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Oskar Niburski
Ai Nakada
Joao crespo
Hadeer khaled
Jia Qiang

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1.1 Abstract

Chinese abstract

针对双引擎飞机飞行过程中失去动力，提出了一种可行的安全降落的方案。我们以庞巴迪的Q-400双引擎飞机为例进行了自动控制系统及机翼的设计。

我们首先探索现有技术。第一是飞行员主动控制飞机安全。当其中一个引擎失去动力，飞行员必须尽力降低失效发动机一侧的拖曳力，控制失效发动机引起的失衡。但是由于飞行员长期依靠飞机自动驾驶系统，遇到突发状况时极易出现误操作。第二我们研究了人工智能领域的无人机自动驾驶系统技术。第三我们对比分析了滑翔机与现有商用飞机的区别。

我们在这三种技术的基础上提出了新的方案。该方案可认为是一种自动的滑翔机系统。该系统主要依靠两个方面工作：先进的机器智能学习算法（强化学习）和可自由伸缩的机翼设计。其中强化学习算法主要依赖Q-学习算法和马尔可夫决策链。可伸缩机翼设计能够增加飞机滑翔时的下滑比。同时，机翼的伸缩可以丢弃一些飞机不必要的设备，例如失效的发动机、多余的燃油等，这将减少整机20%的重量，对安全着陆有着重要意义。机器智能学习和可伸缩机翼协调工作，使整架飞机成为一架自动驾驶的滑翔机，以更有效地帮助飞行员安全着陆。最后，我们分析了该方案的可行性、经济性、存在的问题以及该创新设计的前景

We have proposed a possible solution to power loss in a twin airplane to create a safe, reliable, and efficient crash prevention system. In order to understand this problem, we have made various assumptions on the initial design of the aircraft. We have assumed we are creating a design for the Bombardier Q-400 plane, during flight, and it has a twin-engine model. Moreover, we are assuming that one engine fails, in either wing respectively, and that there is an 80% loss of power.

To solve this problem, we first explored the background of the current field of aviation. The three main solutions are pilot techniques, autopilot systems, and gliders. Pilot techniques involve a combination of stalling techniques, and maneuvers. A pilot, in the loss of power, generally must counteract the yawing force that happens in the direction of the failed engine. This is the simplest action that of decreasing the drag force on the failed side. Next, one looks at autopilot systems, their operation, and how they aid pilots in flight. It however becomes apparent that pilots have technological dependence on these systems, and this creates a paradoxical scenario where pilots are not comfortable with regular flying and make errors when they themselves take over. Numerous examples are given. Lastly with regards to autonomous systems, we explore the current state of UAVs and drones, which offers a new frontier in the world of AI and aviation. Lastly we explore gliders themselves, and contrast them with the current designs of commercial aircraft. To further understand the problem, we give an analysis of the stakeholders in the scenario.

After considering a few alternate designs, we propose our solutions. The solution itself can be described as an autonomous glider transformation system. This system relies upon cutting edge machine learning technologies, like reinforced learning algorithms, as well as a retractable wing design that increases the

glide ratio of a plane. Furthermore, the new wing design works with a decrease in the weight of the plane by jettisoning all the unnecessary parts, for example, the engine, the unneeded fuel, which results in an approximately 20% decrease in weight. This is more in line with a gliding aircraft's appropriate weight. In tandem, the autonomous system and the retractable wings, work together to assist the pilot in a landing. This reinforced algorithm relies upon q-learning and Markov decision chains. Lastly, the report explores justifications, problems, fiscal feasibility, and the future of the design itself.

1.2 Definitions

This report uses numerous definitions and concepts. Below are a few explanations of the terms found in the report:

- *Blue line*: speed at which a double engine twin plane needs to reach to behave like a single engine plane during its climb
- *Asymmetric thrust:*asymmetric power condition when the netcenter of thrust is displaced from the center to one of the lateral wings, depending on the loss of power
- *Twin engine:* Two engine aircraft under a certain weight class.
- *Minimum control speed on the ground*: minimum air speed at which aircraft is directionally controllable during acceleration along the runway with one engine inoperative.
- *Airborne minimum control speed:* Minimum airspeed at which directional control can be maintained during a critical engine failed with the possibility of wind milling
- *Vy*: Optimal climb rate speed with single operating engine in twin engine plane
- *Aspect ratio*: the ratio of wingspan to body. Calculated by dividing the square span of the wing by the area of the wing.

1.3 Background

If there is one constant humanity has always fought with, it is a human's inability to control chaos and the uncertainty of nature. With fire, we forged torches but caused arson in the process. With homes and industry, we created comfort and ease, but at the same time large amounts of pollution. And this inevitability of our want to control nature leads to ineluctable outcomes is perhaps no more apparent than in the world of aviation.

It is almost unbelievable that we can now fly, and the history of aviation speaks to the greatness of men. And yet still, our human ingenuity is itself a problem, mainly that our systems are not foolproof, and people die in the process while we try to control nature and the outcomes we cannot predict.

Within the recent few years alone, there are multiple examples of our foolhardy inability to master flight. One only needs to look at the 2016 Sunbird crash, the EgyptAir Flight 181 accident, or any of the other various crashes this year alone to see that aviation still is far from perfect. And these reoccurring accidents speak to the importance of aviation safety in modern times.

1.4 Problem Statement

As such, the problem we are aiming to understand and explore is aviation safety. More specifically, we are looking to propose a solution for the twin engine Bombardier Q400 aircraft, a common commercial passenger plane[1]and determine a solution for when there is a power loss in one of the engines. We will also only be concerned with in-flight safety, but will speak about take-off and landing as well.

1.5 Current Solutions

Currently there are a multitude of various solutions, ranging from plane design, to wingspan, to aerial techniques, as well as automation systems. However, to analyze our proposed solution effectively, I will compare automation systems and pilot trained aerial techniques alongside gliding technologies.

Pilot Techniques
When a light twin engine plane experiences engine malfunction, often the other engine is used to get the pilot and passengers to the nearest airfield. When the engine does fail, there is an initial effect of yawing. This is because the thrust line (please refer to the thrust definitions above) becomesoff center, and leads to asymmetric thrust. The size of this yawing depends on the enginethrust and center of gravity of the plane. As the plane becomes to yaw, an ever-growing drag force further enhances it.

Afterwards, the yawing becomes too intense and becomes a roll force. The roll force is initiated on the failed engine side, resulting in an increase in drag, and a decrease in lift. Of course, this is very damaging to the planes aerodynamics (as is any chaotic motion). According to Skybrary, a loss of 50% of available power results in as much as 80% loss in performance.[2]

To counteract this yawing while flying, generally pilots are trained and perform various actions. The simplest action involvescountering the opposite side of increased drag of the engine failure. Therefore, if the right engine suffered a failure, the pilot would use the full left rudder input and slow down the left engine. This would cause the plane to tilt against the asymmetric thrust. Generally speaking, you are to counter approximately 5 degrees toward the live engine.[3]

Furthermore, pilots are taught to lower speed, remove excess weight, and lower the nose to maintain speed and prevent uncontrolled stalling. As such, one can immediately see how this flight mirrors gliders, which will be explored below.

[1]http://planes.axlegeeks.com/l/301/Bombardier-Q400
[2]http://www.skybrary.aero/index.php/Engine_Failure_After_TakeOff_-_Light_Twin_Engine_Aircraft
[3]http://www.faa.gov/regulations_policies/handbooks_manuals/aircraft/airplane_handbook/media/faa-h-8083-3a-3of7.pdf

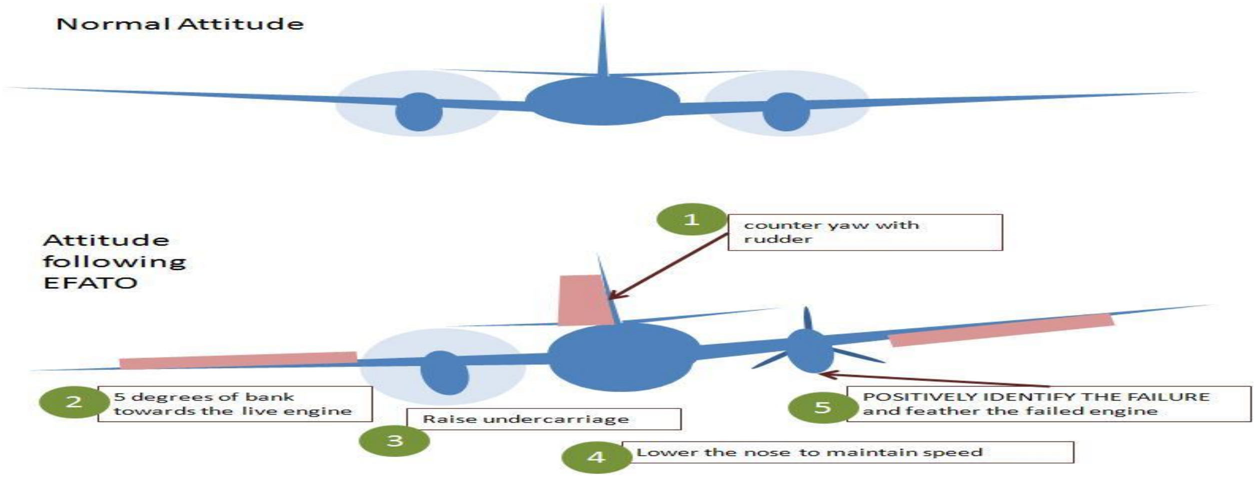


Figure 1. A pilot's techniques to counter engine failure

During takeoff, a series of lifting the flaps and retracting them as well as making appropriate operating engines functionalis necessary. Furthermore, adjustments need to be made in airspeed, as one needs to keep at the airspeed now appropriate for a single engine climb.

As a result, it is clear that pilots are trained in many different techniques to prevent from serious and fatal actions. However, often in moments like this, during engine loss, the pilot takes over from any autonomous system. Therefore, it is important to look at autonomous systems, and see their basic overview for now, followed by an understanding of pilot systems.

Autonomous systems

Autonomous flight systems, or autopilot as it is commonly known, flies planes by counteracting basic stimuli on the plane. A great overview can be seen in the airspace.net.[4] From a basic view, pilots provide the parameters to the automated flight system. This automated system then adjusted itself according to these predesigned parameters. As a result, it is safe to say pilots become passive operators of planes, and not active fliers.

More to the point, autonomous systems respond to the simple stimuli and adjust according to the provided parameters. When something goes out of line, it sends responses to the rudders to adjust the planes forces.

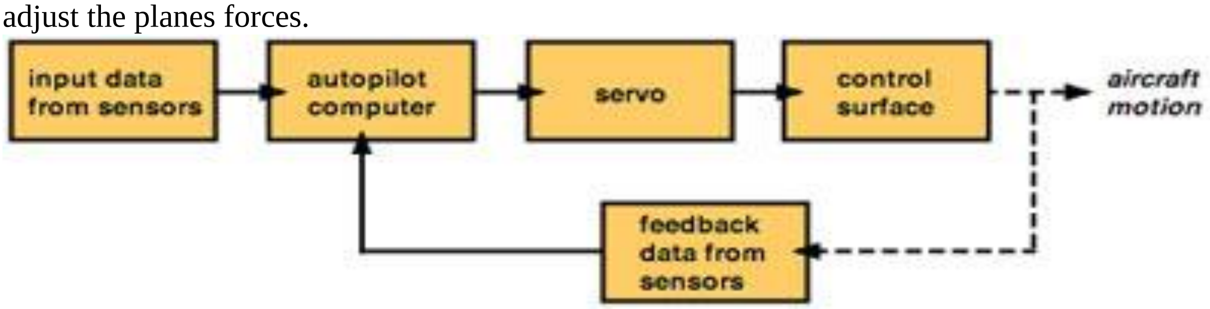


Figure 2: Diagram of Autopilot systems[5]

[4]http://theairspace.net/technology-2/how-does-autopilot-work/
[5]http://science.howstuffworks.com/transport/flight/modern/autopilot3.htm

There are various modes, which determine the type of input the autopilot responds to.[6] The mode of interest here is the power steering mode. In this mode, the plane is controlled partially by the autopilot system as well as through its drive system, thus having a balance of autopilot and pilot control.

Furthermore, when a plane is failing, it is often noted as was the case in the engine breakup in Singapore in 2010, that "the normally 'simple to understand' failure information can swamp the crew and either hinder diagnosis or distract the crew from the principle task of FLY THE AIRCRAFT" [7] As such, it is imperative to design a solution which minimizes this primary engine failure, decrease the amount of information a pilot has to deal with, and lastly, nullify any secondary effects by acting more as a glider.

It should be noted that automation itself introduces numerous problems. When technology automates a large part of anyone's job, they become lazy. This can be seen in the Turkish airline crash of 2009, where the pilots did not recognize the speed decline of the aircraft, which was performed by the autopilot system.[8]

As such, the active role of pilots becomes mainly one of monitoring and maintenance, where they do very little to actually fly the plane other than land and take off. Although the workload is decreased the attention-related resources of a pilot are not well managed. As such, if a pilot could be given the correct information that enhances their attention, they would have a greater situational awareness and partaking in the technology well. Like chess players, the best competitors are those who work with computers. As such, to decrease Automationdependency one must enhance the confidence of the pilots through a combination of knowledge of the automated systems and a greater symbiosis of pilot and technology. This would lead to an enhancement in efficiency as well as safety.

Most UAVs have some sort of autonomous system, often the MicroPilot system.[9] The system itself is powerful. Like most autonomous systems on planes currently, it provides simple route planning, parameter adjustment, and basic flight monitoring. However, as Arstechnica puts it, automation has many problems: "Airflow gets turbulent and mechanical systems continually get more complex, so it can be very hard to accurately predict how an aircraft will respond to a particular control input. This makes designing control systems very hard, and even affects relatively "simple" systems like the quadrotor."[10]

However, with the advent of many autonomous flying systems, from drones to trucks to lawn mowers[11], one must wonder if the same cannot be applied to the world of flight, and especially in terms of engine failure. Furthermore, there have been many developments in the field of aviation automation and understanding of deep learning and neural networks, which may allow for

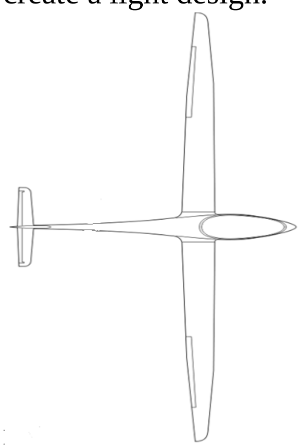
[6]http://tmqeurope.com/information/how-does-an-autopilot-work/
[7]http://skybrary.aero/index.php/A388,_en-route_Batam_Island_Indonesia,_2010
[8]http://skybrary.aero/index.php/B738,_vicinity_Amsterdam_Netherlands,_2009
[9]https://www.micropilot.com/
[10]http://arstechnica.com/information-technology/2012/11/a-beautiful-robotic-mind/2/
[11]http://jmlr.org/proceedings/papers/v28/sutskever13.pdf

advanced automation during a power loss.[12] As such, we are interested in coupling these systems, automation, and increasing the flight endurance of an aircraft, by making it more of a glider.

Gliders

Therefore, it is further necessary to understand glider technology. When a plane loses energy, the need to extend the aviation gliding distance is utmost apparent. Most commercial airplanes and gliders have vast differences between the two.

Gliders have no engine, which means the fuselage is small and light. They are often smaller airplanes, and the design is completely streamlined to create less drag in flight. The planes themselves are made of fiber glass and carbon fiber. The main difference however is the aspect ratio of wings. As is the case with most glider design, the whole hope is to reduce drag and create a light design.



The problem with current commercial aircraft, like the Q400, is that a high aspect ratio is nearly impractical because bending of the wings occurs. Not only that, a dangerous phenomenon known as wing warping occurs where the wings cannot take the aerodynamic forces at high speed, causing them to break. [13] Furthermore, the maneuverability of a plane with larger wings is decreased, as they have an incredibly high moment of inertia. Lastly the limits of airports keep aspect of ratios of planes nple the Boeing 777 has an aspect ratio of 9). A larger wingspan would cause the wings to hang during takeoff and landing.

That being duly noted, when there is a loss of engine power, a commercial airliner often has to have a glider landing, or simulate the flight of one.

1.6 Constraints/Assumptions

The constraints we put on the problem are those we impose on ourselves to provide a more scoped answer. We know the landing safety built must be incredibly light, but it also must be feasible.

We also assumed we are only working with twin-engine planes, especially the bombardier Q400 for reference. We further only dealt with in-flight problems, as well as that only one engine failed. We are also assuming there is the possibility of landing somewhere nearby that is hospitable. Lastly, we are assuming that minimal power is available to the plane.

[12]http://cs229.stanford.edu/proj2014/Anil%20Variyar,Application%20Of%20Machine%20Learning%20To%20Aircraft%20Conceptual%20Design.pdf
[13]http://www.boldmethod.com/blog/article/2015/02/your-guide-to-glider-flying/

1.7 Stakeholders

We have identified a series of stakeholders in this problem.

The first and most obvious are the passengers in the plane. Their safety is most important to them, as well as the convenience and non-obtrusiveness of a solution. If a plane loses power, safety takes priority, however they would be inconvenienced if the solution involved putting them out of control of the outcome. For example, attaching parachutes to all of their chairs and then launching the passenger to the sky would perhaps keep them safe, but would by no means be a way for them to be kept in total convenience. Instead, they feel their safety is more in jeopardy, which causes anxiety, stress, and a lack of trust in terms of autonomy from their airline.

Secondly, the stakeholder most in charge with the safety of these passengers in the airplane is the airline itself. The airline prefers the solution to come at a cost to them, balancing safety, cost, and economies of scale well enough.

Lastly, the pilot who is in ultimate control of the aircraft has the priorities of delivering their passengers home. As the one who is often scrutinized during mistakes, it is up to them to figure out the most effective way of protecting their passengers.

Looking at the table for stakeholder priorities, one can see that safety is ultimately the most important, followed by cost. Thus our solution will be concerned primarily on safety, and give a rough estimate on cost.

Table 1. Stakeholder

Stakeholder	Priority 1	Priority 2	Priority 3
Passengers	Safety	Convenience	Cost
Airline	Cost	Safety	Convenience
Pilot	Safety	Convenience	Cost

Table 1: Stakeholder chart

1.8 Introduction to Solution

As such, with the general understanding of the problem and the state of automation, we are able to come up with an appropriate solution. That solution is to fold, an autonomous transformation of aviation structure to become more glider-esque. This couples the solution of taking over from the pilot to reduces errors, and also make the plane become more like a glider.

If the plane can remove the pilot from the system, and learn from the best glider technologies, it using machine learning and sophisticated control algorithms will be able to remain stable, increase flight endurance, nullify aero-elastic effects, and land safely during an emergency.

2.0 SOLUTION EXPLORATION

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2.1 Alternate solutions

Before we go into our own solutions, it is important to note the various alternative solutions we were considering. The first was complete alternative design of aircraft.

Referring to figure 1 below, providing a gliding structure with at least four rotors (as explored in the patent in the footnote[14]), we thought this would allow for more control vertically in terms of flight. With vertical take offs and landings, we could perhaps provide a better alternative to landing mechanisms currently explored in planes. The horizontal rotors within the wingspan however propose many problems, let alone significantly changing the aerodynamics of planes.

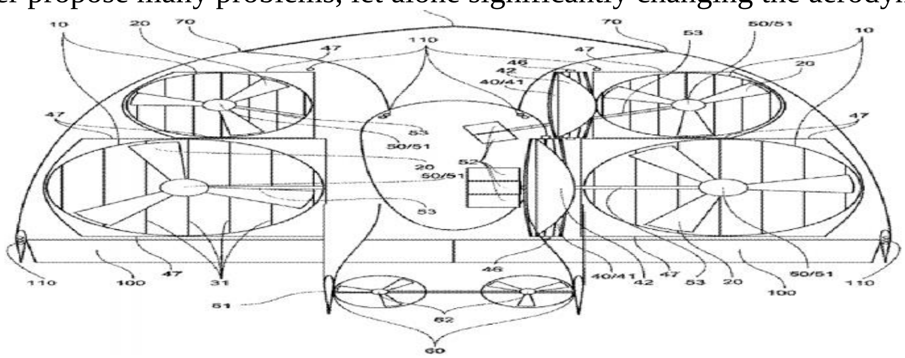


Figure 3. Drone-like airplane design

Yet it’s futuristic slim build led us to gliding technologies, to remove the resistance and drag an aircraft encounters.

Further alternate solutions explored were solar power. Because of the Solar Impulse 2[15] the possibility of alternative power sources when power is lost has never been more reachable. However, we determined that although a viable solution, it is an expensive one. As a result, we decided to focus on post energy loss, and the mechanisms of increasing flight duration in order to land a plane.

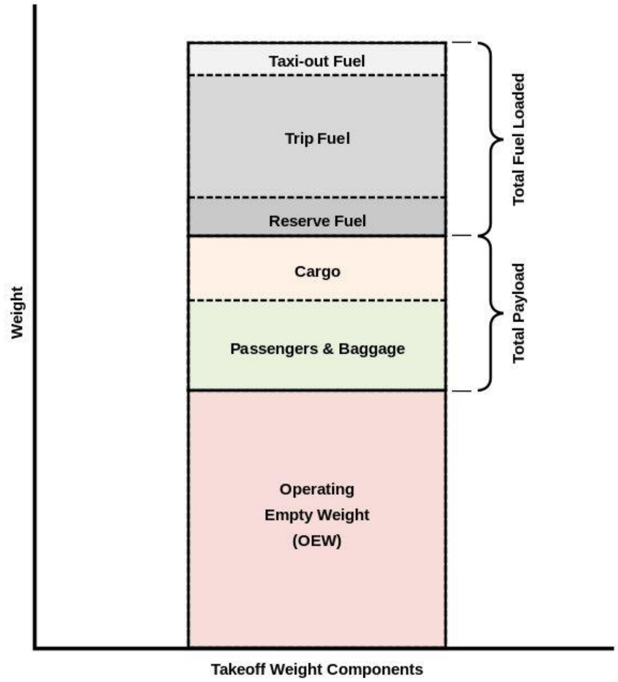
2.2 Solution - Proposed

The proposed solution hopes to

1) Prevent pilots from making rash decisions and information overload
2) Perform FAA approved techniques for gliders
3) Act like a glider in emergency landing

[14]http://www.freepatentsonline.com/20090008510.pdf
[15]http://www.huffingtonpost.com/2015/06/12/solar-flight-japan-hawaii_n_7572872.html

As a result, we believe that creating a semi-autonomous flight control system while changing the



dynamics of the plane during energy loss and engine failure allows for a great solution to this problem.

Concerning the transformation of a plane into a glider, obviously there are unique problems to the solution. Most commercial airlines believe that there is a clear dichotomy to engineless small gliders and fuel powered dream-liners. And this is entirely correct.

However, we believe that during engine loss, if one could loss the engines completely, then one can decrease the weight of the aircraft. Using the formula for aircraft weight approximation below, if an airplane loses its fuselage, engines, and fuel, then the plane is drastically lighter.

$$W = w(fuselage) + w(wing) + w(engine) + w(payload) + w(fuel)$$

Referring to figure 4, we have a weight breakdown. Assuming then we remove the operating weight by 50% (engines) and then the remaining trip fuel, we have decreased the assumed weight by at least 20%. This allows for a more effective glider to counteract the performance failure.

By decreasing three of the above variables, we are ultimately lowering the number of discrete parts of the plane. As such, we now have a lighter plane. Importantly, one of the characteristics of gliders is the actual lightness of an aircraft to have a larger buoyant force.

Once the engines have been removed, the retraction of the wings to increase the aspect ratio begins. These retractable wings would retract based on the control unit system built. It is imperative to realize that at higher speeds, the wings would succumb to warping. To counter this, the design control unit itself would need to retract appropriately to a correct aspect ratio based on speed.

As such, with the longer and narrow wingspan controlled by the automated system, the pilot now has a plane acting like a glider. Here is where the pilot can be semi-autonomous, where the system itself increases the flight endurance so a pilot has not only more time to make a decision, but aid from the system to navigate.

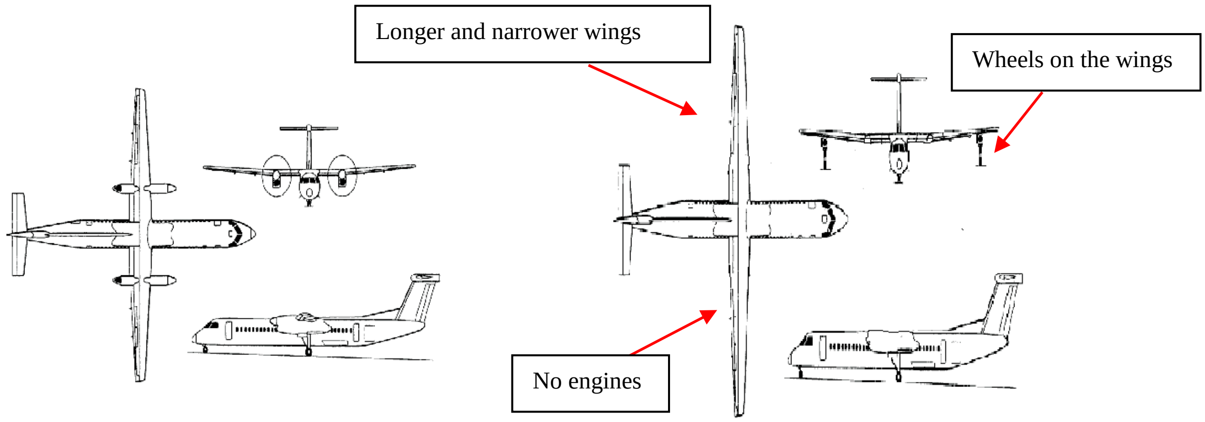


Figure 5. Schematic of the change in the aircraft

During landing, the longer wingspan poses itself as a problem. Two solutions emerge from this however, either the wings retract again, or skidders are used under the wings to prevent from slopping.

The control system itself poses many problems, but because of advancements in machine learning, it becomes a relatively well-known computer science problem. In short, the technique being employed will be a mix of deep learning and reinforcement learning, both being an example of unsupervised learning techniques. Put simply, reinforced learning is where control data is recorded of some model, and then regression models are built on top of it. In our example, one would analyze glider flight by the best gliders, as well as for commercial airliners.

Once the data becomes analyzed and compartmentalized, a control algorithm is applied which runs the simulation of the data hundreds of thousands of times. The parameters of the algorithm with the outcome of how to land successfully can change each time to simulate the real data to the best of its ability. From the control data by commercial airlines we are trying to simulate the glider data, which is what commercial airline pilots are supposed to do when their aircraft is failing.

The learning algorithm eventually creates a model (via regression, Gaussiandistribution, or star-cluster analysis mainly) to map the control data to actual flight data. The control algorithm then can be applied in the numerous scenarios the plane itself would be performing. Although the flight patterns are fairly nonlinear and chaotic, because of the thousands of simulation, it will fit in some likely permutation of the data or can be extrapolated from the algorithms input (known as probabilistic inference). Of course, when things to go out of control, the pilot can certainly take over, and because the plane itself is now more glider-esque, it allows for greater control on the pilot's side of things.

As a result, we now have a fully trained autonomous system with reinforced landing that can take over for the pilot in an emergency-landing scenario. The system itself performs the required techniques based on the best gliders' data. This is far preferred to a pilot taking over and making an incorrect decision because of unavailability of information.

Moreover, coupled with a redesign in this scenarios, with the loss of fuel and excess weight, we streamline the design more to a glider's structure. This glider structure allows us to extend the flight duration and flight endurance, maximizing the time that the airplane has to make a correct decision. This transformation is essential, because most commercial airplanes lack the wingspan and design to be a proper glider structure. With the increased wingspan and smart controllable retracted, we can change the altitude and speed of the aircraft to make the correct decision when the time is necessary.

2.2 Solution – Competition Analysis

In the IDCIC report, we were asked to complete a crash prevention system, which can ensure the landing safety when an airplane loses power. The design itself must be reasonable and reliable with the lightest structure for its best economical efficiency.

Our system is comprised of two things, an additional wing retraction, adding a small amount of weight to the initial aircraft. During the emergency system, the plane itself loses much of its weight to become lighter. Moreover, there is perhaps nothing lighter than software, which itself is used to provide a more reasonable system.

The reliability of the system itself could be questioned. However, referring to the sections below lays credence to the point that our plane represents a reliable and efficient enhancement.

2.2 Solution – Advantages

Our solution has many advantages.

The first is it a sleek, glide like design, seen in the figure below.

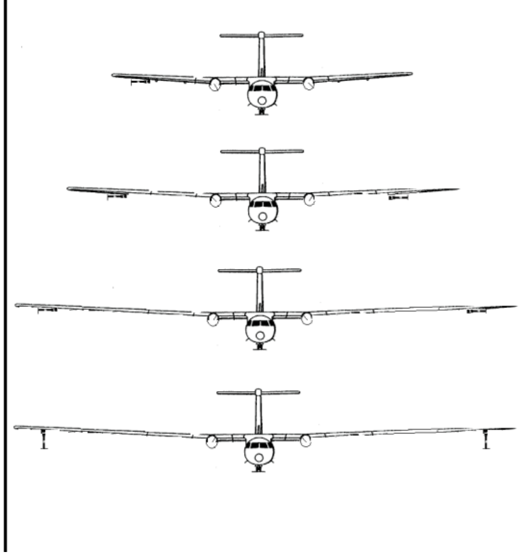


Figure 6. Retractable wings schema front view of the Bombardier Q400

The aircraft itself allows for multiple stages of retraction and modes of flight. In higher altitudes and speed, where large wind warping is possible, the plane itself and the autonomous system would like to try and counteract power lost with more aerobatic moves.

During lower altitudes, lower speeds, where gliding is much more manageable, the wings would retract to larger to distances, thus increasing the aspect ratio.

Besides this retractability, the design itself offers the ideal aerodynamic properties of a glider without sacrificing the aerodynamics necessary in commercial, long-distance flight. Although some wing adjustment would be necessary, we would stay core to the current designs of aircraft, and just add the retractable wings on the underbelly of the current wings. Once initiated, servomotors would control this system and move the plane.

The advantages of the reinforced learning system paired with deep learning are incredibly vast. Not only do we get to simulate the best pilots, but also we get to simulate the best pilots consistently. Of course each scenario involves some amount of creativity and dependence of technology is difficult, but an overdrive by the pilot would allow for the pilot to work with the autonomous system in a symbiotic way.

Furthermore, the software system, used in large-scale flight applications already, is fully tested in companies like MobilEye and others. These companies specialize in the world of UAV drones and self-driving cars. Therefore, using their systems with gliding algorithms would allow for a much-enhanced flight during emergencies.

2.2 Solution – Problems

One obvious problem is the design of an aircraft's engines. Most commercial airlines, the Q400 being no exception, have their engines often built into the underside of the wing. To remove them would require an entire redesign of the respective wing. For the sake of argument and design constraints, we assumed the retractable glider wing design had a relatively simple discharge of engines, which had mini parachutes to prevent them from destroying property below.

Beyond the need for redesign, another problem is the reliability of software systems. There is an often-misplaced lack of trust amongst humans in autonomous AI systems. However, because pilots are already well acquainted with autopilot systems, we believe they can find the new system advantageous. Furthermore, we are confident that proper training with a new, well-trained dataset would provide a certification of trust from the pilots.

The last problem we are aware of is the position of the retractable wings. Because they would be under the belly of the initial wings, they would increase drag force.

2.2 Solution –Approximations

Below is an approximation of the glide ration enhancement with an increased wingspan. Most gliders, by base estimates, have a glide ratio of around 60:1. The Bombardier Q400 has a glide ration of 15:1.

To illustrate these concepts explored above, an example is necessary. Assuming the Bombardier has around 2.5 nautical miles ofglide per 1000 ft altitude.

At a short trip, around 4600 ft, the Bombardier would be able to glide around 11.5 nautical miles, which is around 18 km.

However, with the proposed aircraft change in wingspan, we increase the glide ratio to approximately 20:1. This results in at least 3.3 miles per 1000 ft.

As a result, this gives for a short 4600 ft altitude, the plane would glide for 16 nautical miles, or 25 km. This would provide 16 minutes of flight endurance, 7minutes more than with normal wingspan. [16]

It should be further stated that the lift-to-drag ratio, by increasing the glide ratio, also increases. As a direct result, the aerodynamicproperties of the airplane increase, generating the lift with the drag

2.3 Solution – Justifications

One thing we wanted to allow for is graceful degradation. We believe we accomplished this with both the software system and the retractable wings.

Through the software system, we begin by performing what a pilot is supposed to do. This means that in points of failure, and a changing dynamic, the software will future reference the value and recalculate the correct outcome. However, if the software goes awry, which certainly happens, the pilot can take over. This is useful, more so, because with the improved gliding design, the pilot should have an easier job to land the plane.

Furthermore, the retractable wings allow for a fallback. Assuming their aerodynamics get compromised during flight, once retracted, they would be able to fall off. This allows the pilot to have full control of their original wings. Therefore, they can still perform a rough, low power landing with their regular design. As well, the software will notice these large changes, and make the correct suggestions or adjustments necessary.

It is important to also note, as seen in Appendix 3.1, that fallbacks are necessary in twin engines. Like in multiprocessors, when one engine fails, one can rely on the second engine. More to the point of our own system, when the plane's engines fail, the graceful backup is now the autonomous systems.

2.4 Solution – Fiscal

One obvious important point of note is the feasibility of the designs. Below you will see a rough outline of the breakdown of the new design. Most of this information comes from the opencourse regarding aviation design by MIT.[17]

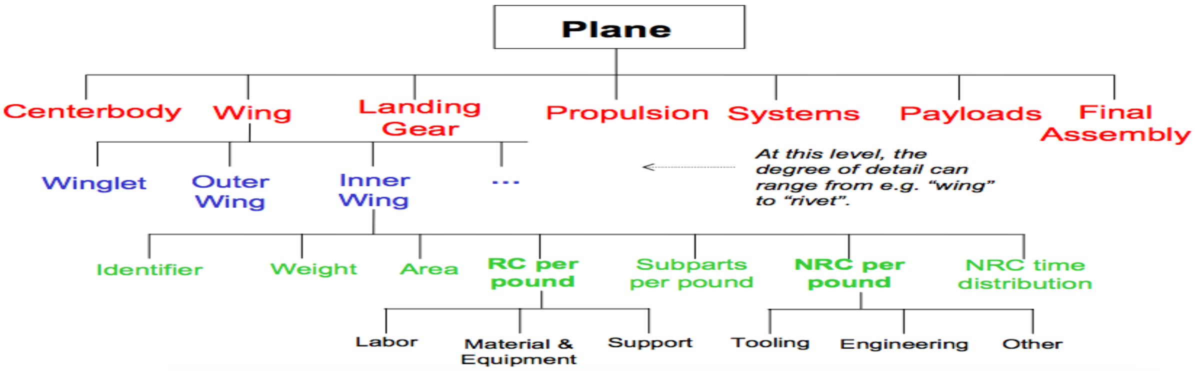


Figure 7. Airline parts

[16]http://aviation.stackexchange.com/questions/2999/how-far-can-airplanes-glide
[17]http://ocw.mit.edu/courses/aeronautics-and-astronautics/16-885j-aircraft-systems-engineering-fall-2004/lecture-notes/pres_willcox.pdf#search='aircraft+wing+the+cost+price'

Most of the price of the can be extracted from the development cost model, visualized here:

$$C(t)\ Kt\ a\text{-}1(1\text{-}t)\ b\text{-}1$$

Using this value, we have a rough estimation of cost, which is around a total cost of 26, 957 dollars. Here is the rough breakdown.

Table 2 Costs breakdown

	Engineering	Tool design	Tool fab	Support	Totals
Wing	$10,640	$2,793	$9,257	$1,250	$26,597
Empennage	$31,293	$8,214	$27,225	$3,812	$78,234
Fuselage	$19,256	$5,055	$16,754	$2,262	$48,140
Landing gear	$1,499	$393	$1,304	$176	$3,749
Installed engines	$5,216	$1,370	$4,538	$612	$13,037
Systems	$20,585	$5,403	$17,909	$2,418	$51,456
Payloads	$5,108	$1,695	$5,619	$759	$16,145

2.5 Solution - Future

Beyond the actual accrual of test data, getting glider’s to agree, and a greater understanding of the problem, one enhancement would be a glider/commercial hybrid design of the aircraft. Currently, we simulate a glider only in emergency scenarios, but there might be an argument for a full hybrid that allows for greater gliding capacity when necessary.

Furthermore, although there is a reliance on reinforced learning and various other machine learning techniques, what would be ideal is true deep learning in this problem. A proper recursive neural network, although not fully applied to flight simulation yet, would explore new techniques to remove pilot error and create a great crash prevention system.

2.5 Conclusion

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3 Notes/Appendices

3.1 Safe Degradation in Multiprocessing CPU

It is important to speak about parallelism and multiprocessing in terms of computing management, as a way to analyze the solution proposed.

Multiprocessors in computer allow for parallel computing, but more to the point, enhance tightly coupled system. A figure of multiprocessing is found below:

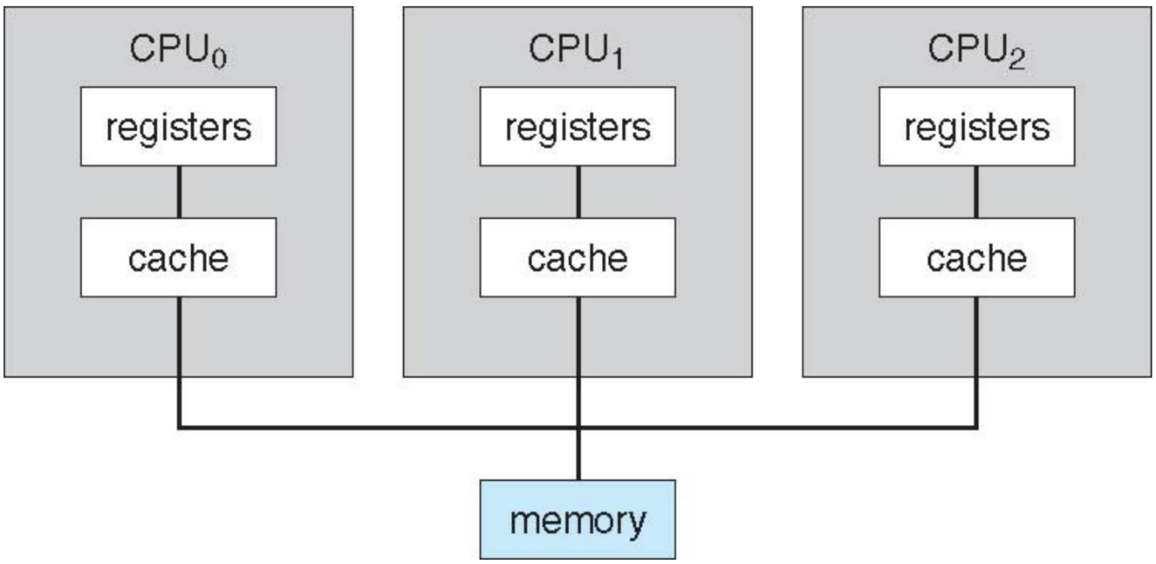

Figure 9. Multiprocessing for CPU's.

The advantages of this, beyond working on many problems at once, are that you have increased throughput. Because you can now process more requests in tandem, you can therefore have a lower CPU per process and still output a larger amount of computing power. The second advantage is economies of scale, in that with more processors, the cost per process goes down the more processors you add. As such, it becomes more efficient to front-end load the number of processes. Lastly, there is increased reliability as there are built in fallbacks and graceful degradation. As such, the fault tolerance of the system is much higher. When one process fails, another CPU process can send an interrupt and take over. As such, the failing of the systems work much better.

In terms of aviation technology, one can see this applied in the twin engine versus single engine aircraft. One can counteract the failing of one engine with another engine, and as such, have graceful degradation. Clearly, one could assume having a multiengine/process aircraft would be best. However, there is a limit (known as the square-cube law), which limits the feasibility of aircraft, and thus it's engine capacity as well.[18]'

3.2 Glider Landing

Most gliders only have one landing gear, and have skids to protect the wheels when the glider lands. Some gliders have water ballast tanks to sink faster in the same amount of distance. A heavier glider has a

[18]http://aero.stanford.edu/bwbfiles/largeACopt.html

reduced climb rate and shorter flight endurance. The landing between commercial airplanes is usually very similar to gliders.

3.3 Reinforcement Learning Exploration

Reinforced learning is a often mix of supervised learning with nonsupervised learning. Most reinforced learning problems have a very simple Markov decision process with various reward states to determine the next state functions. These next states depend on the current state and action. Referring to a Markov chain gives a great visualization of this decision process. Each state has a probability assocaited to it and given the state of the actual model, the next state is deteremined.

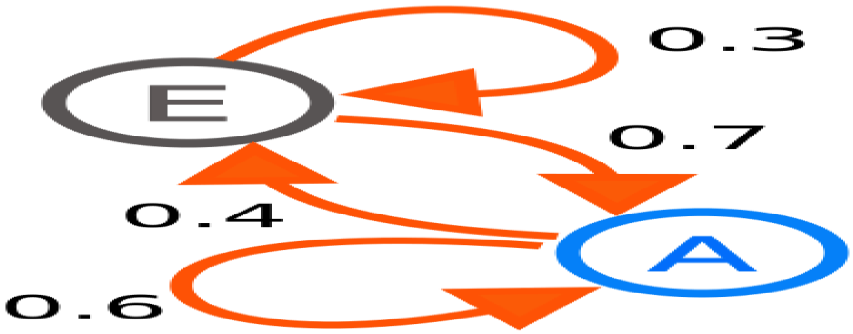

Figure 9. Markov Chain Principle.

The learning process for reinforced learning depends on two main stasticaly learning processes, Q Learning It is important tot note that these type algorthims are often used for temporal difference learning.

Q-Learning

This type of learning assigns state-action pairs to values. If an agent takes a particular action from a particular state, we record the immediate new state. This is assigned to a reward state. If the result is negative, the algorithm is reinforced to counter that result. At its most basic level, the q-value for a state action pair is the summation of all these reinforcements. As a result, the Q-value function is one that performs an immutable map from the state action pairs to their values. Most future weights are assigned a cumulative reinforcement, which is just a figure value multiplied by the respective q-value for an unknown, future based Q value. A rough approximation of these values can be seen below:

$$Q^*(x_t, u_t) = r(x_t, u_t) + \gamma \max_{u_{t+1}} Q^*(x_{t+1}, u_{t+1})$$

where Q* is the q Value of Xt, a state and Ut, an action. R is result of the respective known q action pair from the q-value function, and ymax is the gamma of the unknown future value if necessary (often it is zero if the q is within the data set). Another important note is that all of these values are stored in a lookup table, to update the equation and change the learning rate. Pseudo code for this can be seen as follows in the Ruby programming language:

```
def q_value(action, state, thresshold)
```

```
        state_array = Lookup()
        while(1)
                for each s_value in state_array
                        value = inject(:+, value(action, s_value, threshold))
                end

                if value < threshold
                        for each state in state_array
                                return Math.max(value)
                        end
                end
        end
end
```
[19]

The algorithm itself requires a few assumptions, mainly to have a recursive lookup table that finds approximation values. There have also been some assumptions left out of the above.

Table 3. Existing Price Data

	Engineering	Tool design	Tool fab	Support	Totals
Wing	$7,093	$1,862	$6,171	$833	$17,731
Empennage	$20,862	$5,476	$18,150	$2,541	$52,156
Fuselage	$12,837	$3,370	$11,169	$1,508	$32,093
Landing gear	$999	$262	$869	$117	$2,499
Installed engines	$3,477	$913	$3,025	$408	$8,691
Systems	$13,723	$3,602	$11,939	$1,612	$34,304
Payloads	$3,405	$1,130	$3,746	$506	$10,763

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