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This investigation explores redundancy and reliability within the A380 aircraft and how it was engineered reliably to account for environmental changes during use. This refers to the technological systems within the plane which enable it to function at its safest and avoid/avert problems when encountered.

Redundancy and Reliability

Redundancy within a technological system involves having extra components in case of a system failure. This means although they might not be directly used, they are present as a back up to counter for accidents and failures. These components have identical or similar functions as the primary component. For example this might be making a copy of information in case of corruption, or having a second hard drive with disk mirroring within a computer. This means if one disk fails, the mirrored disk has an identical copy of all data and can continue running with that disk. Another example is a hospital with a back-up power generator which activates in the event of a mains power outage. This redundancy saves lives because when an unpreventable problem compromises a situation, there needs to be a plan B which saves lives.

Although making a system more redundant would seem to make it safer, it can actually do the opposite when a system becomes over complicated and the reliability is compromised. This is why there needs to be a balance to ensure that the system is still reliable and doesn't need 24/7 maintenance.

There are many different kinds of redundancy which deal with failures by acting with different levels of intervention. Factors which limit redundancy typically include price, installation and maintenance. Different kinds of redundancy are used to meet the resources that the engineer has. 'Cold' redundancy refers to systems which in the event of failure can switch off or pause and wait for human intervention. This kind of redundancy is for situations where time is not an issue and human intervention is possible. For example if a pressing machine jams or stop in a factory a second one can be used to continue the task while the first is repaired. 'Warm' redundancy refers to systems where time is an issue, and must act after a certain time period to avoid damage to the system. The system might wait 5 minutes for human intervention before it has to act on its own to solve/avert the problem. For example, if a fluid valve fails to open, the system can recognize this and open a second or even third valve to continue the flow. 'Hot' redundancy refers to systems where time is very important and any systems failures need to be addressed immediately. This often means that human intervention is minimal and systems will operate individually to solve the issue. For example in a hospital, if and when the power cuts, the backup generators will immediately kick in to supply power to the building. This requires fast acting systems to ensure that the power is off for as little time as possible, as this can save lives.

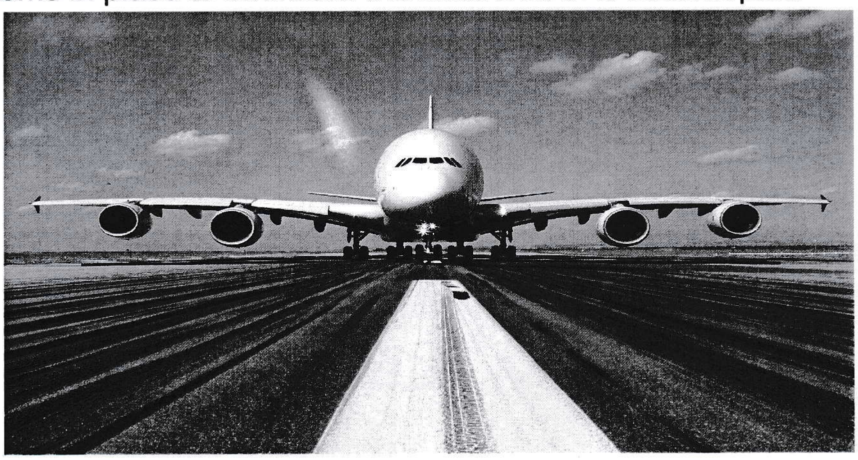
Reliability within a technological system involves the system being able to perform to its specification for an intended period of time. This relates to redundancy as over engineering the redundant aspect of the system will in turn affect the reliability negatively. Reliability can be increased by three main factors; quality of parts, number of parts and the assembly/design of those parts. These three factors help to increase the reliability of the system by lowering the chance of failure and increasing its safety. Quality of parts means that they might be less likely to break, will last longer or function to a greater level of accuracy etc. Increasing the number of parts increases the room for error and the chance of failure as there are more parts that can 'go wrong'. Assembly and design affect reliability because it doesn't matter how good the parts are, or how few for that matter but if the design is no good then the system will be more susceptible to failure.

Reliability within the A380 is also affected by environmental implications. This can often compromise the system's ability to maintain its reliability. For example if weather or climate conditions threaten the systems reliability, the plane will be compromised, either in the air causing an emergency or causing flight delays because it is unsafe to take off. Strong winds and storms can throw the plane around or heavy hail could damage the outer skin. This means that the plane needs higher quality materials and more redundant systems to increase the overall reliability of the plane when faced with unexpected circumstances.

Redundancy and Reliability work together to ensure a safer system is designed. Reliability can be increased with redundancy by providing alternative pathways for systems to operate. For example if the initial sub system fails, there should be an identical system to back it up. This is called double mode redundancy (DMR) which means that if the initial system fails, there are two alternative pathways for the system to function. Triple mode redundancy (TMR) does much the same but with three alternative pathways as opposed to two.

Introduction to A380

While we have been developing aircraft since the early 1900, commercial jet technology is something that we are still mastering. This investigation looks at redundancy and reliability within the A380 airbus which is the largest passenger jet in the world. It cruises at 945km/h and has a range of 15000 kilometers. The A380 has a maximum takeoff weight of 575 tonnes to fly at full speed and can hold a maximum of 853 people. These statistics alone show how vital it is to have redundant and reliable systems in place to decrease the likelihood of a catastrophe.



Planes used to rely purely on the pilot and manual instruments for safety but as the technological revolution has evolved planes rely heavily on electronic embedded systems to deliver the passengers from A to B. As technology has developed it has brought incredible systems which enable a plane to take off, cruise and even land itself with minimal human input. But with this ground breaking technology also brings more hazards as building a very reliable system that can fly a plane thousands of kilometers at tremendous speeds is no easy task.

The difficulty of aviation engineering is that once the plane is in the air, there is no going back and no stopping for a 'quick fix'. Every aspect of the plane must be self-sufficient so that in the event of an emergency, the redundant systems can keep the plane flying or bring it to a safe landing.

Engineers were faced with the challenge of wingspan which would compromise reliability and redundancy for full efficiency and aspect ratio. While the aircraft could have been made with the optimum 90m wingspan, it was reduced to 80 to meet international restrictions. This reduced the fuel efficiency by 10% and increased the operating cost as well. This was a sacrifice that the engineers had to make because of restrictions, which negatively affected the redundancy of the A380. However they counter attacked this by including wingtip devices which reduce drag and therefore increase the fuel efficiency.

An example of redundancy in the Airbus A380 is the electrical power system which provides power for all of the computer systems and electrics of the aircraft. The A380 uses four 150kV electrical generators which are powered by the four turbo fan engines. This way if one fails, there are still three others to keep the systems up and running. In the highly unlikely instance where all four generators fail or there is a shortage in electrical power, the Auxiliary power unit (APU) can be used as a backup. The APU is a small jet engine in the tail of the plane which is primarily used for cabin electronics and other small subsystems. This is a good example of redundancy because a separate system is in place to back up the primary power source as well as providing a primary function. This is useful because it eliminates the need to add a backup supply purely for the purpose of a backup, where the APU acts as both therefore decreases the overall weight and cost by removing the need for both.

Another example of redundancy in the A380 is the Ram Air Turbine which is used in the case of an emergency. The turbine protrudes from the aircraft and converts the wind speed and air pressure into electrical energy that can be used to power the systems. This is an example of triple redundancy because there are the main generators, the APU and finally the RAT. Having three sources of power means that in the unlikely event that the primary and secondary fail, the plane can still continue to fly making it more redundant and more reliable.

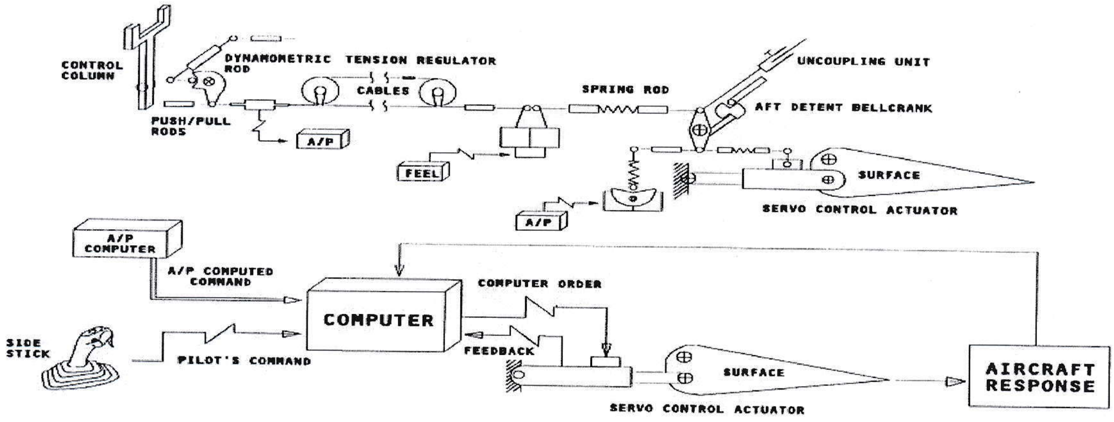
Reliability is increased in the aircraft by using solid state devices to improve performance and reliability. For example using a latching relay which maintains a contact position indefinitely without the need for a constant power supply to the coil. This improves reliability because the coils only need power for instant, so if the power cut after the relay had been activated it would not matter. But if the relay required constant power and the source cut, the relay would switch off and start a problem.

These are two examples of redundancy and reliability influenced the engineers' decision on design and development of the Airbus A380. While not completely necessary, the APU is a form of redundancy *in-case* of system failure by acting as a backup power supply which can keep the aircraft in the air. The latching relays are not 100% necessary, but not using them would be unwise and by using them the reliability of the components and subsystems is increased which overall keeps the aircraft in the air and the passengers safe.

Fly-by-wire Technology

Fly-by-wire (FBW) technology takes traditional manual flight controls and replaces them with embedded electronic systems which control actuators. In the old days, actuators would be controlled by mechanical levers and pulleys which were controlled by the pilot. In the 1930's FBW was introduced to control the actuators with electronic controls which increased the reliability of the systems. The pilot either pushes a button, or moves a lever which creates electrical signals which are then processed by computer systems which correspond to the correct actuators and therefore control the planes movement. This greatly increases the reliability, redundancy and safety of the aircraft because the systems can be set to automatically counter failures, whereas manual controls only operate when operated. For example if the pilot fell asleep unconscious in a manual system, the plane would simply crash, but with electronic systems in place, the redundant detectors recognize the issue and stop the plane from nose diving into ground. FBW improves the reliability of the aircraft and supplies another form of redundancy. It also uses computer systems to guide the pilots decisions and assist the pilot when need be.

An example of this is FBW using multiple channels to send signals between controls, processors and actuators (input>process>output) to ensure that the signal reaches the computer. The computer then sends multiple signals to the actuators which act on those instructions. Another link also sends information back to the computer and then back to the cockpit so that the pilot(s) can see what instructions have been sent to the actuators.



FLY BY WIRE PHILOSOPHY

The photo above shows the differences between manual controls and FBW technology. As pictured, manual aircraft systems contain countless numbers of technical parts which introduces massive rooms for error, as only one part needs to fail and the whole system goes down. Also, parts like cables and springs wear down and need replacement which means ongoing maintenance and money to keep the system up. The FBW diagram shows how much more simple and sophisticated electronic systems are. The pilot produces an analogue input which converts a digital signal which is understood by the computer. The computer decides what action to make based on the input and sends the 'computer order' to the control actuator. While multiple channels is one form of redundancy, another for is used to increase safety and reliability within the system. There is a feedback channel which runs back to the computer and then back to the cockpit so that the pilot can see the instruction sent to the actuator. This improves redundancy because otherwise pilots would have to rely purely on the computer system to send the right instruction to the actuator. By adding this additional channel, pilots can be more dependent on the systems in knowing what the actuator is doing and this was something that was never possible with mechanical controls.

Another input to the computer is the FBW subsystem that helps to stabilize the aircraft. This uses sensors and gyroscopes around the aircraft, as seen in the diagram as 'aircraft response' to gain information about the positions of the actuators and act on them if needed. It does this to assist the pilot and to create a smoother ride. It increases safety of the flight because instead of the pilot constantly focusing on stabilizing the plane, they can focus on more important tasks such as taking off and landing etc.

FBW technology also reduces the overall weight of an aircraft as electronic components weigh very little compared to heavy mechanical parts. This means the plane is easier to control and it will consume less fuel. Lower fuel consumption means that the plane can travel further on a full tank and increases the economy. A lower fuel consumption also increases the reliability because in the case of an emergency the aircraft will have more fuel to work with therefore more time to react to the issue. Another benefit of FBW that increases redundancy and reliability is the low maintenance compared to mechanical systems. Electronic systems are highly reliable and rarely fail or need replacement, compared to mechanical systems which have moving parts which require lubrication, tension adjustment, leak check and fluid changes. Electronic systems often more redundant because given their size, multiple backups can be installed in case of failure but there is typically only enough room for ‘one of each’ type of mechanical system because they are so big and heavy. This improves the overall safety and reliability of the aircraft.

Another feature of FBW technology is the advanced computer systems which interact with each other. For example if one computer fails, the others will remove it from the system by either shutting it down or rebooting it. If a flight control computer proposes numbers or information that doesn’t agree with the other computers, it will be deemed faulty and will be restarted or ignored. The backup computers also run simpler version of the primary tasks to increase reliability. The main systems have to differ from the backups otherwise one electromagnetic pulse could wipe out the entire lot. The simplicity also acts as an aid as more complex programs are more likely to fail or have issues therefore the backups’ will be more reliable.

This is how fly by wire technology has changed the face of aviation engineering and how it influenced the engineering of the Airbus A380. Multiple backups’ increase the redundancy of the electronic systems and therefore make it more reliable. FBW technology helps to aid the pilot in flying the plane by applying systems to stabilize the aircraft. As a result of this the plane is more reliable and safer to fly. Electronic systems also have a much lower failure rate compared to mechanical systems and require only a fraction of the maintenance. FBW also reduces the weight of the aircraft to save on fuel and benefit the economy. FBW is a smarter way to engineer planes as the computer systems installed act like co-pilots which can stabilize, monitor and report back on any errors that might occur during flight. Out of the two options, engineers chose FBW technology because of all of the benefits that come from using it opposed to mechanical systems. This is how FBW technology influenced the design and development of the Airbus A380 systems.

Redundancy and Reliability Avionics

The A380 Airbus requires the highest quality of componentry to ensure the safest flight possible. Engineers explored the world of avionic parts and came up with integrated modular avionics (IMA) architecture which is a military grade avionics system of very high quality. As the A380 is such a large aircraft with complex electronic systems and a large passenger capacity, it is essential that every effort is made to ensure the safety of the passengers and reliability of the plane. Avionics includes communication, navigation, monitoring, flight control, collision avoidance systems and black box devices.

One key piece of redundancy within the avionics system is the Network Systems Server (NSS) which is like the brain of the plane. This network acts as a data base for manuals and charts which were traditionally printed in books. The systems also comprises navigation charts, performance calculations and a aircraft log book. This system is accessed through the eight multi-function LCD displays which are located in the cockpit and can be controlled with a keyboard and trackball. This system as a whole creates a more redundant environment for documentation for many reasons. The NSS can store thousands of pages of resources and can be searched for and retrieved in an instant, compared with traditional manuals which would lose pages, were bulky and inconvenient to use. While the manuals are still required on board, they must be constantly updated which becomes a tiresome task. Software can be easily updated in seconds without the need to write an entire new book. By accessing a data base with a keyboard and mouse, pilots can quickly find the information that they need to solve the issue and potentially save lives, making the system more redundant and reliable.

Like the FBW technology, IMA is used to increase the reliability and redundancy of the subsystems and the aircraft as a whole. IMA acts like a co-pilot, making decisions based on calculations and sensors to stabilize the aircraft and inform the pilot of anything happening in the aircraft. This way pilots are no longer required to constantly check for stoppages, as the subsystems like IMA will do it for them, and much faster, and report with much more accurate detail. A lot of the time minor issue will not make the attention of the pilot, but the IMA will just resolve the issue unnoticed. This is another example of redundancy because the pilot doesn't have to make as many decisions and as we have seen from history, a lot of aircraft incidents have been caused by human error. This makes the aircraft safer and far more reliable.

Reliability and Redundancy of Rolls-Royce Trent 900 turbofan engines

The A380 Airbus comprises four state of the art Rolls-Royce Trent 900 or the Alliance GP7000 turbofan engines which produce three hundred thousand pounds of thrust. Getting something the weighs over five hundred tonnes off the ground and into the air is no easy task, which is why the most powerful, fuel efficient engines were sought after. Many models of engine were available but the Trent 900 supplied the best redundancy and reliability. Unlike older models, the Trent 900 provides greater thrust for the same sized engine therefore no additional drag is brought into the equation. It is also 15% lighter than previous models which means more fuel efficiency. These engines are so efficient that they consume less than three liters of fuel per passenger per 100 kilometers. The engines work in conjunction with the aerodynamic design which enables it to be incredibly redundant even in highly unlikely scenarios. For example even if all four engines fail, the plane can still fly for 240 kilometers (at cruising altitude) which is a massive distance to bring it to a safe landing. If three blew out then with one engine the aircraft can glide for nearly three times the distance, making it 640 kilometers (from cruising altitude). With two engines down, there is only a minor defect and the plane should still be able to complete the flight. With one engine down, there is very little difference felt and the only defect is a reduced amount of thrust. This shows how incredibly redundant the engines are as even without all four, it can still continue to fly! This makes it incredibly reliable and redundant and means that in the unlikely case of engine failure, the plane will remain safe.

The A380 uses disk brakes in the wheels and flap brakes to slow the aircraft. The engineers behind the Airbus originally planned to have enough braking power without the need for thrust reversers. After realizing that this was not the case, they added two inboard engines with thrust reversers to back up the breaks when the runway was slippery. This is a great example of redundancy because the engineers recognized that the system was not at its maximum potential safety so they implemented another system to back up the primary system.

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http://www.r.com/types-of-redundancy.shtml

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