MAE 188: RFID on the Manufacturing Floor of Aerospace Industry

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Abstract

In the aerospace industry, a maintenance history is not that easy to maintain. It can be an arduous task trying to find the part number on a component especially when the component has already been assembled and the number is the back. However, searching for the number is not the only issue in tracking the maintenance history. Since the number is written down by a person, human errors are prone to exist. Perhaps, the human may have copied one number incorrectly or maybe he mixed up the numbers when inputting into the computer. The result of this long process of tracking the history of the part is inaccurate information given to the vendors or airline companies, which will complicate the process when they return the part for service or it is broken already. This long process can be simplified by the use of RFID’s. In particular, for this report, the different RFID tags will be evaluated in this application.

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Background

In the aerospace industry, it is not uncommon for millions of components to be needed. A Dreamliner, that costs more than $100 million, contains 4 million parts. Since RFID is still a new technology and has its limitations, of these 4 million parts, 2,000 will be tagged. Also, it is not proven whether having millions of tags on a plane will affect the plane or the radio systems. The parts that need to be tagged generally are parts with “known low reliability,” “more expensive parts,” and “emergency equipment.” [1] An example of its use is before the plane leaves the plant, all the oxygen masks can be scanned by a person reading the tags as he walks through the aisles. This will ensure that all the safety equipments are in place.

There is a large amount of information that needs to be stored on the tag. The information includes the unique ID, flight time, maintenance, inspection data, part number, serial number, date of manufacturer, lot number, weight, part’s name in English, and so forth. [1] Information such as the unique ID and serial number is for identifying the part and tracking a defective line. The information about the weight is for easy changes to the overall weight in the future since weight is a critical area in aviation and if the Federal Aviation Administration suddenly lowered the weight limit, then the weights of components can be easily calculated and removed or exchanged to meet the new requirements.

Tagging the airline components has many benefits. By tagging with RFID’s, it “will reduce the airlines’ costs of tracking and maintaining service history on parts. It will also reduce the cycle time to solve in-service problems by improving the accuracy of information exchanged between customers and suppliers…[it] will facilitate accurate configuration control and repair history, reduced warranty claim processing costs, accurate and efficient spare parts pooling and easier identification of rogue parts…RFID tags will also reduce airlines’ reliance on paper records and ease future compliance with FAA documentation requirements.” [2] Thus, the main benefits of using RFID technology is are simplifying the maintenance process and improving the accuracy of the information.

Requirements and Ideal Specifications

Currently, there are numerous RFID’s in the market. However, for this specific application in tracking the maintenance history, the number that can be used is limited. Kenneth Porad, the program manager for automated identification programs at Boeing Commercial Airplanes, in 2005, expressed some of the requirements and ideal specifications of the RFID’s:

“We are going to generate the requirements for a robust, high-memory-capacity smart label for aerospace and defense [applications], We're looking at 64 kilobytes, which doesn't exist [in a passive UHF tag] today. It will operate in the UHF band; it will be metal-mount-compatible; and it will be environmentally tested for changes in pressure, temperature and humidity.” [3]

Other ideal specifications of the RFID tags is an average working temperature of 150˚C although the temperature range of the jets varies from -40˚C to 650˚C right outside the exhaust nozzle. [1] However, tagging on such places on the jet engine will not occur until the RFID technology advances significantly to handle elevated temperatures.

Another important requirement is that the tag should comply with EPCGlobal Class 1 Generation 2 and ISO 18000-6C. Following these standards is important to an aerospace company like Boeing since it imports parts from across the world and having an international standard will avoid the need to integrate different systems with different standards from different providers. A common frequency of 860 MHz to 960 MHz will facilitate the process.

Ideally, the tag will have a shelf life of 20 years. [1] The longer the shelf life, the more useful it is. A tag that lasts one year will be useless. Replacing the tag once a year is not much better than having a regular written number or barcode that takes a while to be found. With a longer shelf life, the tag can be read many times and may last even longer than the part, thus avoid the need to be replaced.

Since the components to be tagged are mostly very expensive, price is not much of a concern compared to meeting the other requirements. Porad explained: “A primary flight computer on a Boeing 777 costs $400,000. If you spend $15 on a tag to manage its life cycle, that's okay.” [3] Thus, cost is not much of a factor in this industry since the companies seek high-end and robust products.

Analysis

In order to meet the requirements, some of the RFID tags will be analyzed.

Intelleflex

Standard

In 2006, Intelleflex was chosen to provide the tags for Boeing. [4] After some development, the SXT-7110 battery-assisted tag was created. Being a semi-passive tag, it complies with the EPC Class 3 standard. The operating frequencies are 902-928 MHz for North America and 865-868 MHz for Europe and India. Thus, it can be used internationally by different vendors, which is an important criterion for international corporations in the aerospace industry. [5]

Memory

The tag also has been developed to have a storage of 64 kilobytes. 4 kilobytes will be taken to be used for important information like the serial number and also to implement safety features. Some safety features include the 1Kb block level locking with separate read and write permalock password protection. The remaining 60 kb is the user rewritable memory. Most of this memory will be used to save the detailed maintenance history of the part. The memory type is the EEPROM, which stands for Electrically Erasable Programmable Read-Only Memory and is the standard for most RFID tags. The transfer rate can reach 8 Kbits/sec on the forward link and 32 Kbits/sec on the backward link. Thus, to read the information of a full memory chip will take about 11 seconds to finish. [5]

Range

Since the SXT-7110 is a battery-assisted tag, Intelleflex claims that it can reach a long range of 50 meters, which is larger than most competitors. This range is most likely when the tag and reader has a direct line of sight, but in most cases, a direct line of sight is unavailable because of the tags may be located at the back of a part. So, the range may be much less than 50 meters although it should still have a decent range even when the range is reduced. However, for the purpose of reading maintenance histories of specific parts, a range of 5 meters is more than sufficient. Furthermore, a longer range may become a drawback as with increasing range, the information also becomes increasingly insecure since people are able to read the tags from a far away distance without being caught. [5]

Operating Temperature

The SXT-7110 tag operates from -40˚C to 125˚C. This is a rather large range for temperature. However, it is still a little short of the 150˚C mark for the average systems. Thus, it can be used in areas with room temperature or cooler temperatures, but not so much the place with elevated temperatures. [5]

Lifetime

The battery life of the SXT-7110 tag is claimed to be five years. It will probably vary a little depending on the frequency of the usage. Five years, however, is a decent amount time to record maintenance parts although ideally twenty years would be the best. Other properties like range may be reduced depending on the battery level remain. However, even after the battery dies, the data can be retained for another five years. However, it can only be retained for another five years for environment below 85˚C. A tag in an elevated temperature will most likely not last long. [5]

Cost

The cost as long as it is not overly priced is not concern. However, ideally, the tag should cost a maximum of $15 to $20. The SXT-7110 costs about $5 in 100,000 unit batches, which meets the requirement. [6]

Size

The SXT-7110 is rather large compared to other tags. It has the dimensions of 75mm x 75mm x 15.8mm. The large size is mostly due to the inclusion of the battery. Thus, it is not as easy to attach the SXT-7110 unlike other paper-like tags. [5]

Figure 1: Intelleflex's SXT-7110 tag [5]

<u>Fujitsu</u>

Standard

Fujitsu is currently developing a new tag. This tag will adhere to the EPCglobal Class1 Generation2. Thus, it is a passive UHF tag that runs at 860 to 960 MHz. It also satisfies the SAE AS5678 that is needed for the aviation sector. This standard was issued by the Society of Automotive Engineers in December 2006 that defines the “environmental specifications and test methods for passive RFID tags used in aviation applications. SAE has categorized and defined environmental specifications for RFID tag use, for the three environmental categories of ‘Standard,’ ‘Robust’ and ‘Harsh’”. [7] It also follows the ISO/IEC 18000-6 Type C standard. [7] Thus, this tag fulfills most of the standard and can used anywhere in the world.

Memory

The tag can hold a total of 65,536 bytes. 1,280 bytes are allocated for the system memory, which will include security and 96 bits to meet the EPC C1G2 standard. The remaining 64,256 bytes are left for the user and will mostly be used for storing maintenance data. One distinctive feature is that the memory type is FRAM, as compared to the usual EEPROM. Fujitsu claimed that FRAM (Ferroelectric Random Access Memory) is 30,000 times faster, has 100,000 times higher endurance, and consumes 200 times less power.[8] However, since the technology is still new and based on Fujitsu, further experiments need to be conducted to verify the actual differences.

Size

The approximate weight of the tag is 13.6 grams. This is actually quite heavy for a tag. If 2,000 tags are used on the plane, then the tags will be an extra weight of 26 kg, which is just the same as carrying an extra person. The dimensions are 50.8mm x 25.4mm x 6.22mm. However, Fujitsu has plans on decreasing the size and weight of the RFID tags. [8]

Others

Since the Fujitsu tag is still in development, important specifications like operating temperature, lifetime, range, and cost have not been determined yet. The range and cost probably would not matter too much as long as they are reasonable. The most important specification is most likely lifetime. If the tag can only be used for one year, then it is meaningless. A lifetime of five years or more may be useful. The temperature range should also be sufficiently high. Ideally, it should reach up to 150˚C. [8]

Figure 2: Fujitsu FRAM tag [8]

Hewlett Packard

Standard

The Memory Spot is actually not an RFID, but serves a similar function. Since it is a new technology and not considered to be an RFID, there is currently no standard applied to this chip. It needs to work with the ISO to form new standards or create an extension of the current standard. Also, new readers and infrastructures need to be developed before it can be fully functional. The Memory Spot uses the frequency of 2.45 GHz, which is at a frequency much higher than the common UHF tags. [9] This frequency is the domain of mostly active RFID and may actually interfere with Bluetooth and wifi.

Memory

The Memory Spot has a storage capacity of 512 kilobytes. [10]This is eight times larger than the current largest RFID tag. This capacity should be more than sufficient to store most of the airplane part's maintenance history in great detail. HP claimed that the data transfer rate is 10 Megabits/sec or 1280 kilobytes/sec. [10] It can transfer all the stored information in less than half a second. This is much faster than the transfer rates of RFID tags.

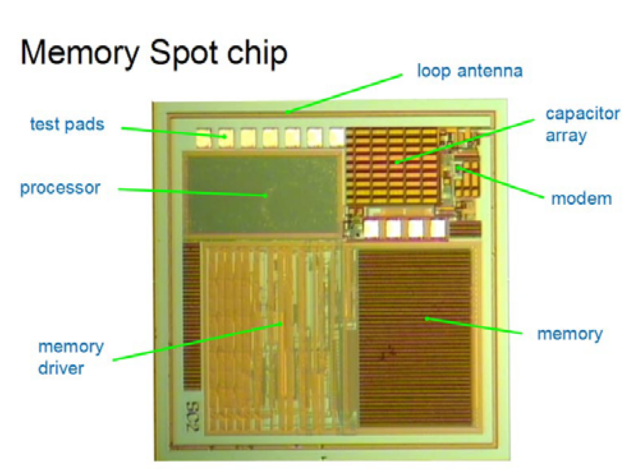

Figure 3: Enlarged View of the Memory Spot [9]

Range

The greatest problem with the Memory Spot is definitely its range. In order for the chip to be read, the reader needs to be within 1 mm. [9] This means that the reader basically has to touch the chip to read or write. With this short range, it is pointless using this technology since even the human eyes have a longer range to read the tag. And for some hard-to-reach areas where the chip is located, it will be impossible to read it. This short range, however, was intentionally created to improve security for other applications. Thus, with further development, it may be possible to improve the range for this application and become suitable for this application.

Operating Temperature

Since the Memory Spot is designed for everyday consumer application, the operating temperature is probably around room temperature. No tests on its limit were conducted, so the highest temperature is unknown. However, it is most likely less than 100˚C. Thus, for the Memory Spot to be used in the maintenance tagging, it needs to be developed further.

Lifetime

The shelf-life of the Memory Spot is also unknown. But most likely, it should last at least a year, but ideally, it should last longer than five years.

Cost

Currently the price is not set yet. However, HP claims that as soon as the Memory Chip is mass produced, it can go down to $1 each. [9] How long it takes for the price to go down still awaits to be seen and is uncertain. But since cost is not much of a concern in the aerospace industry compared to other aspects, the price is not much of a factor in selecting the tag to be used.

Size

The Memory Spot boasts about its small size. It is a 2mm to 4mm square. [9] Because its size is so small, its benefit is that it should fit anywhere, even on the smallest parts. However, the downside is that it is hard to find, so it needs to mount to something more visible, like a card, before it is put onto the part. A more attractive aspect from this small size is its low weight. Although not stated, the weight is probably a few grams at the maximum, which is barely noticeable when incorporated into the plane in large numbers.

Figure 4: HP Memory Spot's small size compared to Pencils [10]

<u>Siemens</u>

Standard

The RF370T transponder does not follow the EPCglobal or ISO standards. Another line of Siemens, the RF600 does comply with the standards, but will be inappropriate for the application in maintenance tracking mainly because of its limited storage. The RF370T operates at a frequency range 13.56 MHz [11]. It is lower than the common UHF frequency of 860-960 MHz.

Memory

The amount of storage of the RF370T can reach a maximum of 64 kilobytes. This will be sufficient for most detailed data. In the memory, 4 bytes are allocated as read-only serial number. Then there is 65,276 bytes for reading and writing. Following the user data is 20 bytes of one time programmable memory. The memory uses the FRAM technology, which is capable of transferring data faster than the usual EEPROM. It can read and write about 0.3ms/byte which translates to about 3 kb/s. Thus, if the data is full, then it will take about 20 seconds to read everything. If the 64 kb of data is not enough to store most of the information, this tag is capable of multitagging up to 4 transponders, which equates a total memory of 256 kb. [11] The readers and middleware, however, will most likely need to be configured before this setup can be used.

Range

The maximum range of the tag is 12.5 cm. Although a slightly longer range is desirable for more convenience, this is an acceptable range in identifying and writing the tags. [12] The range, however, will depend largely on the reader. A weaker reader will decrease the range, so a stronger reader is needed for the application.

Operating Temperature

The RF370T operates between the temperatures of -25 to 85˚C. [12] The range reflects a normal tag with no special differentiation from a normal tag in this area.

Lifetime

The RF370T can retain data for more than ten years. This is a decent length of time for most parts as they may be replaced before ten years. [11]

Cost

Although cost is not much of a factor in choosing the perfect tag, the RF370T is still on the expensive side. According to Housler, the business manager of Siemens's Michigan office, a ballpark price of the tag sold in bulks is about $185. Buying 2,000 tags would cost about $400,000. Considering each plane costs $100 million, this is less than one percent of the total costs. [1] This is not a significant part of cost, but it may be more appropriate to selectively tag the parts and tag less important parts with cheaper tags.

Size

The RF370T has dimensions of 75x75x40mm. This tag is rather sizable especially for a passive tag without batteries. The tag weighs about 200g. [11] With 2,000 tags on board a plane, this will be an extra weight of 400 kg, which is equivalent to about 6 to 8 extra people on the plane. This is a significant weight for a plane where fuel can be saved for reducing the weight.

Readers/Writers

Readers in reading maintenance data will best be handheld. A person will hold a reader and read the different parts. These readers may be connected to a portable device such as the pocket pc to allow more functionalities. A network can be set up with the reader so that as soon as the tag is read, the information retrieved can be sent to a central database using a wifi pocket pc or other devices. The estimated prices for the reader/writer are actually quite high. Each unit is expected to cost about $5,000. [1]

The readers to be used will largely depend on which tag chosen for the purpose. For example, the Siemens R370T will needs go along with the Siemens RF380R reader. The antenna for this reader is integrated and also runs at a frequency of 13.56 MHz. [11]

A better choice, however, may be the Simatic RF310M mobile reader. It has 1.8 MB of internal memory. [13] It is constantly connected to the wireless network. Alternatively, it can be connected to Windows via the activesync if somehow the wireless connection malfunctions. The location of the antenna is labeled 1 in Figure 5. It is also the read/write head of the unit. This reader will only edit the data memories of the RF300 line. Thus, other readers are needed depending on the tags. The data can be inputted by the ASCII keypad or the numeric keys.

Figure 5: Simatic RF310M Mobile Reader [13]

Middleware

For managing maintenance history of individual parts, the middleware can be used to enhance the functions of the RFID tags. Its main use is most likely to capture the RFID data and create a network of readers. It will also probably be a database used to keep track of which components have which tags and which planes have which components. A network can probably be set up by the middleware. Then it will probably collect the information from the reader using a wireless network or when the reader is connected to a computer, which will be limited by the capacity of the reader. The information from the tag will be analyzed by the middleware and then organized.

A case may be that a person goes out to the floor for maintenance work. The middleware will send the tasks he needs to perform via a wireless network to the portable reader connected to a pocket pc that he is holding. After he receives the instruction, he can locate the right part using the unique ID. He can also read the maintenance history that has been performed on the part before. After performing the maintenance check, he can create a brief report on the pocket pc and write information like the checked date through the reader onto the tag. Information he wrote may also be sent to the database wireless if the middleware enables it.

In the case where multiple types of tags with different protocols and standards are used, then the middleware let them work together and unify the data. Also, if the buyer requests for the maintenance history of the part and does not have a compatible reader, then the middleware can share the data with the company.

Results

Standard

Most of the tags meet the EPC standards and run at the UHF frequencies of 860 to 960 MHz. One exception is the Siemens' tag which runs at 13.56 MHz. Also, another exception is

HP's Memory Spot. Since it is a new technology and not an RFID, there are currently no standards.

Memory

All the tags have a minimum of 64 kilobytes. Any tags with less memory were not discussed in this report since this is a fundamental requirement in maintenance history to store enough information about the parts. All tags have a size of 64 kilobytes except for HP's Memory Spot with a high capacity of 512 kilobytes. All the tags allocated at least 1 kilobyte for security. Transfer rates vary rather considerably with different tags. On the faster side is HP's Memory Spot again which is hundreds of times faster than the other tags. In the middle are Fujitsu and Siemens with the FRAM technology with a faster speed than EEPROM of Intelleflex.

Range

The range also varies among different tags. On the high end is Intelleflex with a range of up to 50 meters. This may be a little too high for the application and become a compromise to security. But on the low end is HP's Memory Spot which is only a few millimeters. This is a critical factor since such a short range will be inappropriate for this application. Since HP claimed they designed the short range to enhance security, it may be possible that they can extend the range for this application.

Operating Temperature

Most tags operate around the same temperature. The lower end of temperature is fine. The only problem is the higher end of temperature as most tags barely exceeds 100˚C. Thus, the tags cannot be used for components that will exceed 150˚C during operation. Using them at elevated temperatures is an inherent problem with RFID tags. Thus, in order for the hotter parts to be tagged, more research must be conducted to overcome the heat problem. Of the present tags, it seems Intelleflex's tag operate at the highest temperature of 125˚C.

Lifetime

The lifetimes of the tags vary rather considerably and some are unknown. Most tags can retain data for up to 10 years. The operating time of Intelleflex's tag is probably less since it is battery operated and most of the tag's function is lost once the battery expires. Since other tags do not use battery, research to extend the lifetime of tags should not be hard.

<u>Cost</u>

Although cost is not much of a concern in this application, the costs vary widely. There are low priced tags like the tag offered by HP, which will cost $1. However, this number is still premature since development of the tag is not finished yet. The next cheapest will probably will be the mid-range of around $5 of Intelleflex's tag. There are also expensive tags such as the Siemens' RF370T, which costs around $185 each. The cost will probably be slightly lower for larger batches, but still would exceed $100.

<u>Size</u>

For these high capability and capacity tags, the size is rather huge. The only exception is the tag by HP which is the size of a speck and can be mounted anywhere. Weight is a larger concern than size, however. Siemens' 200 grams tag is a significant weight especially when added to the plane in large numbers. Thus, it may be better to selectively tag important parts with heavier tags. In the middle is Fujitsu's product of about 10 grams. Intelleflex's tag cannot be compared in this category since its weight was never mentioned anywhere. Most likely, however, it is closer to Siemens' heavy weight since they have similar dimensions. The most attractive will probably be HP's memory spot since it is probably no more than a few grams.

Conclusion

The different tags have different advantages. HP's Memory Spot excels with its small size and light weight. However, it is impractical unless its range is increased. Siemens' RF370T is slightly lacking in that it runs at a different frequency, but the biggest problem is its large size and heavy weight which may not be beneficial when attaching thousands of them. Fujitsu seems slightly better in this sense, but it is still in development so a lot of the specifications cannot be compared. Intelleflex's SXT-7110 differed from the rest in that it is battery-assisted with a long range. However, it may have the same problem as Siemens' RF370T because of their similar size, but it cannot be proven until the weight is found. Otherwise, the SXT-7110 meets most of the requirements. Thus, it seems like Intelleflex's SXT-7110 is sufficient for most conditions unless HP's Memory Spot is improved.

Another way of applying RFID in this application is to use smaller and cheaper passive tags and using a more advanced middleware and infrastructure. This way, a larger variety of tags can be chosen and it will be easier to meet the specifications. This method may be slightly more secure in that people need to either hack into the database or the network itself during data transmission. The greatest drawback may be the customers need to contact the database for information on the parts.

In the future, the usage for RFID's may be even extended. With extended temperature, all the tags can be tagged including the nozzle. Lower costs also mean that more parts can be tagged. Perhaps, the usage of active and passive tags can be combined in the future. This will enable the functionality of parts tracking using RTLS tags to be incorporated to the same tags as the ones used to write maintenance history. Also, sensing environments like taking the temperature and pressure at different parts of the plane may become possible with the active tags. If fire starts from an obscure part of the plane, the nearby tags may record a higher temperature and send it to the system for people to investigate and contain the fire. Thus, RFID tags are filled with possibilities in the aerospace industry for the future.

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