Best Practices and Standards in Aircraft End-of-Life and Recycling

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INTRODUCTION

Aircraft decommissioning and recycling is a multi-disciplinary process, with environmental, operational, safety, legal and economic aspects, and related challenges. Therefore, it is important that all involved stakeholders in the aviation sector act together to develop and implement best practices in this area. The aircraft disassembly, dismantling and recycling business is an emerging industry rapidly gaining importance. Its global association, the Aircraft Fleet Recycling Association (AFRA) has concluded MoUs (memoranda of understanding) with both ICAO and IATA to strengthen cooperation across the aviation sector.

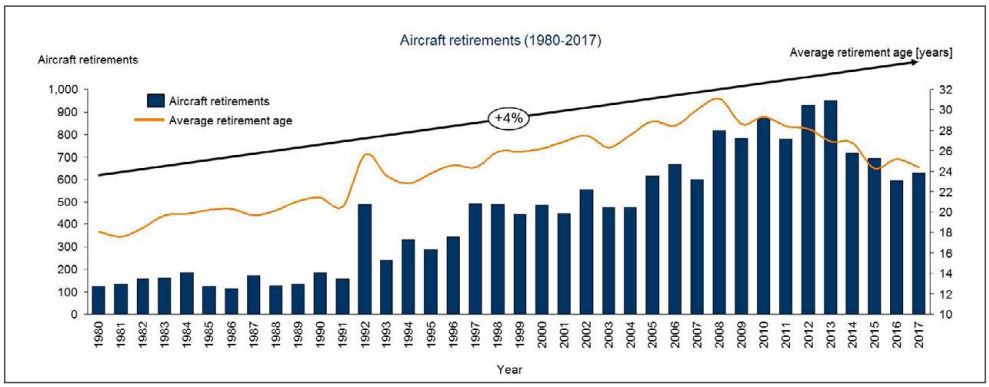
About fifty years ago, with the advent of larger aircraft, commercial aviation started developing into a mass phenomenon. Since then, the number of commercial aircraft has been increasing steadily. In the meantime, these aircraft have aged, and a growing number of them have been retired from service each year. In the light of this growing trend, an increasing number of aircraft operators have begun to focus on the processes to be applied in cases where the retirement of aircraft become relevant. If undertaken in a timely and appropriate manner, aircraft decommissioning can allow recovery of residual value from reused parts and recycled material, while also minimizing environmental and safety risks.

It is highly desirable that all involved stakeholders in governments and industry become acquainted with relevant regulations and business processes, as well as operational experience and best practices in the industry. For this purpose, CAEP undertook a review of existing relevant regulatory documents from ICAO and other international bodies inside and outside the aviation domain, as well as industry best practices and guidance material.

BUSINESS TRENDS

The number of aircraft retirements has been increasing steadily over the last decades (see Figure 1). During the

FIGURE 1: Historical aircraft retirements (1980-2017)



global economic recession starting in 2008, up to about 900 aircraft were retired per year. The current rate is about 600 aircraft per year, and the rate can fluctuate up and down depending on business conditions. The average retirement rate is expected to continue to grow as an increasing fleet is coming of age. Of the more than 27,000 commercial aircraft in service globally, over 20 per cent are older than 20 years and likely to be decommissioned in the coming decade. It is estimated that more than 20,000 commercial aircraft will be retired over the next 20 years.

As indicated in Figure 2, the average age of aircraft at retirement is about 26.5 years. While aircraft retirements for technical lifetime reasons at around 15 years were quite common in the 1980s, this is quite rare today and mostly affects small regional carriers and business aircraft. On the other hand, early retirement for economic reasons is not uncommon today. This occurs when an aircraft is still in satisfactory technical condition, but disassembling it and selling the individual parts is more profitable than continuing to operate it.

Air freighters tend to be retired later than passenger aircraft. Their average retirement age is 32 years, compared with 25 years for passenger aircraft. Many of today's freighters are converted former passenger aircraft. Through freighter conversion, the aircraft in-service time can be extended by typically 10 to 20 years, mostly because the utilization of freighters is normally much lower than that of passenger aircraft.

THE AIRCRAFT END-OF-LIFE PROCESS

As shown in Figure 3, the overall aircraft end-of-life process is divided into two clearly separate phases:

- The first phase, which includes the processes up to the removal of parts for re-use in other aircraft, is part of the aviation domain and subject to the related regulations. During this phase, the retired aircraft is still certified.
- In the second phase, which comprises final dismantling and recycling, the retired aircraft has lost its certification and aviation regulations are no longer applicable.

A well-organized aircraft end-of-life process is carried out as follows:

After the owner's decision to disassemble and dismantle an aircraft, it will enter the disassembly process, the purpose of which is to remove the valuable components from the aircraft. The removed components, depending on their technical condition, will either return to the aviation market directly or need to be inspected and repaired or overhauled by an approved repair shop before returning to service. These activities are performed by competent and authorized/certified actors in the aerospace sector.

FIGURE 2: Retirement age distribution by aircraft usage

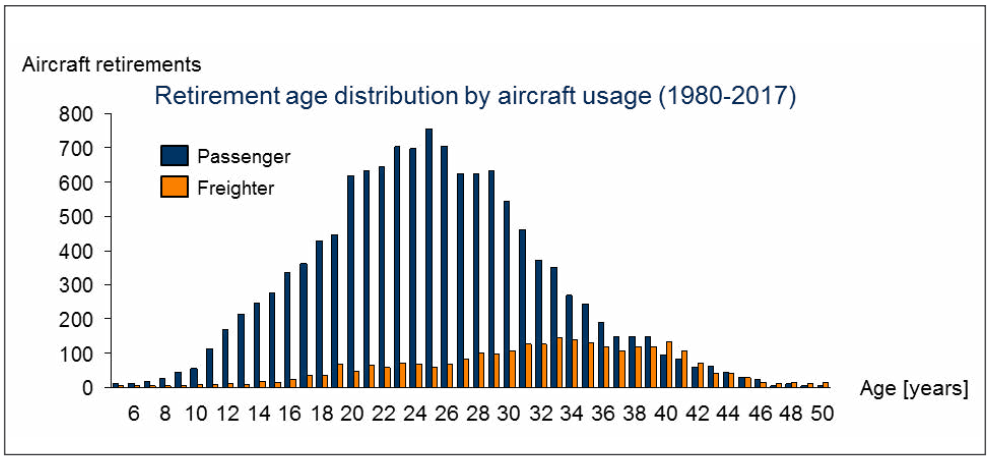
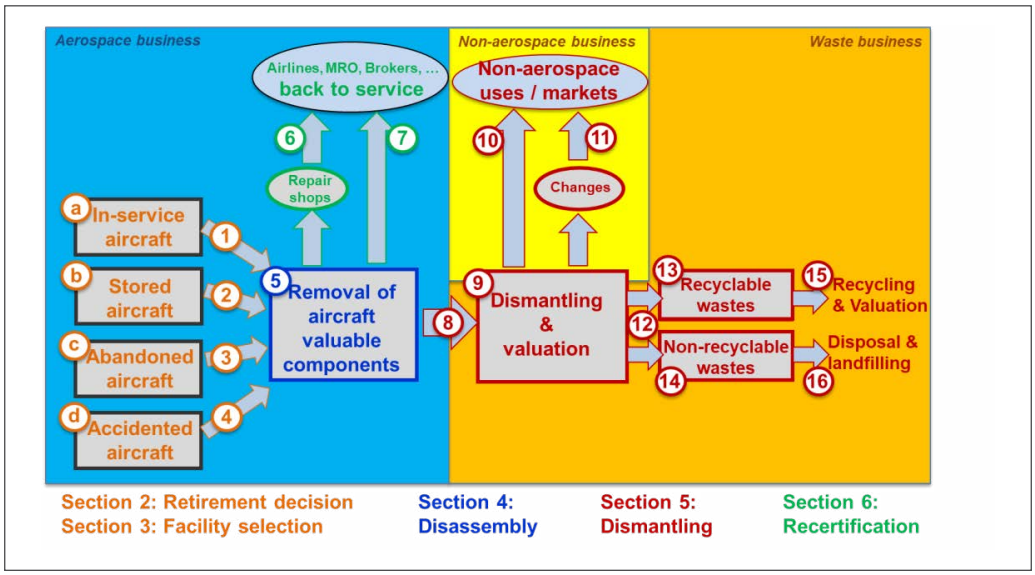


FIGURE 3: Process of aircraft decommissioning



Once the aircraft has permanently lost its airworthiness, it will not be considered as an aircraft under the State of registry's responsibility anymore and may be considered as waste instead. Usually this occurs once the last aircraft owner has sold the aircraft to a dismantling company and all parts intended for re-use have been disassembled. Thereafter, it becomes business waste. Through the process of dismantling, some parts of the aircraft can be re-used for non-aerospace applications, while the rest of the aircraft will be considered as waste and will be extracted and transferred for further treatment. Recyclable wastes will be processed, and batches will be prepared for recycling, and the non-recyclable wastes will be prepared for disposal.

ENVIRONMENTAL ASPECTS

From an environmental point of view, the aircraft end-of-life process presents both risks and opportunities. On one hand, aircraft contain a variety of hazardous materials that must be handled carefully during disassembly and dismantling. On the other hand, the vast majority of aircraft parts can be re-used or recycled without taking special precautions.

Handling hazardous materials requires compliance with national occupational health and safety laws and standards, in order to prevent unanticipated releases of these materials into the environment. Fuel remaining in the tanks, as well as hydraulic oil, waste water, and other fluids must be properly drained before the aircraft can be disassembled and dismantled. Examples of other components requiring special treatment include: emergency oxygen bottles, generators, and halon cylinders. Some aircraft manufactured before the 1980s may contain blocks of depleted uranium, which was used as ballast weight due to its high density. These must be disposed of following nuclear waste regulations, which prescribe special procedures regarding: segregation from other wastes, packaging, transportation, tracking, and final disposal.

End-of-life aircraft that have been abandoned on the edges of airfields present a particular risk of leakage of hazardous material and the contamination of surrounding soils and water. This can be especially problematic if the manufacturer's documentation is no longer available. Because these aircraft are no longer able to fly to dedicated aircraft dismantling facilities, mobile dismantling equipment may need to be used, and particular care is necessary to identify and prevent any contamination risk.

It clearly makes both economic and environmental sense to re-use or recycle parts and components of an aircraft. However, expert knowledge is required to identify which parts of an aircraft can be re-used or recycled, and how much residual value can normally be recovered.

Overall, the current state of retired aircraft treatment is a positive example of responsible environmental practices. Today, 85 per cent to 90 per cent of the weight content of retired aircraft is re-used or recycled, reflecting the fact that both re-usable parts and recycled materials represent significant residual value. It is estimated that between 40 per cent and 50 per cent of the weight of all dismantled aircraft is returned to the parts distribution pipeline. Most of the remaining unserviceable material is recycled and returned to the supply chain as raw materials, although the separation of different structural materials such as various aluminum alloys, titanium, and stainless steel, all require substantial manual work. In some cases, aircraft parts, or even entire aircraft have been repurposed for unconventional uses, ranging from furniture and art work, to hotels inside of an aircraft fuselage (see Figure 4).

Usually, less than 10 per cent of material is treated as waste. Today, the largest part of it is carbon-fiber material, which is more and more widely used for its low weight and related fuel burn reduction. However, there was no method to recycle it in the past, and recycling technologies have been developed only recently. Another type of unrecyclable material consists of cabin interior components such as: insulation blankets, carpets, seat cushions, sidewalls, and ceiling panels. These all contain embedded flame retardants, and safety regulations preclude them from recycling.

In 2018, Boeing, VAS, and ELG Carbon Fibre conducted a joint project to dismantle a Boeing 787. This was notable because it was the first time a composite fuselage had been prepared for recycling. ELG's current process of recovering cured composites for reuse from manufactured components can be utilized for retired aircraft parts as well, which will be useful when more aircraft with large composite pieces begin to retire. Given the long product life-cycles of commercial aircraft, large scale composite structures will not come out of service for at least another decade. The industry is optimistic that today's high recycle rates will be maintained as technology to process the materials continues to mature.

FIGURE 4: Retired aircraft converted into a "Jumbo" hotel in Sweden

Airbus demonstrated a continuous commitment to sustainable dismantling practices when its partner company Tarmac Aerosave dismantled the 140th aircraft since it started operating 10 years ago. Currently, an average of 92% of an aircraft's weight is re-used or recycled.

The Research and Development Committee of the Aircraft Fleet Recycling Association (AFRA) expanded membership, resources and projects to pursue enhanced data, metrics, and innovation for aircraft recycling.

INTERNATIONAL STANDARDS AND REGULATIONS

Aircraft dismantling activities have to comply with existing rules and regulations issued by ICAO relating to aircraft airworthiness, general and hazardous waste management, and recycling activities. CAEP has gathered existing ICAO Standards and Recommended Practices (SARPs), as well as other material of a regulatory nature from various international bodies, including from non-aviation organizations. These bodies include the International Maritime Organization (IMO) and the Basel Convention and the International Telecommunications Union (ITU), which cover aspects of waste management and recycling activities in non-aviation sectors such as shipping and electronics.

It is a very important safety requirement that parts that have been disassembled from a retired aircraft maintain their airworthiness status before being reinstalled in another one. Parts that have been deemed non-airworthy must be recertified by an approved maintenance organization before re-entering service. These companies must ensure that the life history (i.e., operations, modifications and repairs) of the refurbished part is properly recorded. The SARPs in Annex 6 (Operation of Aircraft), and Annex 8 (Airworthiness of Aircraft) to the Chicago Convention on International Civil Aviation, as well as the Airworthiness Manual (ICAO Document 9760) provide related requirements and guidance. Finally, ICAO Annex 14 (Aerodrome Design and Operations) gives guidance in case an aircraft is unable to fly and has to be removed from an airfield.

While ICAO SARPs do not contain specific regulations on environmental aspects of aircraft end-of-life processes, there is material of a regulatory nature coming from other United Nations bodies, including from non-aviation organizations, relevant to waste handling and recycling, such as:

- Guidance on electronic waste treatment by ITU.
- The Basel Convention and related documents on control of transboundary movement of hazardous wastes and their disposal.
- Documents from IMO related to dismantling, waste treatment and recycling of ships, which has some similarities to the situation in aviation.

Some States restrict the importation and inclusion into their national registries of aircraft above a certain age, which has consequences for the second-hand market of aging aircraft[1].

INDUSTRY BEST PRACTICES

Two global industry associations have produced documents describing best practices in aircraft decommissioning and recycling:

- The Best Management Practices (BMP) by the Aircraft Fleet Recycling Association (AFRA).
- The Best Industry Practices for Aircraft Decommissioning (BIPAD) manual by IATA.

AFRA BMP

The Aircraft Fleet Recycling Association (AFRA) is a membership-based not-for-profit association promoting global collaboration on aircraft retirement. Currently, 35 companies are accredited to AFRA's disassembly and

1 As identified by the ICAO Cross-Border Transferability Task Force (XBT)

recycling standards that ensure use of environmental and safety best practices. Its guide, titled *Best Management Practice for Management of Used Aircraft Parts and Assemblies and for Recycling of Aircraft Materials (BMP)* contain recommendations concerning best practices for the management of parts removed from decommissioned aircraft and for the recycling of aircraft parts and materials. The AFRA BMP Guide is a globally applicable voluntary auditable standard to be met by organizations applying for AFRA accreditation. Requiring decommissioning service providers to be AFRA accredited is an option for aircraft owners to ensure that their aircraft are retired with adherence to strict environment and safety protocols.

IATA BIPAD

IATA has developed its Best Industry Practices for Aircraft Decommissioning (BIPAD) manual with the principal aim of providing guidelines for airlines and other aircraft owners and operators to manage aircraft decommissioning in an environmentally friendly and economically sensible way, while meeting all relevant regulations and avoiding safety and environmental risks. The BIPAD manual covers all phases of the aircraft end-of-life process, from the decision to take an aircraft out of service to the final dismantling, recycling, and re-use of parts. The manual also considers the importance of the multi-disciplinary character of the aircraft end-of-life process and covers the economic, operational, regulatory, legal, safety, and environmental aspects of each process phase.