Mark SBIERA

THE DESIGN OF AN DETACHABLE AIRPLANE CABIN AND AIRCRAFT RESCUE SYSTEMS

Abstract: *Air transport is more often used so safety become an important factor in aviation, thereby a variety of rescue system were developed by teams of engineers all over the world. We are talking about systems like ejection seats, ballistic parachutes and of course the detachable airplane cabin which it is still an idea and has never been tested nor prototyped until I discovered this idea and I have begun developing it using technologies like 3D modeling , stress and aerodynamic analysis and building itself.*

Key words: *rescue systems, ejection seat, ballistic parachute, 3D modeling, stress analysis, aerodynamic analysis, prototyping, aircraft*

1. INTRODUCTION

First of all I would like to talk about aviation safety; we all know that aircraft accidents are usually catastrophic even if they are rare. When an airplane, a helicopter or any other aircraft crash, unfortunately there are a lot of people involved and it results in many loss of lives even if those people were not involved directly. According to EASA it is considered an aviation accident an object that fall from the sky and produce damage even if you are not directly involved it is an aviation accident, so aviation safety means the state of an aviation system or organization in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level. It encompasses the theory, practice, investigation, and categorization of flight failures, and the prevention of such failures through regulation, education, and training. It can also be applied in the context of campaigns that inform the public as to the safety of air travel. We also know that in aviation occurred all kind of hazards and I would like to list some of them.

Foreign object debris (FOD) includes items left in the aircraft structure during manufacture/repairs, debris on the runway and solids encountered in flight (e.g. hail and dust). Such items can damage engines and other parts of the aircraft. Air France Flight 4590 crashed after hitting a part that had fallen from another aircraft.

Misleading information and lack of information-A pilot misinformed by a printed document (manual, map, etc.), reacting to a faulty instrument or indicator (in the cockpit or on the ground or following inaccurate instructions or information from flight or ground control can lose spatial orientation, or make another mistake, and consequently lead to accidents or near misses.

Lightning-Boeing studies showed that airliners are struck by lightning twice per year on average; aircraft withstand typical lightning strikes without damage. The dangers of more powerful positive lightning were not understood until the destruction of a glider in 1999. It has since been suggested that positive lightning might have caused the crash of Pan Am Flight 214 in 1963. At that time, aircraft were not designed to withstand such strikes because their existence was unknown. The 1985 standard in force in the US at the time of the glider crash, Advisory Circular AC 20-53A was replaced by Advisory Circular AC 20-53B in 2006. However, it is unclear whether adequate protection against positive lightning was incorporated.

Ice and snow-Ice and snow can be major factors in airline accidents. In 2005, Southwest Airlines Flight 1248 slid off the end of a runway after landing in heavy snow conditions, killing one child on the ground. Even a small amount of icing or coarse frost can greatly impair the ability of a wing to develop adequate lift, which is why regulations prohibit ice, snow or even frost on the wings or tail, prior to take-off.

Air Florida Flight 90 crashed on take-off in 1982, as a result of ice/snow on its wings. An accumulation of ice during flight can be catastrophic, as evidenced by the loss of control and subsequent crashes of American Eagle Flight 4184 in 1994, and Comair Flight 3272 in 1997. Both aircraft were turboprop airliners, with straight wings, which tend to be more susceptible to inflight ice accumulation, than are swept-wing jet airliners. Airlines and airports ensure that aircraft are properly de-iced before take-off whenever the weather involves icing conditions.

Modern airliners are designed to prevent ice build-up on wings, engines, and tails (empennage) by either routing heated air from jet engines through the leading edges of the wing, and inlets [citation needed], or on slower aircraft, by use of inflatable rubber "boots" that expand to break off any accumulated ice. Airline flight plans require airline dispatch offices to monitor the progress of weather along the routes of their flights, helping the pilots to avoid the worst of inflight icing conditions. Aircraft can also be equipped with an ice detector in order to warn pilots to leave unexpected ice accumulation areas, before the situation becomes critical. Pitot tubes in modern airplanes and helicopters have been provided with the function of "Pitot Heating" to prevent accidents like Air France Flight 447 caused by the Pitot tube freezing and giving false readings.

There are also a lot of others hazards, including Wind shear or microburst, structural failure of the aircraft, stalling, fire, bird strikes, human factors, piloting while intoxicated, but I am going to get to point of rescue systems and how they were developed.

2. AIRCRAFT RESCUE SYSTEMS

As I mentioned before, aviation is very focused on safety, therefore engineers all over the world developed all kind of rescue systems that could save lives when pilots or passages are in need.

Ejection seat-The ejection seat is a life-saving system designed to rescue the pilot or other crew of the aircraft. Usually used in military aircrafts, especially supersonic combat aircrafts. In most cases the seat is ejected from the aircraft by an explosive charge or by a rocket engine. Once the seat has been ejected, the parachute connected to the seat is opened automatically (Figure 1).

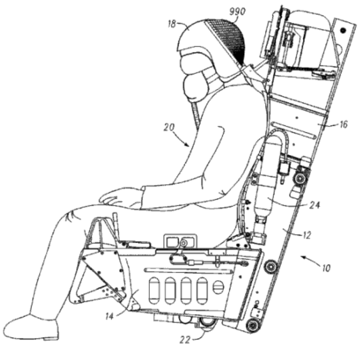

Figure 1 The sketch of an ejection seat [1].

Testing ejection seats has been an important aspect of testing in the aerospace industry for several decades. The identification and tracking of aircraft evacuation seat systems during field tests has had practical a benefit in post-test analysis and real-time tracking applications. Since the advent of modern jet engines, the safety of the crew has been very important. Crew evacuation technology has advanced from simple parachutes to highly sophisticated ejection seats and evacuation blankets capable of returning to the ground safely with pilots and crews on compromised aircraft. The United States Department of Defence devotes time and effort on testing seat exhaust systems to ensure that crews of modern military aircraft have a significant probability of survival in case of need. The United States Department of Defence conducts demonstration tests on e-seat systems in near-realistic conditions. High-speed test devices, such as the Holloman high-speed test track, use rocket sleighs to accelerate test objects to speeds that approximate flight conditions. The equipment for the ejection seats of the crew was tested at sledge speeds between 0 ft. / sec and over 1000 ft. / sec. The video data collected during the tests are used for performance analysis and validation of ejection seat systems.

The inherent complexity of both the tested elements and the test environment can make it difficult to identify the object in the footage [2]. The object of interest is transformative and changes with the evolution of the test. Initially, the object of interest is the rocket sleigh itself, because the test bed is accelerated to test speeds. When the sled has reached the appropriate test conditions, the object of interest is changed in the ejection seat system. The ejection seat system is of interest because it goes from being a component of the sleigh test bed to a dynamically distributed projectile (Figure 2). The object of interest changes again, as the ejection seat system is divided into two objects, the ejection seat itself and the mannequin representing the human pilot in the system.

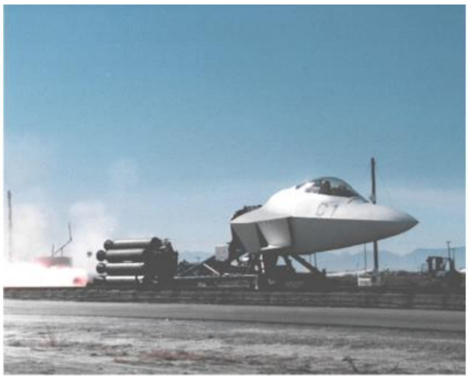

Figure 2 Rocket test sled [2].

The test environment is very complex, as it consists of natural and artificial artefacts that can disguise / camouflage the object of interest. Natural artefacts can include changing landscapes, flora and, in rare cases, wildlife. Artificial artefacts may include buildings, vehicles and test equipment structures. The combination of high test speeds, dynamic test conditions, natural landscape and man-made artefacts result in a very noisy and crowded environment.

Ballistic parachute - Since Boris Popov introduced "ballistic recovery systems" (BSC) for small aircraft in 1980, sceptics have continued to question their value. After surviving the structural failure of his glider, Popov came up with the idea of a parachute for the entire aircraft, and Cirrus Aircraft later incorporated the safety element into its SR20 / SR22 models. The ballistic recovery system, abbreviated BRS [3], is a parachute that allows an aircraft with problems (such as engine failure, loss of control, freezing and depletion of fuel, etc.) to gradually descend to the ground, thus offering a greater chance of survival or avoidance of serious injury. This type of system was originally used by the US military to recover their unmanned surveillance platforms because the equipment worn was expensive and classified. The National Aeronautics and Space Administration also used a similar system for command capsules for Apollo Moon missions. The system consists of a parachute and a rocket with solid fuel that launches a container, usually located behind the fuselage of the aircraft (Figure 3). A cable passes from the container to a handle that is usually above the cockpit. Once the handle has been pulled, the rocket strikes pass through a fragile section of the fuselage (similar to an airbag in a vehicle) and accelerate to about 50 m per second. After the parachute is completely extracted and exposed to the relative wind, it begins to swell, generating traction forces to decelerate the aircraft. The size of these traction forces or the inflation loads for a certain parachute configuration is a function of the weight of the aircraft, of the air speed at the unfolding rate of inflation. Pulling the aircraft causes the more fragile sections along the fuselage to decompose, so that when the parachute has been fully launched, the aircraft will stabilize and descend with its snout slightly below the tail. The aircraft will descend at a speed of about 1000-1500 feet per minute.

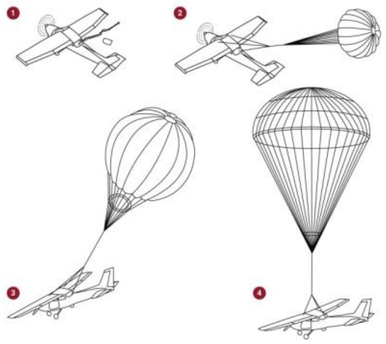

Figure 3 Ballistic Recovery Systems (BRS) [4].

The figures above show in 4 stages how the ballistic recovery system works (Figure 4):

- The rocket is activated. The parachute is extracted from the fuselage;
- The parachute slider controls the parachute opening speed;
- Fully open parachute;
- The aircraft descends safely to the ground.

Currently, this system has only been installed on light aircraft with a maximum weight of up to 3,500 kg. Some of the aircraft that are known to be equipped with such a system are: Cessna 162, CESSNA 172 Skyhawk, CESSNA 182 Skyline, CIRRUS SR-20, the first aircraft to be equipped with a ballistic recovery system.

Figure 4 Ballistic Recovery Systems (BRS) [4].

BRS Aerospace claims that 401 lives have been saved by this system, which implements a parachute that easily brings a defective aircraft back to the ground.

Detachable airplane cabin - The detachable cabin aircraft is just a concept because this idea was launched in 2016 and not enough research has been done to put it into practice. According to ICAO, in the last 10 years 8% of all accidents happen during take-off, 21% during landing, 71% during cruise flights. The analysis of the causes of accidents shows that 75% of them occur due to the human factor, other than manufacturing errors.

Ukrainian engineer Vladimir Tatarenko came up with an idea for a detachable aircraft cabin with which he believes it could save lives during a forced landing. In the event of an accident, the aircraft's passenger cell will detach from the rest of the plane and land safely on the ground or water using parachutes, boosters and rubber tubes that will automatically inflate the water. The design also includes a storage space that keeps the passengers' luggage under the cabin to ensure that no luggage is lost in the event that the aircraft has to detach (Figure 5).

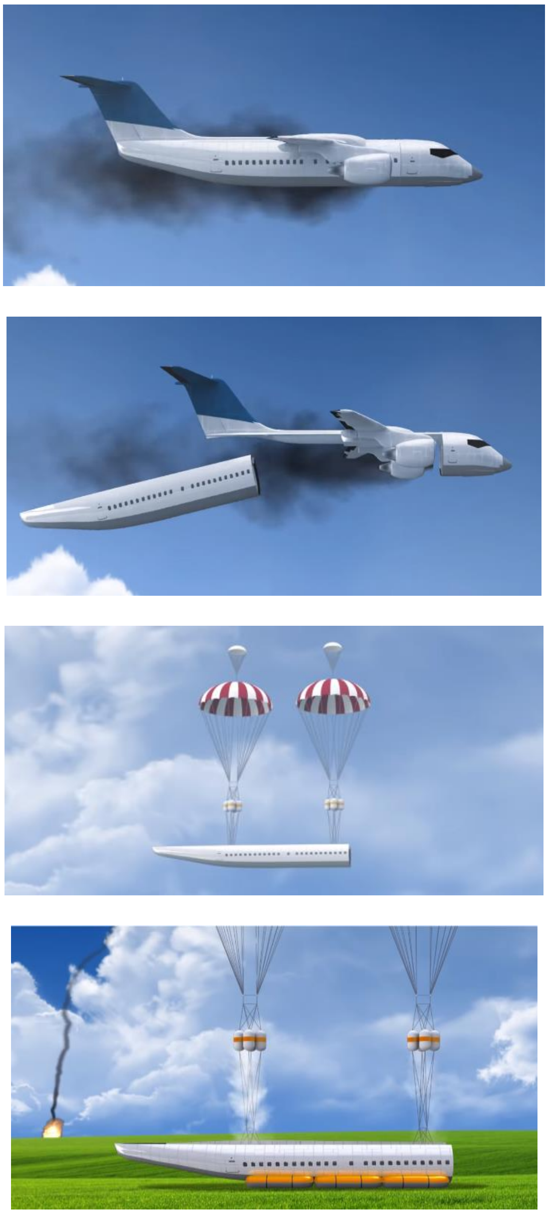

Figure 5 Detachment simulation phases [5].

3. 3D MODELLING OF THE AIRCRAFT

As I said in the abstract I discovered this idea and I have begun developing the 3D model using software's like Autodesk Inventor 2020, Solidworks 2015 and Profili 2.

Components of the aircraft were made, starting from the fuselage, wings, tails, and engine support until the realization of the passenger cell triggering system. The first part of the aircraft that was 3D modelled was the fuselage, which consists of several frames, resistance structure and skin (Figure 6).

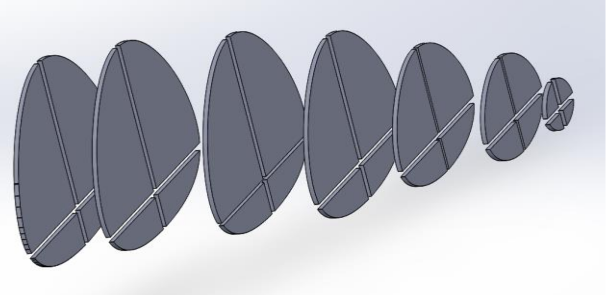

Figure 6 Parts of the fuselage frames 3D modelled.

The frames were assembled in the Assembly module of the Solidworks 2015 program, using the "Mates" function, which allowed the pieces to be constrained by each other by coincidence points, parallel, perpendicular or after a set distance (Figure 7). In the present case, it can also be seen that in the figure below two sections were used as placement plans for frames. A section with a top view and a section with a side view, both of equal length, thus being aligned after the point at the top of the fuselage.

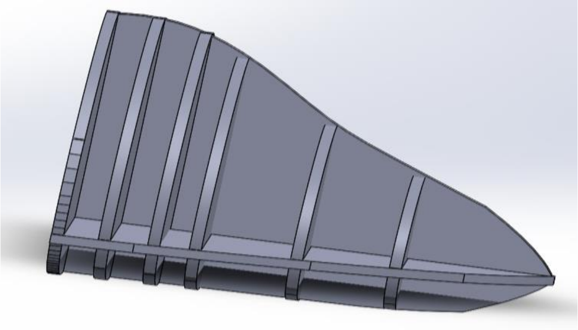

Figure 7 Frame parts assembled.

The components of the fuselage were assembled together, so we can observe the geometric shape of the entire fuselage. Since all the pieces are created with the center in the origin, their assembly was done with the "Mate" function between the front plane, the top view and the side plane, where we selected the distance between the pieces, in this case being 0.

Thus, the final shape of the fuselage was reached with the following geometric characteristics that can be observed in the below survey from Figure 8. That being said, the fuselage has a length of 2284 mm and a height of 196 mm.

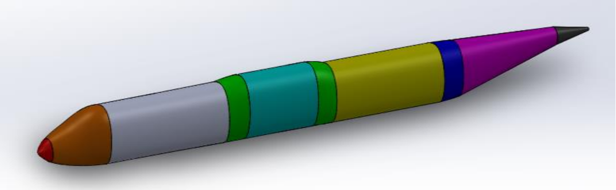

Figure 8 Fuselage parts assembled.

As the wings are the most important part of the aircraft, special attention was paid to their design to achieve the desired performance. That being said, the wing is created from two sections, a straight section with a length of 500 mm and a width of 450 mm at both ends and the second section with a length of 1000 mm, an end of 450 mm and the end of the wing of 300 mm (Figure 9). The wingfoil chosen for the wing is NACA 63-412, because it is a wingfoil that favours the generation of a high load-bearing force at a low speed.

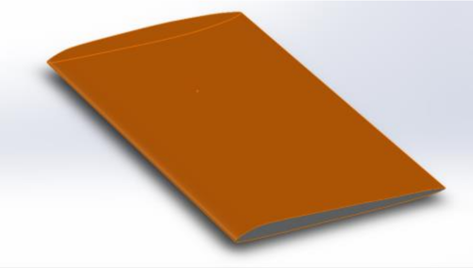

Figure 9 First section of the wing.

Each wing section was created individually with the same method by which the fuselage components were created. At the first wing section, a sketch was created in which a plan was made and the NACA 63-412 profile with a 450 mm chord was inserted, and then the respective sketch was extruded over a distance of 500 mm, meaning the length of the first wing section.

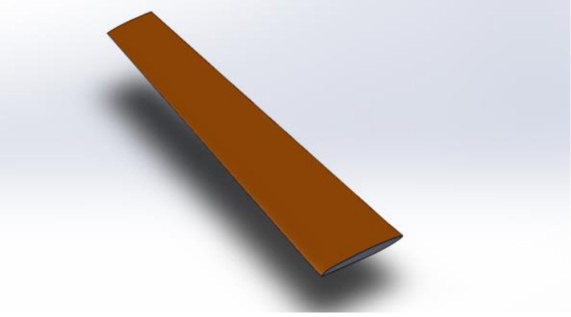

Figure 10 Second section of the wing.

The second wing section, the one in Figure 10, was created with the help of two planes where the aerodynamic profiles were introduced, namely NACA 63-412, the first profile with 450 mm chord and the second profile with 300 mm chord. The distance between the planes is the length of the wing which is 1000 mm. With the help of the "Surfaces" module and the "Extruded surface" function, 3D and the second wing section were created, and will be joined to the first section by means of the engine support.

In the end, after a lot of hours working on modelling and remodelling, because not all parts fit perfectly when they are done individually all the components of the aircraft were built: fuselage, horizontal tail, vertical tail, wings, engine mount, engine mount reinforcements, landing gear, wing tips, the time has come to be assembled in order to create an overview of the plane, for what has been achieved and what will be physically achieved (Figure 11).

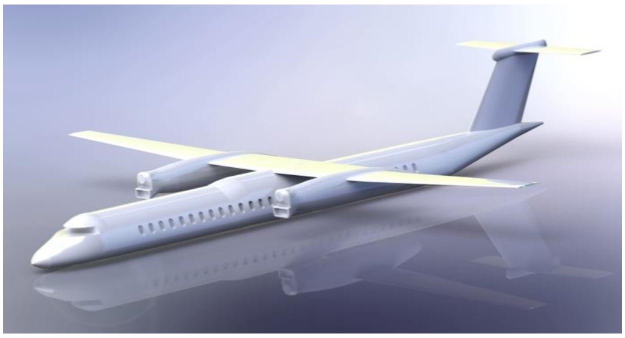

Figure 11 Aircraft assembled completely.

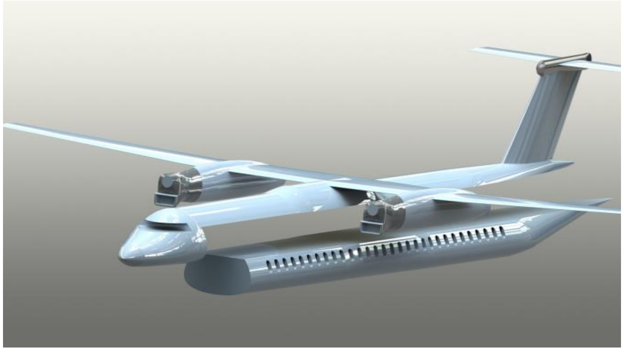

Figure 12 Aircraft with cabin detached.

As can be seen in the figures above, is the set of two planes, top and bottom. As the theme of the project refers to the design and physical realization of a detachable cabin aircraft, in Figure 12, the aircraft fuselage was cut so that the passenger cell was separated from the rest of the aircraft to show a case of passenger cell deployment.

To make this 3D model, the whole plane, except the passenger cell was selected and removed with the "Cut Extrude" function, so I was left with only the passenger cell. The same thing was done a second time, except that the parts were reversed and the passenger cell was removed and I was left with the plane without the passenger cell. Each piece was saved separately, then using the Assembly module; these two pieces were assembled and spaced apart to create this effect.

4. AERODYNAMIC ANALYSIS OF THE MODEL

Due to the 3D modelling of the aircraft, aerodynamic tests of airflow on the surfaces of the aircraft can be easily performed, without the need of using a wind tunnel, but only the introduction of certain parameters for each case. Aerodynamic analysis was performed in order to observe the pressures and flow rates on the model surfaces for 3 different cases:

Aerodynamic analysis of the whole aircraft (Figures 13-14) analyzes the entire aircraft, at a speed of 50 meters per second which is 180 Km / h, on the X axis, on the outer surfaces, excluding the inner surfaces. From the Flow module of the Solidworks program, the air was selected from the gas list using laminar and turbulent flow. The standard pressure of 1013.25 Pa and the temperature of 293.2 K were used. Figure 13 shows the pressure distribution on the surfaces of the aircraft and it can be seen that on the leading edge of the wings, the nose of the aircraft and the front panels of the engine mount, are the highest pressure points on the surface of the entire aircraft. This is natural because these areas are the first to come into direct contact with the air.

Figure 13 Pressure distributions on the surface of the aircraft.

Figure 14 analyzes the trajectory of the airflow as a function of pressure on the entire surface of the aircraft. The values obtained are between 100976.72 Pa and 101496.68 Pa. The parameters of the analysis were the following: the flow velocity of the air nets on the X axis = 50m / s; laminar and turbulent flow; the gas selected was air; standard pressure, sea pressure of 101325 Pa and temperature of 293.2 K.

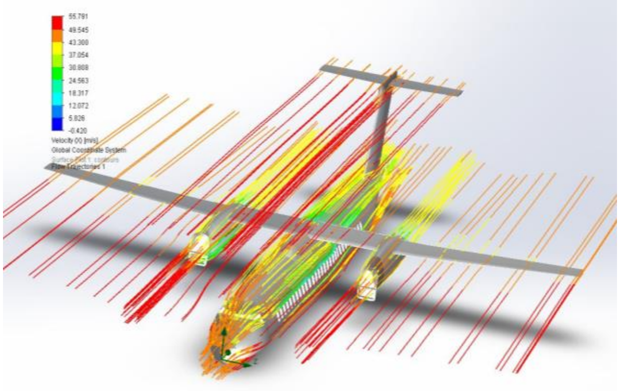

Figure 14 Analysis of the airflow according on the X axis speed.

The analysis of the trajectory of the airflow as a function of the speed on the X axis on the entire surface of the aircraft was performed. The values obtained for the speed on the surface of the engine mount are between 43 m / s and 49 m / s, for the nose of the aircraft are between 37 m / s and 43 m / s; for the sides of the fuselage and engine fairings are between 30 m / s and 37 m / s, and the lowest values are of course on the wing sideboard due to the aerodynamic profile and values were recorded between 12 m / s and 18 m / s, which suggests that the aircraft is able to generate carrier force, so the aircraft will be able to stay in the air and be able to fly.

The parameters of the analysis were the following: the flow velocity of the air grids on the X axis = 50m / s; laminar and turbulent flow; the gas selected was air; standard pressure, sea pressure of 101325 Pa and temperature of 293.2 K.

We continued the analysis on the passenger's cabin because, as this paperwork title mention, it refers to aircraft rescue systems and aircraft detachable cabin. Because the passenger cabin will be detached from the airplane, it will lose its horizontal forward speed and increase its descend speed, which means that we have to change parameters in the Flow module of the Solidworks program, so analyzes will be performed at a speed of 50m / s on the X axis and 10m / s on the Y axis (vertically), on the outer surfaces of the cell, excluding the inner surfaces. From the Flow module of the Solidworks program, the air was selected from the gas list using laminar and turbulent flow. The standard pressure of 1013.25 Pa and the temperature of 293.2 K.

In Figure 15 is performed surface analyzes as a function of pressure on the entire surface of the cell. The values obtained are between 101741 Pascal and 103138 Pascal on the vertical surface of the cell, because it is assumed that the cell still has forward speed and the first contact with the air grids will be on that surface. On the rest of the cell the recorded pressure is 101042 Pascal.

In Figure 16 is performed the analysis of the trajectory of the airflow as a function of pressure on the entire surface of the cell. The values obtained are between 40 m / s and 61 m / s on the surface that makes the first contact with the air and between 19 m / s and 33 m / s on the rest of the cell. Parameters of the analysis were as follows: Flow rate of air grids on the X axis = 50m / s, Y = 10m / s; laminar and turbulent flow; the gas selected was air; standard pressure, ie sea pressure of 101325 Pa and temperature of 293.2 K.

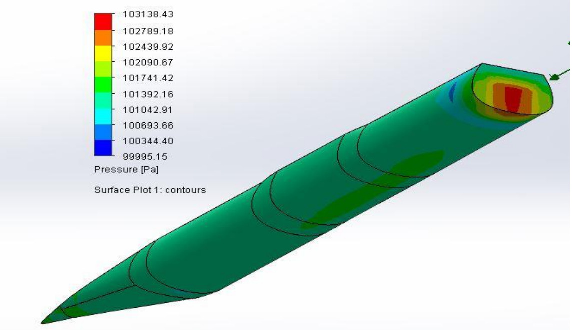

Figure 15 Pressure distributions on the surface of the cabin.

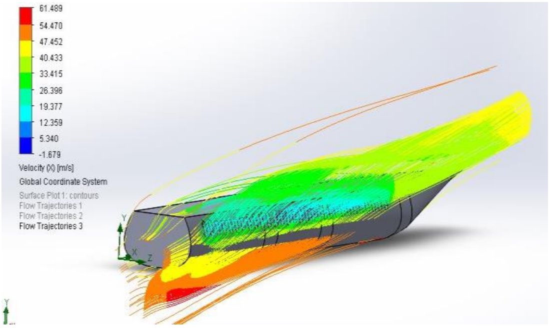

Figure 16 Analysis of the airflow according on the X-Z axis speed.

In Figure 17 is performed the analysis of the airflow as a function of density on the entire surface of the cell. The values obtained are between 1.20 Kg / m^3 and 1.21 Kg / m^3 on the surface that makes the first contact with the air and between 1.19 Kg / m^3 and 1.20 Kg / m^3 on the rest of the cell. The parameters of the analysis were the same as those mentioned above.

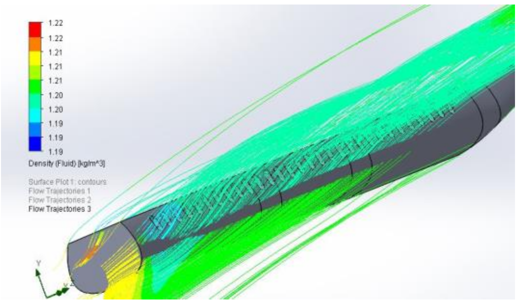

Figure 17 Analysis of the airflow according to the density.

5. CONCLUSION

What if there was a chance of a plane crash? In the last 10 years, 8% of all accidents occurred during take-off, 21% during landing, 71% during cruise flights, which means that most accidents occur at high altitudes between 9500 m and 11500 m , thus the implementation of detachable cabin rescue systems would save hundreds of lives because the detachment of the cell occurs instantly, the cell is able to land on water or land. With the help of current technologies it would be very easy to do this. The cell can be made of composite materials such as: fiberglass, carbon, Kevlar, because they are light materials, very resistant and the technology become more accessible.

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Author:

Eng. Mark SBIERA, student Master, University Politehnica of Bucharest, Faculty of Aerospace Engineering, Department of Engineering Graphics and Industrial Design, Romania.
E-mail: markbf3480@gmail.com