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The Use of Excess Aircraft as Maximization of Resources

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**The Use of Excess Aircraft as Maximization of Resources**

Mr. Gilbert Sinclair, College of Aviation

Ms. Tracey Moon, Military Advocate, Center for Academic Success Programs
THE USE OF EXCESS AIRCRAFT
AS MAXIMIZATION OF RESOURCES

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by
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April 20th, 2012
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ABSTRACT

The United States currently has within just 6 airfields approximately 4,600 grounded aircraft. Out of these excess aircraft, approximately 66,900 metric tons of secondary aluminum could be extracted. All this amount of material equals to approximately 147 million US dollars if sold to the current aluminum market price; the United States government could save up to 450 million US dollars just in electrical power expenses by choosing to recycle these aircraft, instead of producing primary aluminum out of bauxite. Recycling all these aircraft, would also have a positive impact in the environment, since hundreds of acres would be freed from all that metal, cleaning the landscape and reducing landfills; and by processing all that material instead of processing primary aluminum, the gases emissions would be fewer as well. If all of this currently available material is taken in consideration for a future national recycling project, the national economy would go through a positive impact, by the creation of new jobs in a very dynamic industry.
INTRODUCTION

Background

One of the biggest steps in aviation history happened in 1903 in the United States, with the Wright Brothers’ invention, creating a heavy machine called “aircraft”, that could carry a person through the skies, and since then the United States has remained the busiest country with regard to aviation. With all the technological advances aviation is going through every day, old aircraft are being grounded and replaced by newer ones; these grounded aircraft are just becoming part of aircraft boneyards inventories. Recycling is today’s best solution to avoid the increase of landfills, which is one of the greatest threats that face the ecological part of the aviation industry.

Purpose and Audience

The purpose of this research paper is to discuss the possible aggravation of a non-ecologically friendly situation that the aviation industry currently faces: the landfills created by excess aircraft. The audience of this research paper includes pilots, aviation related personnel, aviation enthusiasts, aluminum recycling enthusiasts, ecologically-friendly enthusiasts, and other readers interested in the other topics discussed in this paper.
Sources

The majority of the information sources for this research paper were online. Some information was acquired by directly contacting employees of companies and organizations related to the excess aircraft issue, such as the United States Department of Defense (DoD), Defense Logistics Agency (DLA), Boeing Corp., Airbus S.A.S. and others by means of the Freedom of Information Act. Waldo Library’s online services were also used, and the rest was obtained from credible websites and trade magazines with online publications.

Scope

This paper will cover the background and current situation of excess aircraft within the continental United States. Since aluminum is the most common material in an aircraft manufacturing, a comparison of producing aluminum from its ore the bauxite, versus recycling all the material that possibly could be extracted from all the grounded aircraft is included in this research paper. Possible benefits from recycling all these aircraft; the problems that may occur if more aircraft are to be stored and grounded for an undetermined amount of time; description of the affected sectors, and possible solutions for these problem are also included in this document.
Limitations

Regardless of all of the material that could be recycled from an aircraft’s scrap, this research paper will focus only in the metal than can be obtained, specifically aluminum. Instead of using 90% of the recoverable materials from an aircraft, only 75% will be used to create lower statistics numbers. When referring to the primary aluminum production, the refining process will not be discussed, but the reduction process will be briefly analyzed. The costs that may surge with manpower and machinery use for the initial transportation of the aircraft to a recycling facility, it’s cutting and shredding, categorizing of the scrap and transportation to the final melting location are not included and or analyzed, since hundreds of currently operating companies provide these kind of services, and vary with their processing and transportation methods, times and costs. Also, when referring to the Aerospace Maintenance and Regeneration Group (AMARG) specific public inventory list, it will not be annexed to this document, because of its length and relevance to the content of this paper.
Definitions

- Aircraft Boneyards: airfields that have, within their assigned territories, a significant amount of grounded aircraft that won’t fly anymore.

- Aluminum Alloys: metal created mainly of pure aluminum, but combined with others metals such as nickel, copper, magnesium and manganese.

- Excess Aircraft: all aircraft that were once used for a specific mission, and stopped flying because they were replaced, their specific missions are no longer supported and performed, they were heavily damaged or because they reached the end of their life cycle.

- Maximization: the proper use or management of an asset to extract the biggest profit out of it. While this word is originally an economic term, it will be used to describe the proper use and management of a material to obtain the best possible uses out of it, regardless of the material’s initial purpose.

- Primary Aluminum: aluminum produced by its prime source, the bauxite ore through refining and reduction processes.

- Recycle: describes the classification and re-processing of used items and/or materials in order to create new products, reducing waste, pollution, and greenhouse gases emission.

- Scrap Metal: all the metal that is not desired for use anymore, trashed, and most of the time destined to be part of the landfills.

- Secondary Aluminum: aluminum produced by re-melting, re-casting, and re-shaping of old aluminum scrap.
COLLECTED DATA

Background

Historical Background and Situation Overview

History has shown that humankind has always had the need to travel from and to different places for many reasons, such as: to discover, to conquer, to migrate, to trade or to simply make a visit. With time, humans have evolved and with them, the technology has too, however, the transportation needs have persisted. Transportation methods have evolved from walking, running, sledding and riding horses; to riding trains, boats, cars and airplanes. Since the Wright Brothers’ invention in 1903, creating a heavy machine called “aircraft”, that could carry a person through the glorious skies, transportation methods have evolved with a relatively fast pace, especially the aviation industry. Aviation has allowed a significant reduction in traveling times, and with every newer aircraft model, more people and cargo can be carried and taken to their desired destinations. Currently, the aviation industry invests a significant amounts of resources in the research for safer, faster, more efficient and ecological-friendly aircraft that are compatible with today’s population growth, fuel prices increase, and other current global issues. With the implementation of these new aircraft, currently flying aircraft are destined to reach an “earlier” end of life and stop flying, in order to be replaced by the new technology equipped/capable aircraft.

Boeing Corp. and Airbus S.A.S., the two biggest airlines aircraft manufacturers, estimate that by the year 2025 nearly 12,000 aircraft will reach their end of life limit and stop flying; also by that same year, the amount of flying airliners will increase almost to double today’s flying airliners. This possible forecast triggers a question: what will happen to all those aircraft that
will stop flying? This question causes other doubts, such as: what has happened to those great 
machines that were flying 30 or 40 years ago? What happened to all the technology that now can 
be considered as tons of “junk”?

Within six airfields in the continental United States, over 4,600 aircraft are being kept in 
storage, and probably will not ever fly again. These aircraft, ranging from small helicopters to 
huge Boeing 747s, are part of what is referred to aircraft boneyards. Currently, when the 
maximization of resources is indispensable, having this amount of resources that definitely could 
be used in the same aviation industry or other industries lying idle is unacceptable. 
Sustainability needs are increasing, stemming from the reduction of using oil derivatives 
products and their different types of fuel, to recycling most of the items and waste that create 
landfills that can be processed, in order to be re-used or to create new items. The cost increase of 
processing raw materials to obtain the metal alloys and composites that are used in most of 
today’s products, have led to an increase in demand of ecologically friendly products, to reduce 
manufacturing and production costs of the items and vehicles that represent this century’s 
lifestyle.

Since 1915 with the introduction of the first all metal aircraft, the “Junkers J-1” 
developed by Hugo Junkers, most flying aircraft have been produced with metal, especially 
aluminum, which is still used by many aircraft manufacturing companies in over 70% of each 
aircraft they produce. Aluminum has proven to be a great aviation material, because of its 
strength, light weight, and its capacity to be mixed with other metals to create harder alloys that 
are required in specific parts of most of the produced aircraft. However, among the most 
interesting characteristics of aluminum, is its capability of being recycled an unlimited number of 
times, without losing its qualities. This makes it an excellent material, not only for aircraft, but
to any other transportation method that has a limited lifespan (Tegtmeier, Keeping Aviation Material Flying, 2008).

Most aircraft have an average of approximately 90% of their components that can be recycled. These components vary from different types of metals to plastics and textiles. However, the metals are the most valuable and ecologically friendly materials used on most aircraft. Nearly 98% of all metallic components used in an aircraft can be recovered, such as: steel, iron, titanium, copper, aluminum, and other metal alloys. The metal most used from those mentioned is aluminum and its different derivate alloys (Burchell, 2010). All the different kind of metals that can be extracted from the all of the grounded aircraft could be collected, classified, sorted, processed and re-used, affecting positively the United States’ national economy and environment.

Within the continental United States as previously stated, in just six airfields, approximately 4,600 aircraft are being kept in storage, and could go through this recycling process, providing the nation with a lot of resources that could be destined for other uses and could also free up spaces that are destined for these old aircraft that are grounded, reducing landfills and so improving the environment. These airfields are:

1. 309th Aerospace Maintenance and Regeneration Group (309 AMARG) located in the Davis-Monthan Air Force Base; Tucson, Arizona.
2. Phoenix Goodyear Airport, located in Goodyear, Arizona.
3. Pinal Airpark, located in Marana, Arizona.
4. Mojave Airport, located in Mojave, California.
5. Southern California Logistics Airport, located in Victorville, California.
6. Roswell International Air Center Airport, located in Roswell, New Mexico.
All of these airfields are known by the amount of non-flying aircraft that they have in their assigned territories, and are called “aircraft boneyards”. The biggest one from the previous list is the Aerospace Maintenance and Regeneration Group (AMARG), which by itself has approximately 3,900 aircraft; some of which have been grounded and in storage for decades. One of the most interesting facts about this boneyard is that all of these aircraft remnants were once military aircraft (309 AMARG FOIA, personal communication, November 15, 2011). The approximately 1,700 remaining aircraft, outside of AMARG, are distributed in the other five airfields. However, these aircraft, regardless of their being fewer, can also provide great amounts of recycling material, since most of these are civil aircraft that once carried passengers and/or cargo.

Aluminum, Its Production and its Recycling Facts

Aluminum or Aluminium, represented by the symbol “Al”, is the most abundant metal in the Earth’s crust. This metal is lightweight and malleable; it is not magnetic, does not easily ignite, and is resistant to corrosion. It’s also considered a superconductor, due to its capability of conducting temperature, magnetic fields, and electrical currents. Aluminum is also considered to be a good reflector, due to its capacity to reflect over 90% of visible light and infrared radiation. Its melting point is 660°C, and its boiling point is 2,519°C. Regardless of all these positive and extremely useful characteristics of aluminum, its metal state does not occur naturally, as it is extracted by its main ore, the bauxite (Green, 2007).

Bauxite, as previously stated, is the main source of aluminum. Over 70% of the world’s bauxite is destined through go to the process to obtain aluminum. When the initial aluminum is obtained in its pure form, it is very lightweight and soft, so to make it harder and stronger, it is usually combined with other metals such as nickel, copper, magnesium and manganese, creating
what are known as “aluminum alloys”. The aluminum production can be divided into two
groups, the primary production aluminum, which is produced by the bauxite ore refining and
reduction, and the secondary production, which is obtained from the recycled aluminum. Within
the United States, of the total aluminum produced, approximately 52% is primary aluminum, and
the remaining 48% is secondary aluminum (U.S. Environmental Protection Agency, 1998).

The primary aluminum production encompasses two processes:

1- Refining: grinding and handling of the bauxite ore.
2- Reduction: removing aluminum from the crystalline alumina.

The reduction process starts once the refining process ends, with a material called
“crystalline alumina” (Al$_2$O$_3$), which is then used to produce the metal aluminum by an
electrolysis process. This process requires large amount of energy to raise the material’s
temperature to its melting point and also to provide an electrical current to pass through the
material to force it react; both of these processes happen simultaneously in large furnaces that are
called “Hall-Heroult Cell”, and the output is 99.7% pure aluminum.

The secondary aluminum production encompasses two processes:

1- Scrap pre-treatment: sorting and cleaning of scraps.
2- Smelting / Refining: melting, refining, cleaning and alloying of aluminum.

The “scrap” which is the basically all the metal that is not used anymore, trashed, and
most of the time destined to be part of the landfills, is sorted and processed to remove any non-
desired material, and any other metal that won’t be recycled. The selected aluminum extracted
from scraps is then cleaned by heat, with a process called “pyro-metallurgical cleaning” or by
water, with a process called “hydro-metallurgical cleaning” to remove any potential contaminants. After the material is cleaned, it is then heated and melted in a normal furnace; however, depending on the future use of the aluminum, the produced metal will then be mixed with other metals to create alloys or will remain as pure aluminum. After the furnace, the aluminum can be molded into ingots, going through further processes to remove remaining impurities, and shaped according to the future users’ needs (U.S. Department of Energy, 2007).

As of 2010, the United States had seven states that were responsible for the largest domestic production of primary aluminum. Those states with smelters east of the Mississippi river accounted for 71% of the United States total primary aluminum production; placing the United States as the producer of 4.5% of total global production of primary aluminum. In the same year, the United States recovered approximately 3 million metric tons of aluminum from purchased and gathered scrap. Out of these 3 million tons of aluminum, 54% was obtained from manufacturing scrap and the remaining 46% was obtained from discarded aluminum products (U.S. Department of Energy, 2012).

**Negative Aspects of Producing Primary Aluminum**

The nations that produce primary aluminum are being impacted in their economies and environments, because of all of the disadvantages, when compared with secondary aluminum production. Referring to energy requirements, the production of primary aluminum from bauxite ore requires approximately 23.8 (62.2 $\text{tf}$ $\text{kWh}$) kWh/kg of aluminum, equal to 94% more energy than recovering aluminum from scrap, since the production of secondary aluminum ingots require approximately 6% of the total energy required to produce primary aluminum (U.S. Department of Energy, 2007). Thanks to recycling, in 2003 the United States saved approximately 19,100 Megawatts of energy, since each kilogram of recycled aluminum saves 59.4 $\text{tf}$ kWh of the 62.2 $\text{tf}$ kWh of energy consumed to produce a kilogram of primary aluminum. Also, any process that helps maximize aluminum recovery from scrap, will increase even more the energy savings associated with aluminum production. With the high energy demand to produce primary aluminum, the economical factor is primarily affected by the price of kWh and the differential amount of energy required to produce both type of aluminum. The other factor is the environment. For example, in the state of Washington, primary aluminum facilities are one of
the largest toxic emission producers, and strict emissions regulations must be taken into
consideration. However, the recycled or secondary aluminum production’s emissions can be
controlled by fabric filters, like bag-houses or electrostatic precipitators (U.S. Environmental

Currently, approximately 170 million tons of greenhouse gases emissions per year are
being avoided by recycling aluminum, instead of producing it from bauxite. The most common
power generation sources produce CO$_2$ emissions, and since the secondary aluminum production
requires less power to be produced compared to primary aluminum, fewer emissions are going to
be generated, as well. If the energy required to produce primary aluminum is approximately
94% more than the energy required to produce secondary aluminum, then the emission gases
generated by primary aluminum production will also be proportionally higher, when compared to
secondary aluminum production (International Aluminum Institute, 2009).

Image 2. Annual Avoided Emission by Aluminum Recycling (International Aluminum Institute,
2009).
Current Situation

Actual Excess Aircraft

As of today, Boeing Corp. has approximately 19,410 aircraft in service, and of these, 770 are large airliners, 3,640 are twin-aisle airliners, 12,100 are single-aisle airliners and 2,900 are regional jets (Boeing Corp., 2010). Also, Airbus S.A.S. has approximately 15,002 aircraft in service divided among very large, intermediates, small twin-aisle, and single-aisle airliners (Airbus S.A.S., 2010). Currently, these two companies which are the two biggest passenger aircraft manufacturers in the world, have a total of approximately 34,412 aircraft in service, carrying millions of people and tons of cargo worldwide every day. From the total world air traffic, North America dominates by having 19.4% over its airspace, compared to 19% in South Asia and a 13.7% in Europe (Airbus S.A.S., 2010). However, these two major aircraft manufacturers estimate that by the year 2025, nearly 12,000 aircraft will reach their end of life limit, and that in the same period, their respective flying fleet numbers will increase almost to double today’s flying fleet (Burchell, Salvaging and Scrapping Aircraft, 2007).

Taking information from recent pictures from the software called “Google Earth”, with a database ranging from January, 2009 to July, 2011, just between these six airfields approximately 4,600 units can be counted. From these units approximately 3,905, with a specific serial number per aircraft, were confirmed part of a public inventory as of October, 2011. All these listed aircraft are organized and gathered together in just one airfield, the 309th Aerospace Maintenance and Regeneration Group (309 AMARG) located at the Davis-Monthan Air Force Base in Tucson, Arizona. A brief description of the situation of each of these airfields, and a picture showing the grounded aircraft are presented next.

   Location: Davis-Monthan Air Force Base; Tucson, Arizona.

   Coordinates: 03°09’19.02 N, 110°51’38.16 W.

   Images Database: Google Earth, as of 03/08/2011. (See images 3 through 6).

   Observations: This airfield was divided in 4 images, in order to cover the entire location.

   Approx. number of grounded aircraft: 3,905 aircraft.

   Types of aircraft: most of them are military aircraft and other space aircraft, from small helicopters to huge air bombers.
Image 4. Davis- Monthan Air Force Base; Tucson, Arizona Image B.

Image 5. Davis- Monthan Air Force Base; Tucson, Arizona Image C.
Image 6. Davis-Monthan Air Force Base; Tucson, Arizona Image D.
2. Phoenix Goodyear Airport.

Location: Goodyear, Arizona.

Coordinates: 33°25′42.22 N, 112°21′50.95 W.

Images Database: Google Earth, as of 03/03/2011. (See image 7).

Approx. number of grounded aircraft: 67 aircraft.

Types of aircraft: from small aircraft (capable of transporting approx. 12 passengers) to big airliners (capable of transporting approx. 300 passengers).

Image 7. Phoenix Goodyear Airport; Goodyear, Arizona.
3. Pinal Airpark.

Location: Marana, Arizona.

Coordinates: 32°30’39.24 N, 111°19’13.38 W.

Images Database: Google Earth, as of 03/08/2011. (See image 8).

Approx. number of grounded aircraft: 189 aircraft.

Types of aircraft: from medium (capable of transporting approx. 45 passengers) to big airliners (capable of transporting approx. 300 passengers).

Image 8. Pinal Airpark Airport; Marana, Arizona.
4. Mojave Airport.

Location: Mojave, California.

Coordinates: 35°03’22.45 N, 118°09’28.21 W.

Images Database: Google Earth, as of 07/15/2011. (See image 9).

Approx. number of grounded aircraft: 95 aircraft.

Types of aircraft: from small fighter aircraft, to big airliners (capable of transporting approx. 300 passengers).

Image 9. Mojave Airport; Mojave, California.
5. Southern California Logistics Airport.

Location: Victorville, California.

Coordinates: 34°35’13.75 N, 117°22’34.74 W.

Images Database: Google Earth, as of 01/31/2009. (See image 10).

Approx. number of grounded aircraft: 205 aircraft.

Types of aircraft: from medium (capable of transporting approx. 45 passengers) to big airliners (capable of transporting approx. 300 passengers).
6. Roswell International Air Center Airport.

Location: Roswell, New Mexico.

Coordinates: 33°18’25.34 N, 104°31’10.50 W.

Images Database: Google Earth, as of 03/27/2010. (See image 11).

Approx. number of grounded aircraft: 208 aircraft.

Types of aircraft: from medium (capable of transporting approx. 45 passengers) to big airliners (capable of transporting approx. 300 passengers).

Image 11. Roswell International Air Center Airport; Roswell, New Mexico.
As previously stated, approximately 4,600 grounded aircraft are grounded and stored, with an unknown destiny. In order to get an estimate of a possible average of recoverable material, or available material to be recycled and reused, extracted from all of these aircraft, the empty weight of the most common aircraft from the boneyards are identified and noted; and then combined to be averaged. Since the biggest boneyard of all the previously mentioned six airfields is the AMARG, the most common models are military aircraft (Global Security, 2012).

Possible Models:

- McDonnell Douglas F-15 Eagle, Empty Weight: 28,000 lbs.
- General Dynamics F-16 Fighting Falcon, Empty Weight: 18,900 lbs.
- McDonnell Douglas F-4 Phantom II, Empty Weight: 30,328 lbs.
- Boeing KC-135 Stratotanker, Empty Weight: 98,466 lbs.

If the weights of these aircraft are added, and then divided by their number (four types of aircraft): 28,000 lbs. + 18,900 lbs. + 30,328 lbs. + 98,466 lbs. = 175,694 lbs. If divided by four; 175,694 lbs. / 4 = 43,923.50 lbs.

With these simple arithmetic operations, the average weight of the boneyard’s aircraft can be estimated, being approximately 43,000 lb. (rounded numbers, assuming removal of various equipment from the aircraft). However, not all of this weight is recoverable material, since there’s an average of 90% of aircraft components that could be recycled. If a proper recycling facility is used, and an approved aircraft recycling process is followed, this process could take up to 15 days per aircraft, depending on their size (Burchell, 2008). If 75% of the average weight (43,000 lbs.) is calculated, the average possible recycle material that could be extracted from each boneyard aircraft is approximately 32,250 lbs. (43,000 lbs. X 0.75 = 32,250 lbs.).
So, by multiplying the approximate amount of possible recyclable material by the approximate number of aircraft, an approximate amount of total recyclable material can be estimated, resulting in approximately 66,900 metric tons of recyclable material, especially aluminum, which is the most abundant.

\[
\begin{align*}
4,600 \text{ aircraft} & \times 32,000 \text{ lbs. average recyclable material} = 147,200,000 \text{ lbs.} \\
147,200,000 \text{ lbs.} & / 2.2 \text{ (to convert to Kg.)} = 66,909,090.91 \text{ kg.} \\
66,909,090.91 \text{ kg.} & / 1,000 \text{ (to convert to Metric Tons)} = 66,909.09 \text{ metric tons}
\end{align*}
\]

With this information, an estimated total amount can be calculated, being equal to approximately 66,900 metric tons of secondary aluminum, to be available in the United States. All this material could be designated to lower the costs of aircraft manufacturing or other industries that also have metals as their primary construction material, especially aluminum; such as the ground transportation (cars, buses, trains, etc.), computing or road signaling industries.

**Estimated Budget Savings with Secondary Aluminum Use**

During 2011, the average price of electricity for average residential use was 11.53 cents per kilowatt-hour (kWh) (U.S. Department of Energy, 2007). If it takes approximately 62.2 kWh to produce 1 kg. of primary aluminum and only 6% of that value is necessary to produce 1 kg. of secondary aluminum, it can be calculated that only 3.732 kWh are required to produce 1 kg. of secondary aluminum. To know how much energy is required to produce metric tons of aluminum, these values just have to be multiplied by 1,000.

Energy required to produce 1 metric ton of primary aluminum:
\[
62.2 \text{ kWh} \times 1,000 = 62,200 \text{ kWh}
\]

Energy required to produce 1 metric ton of secondary aluminum:
\[
3.732 \text{ kWh} \times 1,000 = 3,732 \text{ kWh}
\]
If these energy values are going to be translated to economic values, these values have to be multiplied by the average price of a kWh (¢11.53). First, cents values are converted to dollars.

\[ \frac{¢11.53}{100} = \$0.1153 \]

Energy price to produce 1 metric ton of primary aluminum:

\[ 62,200 \text{ kWh} \times \$0.1153 = \$7,171.66 \]

Energy price to produce 1 metric ton of secondary aluminum:

\[ 3,732 \text{ kWh} \times \$0.1153 = \$430.2996 \]

An approximate saving of $6,741.3604 ($7,171.66 - $430.2996 = $6,741.3604) by producing a metric ton of secondary aluminum instead of primary aluminum can be estimated.

If these values are applied to the estimated amount of the currently available recyclable scrap from the boneyards’ aircraft, an approximate amount of savings can be estimated. These savings and possible income could be achieved by just recycling these aircraft that most probably will not fly anymore.

\[ 66,900 \text{ metric tons} \times \$7,171.66 = \$479,784,054 \text{ (primary)} \]

\[ 66,900 \text{ metric tons} \times \$430.2996 = \$28,787,043.24 \text{ (secondary)} \]

\[ \$479,784,054 - \$28,787,043.24 = \$450,997,010.76 \text{ (possible savings)} \]

As stated, just in electrical power, approximately half a billion dollars could be saved by processing secondary aluminum vs. primary aluminum, without even including other expenses that pertain only to the production of primary aluminum.
As of December, 2011, the average price of aluminum within the United States market was approximately $1.20 per pound of aluminum (Bray, Aluminum Commodity Summary, 2012). By considering this value and applying it to the previous calculations:

\[
\begin{align*}
66,909.09 \text{ metric tons} & \quad = \quad 66,909,090.91 \text{ kg.} \quad = \quad 147,200,000 \text{ lbs.} \\
147,200,000 \text{ lbs.} \times $1.20 & \quad = \quad $176,640,000
\end{align*}
\]

These calculations allow the conclusion that the United States has approximately 176 million dollars’ worth of secondary aluminum in just six airfields. However, this is an average of possible income that could be made if the nation decides to scrap and process all these aircraft that most likely won’t fly anymore. The costs to process this amount of material have to be subtracted:

Energy price to produce 1 metric ton of secondary aluminum:

\[
\begin{align*}
3,732 \text{ kWh} \times $0.1153 & \quad = \quad $430.2996 \\
66,900 \text{ metric tons} \times $430.2996 & \quad = \quad $28,787,043.24 \text{ (secondary)}
\end{align*}
\]

Rounding the numbers:

\[
\begin{align*}
$176,000,000.00 \quad - \quad $29,000,000.00 & \quad = \quad $147,000,000.00
\end{align*}
\]

With these calculations, it can be estimated that with an investment of approximately 30 million US Dollars, if the processed material is to be sold internally or for exports, the gains could be approximately 5 times the initial investment, an estimated total of approximately 147 million US Dollars. However, other pre-processing expenses are omitted, since the costs that may surge with manpower and machinery use for the initial transportation of the aircraft, it’s cutting and shredding, categorizing of the scrap and transportation to the final melting location
are considered to be equal or lower to the costs that may be incurred with the production of primary aluminum. These other costs for producing primary aluminum include: manpower and machinery use for that consists of the land preparation, mining and extracting bauxite, transportation to a location to be reduced and refined, in order to produce alumina to be separated through electrolysis, and then smelt it to then produce the aluminum.

**Use of the Produced Aluminum**

Currently, the aluminum industry is very dynamic, but it hasn’t been fully exploited, since the United States has tremendous amounts of available resources that are not being considered in the recycling side of the metallurgic industries. In 2010, approximately 52,700 people were employed in the aluminum and alumina production and processing industry, from which over 29,000 employees worked in the production stage of the process. The National Bureau of Labor Statistics estimated that these jobs have a mean annual wage of almost US $44,000.00. In 2011, within the United States five companies operated 10 aluminum smelters, and 5 more smelters were reopened, from their closure in the years 2008-2009 (U.S. Department of Energy, 2012).

Also in 2011, the United States had a dynamic aluminum supply and market, with diverse destinations for the total aluminum processed. Approximately 3,710 thousand metric tons were accounted in the national aluminum supply; from this amount 27% was internally used for consumption, 26% was imported, 23% was destined for exportation, 14% was locally produced as primary aluminum, and 10% was locally produced as secondary aluminum. The aluminum recovered from scrap was equivalent to an apparent 36% of the internal consumption.
By 2013, an increase of approximately 7% of the total aluminum production per year is expected within the currently operating smelters in the United States, since in average, domestic smelters have been operating at about 64% of their rated or engineered capacity (Bray, Aluminum Commodity Summary, 2012).

![Image 12. 2011s Total Aluminum Distribution within the United States.](image)

When the aluminum products reach the end of their useful life, these products can be recycled in order to be used in almost all aluminum applications, since the metal’s atomic structure is not altered during melting. The resulting recycled product may be the same as the original product, but since all scrap is mixed, the resultant recycled aluminum could be destined for another purpose or product. The aluminum destined for the transportation industry is the biggest percentage of all aluminum produced within the United States, and also this sector is the most important field of application for aluminum worldwide. This industry produces aircraft, cars, ships, trains, etc. made mostly or largely of aluminum, and its demand for this metal increases year by year. As an example, between the years 2002 and 2009, the average aluminum
amount used per passenger car rose from a 100-120 Kg. range to a 120-150 Kg. range (International Aluminum Institute, 2009).

During 2011, the aluminum consumption was centered in the east United States. The transportation industry accounted for approximately 34% of domestic consumption, the packaging industry accounted for 27%, the building industry accounted for 12%, the electrical and machinery industries accounted for a 8% each one, the consumer durables industry accounted for 7%, and other industries for different aluminum use accounted for 4% among all (Bray, Aluminum Commodity Summary, 2012).

![Image 13. 2011s Aluminum Domestic Production and Use within the United States.](image)

During 2011, the United States had approximately 7,710,000 metric tons of aluminum destined for trade. From this total amount, 4,290,000 metric tons of aluminum were imported for domestic consumption, and 3,420,000 metric tons of aluminum were exported (Bray, Aluminum in January 2012, 2012).
If the previously mentioned price of aluminum per pound in the market is applied to this amount, the result is approximately of 20,354,400,000 US dollars worth of just aluminum trade.

$1.20 \times 2.2 = $2.64 \text{ US dollars per kg. of aluminum}

$2.64 \times 1,000 = $2,640 \text{ per metric ton of aluminum}

$2,640 \times 7,710,000 \text{ metric tons of aluminum} = $20,354,400,000

The biggest aluminum imports came from: Canada with 60%, the United Arab Emirates and Russia with 6% each country, Mexico with 4%, China and Venezuela with 3% each country, and the remaining 18% from other countries. The biggest aluminum exports were sent to: China with 43%, Canada and Mexico with 18% each country, Korea with 6%, Taiwan and India with 2% each country, and the remaining 11% to other countries. These percentage values were calculated from the specific real number values of metrics tons of aluminum imports and exports, in order to simplify the information (Bray, Aluminum in January 2012, 2012).

Reasons for Expanding Secondary Aluminum Production

As previously stated, recycling aluminum, instead of producing primary aluminum has its economic and environmental advantages, especially when the market is encouraging the application of sustainability concepts. Recycling the already available metal that can be extracted from these grounded aircraft will help the environment by reducing landfills, removing all these machines from the ground, reducing the mining and bauxite extraction from the land, reducing the gases emissions when comparing its process with the primary aluminum production process, and freeing land space for other purposes. Recycling these aircraft could also save the country a significant amount of money, by electrical power savings and the material’s monetary value when used for exports or internal consumption.

Currently, the metallurgy industry, especially the aluminum sector has seen an increase in employment, seeing an increase of employees from approximately 29,000 employees in 2010, to 30,000 employees in 2011 (Bray, Aluminum Commodity Summary, 2012). These employees were working only in the production stage of the aluminum production process. This employment increase was a result of an aluminum production increase from 2,976,000 metric tons in 2010 to 3,390,000 metric tons in 2011, for an equal of 12.21% increase of the production. If this trend continues, for every extra hundred metric tons of annual aluminum production, there’s an extra job position in the aluminum production process. Then, the 66,900 metric tons of secondary aluminum that could be extracted from the grounded aircraft would represent an increase of approximately 669 new jobs, just in the production stage of the aluminum production process.
Another reason to increase the production of secondary aluminum is to reduce the amount of annual aluminum imports. This measure could help domestic industries and factories by providing them with domestic secondary aluminum to fulfill their production needs. This measure could save those industries and factories time and money, by allowing them to avoid transportation times and customs fees and paperwork.

**Actual Aircraft Recycling Situation**

The AMARGs main mission is the storage and preservation of aircraft, but also they provide operational aircraft with spare and replacement parts from the aircraft that are stored. During the fiscal year 2010, 203 aircraft were recycled, generating approximately 5.12 million pounds of material to be recycled. During the fiscal year 2011, 175 aircraft were recycled, generating approximately 9.31 million pounds of material to be recycled. These aircraft scrapping have generated approximately 7.2 million US dollars to the United States Treasury over the last 3 years (Defense Logistics Agency, personal communication, January 27, 2012).

If this information is averaged, an estimate can be calculated. The average equals to 189 aircraft from the AMARG recycled every fiscal year, generating approximately 7.22 million pounds of recyclable material. If this average is used to calculate the time that it will take to recycle all the aircraft stored in the AMARG, it can be estimated that it would take approximately 21 years to recycle all the stored aircraft, providing approximately 151.62 million pounds of recyclable material.

In order for an AMARGs aircraft to be recycled, the order will come from a liaison officer between the AMARG and the U.S. Defense Logistics Agency (DLA) called the “Special Programs Officer” (SPO). The SPO will specify how long should each aircraft be stored, and
when to be destroyed. The SPO will follow the Department of Defense’s (DoD) Defense Demilitarization Manual, and Defense Materiel Disposition Manual instructions and directives to identify which aircraft are to be stored for longer periods, which will be sold as aircraft for flying purposes, for static displays or to be scrapped (309 AMARG FOIA, personal communication, February 10, 2012).

After the aircraft that are to be recycled are identified, the AMARG turns them over to the DLA Disposition Services. After this process, those aircraft are sold through the Scrap Venture Program (Government Liquidation program), with the condition of the aircraft being demilitarized before the delivery. These aircraft are then scrapped by the buyer, selling the scrap to private industries or transporting it to smelters to produce secondary metal ingots that then are sold to private industries (Government Liquidation Program, personal communication, February 02, 2012).

The existence of more military excess aircraft than civilian aircraft and the reason for the military practicing aircraft recycling in a small percentage of their available and recyclable aircraft could be explained by several reasons, such as:

1. - Most military aircraft were fully operational and were subjected to higher levels of stress than civilian aircraft could possibly withstand, forcing the grounding of these aircraft with no other purpose than to be sold for scrap or display. Since civilian aircraft are subjected to less stress than military aircraft, the lifespan of these aircraft are significantly longer than military aircraft. That’s the main reason why decades old civilian air transport aircraft are still flying today.
2. - The civilian air transportation industry is managed and owned by private parties all around the world, making it to be easier for purchasing and selling of older aircraft to airlines in world regions where aviation is growing.

3. - Most military aircraft are sold or leased in direct government to government agreements. This makes the international status and relationship with the United States a critical factor, shortening the possible military aircraft buyers list.

4. - Most nations that are eligible to buy military aircraft from the United States ultimately opt to buy new aircraft instead of aircraft that were used, stored and then had to be reconditioned to an operational flying status.

5. - The airlines and corporations that own the grounded aircraft, opt to store the aircraft instead of recycling them, because they incur in fewer initial investments and paperwork grounding them instead of recycling them. If the airlines opt to recycle those aircraft, they would make a profit out of the grounded aircraft by selling the extracted scrap on a long term basis, but only a few companies opt for this option.

**Companies and Organizations Cooperating**

In order to reduce the landfills created by those abandoned aircraft, several organizations and associations are working on the proper methods to recycle an aircraft, extracting the most amount of material as possible from them. The most renewed organization regarding to aircraft recycling is the Aircraft Fleet Recycling Association (AFRA). This company was established by Boeing Corp., and was officially announced on April 17th, 2006. Since then, AFRA has grown from originally 16 companies to over 60 companies from 10 different countries on three continents that practice AFRA’s best management practice guides (Rempes, 2007). These
Use of Excess Aircraft

companies work closely with the manufacturers of the aircraft they recycle in order to maximize the parts that can be re-used and or recycled. AFRA covers 45 practices in 7 categories: facility, training, tooling, parts management, assets and parts documentation, environmental controls and recycling planning (Tegtmeier, We Recycle, 2007).

Since AFRA’s inception, its members around the world have returned approximately 2,000 aircraft to service, and scrapped more than 6,000 commercial airplanes, and over 800 military tactical aircraft, producing approximately 25,000 tons of airplane aluminum annually. Since approximately 80% of the aircraft that enter storage never emerge whole again, AFRA provides systematic processes that enable these problems to be maximized, extracting according to manufacturer’s specifications and instructions those components that are still in operating conditions (Aircraft Fleet Recycling Association (AFRA), 2012).

As Boeing Corp. has established the AFRA’s association, Airbus S.A.S. in Europe created a project called: “Process for Advanced Management of End-of-Life Aircraft”, (PAMELA). This process has the same aims as the AFRA association, but Airbus is controlling the PAMELA process rather than collaborating with their partners, like Boeing is doing with AFRA (Boeing Corp., 2007). The PAMELA process started at Airbus S.A.S. headquarters, and then moved to the Tarbes Advanced Recycling and Maintenance Aircraft (TARMAC)-Aerosave, where the PAMELA findings were evolved to industrial scales and outperformed initial PAMELA targets. The PAMELA process helped reduce the amount of material sent to landfill from an aircraft scrap to just 15%, this percentage most likely being the materials used in an aircraft’s cabin interior (International Air Transport Association, 2011).
Another organization that is collaborating, not only with aircraft recycling, but to any other equipment recycling is the United States Governments Liquidation Program. Through this program, the government has available for sale as scrap between 20 to 30 million pounds of metal per month. This is the only sales channel for the U.S. Department of Defense’s surplus inventory. The scrap offered for sale comes from government aircraft, vehicles, medical equipment, exercise equipment, field gear, machinery, industrial equipment and other government excess items, located in over 200 military bases in the continental U.S., Alaska, Hawaii, Puerto Rico and Guam. Through this program, the United States government has generated over half a billion US dollars back to the U.S. Treasury (Government Liquidation Program, personal communication, February 02, 2012).

**Possible Solutions**

**Increase the Excess Aircraft Recycling**

Since all the aircraft stored at AMARGs facility are United States’ government property, the government can choose to increase by significant amounts the annual number of aircraft to be scrapped. The government can create an aircraft scrapping priority list, ordering the aircraft by government needs, aircraft’s stored time, and possibly their size. This list could specify that only a limited amount of aircraft models could be stored for spare parts recovery purposes only, if those models are being currently operated by the different United States armed forces. If such a list is created and established, the DoD could add to their disposal manual a policy that allows AMARG to scrap aircraft by priority needs.
Also, stored aircraft private owners, such as airlines, could also invest in recycling their aircraft that ended their service-life cycle, instead of storing them indefinitely, in order to make a profit from the scrap material they would have available. Another possible way to increase the recycling of excess aircraft is to create a joint operation between the United States Environmental Protection Agency (EPA) and the United States Federal Aviation Administration (FAA), to identify all grounded aircraft in any airport within the United States, besides those aircraft in the six aircraft boneyards that have been described in this research paper. After those grounded aircraft are identified, the joint agency or team could locate the owner or responsible and offer the option to recycle the grounded aircraft in exchange for the resulting metal scrap.

Help the Metal Market Become more Dynamic

If the United States decides to, and actually recycles all the excess aircraft, the United States could provide enough secondary metal to its domestic industries and factories, to fulfill their metal demand. This option could reduce the amounts of annual metal imports, and possibly eliminate the need to import any metal. If this is achieved, the government could opt to export all the extracted scrap metal that exceeds domestic needs and sell it to the countries that the United States has more external debts with. This measure could help lower the national external debt, help reduce the landfills created by grounded aircraft and keep a continuous production trend in the metal market.
Lead by Example

If the United States government decides to recycle all their grounded aircraft, to help the national economy and environment, and completes this task or reduces the amount of recyclable aircraft by a significant amount; the government could demand grounded aircraft private owners to scrap and recycle their aircraft. These demands could be enforced through the EPA, by the means of taxes or financial penalties. The EPA could also give an option to the grounded aircraft owners to donate those aircraft to the government, in exchange for taxes credit. The EPA could set different directives on the grounded aircraft’s storage time and purposes, to determine if the grounded aircraft should be recycled or not, and for how long could the aircraft be stored in open areas before an environmental penalty or tax fee is issued.
CONCLUSION

Summary

The United States has enough grounded aircraft to produce approximately 66,900 metric tons of secondary aluminum, if the nation decides to recycle these aircraft. This amount of secondary aluminum represents an approximate saving of half a billion dollars worth of electrical energy when compared to the primary aluminum production. Also, if all this metal can be recycled and then sold to the domestic or international market, this could help the metal market to become more dynamic, and could represent earnings of approximately 147 million US dollars. Besides all the economic benefits of recycling all these aircraft, if this measure is adopted, the nation could impact positively the environment by reducing the landfills created by these excess aircraft and by reducing the amount of greenhouse gases emissions generated by the production of primary aluminum.

Interpretation of Findings

The best way to take advantage of all the excess aircraft within the United States is through recycling. Recycling helps nations’ economies and environments by reducing landfills and gasses emissions. This measure also creates new jobs and saves those countries millions of US dollars worth of electrical power. There are more advantages than disadvantages in recycling those aircraft, but decisions have to be made, and actions have to occur to make this situation change.
Recommendations

The DoD could authorize the increase of annual aircraft to be recycled from 189 aircraft to approximately 400 aircraft per year. This measure could increase the fiscal earnings per year, and would provide enough area to storage other aircraft that would be taken out of operational service. If this measure is taken into consideration, the government could recycle all their stored aircraft in approximately 10 years, and they could start by recycling the remaining F-14s Tomcat that were destined to be scrapped when they were taken out of service in 2006, in order to avoid any spare parts or component to be shipped to Iran through the black market, since Iran is the only active F-14 user, and has been imposed an arms embargo. After all the stored Tomcats are recycled, the DoD could order to scrap the oldest stored bombers and cargo aircraft, that could provide the greatest amount of recyclable material per aircraft.

Another recommendation could be to implement regulations that control the land use and land fill by equipment that is not being utilized. These regulations could be enforced through the EPA and could force the grounded aircraft owners to recycle their aircraft or to donate them to the government to be recycled, in exchange for tax breaks. If the owner does not wish to donate the aircraft, the government could encourage them to recycle those aircraft themselves or donate them for static displays on closed doors museums. These options could be encouraged by means of economic penalties or taxes implementation if no action is taken, and grant a tax break if the owner proceeds with the recycling of the aircraft. If all these measures are taken into consideration, and promote a recycling vision and behavior to the main responsible of the landfills created by grounded aircraft, the government could start implementing these measures also in the ships industry, starting by recycling all decommissioned military ships, like aircraft carriers, that could also provide a significant amount of recyclable metal.
REFERENCES


