Helios

Proyecto: PE-BEE (Fly by Wireless)

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Introduction

Motivation is a main point for the development of a project, which for the team is passion for aircrafts. The great opportunity that it has to innovate in the aerospace sector, create more comfortable flights, improve airline finance, and of course taking care of the environment, these are the keys of the goal. Always keeping an attitude to improve what is offered by every member of the team in order to reach the objectives.

It was chosen the challenge Fly-By-Wireless, which was proposed by NASA, and where the objective is to design an aircraft, that flies using wireless technology, so with this can be reduced partially the wiring's weight of the aircraft, it's also proposed the reduction of any weight without damaging the integrity, security and comfortability. In other words, the project consist in reducing as much as possible the unnecessary wiring like cables, connectors and penetrations, in order to gain more payload.

Data

For example, the airplane A-380 [10], which has a total of 100,000 cables, that have a length of 470 km in total and a weight around 5.7 tons. It can be replaced about 30% of the components, which can be decreased using new technologies of wireless connections.

The objectives of the team are:

-Reduction of the wiring that transmit data

-Reduction of connectors

-Reduction of penetrations

-Reduction of the total and in percentage of the weight

-Increase the functions (specific benefits, security, reliability and efficiency).

-Safe Data Transmission System

-Implementation of technology able to produce energy by vibrations

According to data of NASA [1], the areas where it must be applied a wireless transmission data and technology method are the following:

-"Systems engineering and integration for the reduction of wiring and connectors".

-"Provision for modularity and accessibility of the vehicle".

-"Alternatives to cable connectivity for designers and system operators".

The wiring system has different alternatives when replacing them for payload such as the implementation of a new emergency system, new components, or optical fiber, due to the increase of copper worldwide.

The potential wiring components to be replaced for wireless signals are divided in four parts:

-Low data system in interior applications:
Pressurization sensors, smoke detection, fuel quantity on the aircraft, proximal temperatures, structural life, corrosion and humidity detection.

-Low data system in outdoor applications:
Ice detection sensors that deform the aerodynamic profile, the landing gear position, the outside pressure, door sensors and structural sensors.

-High data systems in interior applications:
Air data sensor, engine forecast, flight images, of cabin

-High data systems in outdoor applications:
Structural life sensor with constant monitoring

Besides, an aircraft has classification systems, which is a good starting point, so it can be chosen the systems able to be replaced by wireless technology. The analyzed systems were:

-Electric system
-Fuel system
-Flight controls system
-Hydraulic system
-Pneumatic system
-Oxygen system
-Environmental control system
-Power plant
-Landing gear system
-Interior conditioning system

The systems where it can be implemented the new wireless technology are the following systems: electric, power plant, landing gear, interior conditioning system. Some parts of the aircraft could be modified, but these have less risk when implementing them.

From the previously mentioned, only some of them can be replaced because it is used technology in prototype phase, which is insecure. Thus, the systems that can not be replaced with wireless components are fuel system, flight control, hydraulic, pneumatic, and oxygen system; this because, since they are vital for the control and security of the aircraft and is complicated due to the risk of sabotage.

Of all the systems, the most viable to be used as part of the solution of team “Helios” is the partial modification of the electric system, because the progressive usage of hacking technologies does not allow to implement wireless technology to more important systems. Since is a complex job in a big aircraft, it was chosen just the modification of the electric system, centralized in the cabin of passengers.

According to data of NASA [1], some of the systems where it is possible to take technological alternatives to wires and connectors is adaptive modular instrumentation.

1. The only wireless data acquirer and the active sensor tags provide belt instrumentation with remote access
2. No energy RFID and with passive sensor tags that provide direct access to sensors with no batteries or wires in a determined distance.
3. Sturdy radios and adaptive that attach characteristics to optimize the RF communication by the interferences/low signal noise.
4. RF interoperability onboard and frequencies authorizations that are approved internationally through air space.
5. Adaptive instrumentation hubs that are made with standards of the avionic “plug-and-play” for its quick configuration.
6. Data transmission in energy points is certified for certain applications.
7. Optic fiber systems are “plug-and-play” for measurement of high density with high data.
8. Coatings and shielding of the illumination weight which are developed for interferences RF and EMI/EMC
9. Instrumentation tests “Ground-and-Flight”.
10. Wireless connection for acquisition of standalone data o direct to sensors.

Protocols that were not used

The functioning of wireless technologies is about the transfer of information in signal forms, since nowadays the cell phone is starting to be used in long distances in certain aircrafts, it was given the task to implement a new type of data transmission, for that different types of wireless sensors were searched; one of them was the transmission of data with X-Rays, which was a viable option because of the data security, however at the moment of implementing it in a commercial aircraft this loses importance, because the radiation that is exposed to tripulation and passengers is dangerous for human health.

After that, it was dealt with other signals types such as WiFi, which was almost an instant deleted option due to the easy access of people trying to spoil the flight; Also the RF and NFC signals. It was taken in consideration the implementation of ultraviolet rays, which were not possible to implement due to the small maneuvering space without mentioning the radiation this rays emit. On the other hand, microwave signals are disturbed by cell phones, which thinking about it, will be an essential part of the flight comfortability. It was thought working with frequencies that are located in not used zones, this with the objective, in a near future, because an aircraft that has even more signals, cell phones don't affect and these are not affected by the electromagnetic waves that will be processed on the aircraft, besides avoiding complications with persons that have vital instruments, such as pacemaker.

For the data transmission system, these must have reliability in health aspects for passengers and tripulation; compatibility with other systems, but overall security, if the net is intercepted by a third party, this will not only have access to zones of the aircraft that control the cabin passengers, which will be lights, security seatbelts sensors, cargo service, smoke detectors on a commercial aircraft. Besides, the signals can be divided in geographic parts of the aircraft o by the systems previously mentioned. For the signals between transmitters depend on the quality between space of the transmitter and receptor, the applications that will be use are low data rate.

For the transmission of control signals of an isolated system like the aircraft itself, it was analyzed using retro technology, the reason is the interference with cell phone that have networks 3G and 4G, was taken in consideration the method of a network more powerful such as 5G, but it would not be so useful, because in a couple of years a variety of devices will have access to these networks. For an isolated system, technologies 2G it would be ideal, but due to the vibrations caused by different oscillations of the components, makes difficult the task to calculate the position. Also, this signals does not have all the time a great power.

Zigbee

Given all the information, it was chosen the signal transfer, but using a set of protocols as is indicated by NASA [2], which give security when using the aircraft. Thus, the communication without cables, it was chosen to implement ZigBee, which is the name of the specification of a set of protocols of high level wireless communication for its utilization with digital broadcasting of low consume, based on the standard IEEE 802.15.4 of Wireless Personal

Area Network (WPAN) [5]. Its objective is to enable wireless networks with control capacity, monitoring of low cost as well as low reliable consumption. ZigBee is for private use, and its main characteristic is that it is very reliable. Which objective is to enable wireless networks with control capacities and monitoring that are reliable, low cost and energy consumption.

This system has a great number of alternative routes to guarantee that the information arrives to its destination. It is used currently in the robotics world (smart house) and one advantage of using this technology is that its cover range is ideal for aircrafts. Its performance is not affected by networks (like WiFi or Bluetooth) because its low data transmission rate and the characteristics of the same protocol.

-It is of private use, has a high reliability level, and low cost.

-Its performance seems to not be affected by other networks (like WiFi or Bluetooth) because its low data transmition rate and characteristics of the same protocol.

-Besides, the system has a great amount of alternative routes, so the information always arrives to its destination.

-In order to implement a ZigBee network, it must be composed by:

  -A stand-alone coordinator

  -One or more routers

  -One or more terminal devices

ZigBee Xbee: An Xbee module can be configured so it accomplished the three functions.

-Coordinator:

Has the task to form the network

Deals with all nodes' directions

Deals with security

Deals with auto-regeneration

-Router:

It joins a network formed by the coordinator

It can deal and receive its own data, in other words, the data coming out of it own ports

It has the capacity of rooting or routing the traffic of different nodes.

Its usage is optional if they're no distant nodes (out of range).

-Terminal device:

Sends/receives its data.

How does ZigBee work?

The way NASA used the protocol ZigBee [9], was for an easier communication, because before, the monitoring and intercommunication program was tedious and consumed a lot of time, the tripulation took precious time that can be used on accomplishing the real mission that were ordered to them. The environment of the international space station must be quiet, without sound perturbation, in order for the work environment to be healthy, helping that way the tripulation to develop better the investigations, so they last longer and uninterrupted, all this under the conditions of microgravity. Thus it was decided a method that provides the usage of microphone, data sampling and signals processing as well as ZIgBee norms.

All the aircraft's systems have currently a data redundancy model, the systems that feed these parts or components of the aircraft while is in flight are designed so they never stop working. It is called redundancy to the practice of ensuring an aircraft's part so all the moment can accomplish with its task and operation. Redundancy is that, if a part of a system cannot act as normal, it could do it in an alternative way, even in a third, or fourth way. With ZigBee protocol it could be cover this redundancy system making the aircraft safer because the protocol works in a certain way that the data sent if they can't arrive by the indicated path for some failure, the information would be routed by near nodes and complementing the data transmission to the node that has been predicted [12].

Battery

Once selected the information process of the aircraft systems, it was given the task to find the best way to not implement wiring, this entails the isolation of the systems in physical form of the energy components of the aircraft, thus it was needed an independent source where the new wireless components can operate, which could be batteries. The problem of using the batteries is that they would have to load constantly and it would have a problem of maintenance, even when using a central battery, the battery charge would have an easy usage, but the wiring system would still be a problem, since the percentage of reduction would be minimum.

In an investigation on the NASA database [4], it was achieved to obtain information of the piezoelectrics sensors, which were previously inquired. The reports explained that in most cases of the space missions, they last a lot of time, even decades, so having batteries that require a lot of space is so counterproductive in terms of space optimization, since deleting these batteries can substitute the areas that are used by useful equipment that support the tripulation, combined with these, other complications are the risk of explosions, they're inconvenients with reloads and their lifetime doesn't last a lot.

What are piezoelectrics? And how does it work?

While seeking other solutions to this problem, investigators, specifically from NASA [4], they inferred that the development of light energy harvester devices with outputs of high power and low cost was essential. It was obtained information of piezoelectric material sensors, which were a way to collect through vibrations generated by air vehicles. In previous investigations, they had nano-generators of simple layers of MoS_2, that resisted high tensions, and at the same time were light, but they believed it could be obtained more efficiency, idea where they were right, and it was proposed the idea of a piezoelectric energy producer that was light and highly effective with the same materials.

With investigations previously done by the team, and these bases of the main problems and partial solutions by NASA [4], it was chosen to go deeper and implement a new generation energy more efficient, grounded in a Ph.D dissertation, it was obtained information of piezoelectric energy harvester, being these ideal due to their performance, which is good in small quantities while moving.

It was reached to the idea of using piezoelectric technology, due to the environment generated during the flight, there is mechanical vibrations, this technology can operate with a great quantity inside the aircraft, in non-busy area like the parts beneath the seat, services doors, generating that way, and besides reducing wiring in considerable amount.

Piezoelectrics are minerals that generate energy when they deform. The materials of this are regularly no effective if they don't produce electricity, but using these manufactured components specially for this method, they could be implement in a lot of parts of the aircraft.

This components are capable to generate energy for another components with only vibrations caused by minimum air currents or accelerations from 0.05 G to 0.3 G [6]. For this reason this will be implemented in parts of the aircraft where vibrations are bigger like seats or wings. This components have a very low price, so price ain't a problem. Also, manufacturing them is really simple, if any problem or failure is presented replacing them is a very viable option.

Piezoelectrics harvesters

According to Leon, E. [6] this devices made by them are based in an insulating of silicium (SOI), silicon wafer. The layer of the device is used to define the beam and the bulk coat is used for inertial mass. On top of the beam, a layer of aluminum nitride forms the transducer piezoelectric. The layer of the piezoelectric is squashed between two metal layers that form the electrodes Ti/Pt. The materials of the piezoelectric consists of silicon material, silicium oxide SiO2, piezo material, capacitor, CMOS integrated circuit, and Ti/Pt electrode.

The piezoelectric harvesters that will be used [6], have a quadratic shape and in the center it has a trapezoidal shape and rounded corners. This design was evaluated in a FEM simulation, it has a uniform distribution of stress over all the layer. In this way, a higher charge density is generated and therefore, it is a more efficient device. In this design an increase in the power of the 60% was obtained. The total volume of one of this is 12.9mm^3(5mm*5mm*0.516mm) and 1.54mm^3 (1mm×3mm×0.516mm) for the functional structure composed by the cantilever and the inertial mass. To obtain the results of the piezoelectric harvesters the simulator COMSOL MULTIPHYSICS. It was simulated with resistors from 50KΩ to 950KΩ, they were used to find the optimal value where the extracted power reaches a maximum value of 0.32μW and 1.3μW for a 0.1 G and 0.2 G of acceleration. The effective power density is 665.4μW/cm^3 for a vibration acceleration of 0.2 G and a frequency of 575 Hz, and a voltage from 0.75V to 1V is obtained.

It was searched for cons for the piezoelectrics elements system it was thought in the probability that these were affected by some electromagnetic, this is because the luggage organization at the moment of boarding it would have to be very specific due to the different types of loads that go in the luggage compartments, whether they are producers of electromagnetic fields elements like speakers it would pay more attention when deciding in which compartment to put this type of loads, besides of limiting zones where piezoelectric can work. It was founded that the piezoelectric effect is related with electric fields. The piezoelectric actuators do not produce magnetic fields neither are affected by these ones. They are specially appropriated where magnetic fields can’t be tolerated.

IMPLEMENTATION

At the moment of implementing a great handling of wireless technologies, it was thought in isolating all components from the aircraft’s perimeter, this with the objective of avoiding the loss of components due to impacts from objects like drones, birds, or something else and with those that generate decontrol of the aeronautic systems.

It is considered that the control systems must be independent, all the systems must be redundant, in most aircrafts like this, the system is duplicated, in such way that if one of the systems fails, there will be one as a reserve, ZigBee accomplish with the process of redundancy, the passenger's cabin also has a double one, if one fails the other one enters, all circuits are with double protection, such the navigation like the command controls have redundancy.

The team "Helios" proposes with the technologies previously mentioned and the implementation in aircrafts supported, which could be in different ways, so it is only proposed two ways of demonstrating that the usage of wireless networks is practical, one of them is the implementation on flight systems more indispensable of a trainer aircraft and the other theoretical way on a commercial aircraft; for the trainer aircraft it doesn't have problem of information stealing since being an exclusive use aircraft in military zones is possible to modify systems even more specifics without compromising the security, saving a big number of wiring kilograms. The aircraft that was used is the trainer aircraft PC-7, which is an aircraft given by the Mexican Air Force as a learning method.

For the PC-7 aircraft it was partially disassembled to check in which parts the cables were located, doing this the team identified the parts that could be replaced, this aircraft has a lot of cables with a wide area, which are potentially replaceable like the ones that are connected to LEDS, radio systems, etc. This systems are going to be replaced by ZigBee sensors. PC-7 vibrations are always there, therefore the objective is to place the piezoelectrics near to the seat by the sides or in the floor. This because the seat needs to have a parachute in, the parachute acts like a seat and needs to have an easy access that also do not obstruct the piezoelectrics.

For the wing tip lights the piezoelectrics could be located inside the wings, in this aircraft the fuel tanks are inside the wing but only in the wing root, having a hollow wing tip, therefore placing there the piezoelectric won't be a problem. The weight aspect isn't a problem either because the weight of the cables is being reduced. This plane's lights are incandescent and are going to be replaced by LEDs consuming less energy, doing this the weight is reduced and the battery efficiency is increasing.

To get concrete numbers and validate the percent of cables in an aircraft, the PC-7 wire system was used as a reference. A wire system in a PC-7 weighs 51.651 kg, this data is known because of a field research. Taking into consideration that the most of wires have a 2mm diameter and the most of wire systems are distributed by the floor at both sides of the plane the following calculations were made.

Each cable area.

$$A = (\pi)(0.1cm)^2$$
$$A = 0.03141592cm^3$$

To power the LEDs that goes to the wing tip 12 cables are used for each semi-wing. The length of the wires coming out of the battery to the controls is 350cm, from the controls the wires return 320cm to pass through the perforation and finally reaching the wing tip 588cm away from the perforation. This for each wing tip light.

$$\mathrm{A} = (0.031415926\mathrm{cm}^2)(24) = 0.75398\mathrm{cm}^2$$
$$\mathrm{V} = (0.75398\mathrm{cm}^2)(1258\mathrm{cm}) = 948.5\mathrm{cm}^3$$

To power the LEDs that go to the landing gear (left side and right side) 6 on each side, in the same way, cables come from the battery to the flight deck where the length is of 350 cm, then they go back from the controllers until the perforations where the length is 320 cm, and from there, the cables go to the landing gear where the distance is 225 cm. Adding everything it has a total length of 895 cm per cable.

$$\mathrm{A} = (0.031415926\mathrm{cm}^2)(12) = 0.37699\mathrm{cm}^2$$
$$\mathrm{V} = (0.37699\mathrm{cm}^2)(895\mathrm{cm}) = 337.407\mathrm{cm}^3$$

To power the LEDs that are at the end of the tail are needed 8 cables. Cables come from the battery, then to the flight deck, and then they go to the tail covering a length of 1130 cm.

$$\mathrm{A} = (0.031415926\mathrm{cm}^2)(8) = 0.251327\mathrm{cm}^2$$
$$\mathrm{V} = (0.251327\mathrm{cm}^2)(1130\mathrm{cm}) = 283.999\mathrm{cm}^3$$

Headlights have a cable of 2m long and a thickness of 4mm each, an area of 0.1256cm^2, therefore a volume of 25.1327cm^3, the aircraft has 2 headlights so the total volume is 50.26548cm^3

Adding all the volumes of the cables it gives a total of

$$V = 1620.1714cm^3$$

Copper's density is 8.96 $^{g}/_{cm^3}$, with the formula of the density we can obtain the total weight of the wires

$$\rho = \frac{\mathrm{m}}{\mathrm{v}}$$

$$\rho\mathrm{v} = \mathrm{m}$$

$$\left(8.96\ ^{\mathrm{g}}/_{\mathrm{cm}^3}\right)(1620.1714\mathrm{cm}^3) = 14{,}516.73\ \mathrm{g}$$

$$14{,}516.73\ \mathrm{g} = 14.51673\ \mathrm{kg}$$

Making a relation between the total weight of wires and the weight of the wires that are going to be quit it was obtained that:

$$\left(\frac{14.51673\ \mathrm{kg}}{57.346\ \mathrm{kg}}\right)(100\%) = 25.3142\%$$

Just with this part of the wiring it was reduced a 25.3142% of the total weight of wiring present in the aircraft.

In total the PC-7 has 778 cables according to the field research and everyone of this has 3 connectors, therefore it has a total of 2,334 of which 44 cables were reduced making a total of 132 connectors, this represents a total of 5.6555% of the connectors. For the control of this it will be used the protocol ZIGBEE with a receptor and a transmitter. Also, it was reduced both perforations that go to the wing tip and another one that goes to the tail.
In total the empty weight of the aircraft is 1330kg of which the 4.3117% is the total of the wiring, it was reduced 14.51673kg, this represents a total of 1.09% of the total empty weight of the aircraft

The implementation of the piezoelectrics will be located in the wing tips and in the floor of the aircraft, depending of the demand of the LEDs it will have different layers, either in series or in parallel depending on the necessities of the system. Furthermore piezoelectrics layers will be implemented.

For the implementation of wireless systems in commercial aircrafts it can’t be compromised the security of the passengers and tripulation, besides navigating in air zones where there is cities, thus the wireless systems can only be used on regulated zones like the passenger’s cabin. The aircraft that will be worked on theoretically is Boeing 737, which is the best-selling aircraft of all history, an aircraft’s passengers with a capacity of 110 passengers.

These piezoelectric systems generate energy for different functions on the passenger’s cabin, where the individual LEDs of white light are located, on the superior compartment where there is warm light, cargo service is blue light, seatbelts sensors, smoke sensors and no smoking warming with red color, weak light in the night that passes through the whole aircraft of purple or blue light, WC light is yellow, all these can be modified without damaging the security of them, besides that cargo service has a screen to observe who is sitting.

To decide in what parts of the aircraft must be located the piezoelectrics so these produce more energy, they must be done vibration analysis in flight in simulators like COSMOL MULTYPHYCIS or in a practical way with sensors in a test flight, but it is well known that is generated more vibrations in the wing tips, but a commercial aircraft, these are busy by the tank fuels, but since they are so small, piezoelectrics could be in a isolated zone where the generated energy do not intervene with the fuel tanks and can cause an accident

Researches indicates that the piezoelectrics location must be in zones that are near from the devices that are going to be powered. Some options for the implementation are under the passenger seats, in the fuselage, the upper compartment and the air conditioning pipes in where the air current can activate the piezoelectric, the same for the W.C. areas. The weight issue isn’t important because the cables weight is being reduced. A B-737 seat has a useful base from 65cm by 53cm having an area of 3445cm^2 that could be used for the piezoelectric implementation. This system is going to be over the lifesaver. In the superior compartment is planned to locate more piezoelectric.

Usually the Xbee modules that are going to receive the seatbelts signals that are located under the seat works with 3.3V and for the LEDs which are 8, consume 5V, 0.72W and 0.144A. Each cubic centimeter of piezoelectrics produce 665.4µW with a 1V voltage, to get the intensity you value the 665.4µW and 1V in I=P/V

$$I = \frac{665.4\ \mu W}{1V} = 665.4 * 10^{-6} A$$

Getting a 665.4µA amperage, but increase the voltage is a need; $6cm^3$of series circuit are pretended to be used, a series circuit generates a 6V voltage, 6.654µA and 3.9924mW; mentioned systems will have and output in which 550 parallel circuits are going to be connected to take advantage of all the space of a seat getting with this a 6V voltage, an amperage of 0.36597A and a wattage of 2.1958W for a 0.2G acceleration.

In the process of calculating the amount reduced in wiring it was used the aircraft design Boeing 737, where it was dimensioned in real measures placing the respective seats. With this we obtained the measurements of the cable that connects to the sensor of the seatbelt, the sensor “back to sit” activates at the moment the flaps extend. Also, the wiring of the LEDs in the passenger cabin was traced in optimum measurements from the battery to each seat, it was taken in consideration the cable AWG 26, also that it needs 1 cable for the positive pole, for the negative pole, and another one for the transmission of information. It is dictaminated a total of 5 cables per seat and that each seat has its own system. It was reduced a total of 12,973m of wires and a weight of 365kg.

This data was obtained with the following calculations:

The quantity of meters to the last row of seats (6 seats with 5 cables each one) is of:

$$d = (24.65m)(5)(6) = 739.5m$$

Taking in consideration for each row decreases 18m and is sectioned for 16 row it is obtained the formula $d = d_0 - 18m$.

At the end of the 16 rear rows it is obtained a length of 9672m. Later there is a row that is located 1.3m from the 16 rows, this reduces 39m the distance of the last set of rows which 469.5m being 430.5 the set of cables of the last row that is alone.

Later was taken in consideration another separation of 1.3m decreasing other 39m the distance 430.5m giving a result of 391.5m.

Now it was applied the formula $d = d_0 - 18m$ for 7 rows. Obtaining a total of 2362.5m. After that, it has the fact that in the premiere space the difference of 2.5m between seats, and also of 1.3m from the last counted row decreasing 39m for the first row being 244.5m and decreasing 75m between seats. In this section 508.5m of distance. Finally it is obtained a distance of 12,973.5m = 12.9735km = 1,297,350cm.

The cables have an area of 0.031415926cm^2

$$V = (0.031415926cm^2)(1{,}297{,}350cm) = 40757.45229cm^3$$

Obtaining a total weight of:

$$\rho v = m$$

$$\left(8.96\, {}^{gr}/_{cm^3}\right)(40757.45229cm^3) = 365{,}186.7725gr$$

$$365.1867kg$$

The aircraft has a total weight of 41,145 kg, which represent a reduction of 0.88756% of the total weight.

Benefits

The systems that were worked on can be applied in a variety of parts, industrially or in manufacturing, the use of commercial aircrafts, in its building would save a great number of costs because of the copper, since implemented in a massive way and with more investigation would achieve that even more systems can be modified. It would also apply in the automotive industry, because if it is possible to apply it on an aircraft it can also be applied on a car, bus, or motorcycle: where the lower weight. Will make it to consume less fuel, generating a big saving without mentioning that the piezoelectrics will keep using, because in these systems are presented a big number of vibrations.

For the airlines, this implies a lot of advantages because one of the most difficult things in maintenance is the wiring part, since they are a lot and accessing to them makes its service complicated, without mentioning that a defective cable needs to be located inside a great number of cables, even though there is a specific color for each system and there is also computers that help you locating the failure, the method that is thought to be implemented is more effective, because it would not only prove if the receptor or transmitter are good and for the piezoelectrics, these must be substituted for new ones, but since they are so cheap, it would no be a problem. All this is related with the usage of predictive maintenance, which make it easier.

Creating a project to apply it in the present but also focusing in the future was the principal objective, its applications in the aeronautical field, specifically in the Boeing 737-800, therefore it is planned that this can be applied in the future in every single aircraft.

For the aerospace industry or space exploration the reduce of wires is so important because instead of the space used for the wire systems, a new security system or space for a useful cargo can be implemented. Also in the space being an isolated environment the interferences will be null, it will only need to make sure that the data transmission in the vehicle won't be bothered.

Another advantage is the less contaminants emissions, this because to produce a copper kg you need to emit 6kg of C02 which translate as greenhouse effect. Also this idea can be implemented in an others electrical components such as stove, computers, washing machine, etc. reducing significantly the use of copper.

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