Winter 2001

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Baker, B. J. (2001). Identifying the Probability of an Accident Occurring with Suspected Unapproved Parts as a Contributing Factor. *Journal of Aviation/Aerospace Education & Research*, 10(2). <https://doi.org/10.15394/jaaer.2001.1275>

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**IDENTIFYING THE PROBABILITY OF AN ACCIDENT OCCURRING
WITH SUSPECTED UNAPPROVED PARTS
AS A CONTRIBUTING FACTOR**

Brett J. Baker

The purpose of this study was to determine if aircraft accidents and incidents, which involve Suspected Unapproved Parts (SUPs), are a major threat to aviation safety. In order to make this determination, the study sought to establish the probability of such an event occurring. The Federal Aviation Administration's Office of System Safety provided general aviation accident and incident data for the period spanning 1987 to 1999. In an attempt to provide the most accurate results, the full sub-population was studied, and subsequently analyzed using descriptive statistics. SUPs were found to contribute to 0.008225 mishaps every 100,000 flight hours, approximately 1,928 times less than the national accident and incident rate of 15.8667 mishaps per 100,000 flight hours. As a result, the null hypothesis was rejected and the conclusion drawn that the probability of an accident and/or incident occurring with SUPs as either a causal or contributory factor is unlikely.

INTRODUCTION

Aircraft parts that are not eligible for installation do circumvent the controls set forth by the Department of Transportation (DOT) and Federal Aviation Administration (FAA), whether by inadvertent or deliberate action. The potential for loss of life, an aircraft hull loss, or other catastrophe, with Suspected Unapproved Parts (SUPs) as a contributing factor in an accident or incident must be considered. Therefore, it is necessary that the magnitude of the SUP problem be identified thereby allowing corrective action to be made by the appropriate authorities and allowing potential users of SUPs to identify the threat.

Statement of the Problem

The danger posed by SUPs is enough to threaten a significant economic loss to an aircraft owner or operator, as well as jeopardizing human life. The authorities plan to minimize this danger by "promoting the highest level of aviation safety by eliminating the potential safety risk posed by the entry of unapproved parts in the United States aviation community" (FAA, 1995, p. vi). The Federal Aviation Administration began this process by defining a SUP as any part, component, or material that is suspected of not meeting the requirements of an approved part; that is a "part that has received a formal Federal Aviation Administration approval" (FAA, 1995, p. 18). In addition, a SUP working group was formed within the FAA to

develop a plan to address the SUP issue. Despite these efforts, the size and extent of the SUP problem remains unknown.

Review of Related Literature

Unapproved parts have become a cause for concern over the past decade, yet unapproved parts have not developed into a significant statistical factor in aircraft accident investigations. The dangers posed by the installation and use of unapproved parts not only threatens the US aviation industry, but reach beyond the borders of the US with many airlines in developing nations, particularly those located in Africa and South America, "knowingly and openly" placing unapproved parts into service (Stern, 1996). The number of unapproved parts placed in service within less developed countries is primarily due to virtually nonexistent legislative oversight and control of the air transport industry in these regions. Under ideal circumstances unapproved parts are prohibited from being installed on an aircraft by a comprehensive network of controls that govern the design and manufacture of aircraft parts within the US. Additional inspections and checks occur between the manufacture and the installation of the aeronautical part by the maintenance technician who purchases the part or selects it from a parts room for installation on an aircraft, aircraft engine, propeller, or other component (FAA, 1995). Nonetheless, parts that are

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not eligible for installation do circumvent these controls, whether by inadvertent or deliberate action.

History of Suspected Unapproved Parts

Although the problem of unapproved parts has come to the public's attention in recent years through the broadcast media, congressional hearings and written press, the problem has posed a potential threat to the aviation industry for several decades. In 1957 the Flight Safety Foundation (FSF) warned that the "stream of parts necessary for the maintenance and overhaul of aircraft engines has become polluted." Within the report, Joseph Chase described the growth of the suspected unapproved part problem. "Parts that are not airworthy, parts the source and identity of which have long been lost, parts of unknown material, fabricated by processes at variance with industry and government specifications, have entered the channels of trade" (Chase, 1957, p. 3). The report traced the origin of these unapproved parts to the years that immediately followed World War II. This growth in SUPs was determined to be primarily due to the vast numbers of aircraft engines that were sold by the US Government as surplus, and with the engine manufacturers' decision to no longer produce or stock replacement parts for those war time models. Following these events "many new and genuine surplus parts had lost their identity in the process of sale and resale, shipment and transshipment. Original packages had been opened and destroyed. Markings had been obliterated" (Chase, 1957, p. 4).

As these parts could not be determined to be genuine, it became unacceptable to the US Civil Aeronautics Administration, the forerunner of the FAA, to install these parts in aircraft. As the supply of usable parts diminished, the economic laws of supply and demand prevailed, driving the price up. The price increase in parts encouraged dealers and brokers to allow uncertified parts into the market. Chase went on to write that "We might have forgiven the people involved...they were dealing in genuine parts even though these parts could not be identified positively as such and so could not be used in certificated aircraft" (1957, p. 4). With business ethics weakened or destroyed, it was but one step to modifying parts without the benefit of engineering data, and another step to outright counterfeiting (Chase, 1957).

In 1964, Chase again expressed concern about the proliferation of unapproved aircraft parts.

Many of the difficulties remain unchanged...they are marked with the... part number of the original

manufacturer and represented by the supplier as 'Surplus, New, or Serviceable.' Their record has been anything but reassuring. Deviations from the conditions represented ran the full scale from honest mistakes...to outright fraud. (Chase, 1964, p. 5).

He concluded the report by stating, "bogus parts continue to be a threat to aviation safety" (Chase, 1964, p. 8).

The problem of SUPs has not been limited to fixed wing aircraft; it poses a significant threat to helicopters which are especially vulnerable to substandard critical parts. The threat to helicopters from SUPs predates 1980 to the US involvement in the Vietnam War. "Many of these parts undoubtedly came from the almost 6,000 helicopters destroyed or captured in... Vietnam (Robinson, 1993, p. 10)." Many of these SUPs would have entered the US in the early 1980s and may continue to be imported into the US even today (Robinson, 1993).

Accidents Attributed To Unapproved Parts

Air travel is one of the safest modes of transport, according to the National Safety Council (1998) and Bureau of Transportation Statistics (1996). The fatality rate for people traveling by car, for example, was 110 times greater than the rate for people traveling on scheduled US airlines (National Safety Council, 1998). Despite an outstanding safety record, the industry has experienced accidents that can be attributed to unapproved parts. According to Stern (1996), accidents whose cause has been confirmed to be the result of the installation and subsequent failure of unapproved parts in the US include: A Louisiana crop duster, who was killed in 1992 when his aircraft nose-dived shortly after takeoff. Accident investigators found an unapproved part in the propeller's pitch control unit that had been installed by a local aircraft technician (Stern, 1996). The aircraft technician pled guilty to making false statements on maintenance documents and was fined \$10,000. In the past several years, two more fatal crashes involving private aircraft have occurred, including a Cessna 172 that crashed on takeoff in September 1994, in Oklahoma City, killing two people. National Transportation Safety Board investigators found that unapproved engine bearings led to the accident (Stern, 1996). In October 1995, another pilot was killed in Longmont, Colorado when an unapproved propeller failed in flight (Stern, 1996).

Outside the US the record is even more troubling. The worst confirmed accident, according to a report by the

Flight Safety Foundation in 1994, occurred on September 8, 1989 and involved a Convair 580 aircraft belonging to Norway's Partnair charter airline. The aircraft on route from Oslo, Norway to Hamburg, Germany disintegrated 22,000 feet over the North Sea, killing all 55 people aboard. Norwegian investigators recovered 90% of the 36-year-old plane and determined the cause of the accident to be a result of counterfeit bolts, bushings, and brackets in the aircraft's tail. According to the Norwegian investigating authority, the plane's tail vibrated violently as the bolts came loose and fell off in midair (FSF, 1994). Lawyers for the now defunct airline reportedly denied that unapproved parts caused the crash.

Recently, airlines have become increasingly concerned with the issues posed by unairworthy parts and their effects on the air transportation system. American Airlines made public a 14-page list, complete with serial numbers, of parts missing from the remains of Flight 965 after it crashed near Cali, Colombia in December 1995 (Bajak, 1996). This public announcement is unprecedented within the industry.

Parts Considered To Be Acceptable For Aeronautical Use

There are a number of acceptable methods for aeronautical parts to be designed and produced, most of these methods require specific FAA approvals. This is usually the case for major aircraft products such as airframes, engines, and propellers, as well as key components or parts that could significantly affect the operation and safety of an aircraft. The FAA grants approvals only on the basis of a stringent overview of design criteria, facilities, processes and quality control systems (FAA, 1995). FAA Production Approval Holders (PAH) are subject to continual FAA surveillance and inspection to verify their compliance with the Federal Aviation Regulations (FAR) and the conditions of their approvals (FAA, 1995).

There are a number of sources of acceptable parts that are not produced under specific FAA approvals. For example, it is permissible for the owner or operator of an aircraft to "produce parts for maintaining or altering that person's own product" (FAA, 1998, p. 3). Manufacturers often specify that it is acceptable to use "standard parts," such as nuts and bolts, for production and maintenance. Standard parts production is not monitored by the FAA, but must conform to specified industry accepted criteria. Standard parts can be tested for conformity and may be used in aeronautical products only when specified in the design (FAA, 1998). Other parts not formally approved by the

FAA that are acceptable if used in the proper application are parts "fabricated" by maintenance personnel in the course of performing a repair and returning a product to service (FAA, 1998). However, such parts are still required to meet applicable design criteria as explained by the following definition.

Standard Part. A part manufactured in complete compliance with an established industry or US government specification which includes design, manufacturing, test and acceptance criteria, and uniform identification requirements; or for a type of part which the Administrator has found demonstrates conformity based solely on meeting performance criteria, is in complete conformance with an established industry or US Government specification which contains performance criteria, test and acceptance criteria, and uniform identification requirements. The specifications must include all information necessary to produce and conform the part, and be published so that any party may manufacture the part. Examples include but are not limited to, National Aerospace Standards (NAS), Army/Navy (AN), Society of Automotive Engineers (SAE), SAE Sematec, Joint Electron Device Engineering Council, Joint Electron Tube Engineering Council, and American National Standard Institute (ANSI) standards. (FAA, 1998, p. 4).

In addition to regulating the design and manufacture of aeronautical parts, the FAA regulates the individuals and organizations that use parts. These regulations specify quality control and inspection procedures for certificate holders such as air carriers and repair stations, which include procedures to carefully inspect incoming materials and parts for authenticity and conformity with applicable standards as outlined in Advisory Circular (AC) 21-29B (FAA, 1998). These controls are designed to ensure that parts that are produced and used meet applicable design requirements, are eligible for installation, and are appropriate for a given situation. However, there are numerous sources of parts that do not meet applicable requirements but do enter the aviation system. Collectively, these parts are called "unapproved parts".

Parts Considered To Be Unsuitable For Aeronautical Use

The intentional installation of unapproved parts on

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an aircraft is punishable under civil and criminal law. If caught a person may be charged with falsifying statements, committing wire fraud, mail fraud, and endangering the safety of an aircraft which is punishable by fines or prison (FAA, 1994). To avoid the inadvertent installation of parts considered unsuitable for aeronautical use, unapproved parts are defined within Advisory Circular 21-29B, Detecting and Reporting Suspected Unapproved Parts (FAA, 1998, p. 4):

A part that does not meet the requirements of an "approved part." This term also includes parts which have been improperly returned to service (contrary to FAR parts 43 or 145) and/or parts which may fall under one or more of the following categories:

- 1) Parts shipped directly to the user by a manufacturer, supplier, or distributor, where the parts were not produced under the authority of an FAA production approval for the part, such as production overruns where the parts did not pass through an approved quality control system.
- 2) New parts which have passed through a PAH quality control system which are found not to conform to the approved design/data.
- 3) Parts that have been maintained, rebuilt, altered, overhauled, or approved for return to service by persons or facilities not authorized to perform such services under FAR parts 43 and/or 145.

- 4) Parts that have been maintained, rebuilt, altered, or approved for return to service which are subsequently found not to conform to approved data.

- 5) Counterfeit parts.

A summary of parts that may constitute an unapproved part may be found in Table 1.

Counterfeit parts, a type of "unapproved part," may be new parts that are deliberately misrepresented as designed and produced under an approved system or other acceptable method even though they were not designed and produced under such a system. Counterfeit parts may also be used parts that, even though they were produced under an approved system, have reached a designed life limit or have been damaged beyond possible repair for aviation standards, but are altered and deliberately misrepresented as acceptable, with the intent to mislead or defraud.

If an "approved part" is not salvageable, i.e., thought to be worth saving under controlled conditions for potential future repair, it is considered scrap and should be disposed of in such a way that it cannot be returned to service. However, if a part is salvageable, it should be "documented and controlled so that it is not returned to aviation service until all requirements are met." (FAA, 1995, p. 58). Both salvageable and scrap parts are sometimes misrepresented as having useful time left or as having been repaired in accordance with regulations.

Table 1

Summary of What Constitutes an Unapproved Part

<u>Bogus and Unapproved Parts</u>
<u>New Parts</u> <ul style="list-style-type: none"> • No Production Approval (Counterfeit and Fraudulently Manufactured Parts) • No Individual Production Approval (Current PAH Relationship-But Also Manufacture Other Parts-PMA Issues) • Rejected Parts Sold by PAH <u>Scrap/Used Parts</u> <ul style="list-style-type: none"> • Counterfeit and Fraudulently Overhauled Repaired Parts • Salvaged Parts From Stolen, Scrapped or Crashed Aircraft • Military Surplus Parts (Not FAA Approved) • Inventory Exceeding Shelf Life And/Or Unknown Origin • Owner/Operator Produced or Modified Parts Sold by Another Party
<u>Suspected Unapproved Parts: The Paperwork Problem</u>
<u>New Parts</u> <ul style="list-style-type: none"> • An Approved Part with Missing Paperwork <u>Used Parts</u> <ul style="list-style-type: none"> • A Properly Repaired Part Which Was Certified But Paperwork Lost

Note. Adapted From Unapproved Airplane Parts and Air Safety, 104 Cong., 1st. Sess. (1995) (Testimony of Mary Schiavo)

Other examples of parts that are not eligible for use, or “unapproved parts,” are parts rejected during the production process because of defects; parts for which required documentation has been lost; parts that have not been properly maintained; and parts from military aircraft that have “not been shown to comply with FAA requirements” (FAA, 1995, p. 3).

Unapproved parts also occur when a supplier, that produces parts for an approved manufacture, directly ships to end users without the approved manufacturers’ authorization or a separate, applicable Parts Manufacturer Approval (PMA). An example of this is “production overrun” parts. These parts are not authorized by the PAH, so it cannot be assumed that they have undergone all of the requirements of the approved holder’s required quality control process.

Unapproved parts have been found to be a determining cause of several accidents and incidents involving private

and commercial aircraft, worldwide. Unapproved parts played a role in at least 166 US based aircraft accidents or incidents (Bajak, 1996). Four of these accidents involved commercial carriers that resulted in six fatalities. However, just how many unairworthy parts have claimed lives is in dispute. The number may be far greater according to James Frisbee, quality control chief at Northwest Airlines, “It’s very, very hard to pin the cause of an accident on a part that has failed...especially when the airplane is scattered over five acres” (Frisbee, 1995).

Official Status of Unapproved Parts

There have been few formal studies conducted to try and determine the statistical probability of unapproved aircraft parts being a contributing factor in an aircraft accident or incident within the US. However, a rudimentary search of the FAA accident and incident database by the Associated Press found that unapproved parts played a role in approximately 166 aircraft accidents or less serious

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incidents from May 1973 through April 1996, resulting in 17 deaths and 39 injuries (Bajak, 1996). According to Baumgarner (1995) the FAA has received fewer than 1,300 reports of SUPs since 1989; and investigations have led to over 100 enforcement actions. Despite the low number of SUP reports, it should be noted that each SUP report can constitute thousands of illegal parts, for example the grounding of 6,000 light aircraft powered by Textron Lycoming reciprocating engines for inspection for unapproved bolts (Baumgarner, 1995). The SUP problem is further exemplified in a Flight, Safety Digest (1994) report which stated that a US Department of Transportation's (DOT) Office of the Inspector General (OIG) audit of 12 repair stations found that of parts sampled, "43 percent of all newly purchased parts and 95 percent of parts purchased from distributors or brokers did not have reasonable evidence of either FAA production approval status, production origin or conformance with established U.S. or industry specifications" (p. 1).

The literature supports the idea that regulatory control is inadequate and the problem of SUPs is aggravated further by the fact that the FAA does not have enough money or inspectors to monitor the nation's 2,000 parts distributors and brokers.

US Federal Aviation Regulations (FAR) do not prohibit the sale or distribution of unapproved parts; therefore, this problem is further exaggerated ("Bogus Parts," 1994).

Despite widespread claims that illegal parts traffic poses a major safety threat, Schultz (1995) claims that SUPs pose a very limited risk, and that aviation safety statistics appear to remain largely unaffected by SUPs. The question remains though, with no assessment of the risk magnitude or the failure consequence of a part, is this statement unbiased? The DOT/OIG has underscored the importance of developing or obtaining statistical information with regards to monitoring SUPs within the aviation community (FAA, 1995).

Although investigations of fraudulent aircraft parts launched by the DOT/OIG have led to 164 indictments and 130 convictions since 1990, such actions do not appear to have been a deterrent. There are 26 million parts installed on aircraft each year within the US. If only two percent of these parts have been intentionally substituted with counterfeit parts, as estimated by an internal 1995 FAA audit, that leaves more than half a million unapproved parts installed every year (Stern, 1996).

Summary

Despite the overwhelming view presented within the literature, that SUPs present a danger to the nation's fleet, not all concerned parties have acknowledged the problem. The FAA has disputed many of the claims made by the DOT/OIG and "contends that bogus parts have never caused a plane to crash, and that there is no increase in the number of bogus parts, just more reports" (Schiavo, 1997, p. 256). The FAA has maintained the argument that "there is no safety problem associated with undocumented parts: there is no safety problem associated with Parts Manufacture Approvals, and that they have never encountered an accident caused by a counterfeit or fraudulently documented part" (Air Transport World, 1994, p. 1). However, this view differs significantly from those of the Professional Airways System Specialists (PASS), a union representing FAA engineers and electricians. In testimony presented to Congress, PASS stated;

Unfortunately, PASS strongly believes that aviation safety is seriously jeopardized by the FAA's continued failure to identify and to curtail the use of suspected unapproved parts in our nation's aircraft...The production of unapproved parts is egregious and out of control. Eventually, PASS fears that bogus parts will have a direct adverse impact on operating safety and on the unsuspecting flying public. (104 Cong., 1995).

Other organizations have also conveyed that this problem is new, that it is rapidly growing, and that it presents a major threat, in the present or future, to aviation safety (Schiavo, 1997). However, the FAA is unaware of any evidence that shows that instances of safety-related unapproved parts being sold are substantially more prevalent now than a few years ago (FAA, 1995).

Pressure to improve safety will continue to be placed upon the administrative branches of Government. Political pressure will continue to drive technically unreasonable demands on safety regulators, and make outrageous claims about safety problems, or safety improvements. Newspapers and television will continue to sensationalize air safety issues, as a result politicians can be expected to take advantage of potential press coverage, and make demands or claims that do not advance anything but coverage of their own statements. Cries to "do something," regardless of the significance of the problem or the practicality of the proposed solution is the unfortunate result of such coverage (Broderick, 1997). These "false alarms" result in wasted

resources and provide instant credibility to those who criticize air safety authorities or programs. Taken together, these factors create a bureaucratic environment that encourages that excessive resources be allocated to air safety programs, resources far in excess of other similar (or even more deserving) government programs (Broderick, 1997). They also provide a regulatory environment that permits extraordinarily high levels of safety by imposing systems and procedures on the aviation industry.

Statement of the Hypothesis

It is hypothesized that the probability of an accident and/or incident occurring with Suspected Unapproved Parts being a causal or contributory factor is significant.

METHOD

Subjects

Study participants consisted of aircraft that had been involved in either an accident or incident between January 1987 and March 1999. However, physical evidence left by the majority of these events had become intangible with time. In addition, economic and time constraints forced the author to rely on official accounts of each accident or incident in order to determine what role SUPs had played, if any. Therefore, each aircraft was represented by a factual accident or incident report filed as a matter of public record. Records were limited to those that were retrievable from the Aviation Safety Reporting System (ASRS), National Transportation Safety Board (NTSB), and FAA accident/incident databases. Additional criteria further defined the subjects; only those aircraft that could be considered to fall within the classification of general aviation were selected. For the purposes of this study, general aviation was considered to consist of normal category fixed wing aircraft and rotorcraft, if they had a seating configuration, excluding pilot seats, of nine or less, and a maximum certificated takeoff weight of 12,400 pounds or less. An additional requirement was that aircraft operating under Federal Aviation Regulation, Part 135, (FAA, 1994) were excluded from the study. Sampling bias was limited by avoiding aircraft activity indicators that did not reflect differences in frequency of landing and takeoff or route length. A means of avoiding or eliminating sampling bias created by under reporting could not be established.

Instrument

The instrument utilized during this study consisted of the Aviation Safety Reporting System (ASRS), National Transportation Safety Board (N.T.S.B.) and FAA

accident/incident databases. Data retrieved from these databases were obtained under the Freedom of Information act, and procured from one of two sources: (a) a public domain database located on-line at http://www.asy.faa.gov/asp/asy_crosssys.asp, and (b) cd-rom edition, located at the Jack R. Hunt Memorial Library at Embry Riddle Aeronautical University, Daytona Beach.

Reliability and validity were dependent upon the design and content of these databases. Although varying representations of the data were found between databases, data elements used within this study were standardized. The data were presented for analysis in a brief report format that was divided into the following categories: location information, aircraft information, operator information, narrative, sequence of events, findings, injury summary, weather/environmental information and pilot information.

However, an additional measure was incorporated into the handling of the instrument in an effort to further increase the studies reliability and validity. In order for narrative data to be standardized, the narrative discussion had to be converted to a numerical value. In order to achieve this, the level of damage for each incident and/or accident was categorized in terms of mishap severity, as defined within MIL-STD-882D (1997). The reliability coefficient is considered high as the data and its subsequent analysis did not require subjectivity, but relied on consistent and factual information in order to draw a conclusion.

Design

The research method used within this study had to have the ability to test a hypothesis, investigate relationships, and describe conditions. In addition, when determining the type of methodology to utilize in this study, the technique for collecting data, data format, and the number of valid subjects had to be considered to ensure both data and method were compatible. A quantitative approach was selected to test the hypothesis, and the focus narrowed so that the descriptive method, outlined in the textbook Educational Research, by Gay (1996, p.19), was used exclusively. This provided the author the ability to test the hypothesis that the probability of an accident and/or incident occurring with SUPs being a causal or contributory factor is significant.

Procedure

The data utilized for this study was obtained from the Aviation Safety Reporting System (ASRS), National

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Transportation Safety Board (NTSB), and FAA accident/incident databases. Retrieving data from these databases was made possible by the use of two separate resources, (a) a public domain database located on-line at http://www.asy.faa.gov/asp/asy_crosssys.asp, and (b) cd-rom edition, located at the Jack R. Hunt Memorial Library at Embry Riddle Aeronautical University, Daytona Beach. The use of FAA Form 8120-11, 8020-2 and NTSB Form 6120.19A and 6120.4 by the authorities allows data to be presented in a consistent and manageable form, improving integration across databases. However, the synopsis found within each accident and incident report could not be interpreted consistently without translating the narrative text into a numerical value. In order to achieve this MIL-STD-882D, (1997) mishap severity categories, were used to define the level of damage for each incident or accident.

The search queries used to retrieve the data from these databases utilized the following search terms: bogus parts, unapproved parts, counterfeit parts, suspected unapproved parts, and SUP. The records returned by these searches were then screened to ensure that they met the requirements defined earlier in this chapter, ensuring that the desired sample was obtained.

The data was then sorted and ranked according to date, and mishap severity. This enabled the records to be analyzed using descriptive statistics, as outlined in A Programmed Introduction To Statistics (Elzey, 1971) and Complete Business Statistics (Aczel, 1996). The primary measure used to evaluate the SUP combined accident and incident (CAI) rate was the monthly accident/incident rate, per 100,000 flight hours, which was calculated using Equation 1.

$$\text{Monthly CAI Rate (per 100,000 flight hours)} = \frac{\text{No. of CAI in Month}}{\text{No. of Flight Hours in Month}} \times 100,000 \quad (1)$$

Additional data was required to solve Equation 1, which was not available from the accident and incident databases described previously. This data was obtained from the FAA Office of System Safety located on-line at http://www.asy.faa.gov/safety_analysis/si.zip.

The use of combined accident and incident rates (per 100,000 flight hours) has the effect of making the combined accident and incident rate an equal measure across months. That is, despite a fluctuating number of flight hours flown per month or number of days available for flight within the month, the rate provides a consistent measure across months. In addition, a twelve-month moving average was used in order to dampen seasonal and other fluctuations in the data. The twelve-month moving average rate indicates the number of combined accidents and incidents that occurred over the twelve proceeding months divided by the total number of flight hours flown in the preceding twelve months.

The realization that the term "significant" would have to be further defined, prior to completing analysis of the data, was made early in the study. What could be considered a significant number of aircraft accidents or incidents, caused

by SUPs? The best means of accomplishing this was determined to be a comparison between the rate of accidents and incidents involving SUPs and the accident and incident rate of accidents that did not involve SUPs. This was accomplished in terms of probability as shown in Table 2, and was applied to the CAI rates per 100,000 flight hours.

Once the data had been analyzed, the results were compared to the null and alternate hypotheses. The Null hypothesis (H_0) states that "the probability of an accident and/or incident occurring with SUPs being a causal or contributory factor in a mishap is significant," while the alternate hypothesis (H_1) is defined as "the probability of an accident and/or incident occurring with SUPs being a causal or contributory factor is minor".

Table 2

What Constitutes a Significant Number of Accidents and Incidents?

Interpretation	p
Event is not very likely to occur	0.00 to 0.24
Event is more likely not to occur than to occur	0.25 to 0.49
Event is as likely to occur as not to occur	0.50
Event is more likely to occur than not to occur	0.51 to 0.74
Event is very likely to occur	0.75 to 1.00

Note. Adapted from Complete Business Statistics, 1996, p. 65

ANALYSIS

A total of 54,184 accidents and incidents occurred within the transportation category of general aviation between January 1987 and March 1999 (FAA, 1999). Two sets of data were calculated; the first providing the proportion of accidents and incidents with SUPs as either causal or contributory factors, in relation to the number of flight hours flown. The first data set shall be referred to within this narrative as CAIR(SUP). The second set of data provides the sum of accidents and incidents per 100,000 flight hours for all accidents and incidents nationwide that fell within the class of general aviation. This second set of data is intended to serve as a benchmark to compare the first set of data and was assigned the label CAIR(NAT). It should be observed that a complete data set for the period spanning January 1999 and March 1999 was not available, hence CAIR(NAT) for this period were not included in the analysis of data. The size of the sample CAIR(SUP) was 147 months while the population CAIR(NAT) was limited to 144 months.

As mentioned previously, CAIR(SUP) represents observations made over a period of 12 and a 1/4 years.

During this interval, according to records retrieved from the ASRS, NTSB, and FAA accident/incident databases, initial results indicated a combination of 62 accidents and incidents. Despite having used specific search criteria each of the 62 associated records was screened to ensure they met the needs of the study. Of these records, approximately half met the prerequisite requirements defined within the methodology. Those records that did not meet the prerequisites were not included within the study. For example, the search term SUP returned records containing information irrelevant to this study, the search engine having confused the acronym SUP and the prefix *sup* used in words such as *supervised*, *supercharged* and *supply*. The record attrition was exaggerated further by the lack of statistical data prior to 1987. The absence of data for this period increased the record attrition by an additional five records. A summary of records returned by the database search is shown in Table 3.

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Table 3

Summary of Record Treatment

Search Criteria	Records	
	Returned	Attrition
Bogus Parts	8	3
Counterfeit Parts	3	1
SUP	16	16
Suspected Unapproved Part	3	1
Unapproved Part	32	6
Total Number of Records	62	-
Number of Usable Records ^a	-	32

Note. ^aThe number of usable records reflects the total number of returned records minus the record attrition.

The data set representing CAIR(SUP) was determined to have a mean of 0.008225 ($SDs = 0.020436$) with a total of 147 observations and a confidence interval at the 95% level of 0.0033. The range equaled 0.1038, while the minimum number of combined accidents and incidents CAI per 100,000 flight hours were zero and the maximum number shown to have occurred was 0.1038 CAI per 100,000 flight hours. The mode and median of this data set are both equal to zero. CAIR(SUP) is a positively skewed leptokurtic distribution with a kurtosis value of 6.0281 and a skewness value of 2.536817.

In contrast, the data set representing CAIR(NAT) has a mean value of 15.8667 CAI per 100,000 flight hours ($SDs = 2.8126$). The number of CAIR(NAT) observations, as mentioned previously, differs from that of CAIR(SUP) in that it was limited to 144 observations. A confidence level of 95% produced a value of 0.4633. The mode was not applicable to this data set as each observation differed, however the median was equal to 15.8667 CAI per 100,000 flight hours. The range equaled 14.3876, while the minimum number of CAI per 100,000 flight hours was 8.8369 and the maximum number that occurred was 23.2245.

In addition to CAIR(SUP), the accident and/or incident severity was determined for accidents and incidents having SUPs as either a causal or contributory factor using a

definition of hazard severity obtained from the Department of Defense publication, MIL-STD-882D. The review of accident and incident severity revealed that the majority of mishaps fell within the classification of the critical category (40.74 %), and catastrophic category (37.04 %). The catastrophic category and the critical category are equivalent to the NTSB definition of an accident, while the marginal category (7.41%) and the negligible category (14.81%) in turn meet the NTSB definition an incident.

The accident and incident rate, per 100,000 flight hours, in relation to time is presented in Figure 1. The twelve-month moving average for each year was used to plot each point in order to dampen seasonal, or other fluctuations in data. Due to the logarithmic scale of Figure 1, the graph line symbolizing CAIR(SUP) is interrupted for the periods representing 1987 to 1988, 1989 to 1992 and 1997 to 1999. These interruptions represent a value of zero CAI per 100,000 flight hours. The line is presented at a much larger scale in Figure 2, and can be seen to fluctuate alternately between 0 and 0.01 CAI per 100,000 flight hours with the exception of the period that falls between 1993 and 1995 where the CAI rate increased to a maximum of 0.03337 CAI per 100,000 flight hours. The line representing CAIR(NAT) remains relatively constant, with a very gradual decrease after 1993. However, at no point does the line drop below 10 CAI per 100,000 flight hours.

Figure 1. Accident and Incidents Rate (Per 100,000 Flight Hours)

Figure 2. Combined Accident and Incident Rate (SUP)

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CONCLUSIONS

The results of this study contrast with the majority of views held by the popular press, trade organizations, and government representatives presented within the review of literature. From the data presented in the previous chapter, one must conclude that the probability of an accident or incident occurring, which involves SUPs as a contributing or causal factor, is remote. Therefore, the null hypothesis (H_0) is rejected in favor of the alternative hypothesis (H_1), which states that the probability of an accident and/or incident occurring with SUPs being a causal or contributory factor in a mishap is minimal.

The rationale for rejecting the null hypothesis centers on the dissimilarity between CAIR(SUP) and CAIR(NAT). Given that the mean CAIR(SUP) equals 0.008225 CAI every 100,000 flight hours, a prediction may be used to determine when a single accident or incident may be expected to occur by solving the unknown variable in the following ratio, $0.008225:100,000=1:X$. This suggests that an accident or incident will occur with a SUP as either a causal or a contributory factor every 1.2158×10^7 flight hours flown. In comparison, a single accident or incident can be expected to occur within general aviation at a rate of one accident or incident every 6,302.51 flight hours flown. Note that this value is inclusive of all causal and contributory factors. Given that between 1987 and 1998 the average number of hours flown by general aviation aircraft is 2,344,407 flight hours per month it can be said that an average of 0.19283 accidents or incidents can be attributed to SUPs per month compared to an average of 371.98 accidents or incidents nationwide every month. These predictions compare favorably with the actual CAI rates presented within the previous chapter.

To summarize, the Pocket Guide to Transportation (1998), estimates that the general aviation fleet consisted of 182,605 aircraft in 1995 and 187,312 aircraft in 1996. Of these aircraft, 2,3140 could be expected to have been damaged or destroyed in SUP related mishaps each year. This accident rate is approximately 1,928 times less than the national accident and incident rate (based on CAI per 100,000 flight hours) and therefore cannot be considered significant, as defined within chapter two. As a result, the alternate hypothesis was found to be favorable.

RECOMMENDATIONS

The results of this study suggest that a pilot flying eight hours daily, in a general aviation category aircraft, would not experience an accident or incident involving SUPs for

4,221.55 years. However, the same pilot under similar conditions could expect to experience an accident or incident, inclusive of all causal factors, within 2.19 years. Given the vast difference in these two probability rates, one must reconsider the amount of time and resources that are currently being focused to mitigate the risks associated with SUPs. Do the number of fatalities and injuries associated with an average of 0.19283 CAI, with SUPs as a causal or contributory factor, encountered each month within the United States justify the expense of implementing new programs and regulations to curb the use of SUPs?

The author believes that a combination of existing Federal Regulations, aircraft design philosophies (e.g., Maintenance Steering Group-3), and standard industry practices such as Reliability Centered Maintenance serve to adequately reduce the risk associated with a particular SUP component prior to its use and subsequent failure. This assertion can be demonstrated by considering the following hypothetical scenario. A repair station purchases a hydraulic pump, which is to be installed on a light twin aircraft. The pump serves as the primary means of actuating the landing gear retraction and extension mechanism. Upon receipt the part is inspected by an authorized inspector, following the basic requirements presented within 14 CFR Part 145, the part is then given to an aircraft technician.

The aircraft technician is tasked with installing the component on the aircraft, and is mandated by law to ensure that the requirements of FAR 21.303, FAR 43.13 and FAR 145.57 are met. For the purposes of this discussion, the probability of the authorized inspector failing to identify a SUP amongst parts received from a vendor or distributor is 1/100 (one SUP not correctly identified out of every 100 SUPs). In addition, the probability of the maintenance technician installing an SUP component, unknowingly, is 1/10 (one SUP not correctly identified out of every 10 SUPs). Therefore, taking into account the hypothetical probabilities, one out of every 1,000 SUP components will not have been identified before being placed in service.

A SUP component that escapes detection during this process has an additional chance of being discovered during future maintenance activities. A SUP component should be identified prior to failure through progressive, 100 hour, and annual inspections as required by FAR 91, Subpart E. The hypothetical probability of personnel failing to identify a SUP during an inspection is 1/20 (1 SUP not

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correctly identified out of every 20). Should a SUP part however fail to be removed and continue in service until the number of cycles flown results in failure, the redundancy of flight critical systems is designed to prevent a catastrophic failure. This design philosophy helps reduce the accident and incident rate by SUPs by apportioning risk throughout the system, so that a catastrophic failure is nearly impossible. Assume that the hypothetical probability of the hydraulic motor failing during operation is 1/1,000 (one failure per 1,000 flights). The hydraulic system incorporates a hand operated emergency hydraulic pump, which is to be used to lower the aircrafts undercarriage should the primary pump fail. The hypothetical failure rate for this component, like the hydraulic motor, is 1/1000 flights. Under normal circumstances, the redundancy designed into this system would have reduced the probability of a catastrophic failure by 1×10^6 . However, the hydraulic motor is a counterfeit part that has been unknowingly installed on the aircraft and its failure rate is 1/10 flights. The probability of an accident or incident occurring because of this SUP is reduced further when the failure rates of events upstream are calculated, that is considering the design, maintenance and inspection procedures. In simplistic terms, the probability of catastrophic failure occurring in this scenario is one in every two billion flights. This scenario demonstrates that a number of filters already exist to remove SUPs from the system and that aircraft design philosophies and modern maintenance practices make the likely hood of a catastrophic system failure due to a SUP improbable.

There can be no doubt that SUPs have manifested themselves as a safety problem and that SUPs can be found within the nations' aircraft parts inventories. As there is no conclusive evidence of the number of SUPs in these parts inventories, with the exception of a controversial audit conducted by the DOT/OIG (1996), the ratio of parts that are rejected from the system and the number of SUPs eventually installed on aircraft cannot be determined. Although the result of this study suggest that little threat to public safety is presented by SUPs, it is incapable of determining the relationship between the number of SUPs in parts inventories, and the number of SUPs installed within the commercial and general aviation aircraft fleet. It is therefore recommended that further research is conducted to determine this ratio and its effect on the national accident and incident rate.

It has been argued that the dangers of SUPs to airlines

poses an even greater threat to the flying public. National Transportation Statistics (1998) show a significantly lower fatality rate for commercial aircraft operations, and it is reasonable to suggest that the CAIR(SUP) rate is lower than that of general aviation. However, due to passenger capacity when an accident or incident does occur with SUPs involved, the number of injuries and fatalities can be expected to be much higher.

The public's view that airlines are more concerned with profit than safety has played a significant role in SUP 'hysteria'. The loss of an aircraft can prove to be extremely expensive, making it more cost effective to invest in safety programs, additional training, etcetera. For example, the loss of a scheduled American Airlines flight from Miami to Cali, Columbia, would have meant a minimum loss of an asset valued at 73.5 million dollars (Boeing, 1999). The crash of the Boeing 757 required that company representatives be flown to Columbia, requiring that another aircraft be removed from revenue service, in addition staff were accommodated and fed at the company's expense while the logistics of investigating the accident and providing care for grieving family members, immediately after the accident took place. In addition, the airline would have been liable to pay \$75,000 to each family under the Montreal agreement, if the airline was a signatory, otherwise the victims relatives would be eligible to receive approximately \$13,782 under the Warsaw convention. The airline would also forego opportunity costs associated with lost revenue and other miscellaneous items. Given these unexpected expenses, it is in the best interest of the airline to protect their fleet from SUPs by purchasing parts from credible suppliers, tracking rotatables, destroying unairworthy parts before selling them for scrap, and following AC 21-29B.

The allocation of scarce resources to the SUP 'threat' can be considered the result of mismanagement by involved parties. Over the last ten years, 70.6% of aircraft accidents have been caused by human factors. Logic would dictate that the greatest reduction in the number of injuries and fatalities could be achieved by targeting human factors, by using those resources currently allocated to reducing SUPs to better train flight crews, maintenance technicians and design new technology to help eliminate human error.

Social and legal issues are in a constant state of flux, and in recent years require that those persons or organizations that jeopardize public safety within the aviation arena be severely penalized. This has resulted in organizations and

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personnel being held liable under tort law for products or services that have led to an accident or incident. The threat of litigation is increased by the economic doctrines of caveat emptor (let the buyer beware), and increasingly caveat venditor (let the seller beware) that provide the buyer or seller the legal right to demand punitive and compensatory compensation for any deficient product. In addition, legal precedence is currently being made as a direct result of the Value Jet Flight 592 tragedy. If this

precedence is passed into law, maintenance organizations and their employees will be held accountable under criminal law. Should maintenance be determined to be the cause of an accident, corporate officers and maintenance personnel may be indicted for criminal conspiracy and manslaughter. These changes in social norms and law should have the desired effect of decreasing the number of SUPs with the nations' parts inventories.□

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REFERENCES

- Air Transport World (1994). Aviation Safety: Confronting the Future. [On-line]. Available: <http://www.atwonline.com/oct0594.html>
- Aczel, A. D., (1996). Complete Business Statistics, (3rd ed.). New York, NY: Ricard D. Irwin.
- Bajak, F. (1996, December 8). Bogus plane parts putting more passengers in peril. Daytona Beach News Journal, p. 11A.
- Baumgarner, J. (1995). Senate hearing on unapproved parts. Overhaul & Maintenance Quarterly, 8, 39-4.
- Boeing (1999). 1999 Airplane Prices. [On-Line]. Available: <http://www.boeing.com/commercial/prices/index.html>
- Broderick, A. J. The Politics of Aviation Safety. Symposium conducted at a joint meeting of Flight Safety Foundation 50th Annual Air Safety Seminar and the International Federation of Airworthiness Inspectors 27th Annual Conference, and International Air Transport Association, Washington, DC, November, 1997.
- Chase, J. (1957). The Problem of Bogus Parts. New York, NY: Flight Safety Foundation.
- Chase, J. (1964). Bogus Parts: A Continuing Threat to Aviation Safety in Aviation. New York, NY: Flight Safety Foundation.
- Department of Defense. (1997). MIL-STD-882D, Standard Practice for system safety program requirements. Washington, DC: U.S. Government Printing Office.
- Department of Transportation, Office of the Inspector General. (1996). Audit report, Suspected Unapproved Parts Program. (Department of Transportation Publication Number, R4-FA-6-026). Washington, DC: Author.
- Department of Transportation, Bureau of Transportation Statistics, National Transportation Statistics. (1998). Pocket Guide to Transportation. [On-Line]. Available: <http://www.bts.gov.ntda/nts>
- Elzey, F. (1971). A programmed introduction to statistics. Belmont, CA: Brook/Cole Publishing.
- Federal Aviation Administration. (1994). Air taxi operators and commercial operators, FAR 135. Washington, DC: U.S. Government Printing Office.
- Federal Aviation Administration. (1995). Suspected 'unapproved parts' program plan. Washington, DC: U.S. Government Printing Office.
- Federal Aviation Administration, Office of System Safety. (1998). [On-Line]. Available: http://www.asy.faa.gov/safety_analysis/si.zip
- Federal Aviation Administration. (1999). Accident and incident database. [On-Line]. Available: http://www.asy.faa.gov/asp/asy_crosssys.asp
- Federal Aviation Administration (1999). Chapter 1, Title 14 of the US Code of Federal Regulations. [On-Line]. Available: http://www.faa.gov/avr/afs/fars/far_idx.htm
- Federal Aviation Administration, Office of System Safety. (1999). [On-Line]. Available: http://www.asy.faa.gov/safety_data/
- Unapproved Airplane Parts and Air Safety, 104 Cong., 1st. Sess. (1995) (Testimony of James Frisbee).
- Gay, L. R. (1996). Educational research. Upper Saddle River, NJ: Prentice Hall
- National Safety Council. (1998). Accident Facts, 1998 Edition. [On-line]. Available: <http://www.nsc.org/lrs/statinfo/af1998.html>
- Unapproved Airplane Parts and Air Safety, 104 Cong., 1st. Sess. (1995) (Testimony of Professional Airways System Specialists)
- Robinson, R. (Fall 1993). Timed Out Vietnam-era Parts Should Not Be Allowed in US. Rotor, 6, 36-39.
- Schultz, W. (1995). The unapproved parts status. [On-line]. Available: <http://www.generalaviation.org/techpoly>
- Unapproved Airplane Parts and Air Safety, 104 Cong., 1st. Sess. (1995) (Testimony of Mary Schiavo)
- Schiavo, M., Chartrand, S. (Eds.). (1997). Flying blind, flying safe. New York, NY: Avon Books
- Staff. (1994, January). Bogus parts – Detecting the hidden threat. Flight Safety Digest, 1, 1-17.
- Staff. (1994, January). Fatal Convair Crash Linked To Suspect Parts, Improper Maintenance. Flight Safety Digest, 1, 18-30.
- Staff. (1994, September). U.S. Audit finds some F.A.A. approved repair stations using bogus parts. Flight Safety Digest, 9, 1-8.
- Stern, W. (1996, June 10). Warning! Bogus Parts Have Turned Up in Commercial Jets. Where's the FAA? Business Week. [On-Line]. Available: <http://www.businessweek.com/1996/24/b54/91.htm>