the switch handle.	Does the drawer lock, unlock and open easily using they key lock?
The safe has the ability to be powered by a wall power supply or a rechargeable battery pack.	I am using a 3A wall power supply as the primary power for the device but I also have to opportunity to use a 12V Rechargeable battery pack. The battery pack allows the user to have the safe in a place without power such as a shed or in the back of builders van to secure expensive tools such as laser levels. The battery has a capacity of 3000mAH so it will require charging through prolonged use.	Can the safe be powered by a battery pack or the 3A power supply?

Product Design Brief

These pages will summarize what features and mechanisms will be in my completed product:
For more justifications on certain aspects of the design see the analysis section

- The safe external dimensions are 250mm (Height) X 450mm (Width) x 200mm (Depth). These dimensions are suitable for small/medium size safe which is perfect to hold numerous documents, phones, wallets and keys.
- The main material used to make the safe is 18mm MDF sheet board. This material is easy to work with and is cheap for the prototype. Its thickness is ideal for screws and dowels to hold the safe together. The MDF on the front of the safe will be wrapped in half gauge 3D Carbon Fibre wrap (see more bellow).
- Iron on edge banding will be used on the edges of the MDF to cover the unsightly appearance of cut MDF. This edge banding can then be painted, along with the whole product, to a dark grey/charcoal colour. This colour is a sleek and neutral design so is ideal for the product's target audience.
- The front face of the safe is covered in a 3D Carbon Fibre Vinyl wrap. This material is an aesthetic choice for the product, it is something that I personally like and have used before. The wrap is applied by first sealing the MDF box with a thin layer of water:PVA mix. This seals the safe and removes small impurities in the surface. Then, the vinyl is applied by removing the sticky back Paper of the vinyl. Then, with care, the vinyl can be stuck over the safe door and door frame. A flexible scraper can be used to push out any air bubbles caught in the process of applying the vinyl. The MDF material can sheet be worked and cut after the vinyl has been put on.
- Dowels are used to join the six faces of the safe together. Dowels are a better choice than screws in this case for two reasons. MDF can split hen a screw is put through the edge of the board, this can possibly render the material useless and prone to breakage through use. Moreover, screws can be removed by a thief to open up the safe whereas dowels cannot. Overall, the used of dowels are by far a better choice for the manufacture of the product.
- The door of the safe is also made from MDF and can be cut easily using a table saw. There are however some problems which need to be overcome. When mounting the hinges, screws split the MDF side if mounted directly to the side of the MDF as shown in my modelling of this (see production log). This problem can be fixed using a custom cut channel where the door of the safe can me mounted to. This channel is mounted to the hinges using regular wood screws as the channel is made from CLS Pine Whitewood Timber. The channel also adds rigidity to the door and hinges when in use.

Product Design Brief

Door Lock Mechanism:

- There are 2 types of locking mechanisms in the product. Custom made servo controlled door bolts (SCDL) and 12V latching solenoids (LSL)). The SCDl's are made by using an SG90 9g servo which is connected using custom designed 3D Printed arms as linkages. M3 nuts and bolts used in conjunction with spring washers and slip washers to allow free movement of the linkages. The 3D printed arms measure in at 30mm and 40mm each. A door lock bought from Toolstation at £0.97 each is used as parts for the mechanism. It comes with a 11m bolt which has 25mm of lateral movement to go from the edge of the door to the door frame. This part is adapted but cutting the toggle bolt used to lock the door by 6mm to allow the servo to lock the door with the help of the linkages. The bolt holders on base plate of the part are cut of and then a new custom made pipe channel is added to fix the bolt movement to only lateral. This is essential to prevent the locking mechanism to malfunction. The servos themselves are mounted to the door using 3D printed servo mounts. These mounts increase the durability of the mechanism as they allow the system to be incredibly reliable over prolonged use.
- The LSL's are standard bought 12v Linear Latching Solenoids off the internet. They are an incredibly reliable product and have few moving parts so there is little to go wrong over prolonged use. The LSL's are small compact units which use electromagnets to grip a lath and pull the latch inwards when a voltage is applied to the electromagnet coil. There are 2 of the LSL's in my product, they are positioned on the edge of the door next to and in conjunction with the SCDL's. Together, they offer an immense amount of security for the system; there is over 30mm of metal to cut through if a thief attempted to access the safe. The arduino that is used in the product can only provide 5V of voltage as an output. To provide enough voltage for the LSL's to work, a NIP122 transistor must be used in conjunction with the arduino and a 12v power supply. An analogue output from the arduino is sent to the NIP122 to close the LSL circuit allowing the electromagnet in the LSL to operate. The only disadvantage for the LSL's is that they take up a considerable amount of current when in the unlocked position. This issue is overcome by using a higher current 12v DC supply, in this case a 3A supply is used for the whole system.

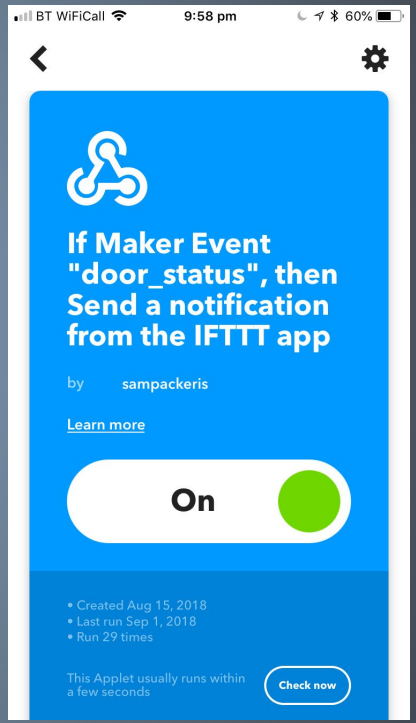
Product Design Brief

Alerts and notifications:

- For alerts when the user is not nearby, a node MCU can be used to connect the device to the local Wi-Fi network. This allows me to emit WiFi alerts to the users phone using the software known as IFTTT (if this then that) which runs on this arduino compatible board using an API key in the code and the correct WiFi settings in the code. This system requires a WiFi Network so this works in my home where I have a WiFi router which connects my phone, laptop etc. What is ideal about this NODEMCU is that I can receive alerts when not in my home using the mobile data feature on all phones today. This works by the node MCU being triggered, router communication, satellite communication and finally to my phone. It is very reliable and is an excellent feature of the safe. The image opposite shows a screenshot of my phone with some basic details of the instruction running on the NodeMCU with the webhook installed.
- I am also using the NE555 IC circuit configured in monostable mode to create an alert when the motion detector is triggered. Using the SW420 and some resistors and capacitors with a potentiometer I can make this circuit.

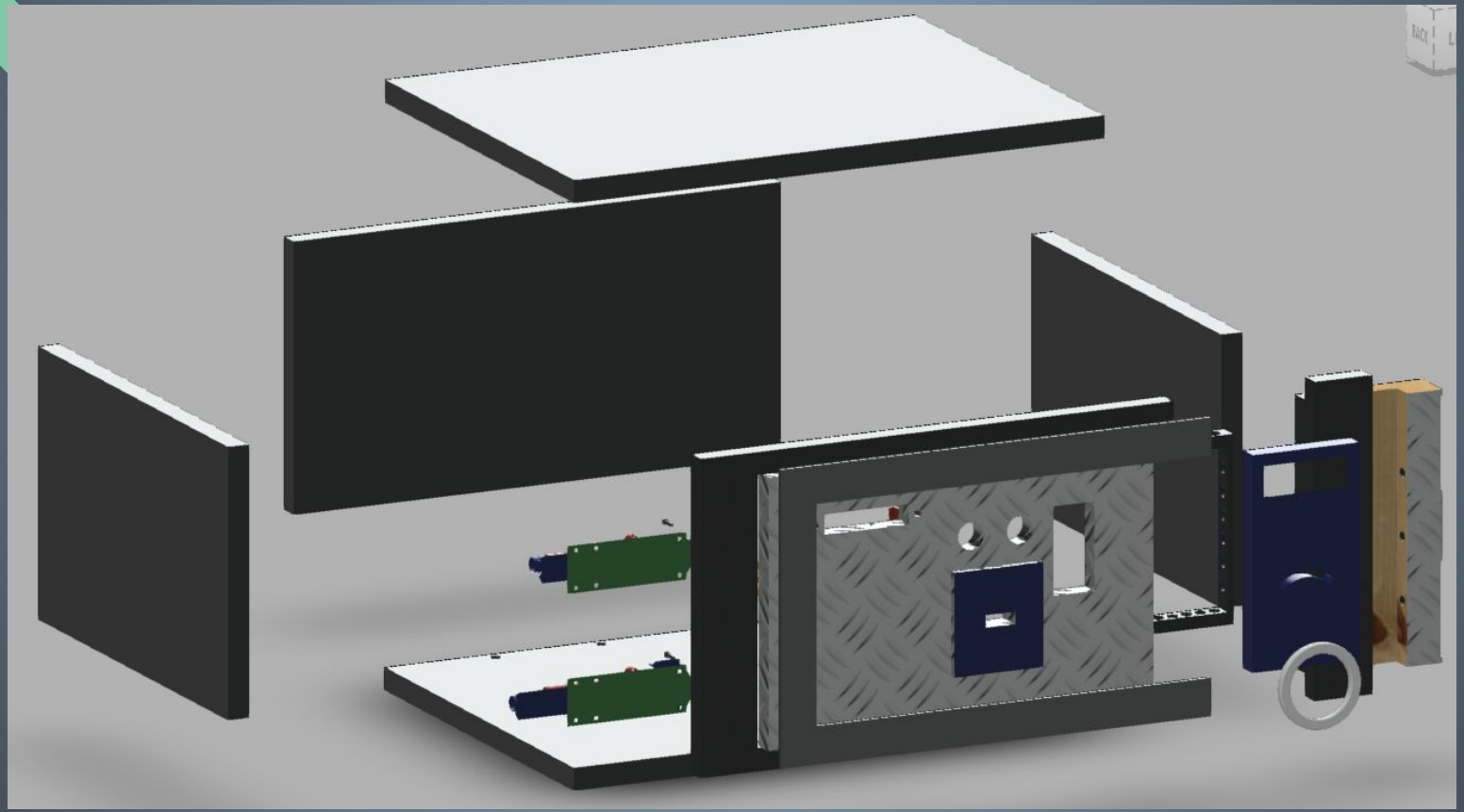
Other features of the product:

- From my research, there is this feature seen on many high security buildings that I think would further increase the security of my device. That is the use of a security door bolt. I have bought a security bolt from the company YALE who supply high quality locks and are under the BSE standards - as required for the commercial product. This is inserted into an 8 mm deep by 10 mm diameter hole in the side of the door connection piece (S1). For this simple mechanism to work and NOT infringe the movement of the door then I need to cut out a large 20x20mx17mm section out of the wood using a dremel tool and then 3D print an inner casing to neaten up the safe.
- My safe also will includes an internal drawer that offers an extra level of security for small valuables such as mobiles, passports or pens. The drawer front is carbon fibre wrapped for aesthetics and had a switch handle as well as a small door lock designed for these applications. So to access the safe, the user will have to pass 4 levels of security; the power switch, the keypad, the rfid and the internal lock of the drawer. This drawer is held upon drawer runners and they are screwed to the bottom of the drawer and the base of the safe.

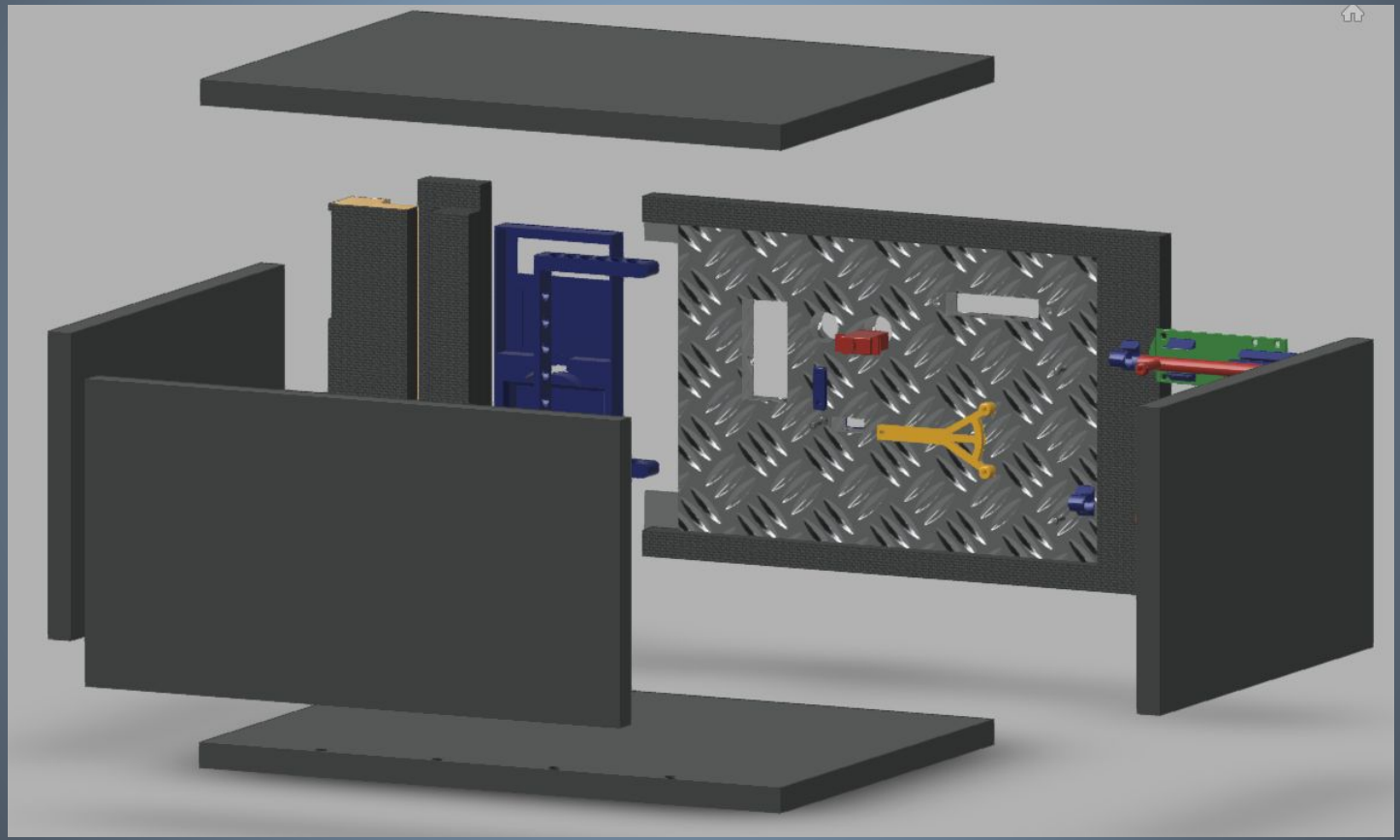


CAD Isometric/General View

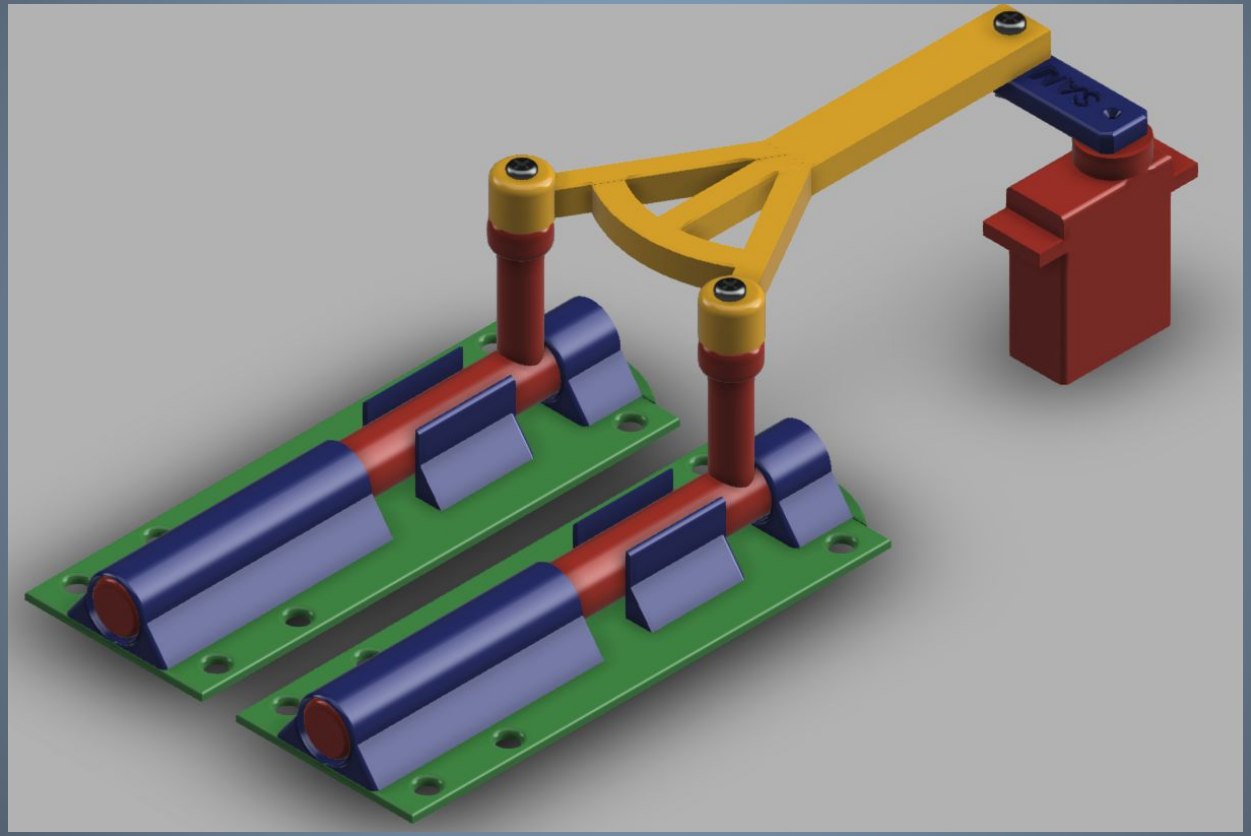
Exploded view (front) using CAD



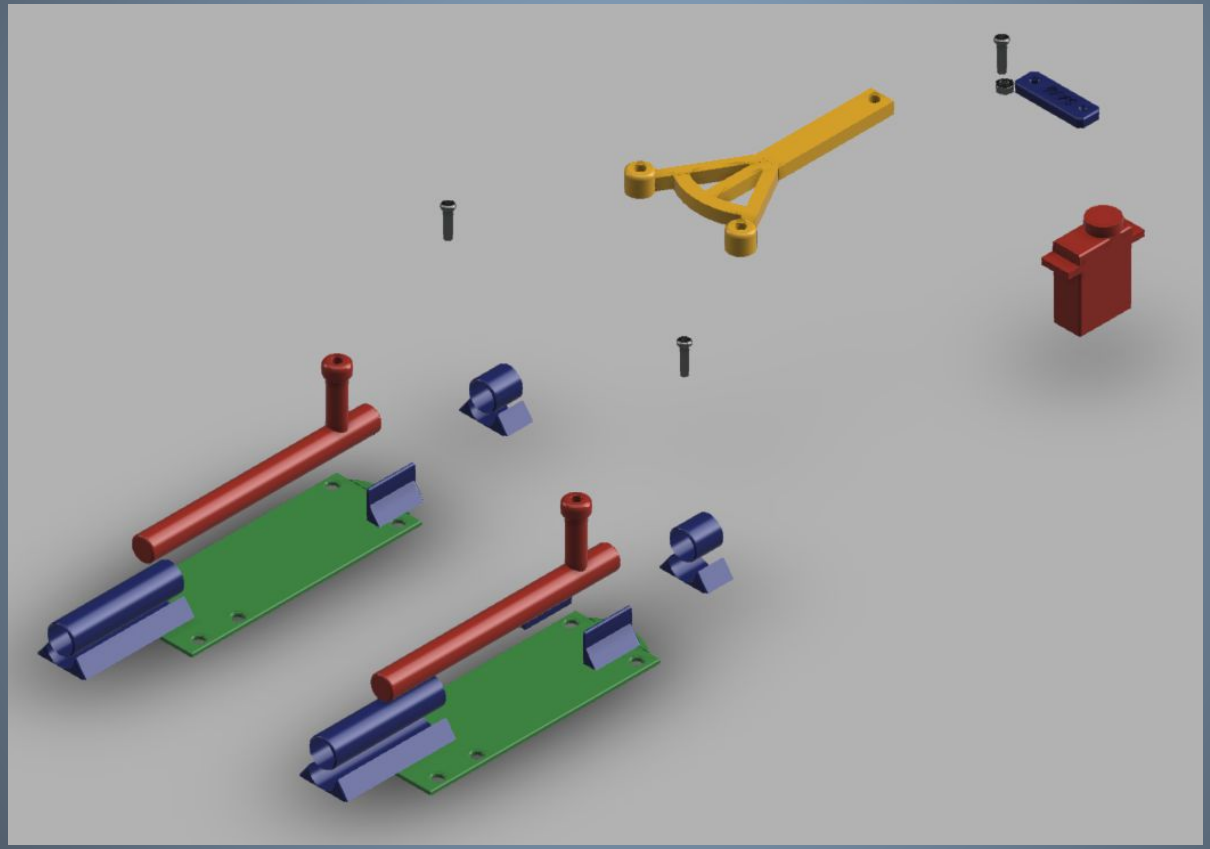
Exploded view (rear) using CAD



Door lock mechanism isometric/general view



Door lock mechanism exploded view



Problem Solving & Resolutions from QC checks

Problem 1: In my modelling of the electronics I found that the servo motor would shake when in a fixed state. It made a shudder/shake noise and did not seem right. To solve this issue, I used a 10k resistor on the Pulse Width Modulation pin on the servo with the arduino. This removed some of the shake noise and the issue was solved reasonably easily. The shaking initially occurred due to the changing processor speed of the ATMEGA 328P on the uno board.

Problem 2: When operating with the Arduino Mega 2560, I had repeated problems with it. On my first board I had multiple issues with the 5v regulator heating up. I was using a 12v input to the board which was well within the operating values for the arduino. Eventually, the 5v regulator blew and the board was fried. Upon this event, I decided to use a 5v regulator circuit to prevent frying another arduino. I also had to buy another arduino Mega. This regulator uses a 12v input and provides a maximum of 3A of 5V in two USB outputs. This part was purchased for a low cost and I was now able to charge low current USB devices which was a great extra feature for my project. At first this was working well with the arduino and I saw no problems. However, I soon saw that the board's 5V regulator was heating and eventually it to broke and the arduino was fryed again.

Problem 3: Following further issues with the mega, I decided to use the more popular uno board since it promised more reliable results. After changing the code accordingly, the electronics worked perfectly on the uno board.

Problem 3: When wiring up the solenoids, I found the 12v control circuit to be at first ineffective at operating the solenoids . This was solved by fixing the wiring in the electrical housing boxes since i found some shorts in my design.

Problem 4: The 3d printed bolt insert was meant to fit in the routed hole that I made. This was simply a cover to hide to rough cut wood on the inside. At first, this part was too tight in the cut out so the door did not close properly. I fixed this issue by redesigning this part and then printing it again.