Passenger Aircraft at End-of-Life

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Abstract

Purpose – The presentation summarizes the state-of-the-art in aircraft end-of-life strategies.
Methodology – A literature review is the basic research method utilized. A visit to a dismantling site complemented the findings. Journeys and the Internet show examples of special reuse approaches giving aircraft and components a second life.
Findings – In the past aircraft went to "boneyards" at their end-of-live where they were simply left on their own. This should be avoided in the future. Instead aircraft are initially parked and stored. If no further operation is possible, aircraft are dismantled. Components and material is recycled as far as possible. The rest is disposed. Research has been done on the topic by Airbus, Boeing, other industrial companies, and academic institutions. The aircraft recycling industry starts to build up now by the launch of several recycling plants. The aircraft recycling market will slowly mature with associations like the Aircraft Fleet Recycling Association (AFRA) and with the publication of guidance material for best practices. The significant higher percentage of composites in modern aircraft types is a challenge for aircraft recycling. Special reuse approaches are only a niche market and not able to cope with the number of aircraft that need to be decommissioned each year.
Value – The presentation gives a year 2022 overview on the state-of-the-art of aircraft end-of-life handling with many pictures.
Passenger Aircraft at End-of-Life

Motivation

- About 1,000 commercial aircraft reach the end of their lives every year.
- The safe, responsible and at the same time economical recycling of these machines is a major challenge.
- This must be considered when designing new aircraft.
- However, the composite materials that are increasingly being used are a recycling problem.
- A new aircraft dismantling industry is emerging.
- Much is developed in the recycling processes.
This lecture is based on:

- **Project: HAW Hamburg, Aeronautical Engineering Studies**

- **HAW-Bericht: Verkehrsflugzeuge am Lebensende**

- **Artikel in Airliners.de, die Wissensplattform für die deutsche Luftverkehrswirtschaft**

- **Online News der HAW Hamburg**
Passenger Aircraft at End-of-Life

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Aircraft Boneyards
Aircraft Boneyards

- Boneyards in the USA

https://AirplaneBoneyards.com
Aircraft Boneyards

- 309th AMARG, Tucson, Arizona, USA

https://AirplaneBoneyards.com
Aircraft Boneyards

- By far the largest site is 309th AMARG, Tucson, Arizona, USA.
  Dedicated to military aircraft.
- These F-84 were decommissioned in the 1950th to AMARG. A photo from 1980.

Aircraft Boneyards

- 309th AMARG, Tucson, Arizona, USA (1946)

https://AirplaneBoneyards.com
Aircraft Boneyards

- 309th AMARG, Tucson, Arizona, USA: B36 Peacemaker

https://AirplaneBoneyards.com
Aircraft Boneyards

- 309th AMARG, Tucson, Arizona, USA: B47 Stratojets

https://AirplaneBoneyards.com
Aircraft Boneyards

- 309th AMARG, Tucson, Arizona, USA: Boeing B29 Superfortress

https://AirplaneBoneyards.com
Aircraft Boneyards

- Kingman Airport, Arizona, USA

https://AirplaneBoneyards.com
Aircraft Boneyards

- Pinal Airpark, Arizona, USA
- Kingman Airport, Arizona, USA

http://www.aeroprints.com

https://AirplaneBoneyards.com
Aircraft Boneyards

- Boneyards in Europe

https://AirplaneBoneyards.com
Aircraft Boneyards

- Chateauroux, France: British Airways, A380

- Bournemouth, UK: Planes from British Airways

https://AirplaneBoneyards.com
Aircraft Boneyards

- Tarbes-Lourdes Pyreness Airport, France

- Tarmac Aerospace, Teruel Airport, Spain

https://AirplaneBoneyards.com
Aircraft Boneyards

- eCube Solutions, St. Athan, UK
Aircraft Boneyards

- Boneyard in Australia

Alice Springs Airport

https://AirplaneBoneyards.com
Recycling
Aircraft End-of-Life: Parking => Storage => Dismantling

- Aircraft end-of-life has become increasingly important over the past two decades.
- It is no longer about parking the aircraft forever, but rather about a temporary storage, followed in the best case by the restart or dismantling.
- This procedure avoids the accumulation of more and more aircraft.
- The largest operation in Europe is located at Teruel Airport in Spain.
- 140 aircraft can be accommodated at Teruel Airport.

Teruel Airport, Spain. Attaching foils to protect the cockpit windows for an aircraft to be stored. Source: https://www.tarmacaerosave.aero
Aircraft stored at Tarmac Aerosave. Source: https://www.tarmacaerosave.aero.
The Life Cycle of an Aircraft

- The life cycle of an aircraft can be divided into basic phases:
  - development,
  - production,
  - operations/maintenance and
  - end of life.
- The life cycle can be analyzed with a life cycle assessment (LCA) according to ISO 14040 and ISO 14044.
- The method was extended for use in aircraft (dissertation, Johanning, HAW Hamburg<sup>1</sup>).
- Flight operations dominate with more than 99% over the entire life cycle.
- This is because flight operations take place every day, but production and end-of-life processes only occur once in an aircraft's lifetime.

The Life Cycle of an Aircraft

- This presentation is about the end of life of aircraft – and thus actually about a tiny part of the environmental impact of aircraft.
- Nonetheless, the task at hand is gigantic:
  - Over the next 30 years,
  - 29000 passenger planes will reach their end-of-life,
  - no matter how civil aviation continues to grow. That's about 1000 planes a year.
Tasks at End-of-Life

- These tasks are pending at the end-of-life:
  - decommissioning, careful disassembly, and violent dismantling.
- After the aircraft has been dismantled, a distinction is made between reuse (recycling) or disposal (disposal) depending on the component or material.
- For economic and ecological reasons, we aim to achieve as high a percentage of reuse as possible (recycling rate).
- But what cannot be reused must be disposed of:
  - landfill or incineration (burning).
- When it comes to recycling, a distinction is made between
  - the use of secondary components and secondary raw materials.
- Accordingly, a distinction can also be made between
  - component recycling rate and a material recycling rate.
  - Aircraft achieve a recycling rate (based on mass) of 60% ... 85%, with more being sought.
Disassembly of an aircraft at Tarmac Aerosave. Source: Airbus, https://perma.cc/SZS7-CDBX.
Cutting a wing at Tarmac Aerosave. Source: https://www.tarmacaerosave.aero.
When an aircraft is dismantled by force, a voluminous heap of scrap is initially created. The parts are shredded, separated according to their density and fed into further recycling processes. What is left is disposed in a landfill.

eCube Solutions, St. Athan, UK
eCube Solutions, St. Athan, UK
Recycled Components

- In the case of aircraft, the recycling of components is of great economic importance.
- Aircraft components are expensive, so used parts can still fetch high prices.
- Certain components on the aircraft are designated as Life-Limited Parts.
- These components have a lifespan described in flight hours, cycles, or calendar time.
- Proper technical documentation is part of airworthiness and must allow back-to-birth traceability.
- The documentation must always show the life status in flight hours, cycles or calendar time.
- For used parts from recycling, the functionality results from the fact that they were operated correctly on the last flight or from a quality check.
- Recycled components can be
  - sold with their current life status, or
  - sold as new after appropriate maintenance.
Recycled Components

Aircraft parts are removed, labeled, checked for quality, serviced if necessary and packaged for sale.

eCube Solutions, St. Athan, UK
End-of-Life
End-of-Life Does Not Necessarily Have Anything to Do with Age

- **End-of-life** does not necessarily have anything to do with age or overall use of the aircraft.
- Irrespective of flight hours and flight cycles, an **aircraft becomes obsolete if its operating costs are too high** compared to other aircraft, or if there is simply no demand for flights.
- Under favorable circumstances, passenger **aircraft can be operated economically for around 30 years**.
- However, the end of an aircraft's life is always determined by an **economic consideration**.
- **End-of-life can occur after as little as 13 years**, as was recently the case for some Airbus A380 aircraft.
- If there is no buyer for the used aircraft, then the only choice left is between further **operation** or **scraping**.
- You try to sell the aircraft in individual parts. The **engines are the most valuable**.
- **Cargo aircraft** have lower usage than passenger aircraft and do not require regular expensive cabin renewal and can therefore **be kept in service longer**.
Among the early A380s due to be dismantled is this ex-Singapore Airlines aircraft. It only lived to be 13 years old.

Source: Flight Global (2021-11-09)
The End-of-Life often Begins Slowly

- An **aircraft** that has no place on the market today can possibly be used again later.
- This is due to fluctuations in supply and demand and changing opportunities to make profits.
- An operator will therefore be willing to **leave the aircraft idle at low running costs** for the ability to **reactivate the aircraft if necessary**.
- A distinction can be made between **parking** and **storage**.
Airbus and Boeing Activities
Airbus and Boeing Started Research and Recycling Facilities

- The two major civil aircraft manufacturers, Airbus and Boeing, both independently started research projects and recycling test facilities.
- Both manufacturers are benefiting from the results of their efforts by being able to incorporate the learnings into the development of their next-generation aircraft.
Airbus started the PAMELA Project

- **Airbus** started the **PAMELA (Process for Advanced Management of End-of-Life of Aircraft)** project in 2005 in collaboration with
  - Suez-Sita - a French recycling company - and
  - the LIFE working group (l'Instrument Financier pours l'Environnement).
- In early 2006, an **Airbus A300-B2 was completely dismantled** and dismantled at **Tarbes Airport**.
- In **2006**, it was the world's **first demonstration of a complete dismantling** of a passenger aircraft.
The so-called 3D approach to aircraft dismantling from the PAMELA project

Adopted from:
Airbus Founded Tarmac Aerosave

- After the PAMELA project, Airbus, together with other companies, founded the *Tarbes Advanced Recycling and Maintenance Aircraft Company* (Tarmac Aerosave).
- In 2020, Tarmac Aerosave has recycled a total of 170 aircraft since inception.
- In addition to Airbus, the two shareholders of Tarmac Aerosave are today
  - the *Safran* Group and
  - *Suez*.
- Around the same time, many other similar companies emerged in Europe.
Boeing Founded the Aircraft Fleet Recycling Association (AFRA)

- In April 2006, **Boeing** founded the **Aircraft Fleet Recycling Association (AFRA)** in partnership with ten European and American companies.
- The founding members come from sectors such as **waste management**, raw **material production**, **aircraft maintenance** and manufacture, parts **suppliers** and service providers.
- They are committed to using their combined know-how, including aircraft scrapping, at the **highest technical level**.
- **AFRA** is a self-financing non-profit organization whose members work under a certificate with defined processes.
- With the collective experience of AFRA members, a guide to "**Best Management Practice for Management of Used Aircraft Parts and Assemblies and for Recycling of Aircraft Materials**" (BMP) was developed.
- For members or companies applying for **membership**, the BMP document sets out the verifiable **standards**.
Composite Materials
Challenge: The Increasing use of Composite Materials

- A particular challenge is the increasing use of composite materials for which there are still no mature recycling processes.
- In 1970, the Boeing 747 still managed almost entirely without composite materials.
- Since then, the proportion of composites has increased with each new aircraft type, reaching 50% with the Boeing 787 and Airbus A350.
COMPOSITE MATERIALS

- Carbon Fiber Reinforced Plastic (CFRP)
- Glass Fiber Reinforced Plastic (GFRP)
- Quartz Fiber Reinforced Plastic (QFRP)
- Glass Reinforced Aluminum Laminate (GLARE)

Airbus,
https://perma.cc/9PXR-DDMF
Compound Waste Can Be Processed in Three Ways

- Carbon fiber and epoxy are most commonly used in large commercial aircraft.
- The composite parts from the aircraft will only be produced in large quantities in 25 years.
- This means the problem is still ahead of us.
- The compound waste can be processed
  - mechanically,
  - thermally or
  - chemically.
Processing Composite: Thermally

- Thermal processes use high temperatures.
- First, the parts are mechanically broken down into manageable pieces, which are then fed into a fluidized bed reactor.
- The hot air flow decomposes the matrix.
- The clean fibers are then separated from the air by a cyclone:
  - Heavier components such as metallic components are not carried up with the airflow and are therefore separated.
  - The resin from the matrix is completely oxidized in an afterburner that produces energy.
- The resulting fibers have a fluffy shape and a length of up to 10 mm.
- So far, it has not been possible to prevent a reduction in tensile strength, but the modulus of elasticity and the surface quality of the recycled fibers are comparable to fresh fibres.
- The recycled fibers can only be used in non-oriented fabrics.
Special Reuse
Special Reuse Approaches

● In contrast to these common disposal strategies, there are special reuse approaches.

● The general idea is to **give an aircraft component a second life** outside of aviation.

  To be distinguished:
  o **raw parts** for collectors or used for similar purpose (pump, electric motor, seat),
  o **art work** from aircraft parts (wall decoration, sculpture),
  o polished and extended **parts for a new purpose** (chair, table, lamp, clock).

● **Aircraft** or **fuselages** with new or intact cabin interiors used as:
  o **apartment** (home),
  o **hotel**, café,
  o **registry office**,
  o **eye-catcher**, monument or aircraft in a museum.

● Note: **This** is only a **niche market** and not able to cope with the volume of material to be handled when 1000 aircraft have to be decommissioned each year.
Airplane Raw Parts

https://planereclaimers.aero/product/airbus-cockpit-panels-a318319320321330340

https://planereclaimers.aero/product/aircraft-remove-before-flight-ribbon-3

https://www.etsy.com/de/listing/1189498823
Airplane Parts for New Purpose

Table
https://www.etsy.com/de/listing/897207377

Bar from fuselage structure
https://www.etsy.com/de/listing/877297683

Clock from window
https://www.etsy.com/de/listing/714347807
Wall clock from turbine disk

https://www.etsy.com/de/listing/622147065

Wall illumination (LED) from slat

https://www.etsy.com/de/listing/980810739

https://www.etsy.com/de/listing/903331577
Table from slat
https://www.etsy.com/de/listing/897207377

Illumination hanging from the ceiling based on aircraft structure
https://www.etsy.com/de/listing/897207377
Airplane Art Work

Painted A320 pylon fairing
https://planereclaimers.aero/product/jim-vision-painted-a320-r-h-pylon-fairing

View from back

Airbus A319 brushed aluminum window
https://planereclaimers.aero/product/airbus-brushed-aluminium-window
Aircraft or Fuselage as Home

Bangkok airplane graveyard becomes home for families

https://planereclaimers.aero/2021/10/14/are-aircraft-pods-the-new-outdoor-craze

https://planereclaimers.aero/custom
A Boeing 727 is the home of Bruce Campbell in Oregon, USA, http://airplanehome.com
House extension with an Iljuschin IL-18 in Russia.
Home of Joe Axline is a MD-80 and a DC-9-41 at Sport Flyers Airport (27XS), Brookshire, Texas, USA
https://www.newsweek.com/airplane-home-unusual-property-1652350

https://www.facebook.com/PlaneHome
Aircraft as Hotel

This suite at the Hotel Costa Verde on the coast of Costa Rican was once a Boeing 727. You can sleep with sea view next to tropical beaches in this "727 Fuselage Home". Puntarenas Province, Quepos, Costa Rica. https://costaverde.com

**Vliegtuiguistsuite**

Hotel in IL-18: De Zanden 61b, 7395 Teuge (airport near Apeldoorn), The Netherlands, https://www.vliegtuighotel.nl
Hostel in a Boeing 747, JUMBO STAY, Jumbovägen 4, Stockholm Arlanda
https://www.jumbostay.com
Projet Envergure
Artist's impression of planned Airbus A380 hotel

https://www.projet-envergure.com
Aircraft as Restaurant, Café or Registry Office

Douglas DC-3 plane attached to the McDonald's restaurant in Taupo, New Zealand. Photo by Fuwuyuan, 2012, CC BY-SA
Restaurant in a Boeing KC-97
1665 N. Newport Rd.
Colorado Springs
Colorado, USA

http://www.theairplanerestaurant.com
Airplane café in a Lufthansa Lockheed Superconstellation. Details next page.
A Heavenly Delight – Airplane Café in a Lufthansa Lockheed Superconstellation

From 1967 to 1975 one of the most bizarre cafés in the world was in Neu Wulmstorf near Hamburg, Germany. In addition to the mini golf course, opposite the outdoor pool, you will find four tennis courts today. That wasn't always like that. Fifty years ago you would have had a 33 meter passenger plane found there with a wingspan of 44 meters - a discarded Lufthansa Superconstellation D-ALOP at the age of 12 and with 26715 flight hours. Butcher Siegfried Karas, then chairman of the mini golf club, bought it for 23000 DM (11500 EUR), transported it to Neu Wulmstorf and converted it into a cafe. He invested a total of 75000 DM (37500 EUR) before opening his curious restaurant called "Flugcafé" (flight café). The transport should have swallowed a good chunk of the money. The aircraft was transported from Hamburg airport to the harbor, from there on a pontoon across the river Elbe to Hamburg-Harburg and then to Neu Wulmstorf again by truck via the country road B73. Finally, two 45-ton cranes assembled the giant bird on site. Three stewardesses served for the first time on October 21, 1967 hot and cold meals, cakes, pastries and international drinks in three rooms (a bar, a restaurant and a club room). For many this was the attraction of the region, for others an eyesore and cause for complaint. As spectacular as the story begins, its end is unfortunately terribly unglamorous. After the first good years, the airplane cafe was no longer an attraction, the guests stayed away, the business barely made a profit. A rescue attempt by an interest group for the preservation of old commercial aircraft failed after the closure of the cafe in 1975. The deceased owner's widow had to vacate the place. An investor was found who left the same year with the good old super bird. Here the story ends for the village New Wulmstorf.

Translated from:
On October 23, 1989, captain Heinz-Dieter Kallbach managed the spectacular landing of the four-engine long-haul Interflug aircraft of type Iljushin 62 on the only 860 m short glider airfield in Stölln. Otto Lilienthal carried out his pioneering flight tests on this site from 1893 to 1896.

A Tupolev TU-134 as a monument in front of Chișinău International Airport. Chișinău, is the capital of the Republic of Moldova. On September 13, 1990, a TU-134 made the first flight on the international route Chisinau-Frankfurt.
Aircraft in a Museum

Summary
Passenger Aircraft at End-of-Life

Summary (1 of 2)

- Aircraft Boneyards
  - USA
  - Europe
  - Australia

- Recycling
  - Aircraft End-of-Life: Dismantling
  - The Life Cycle of an Aircraft
  - Tasks at End-of-Life
  - Recycled Components

- End-of-Life
  - End-of-Life Does Not Necessarily Have Anything to Do with Age
  - The End-of-Life often Begins Slowly
Passenger Aircraft at End-of-Life

Summary (2 of 2)

- Airbus and Boeing Activities
  - Airbus and Boeing Started Research and Recycling Facilities
  - Airbus started the PAMELA Project
  - Airbus Founded Tarmac Aerosave
  - Boeing Founded the Aircraft Fleet Recycling Association (AFRA)

- Composite Materials
  - Challenge: The Increasing use of Composite Materials
  - Compound Waste Can Be Processed in Three Ways
  - Processing Composite: Thermally

- Special Reuse
  - Home
  - Hotel / Hostel
  - Café
  - Registry Office
  - Monument or on display in a museum
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