Analysis

of

&&&&& &&&&&&&’s Narration

for

Installation of Light Speed Engineering

Ignition Systems

on

Lancair N811HB

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Abstract:

On 26 February 2008 a Lancair IVP, registration N811HB lost power and made an off-runway landing at French Valley airport in Murrieta, CA. An investigation revealed that both fuses feeding a common bus for both ignition systems were failed. This analysis will show that the system for powering to the ignition systems was a inappropriate mixture of ideas lifted from several published designs. Further, a combination of poorly selected components produced a system with a high risk of failure.

This report will further illustrate how designed-in failure conditions on N811HB should have been discovered and corrected by use of design validation techniques common to all disciplines involving critical systems.

Forward:

The following document is an analysis of narration written by Mr. &&&&& &&&&&&& describing design decisions and events leading up to a simultaneous in-flight failure of both ignition systems. &&&&&&&'s document was provided to me by the law offices of *** @ ######## on or about the 15th of March, 2010. Mr. ######## tasked me with evaluating &&&&&&&'s assertions and comparing them with my own perceptions of cause and effect for the failure event.**

The quoted text in this analysis was secured by scanner and optical character recognition software not studiously proofed against the original document. Discrepancies between the quoted text and the original are inadvertent and incidental to the study at hand. Further, where discrepancies are discovered the original document prevails.

I am privy to numerous discovery documents provided by Mr. ########. I also inspected the wreckage on the salvage company's storage site. None of these documents or discoveries made during that inspection go to more than simple amplification of &&&&&&&'s narration and are incidental to conclusions offered at the end of this report.

Attachments:

See Appendix A for copies of documents referenced in this report.

Analysis:

&&&&& &&&&&&&
EAA Technical Counselor
Independence, OR 97351 Date: Dec 15th, 2009.

National Transportation and Safety Administration

Attn: Investigator in charge

RE: 1VTSB report #LAX08LA066; N811HB, Bartle Lancair IV-P accident

To Whom It May Concern:

I am preparing this letter on behalf of Mr. Henry Bartle in effort to provide a compete understanding of the ignition system installation that was in Lancair, N811 HB. My professional background includes over twenty years of aircraft electrical and electronic systems. In addition to being a Technical Counselor and Flight Advisor for the Experimental Aircraft Association, Aircraft Mechanic at the Reno National Championship Air Races, Commercial Pilot and Flight Test Pilot, I am a professional degreed engineer working for $$$$$$ and hold a consultant FAA delegation in Electrical and Electronic systems for certified aircraft (FAA DER).. In my salaried career, I have designed aircraft electrical systems for most of the major aircraft OEM's including Beechcraft, Piper, and Mooney aircraft. These designs included complete electrical system layouts as well as incorporation of leading edge glass panel cockpits into these well established airframes.

I was able to take my professional experience to counsel and aid Mr. Bartle on the installation of the electrical equipment in his Lancair IV-P. I would like to concentrate this letter specific to the ignition system in the aircraft, as this may have been a primary contributor in the accident which you are now investigation.

Mr. &&&&&&&’s experience and credentials are noted.

From my understanding, the ignition system came with the engine purchased from Performance Engines. The system was a dual Light Speed Engineering, Plasma III CDI system which was installed and operating on the engine prior to delivery. The system includes several main components, the majority of which were installed directly on the engine itself. Unlike a magneto system, the electronic ignition system requires engine sensing components, coils and an external processing box. All of these components including a pre-wired harness, and "quick-start instruction manual" were included with the engine. Another major difference is that the Plasma III ignition system is not self energizing like a magneto, meaning it requires an external power supply to maintain proper operation.

Agreed.

Our initial intensions were to install the complete "kit" within the engine compartment of the aircraft such that the Light Speed Engineering wiring harness could be used as fabricated by the manufacture. But after reading the installation manual and consulting the manufacture it become evident that the processing modules needed to be installed within the pressurized cabin of the aircraft. In addition the manufacture recommended a "wisp of air" be used to aid in cooling the electronic devises.

Understand. It is noteworthy here that the Light Speed Engineering (LSE) was consulted with some diligence concerning questions about installation locations and cooling.

Mr. Bartle's aircraft was designed with a fully redundant dual battery, dual alternator electrical system, and could power both left and right ignitions from either bus such that a failure of any or multiple electrical sources would allow both ignition modules to remain powered and operating. This was accomplished via a Hot Battery Bus with dual feed lines.

The basic architecture for the subject aircraft appears to be adapted from drawings included in the installation manual for the $$$$$$ integrated flight instrumentation system installed aboard N811HB. The drawing suggests a combination of:

- **A main alternator capable of carrying all of the ship's normal electrical loads.**

- **An auxiliary alternator of limited capability was installed along with a specialized regulator/controller that brings the aux alternator on line automatically in the event of main alternator failure.**

- **To prevent the aux alternator from becoming overloaded by application of ship's full electrical demands, the aux alternator drives a bus tasked with powering only essential items at much less total demand.**

- **A diode (electrical power check-valve) that prevents the auxiliary alternator from being overloaded by the main bus. While the main alternator is functioning, the diode between the main bus to the auxiliary bus causes the main alternator to pick up all electrical loads.**

- **If the main alternator fails or is turned off, total system voltage falls slightly thus signaling the auxiliary alternator regulator/controller to assume loads on the auxiliary bus only.**

- **Each alternator is paired with a battery connected to their respective busses.**

The $$$$$$ drawing suggests the use of independent breaker-protected feeds from each alternator bus be combined using a pair of diodes to offer a redundant power source for an electronic ignition. One could extrapolate this suggestion out to say that a similar technique could be considered for powering ANY component necessary for continued flight. For example, some aircraft must move fuel from the tanks to the engine with electrically driven pumps. In this instance, failure-tolerant design calls for more than one pump and perhaps multiple sources of power for those pumps.

Functionality of any critical item would benefit from an independent dual-feed, its own set of breakers and diodes as illustrated in the $$$$$$ drawing. While this design philosophy will perform as advertised, it is parts-intensive and not widely practiced in the crafting of failure-tolerant designs.

Since Light Speed Engineer specified that the processing modules of their system needed to be with in the pressurized aircraft cabin, fuse were necessary in order to protect the bus from being an inadvertent source of fire inside the cockpit should a fault arise.

Had the ignition modules been mounted outside the cockpit on the forward side of the firewall, protection of wires from the always hot battery busses would still have been necessary. Further, that protection may take the form of either a fuse or a circuit breaker. It follows that need to protect of wires connected to the batteries is not a function of location for the ignition system components.

Historically fuses were protection-of-choice when electrical systems were introduced into popular light aircraft in the 40's. The aircraft industry upgraded to circuit breakers in the early 60's. The automotive industry is still a major user of fuses. The reliability and quality of fuses has improved steadily over the years. Significantly the amateur built aircraft industry has successfully integrated fuses onto thousands of modern aircraft

The electrical system on N811HB was only similar to the $$$$$$ drawing. $$$$$$ suggests a means by which a critical system component be offered two power sources: First from the main bus and a second from the auxiliary bus. Contrary to $$$$$$ recommendations, the incident aircraft took power directly from the batteries which were located outside the cockpit instead of alternator busses which are traditionally located inside the cockpit.

The Hot Battery Bus was fuse protected with the fuses mounted in the engine compartment near the batteries, and pilot accessible circuit breakers were installed in the cockpit. The Hot Battery Bus circuit always has power on it regardless to the position of the master switch or any other pilot controllable device inside the cockpit, again requiring the use of fuses near the battery source, in the engine compartment in order to protect the occupants from fire in the cockpit.

A true statement but with errors of logic in the selection of components.

The installation manual provided with the Plasma III CDI system from Light Speed Engineering did not include any electrical current draw information about the system, in fact the manual provided very little electrical information and no operating characteristics which would be standard and expected in an installation manual of any electronic device.

After contacting the manufacture about installation questions and missing information, Mr Bartle was referred to the Light Speed Engineering website. From there he obtained the manufactures trouble shooting guide for the Plasma III CDI system in which it stated the systems current draw should typically be 200 ma, and if the system current draw was more then 400 ma to return the unit to the manufacture. At that time, I also scanned the Light Speed website for information on the Plasma III CDI electrical characteristics of the system and did not see any additional data.

Are we given to understand that the LSE was contacted to inquire about ignition system current demands and was refused access to that information?

Based on this information from the electronic ignition manufacture it was determined that 5 Amp fuses in each Hot Battery Bus feeder line would adequately protect the wiring which was utilized. Please note, the current draw determined via the information sourced from the manufacture was well over 5 times less then the rated fuses used in the circuit.

The trouble shooting procedure was for a powered-up but non-operating system. I.e. engine not running. The troubleshooting procedure did not call for securing any current measurement while the engine was running. It was a simple go/no-go test to discover a damaged unit. This 400 mA max current data point used as an operating condition is not supported by any train of logical thought.

A synopsis submitted to the NTSB by Light Speed Engineering appears to draw conclusion to the "unfortunate choice of component values and unusual wiring", but clearly did not understand, the electrical aircraft design and safety margins used in each selected component. These large conservative margins eliminate the need for the detailed analysis, as described in the report.

It is not clear what "safety margins" are being considered. To be sure, the 5A rating for circuit breaker and fuse sizing was consistent with LSE's recommended wiring architecture. But in no case did the LSE's wiring illustrate or suggest that TWO ignition systems should share the same 5A protection. Nor does any document cited as a reference source for designing this system suggest automotive fuses be incorporated upstream of circuit breakers.

To clarify the incorrect speculation of the aircraft electrical system made in the assumptions of the Light Speed Engineering report I feel it is important to bring to light the following:

a. If LSE understood aircraft, especially certified aircraft, it would be clear that you do not bring unprotected (i.e. un-fused) power source into the cockpit.

Correct. It's a matter of common practice for limiting the length of unprotected wires to (1) very short runs, typically 6" or less and protecting always-hot wires for crash safety at 5A or less (more on this later).

Hence all installation need an appropriately fused feeder power wire, and individual system Circuit Breakers. Their system is slightly unusual in the industry as it requires a live continues battery feed, and the typical CB panel in the aircraft is switched via the Master Switch, and / or Avionics Master Switch.

Correct. But the LSE product was not intended for use on type certificated aircraft so the builder IS free to adopt alternative designs more in conformance with type certificated standards and practices.

b. Diode isolation of busses is extremely common in the industry. It allows for better power distribution and proper shedding of systems which may be considered primary, secondary, or essential, non-essential, and critical.

I cannot imagine a multiple-source, diode-isolated bus connected directly to batteries. Multiple feed busses in aircraft are sometimes used to power a suite of essential or critical systems. They get their power from batteries and alternators controlled by crew from cockpit switches.

The $$$$$$ drawing suggests a technique for powering one ignition system from crew controlled alternator busses in a manner consistent with my experiences and observations of industry practice.

c. The de-rating calculations for the fuse and placement information seems plausible, however based on the design current draw of 800 mA worse case (the data available and used during the time of the design) even the de-rated value of 4.7A - 75% or 3.SA would have left a safety margin of nearly 450%.

Discovery of real operating current values for LSE systems shows the fuse de-rating analysis to be flawed. Data assumptions, unusual architecture and improper application of fuses combined form a system with a high risk of failure.

d. The report is incorrect in stating that the Plasma III CDI uses two parallel pins, and the aircraft bulkhead used one. There are two sets of bulkhead connectors and a set of power and ground lines in each of these two bulkhead connectors. Also, just as a point of statement - the type of bulkhead connectors was not identified, so it could be that a single pin would be rated higher then the contactor on their D-Sub connector. This was not analyzed in his report.

Not germane to this study.

e. Improperly stated in the report was the fact that the aircraft did not have a return line for the power. In fact, this was properly done and it is in the drawings which LSE reviewed from the NTSB.

Not germane to this study

f. The report indicates that LSE recommends and 18 GA wire, when in fact their drawings says 18GA or 20GA.

LSE drawings never suggest two ignition systems receive power through a common feed path. Worst case current demands of a single LSE system would not have put a wire as small as 22AWG at risk. 22AWG wire is conventionally protected at 5A in type certificated aircraft. 20AWG at 7.5A and 18 AWG at 10A. Therefore, protecting 18, 20, or even 22AWG wires at 5A offers no risk of wire ‘overload’. Therefore, discussion of wire sizes is not germane to this study.

g. There are a lot of calculations for wire resistance, fuse resistance, junction temperatures and forward voltage drops which are great when designing a system to operate on the edge. But why do that when someone can just utilize large enough wire, and fuses to supply each load with a 2x or in accordance with this detail analysis a 4x margin. If the design has a safety factor of two or three, you do not need to calculate all the details. Hence, the 800 mA needed was no factor with 20GA wire and a 5A fuse.

Not germane to this study.

h. The diode calculations in the report are made to show, that you could not efficiently balance the regulators in a dual alternator design, such that exactly 1/2 the current would flow through one 5A fuse and 1/2 the current would flow through the other. In the Bartle aircraft design there was no desire to try and balance the regulators, in fact the system was specifically setup with a 1 volt difference between each bus such that no detailed diode junction calculations would be necessary. Mr. Bartle's aircraft was not a balanced regulator design, it was the intent of the design that all the current would feed through one fuse, and the second fuse was a backup or alternate path in the event of both alternators failed and one of the batteries was depleted prior to the aircraft being able to land.

This statement is consistent with the architecture of the $$$$$$ power distribution diagram and the functionality of the 20A aux alternator and its companion regulator/controller. I agree with &&&&&&&’s perceptions and assertions.

i. The report indicates that the typical current draw is about 2.35A at 2500 RPM. The latest manual available (12-17-08) lists the current draw at 2.1A at 13.8 volts. 'First off, these numbers do not agree, they are off by 12% (which is nearly 1/2 of the fuse de-rating value). The report says this is "typical" current, the manual says "current consumption" there is no mention of "typical" or "maximum". The report says 2500 RPM, making you-think that the current required is related to the RPM of the engine. This makes sense, but the manual does not list RPM, it says 2.1A at 13.8V, no qualifying engine speed. Finally, I must ask why 2500 RPM? Most all aircraft engines have a redline of 2700 RPM, and typically the homebuilt aircraft will go beyond that limit, I think Mr. Bartle's aircraft engine was set up with a 2800 RPM redline.

j. The conclusion of the document reiterates the attempt to match the alternators resulting in the entire ignition load passing through one fuse, and then the other. The conclusion indicates that if the fuses chosen were of a higher rating then this design may have worked. In retrospect, had the Plasma III CDI system manufacture specified the operating current of the system, and indicated the current varied with engine RPM, a higher rated fuse would have indeed been used in the system, and a larger gauge wire would have been specified.

Recently I have found that Light Speed Engineering has updated their installation manual to list a current draw of 2.1 Amps per unit. They have also recently updated their website to contain this information as well. In place of making detailed analysis of the fuses, temperatures, voltage drops, and currents in the system the simplest and safest approach is to specify large rated components. With a margin of over 50% none of the calculations detailed in the Light Speed Engineering report would be needed. Had this current draw information been made available at the time the aircraft was designed, with a Hot Battery Bus load of 4.2 amps times a factor of 2 equaling 8.4 amps, 10 amp fuses and 18 gauge wires would have been used. More over, with recent laboratory test data showing the combined current draw of both units, at typical operating temperatures and typical engine RPMs, in excess of 6 amps; the Hot Batter Bus should have conservatively used 15 amp fuses in each feeder line utilized 16 gauge wire.

It's true that upsizing to 15A fuses and 18AWG wire would have prevented the particular failure demonstrated on the accident aircraft. However, upsized fuses bringing power from an always-hot battery connection would be inconsistent with production aircraft practices for limiting the sizes of such feeders to 5A or less.

Further, a simple upsizing of fuses would not have mitigated a single point of failure for both ignition systems. My assertion is based on the significant differences in the operating speeds for fuses versus circuit breakers.

There are large differences in response time between 5A breakers and 5A fuses used in this aircraft. For a mild overload (2x device rating), a breaker will typically open in 1.5 to 15 seconds to while a fuse takes about 1/20th of a second. During severe overload (dead shorts) the relative difference can be still greater. This illustrates the faulty reasoning that called for use of fuses upstream of breakers to protect the power wiring for the LSE ignition systems.

This concept is fundamental to a well considered power distribution. A fuse inside a toaster is much less robust (faster acting) than the breaker in a home's power distribution box. The breaker in the box is much less robust than the protection for a transformer on the pole which powers multiple houses. As one moves upstream toward the power source, the relative robustness of each protective device must be sized to allow operation of any single protective device in the system without tripping any protection upstream. This prevents a short in a toaster from turning out lights in the whole neighborhood.

Suppose one LSE system failed in a manner wherein the breaker dedicated to that system was EXPECTED to trip. The fuses are so much faster than breakers that a hard fault an N811HPB ignition module would first open the main battery fuse followed a few millisecond by trip aux battery fuse thus bringing down BOTH ignition systems.

I hypothesize that &&&&&&&'s decision to use fuses upstream of breakers was driven by a casual observation of wiring diagrams for much larger airplanes where he may have observed "fuses" situated upstream of breakers. However, such fuses are specialized devices called "current limiters". Relative robustness of fuses used in the N811HB system was a small fraction of that for breakers. Current limiters used in aircraft power distribution are many times MORE robust than breakers.

VERY FAST plastic fuses used in the N811HB and current limiters use on large aircraft have the same schematic symbol. However, their functionality and proper application are vastly different. Even if

fuses in N811HB had been “properly sized” for normal operations, there was still risk for simultaneous loss of both ignition systems. A hard fault downstream of either breaker would have opened BOTH fuses culminating in complete loss of ignition.

Fuses have another characteristic apart from circuit breakers. They can suffer ACCUMULATIVE effects of TRANSIENT conditions. The fuses in this airplane were only occasionally loaded beyond their recommended operating points. But they were weakened with transient, repetitive, mild overload events. This is why the series of fuse failures in N811HB took tens of hours to occur.

In my professional opinion, the root cause of the failure tracks back to the manufactures inappropriate omission of critical current specification in the product's installation manual, compounded by providing misleading information on their website of the systems actual current draw.

It is a fact that the LSE documents published at the time did not offer detailed performance data. LSE offers a product to a relatively unsophisticated target market. 99% of LSE’s customers DO NOT possess the training and experience of Mr. &&&&&&&. LSE’s recommended architecture for powering dual ignition systems was quite clear. The LSE system was failure tolerant. It avoided single points of failure for both ignition systems. If LSE is guilty of transgression, it was the practice of bringing always-hot battery wires into the cockpit. But this is more a crash safety issue than a flight reliability issue. Further, it is not a regulatory issue applicable to amateur built aircraft.

The system installed aboard N811HB did not in conform with the $$$$$$ drawing.

- **Ignition system feeders were MOVED from crew controlled alternator busses to always-hot batteries (See Appendix A, Figure 3).**

- **The $$$$$$ drawing did not suggest that the single dual-feed bus be used to feed TWO ignition systems as implemented on N811HB (See Appendix A, Figure 2).**

- **Fuses were substituted for breakers.**

- **Fundamental design practice calls for elimination of all opportunity for undetected, latent failures. For example, the $$$$$$ drawing calls for “press-to-test” buttons or switches used to open first one and then the other ignition system power feeder. This is generally accomplished during pre-flight to test functionality of both power paths. This feature was omitted for some reason not explained in &&&&&&&’s narrative. If one of the two fuses were open, it would not be possible to detect it before flight.**

It is likely that the fuse from the main battery was failed some time before the fuse from the auxiliary battery failed. This span of time was probably many hours in duration. Had the press-to-test feature been

adopted as suggested by the $$$$$$ drawing, preparations for flight would have discovered the condition thus initiating an investigation of cause followed by appropriate remedy.

More over regardless of the present published data, there is still no mention of increased current draw, over temperature or engine RPM in their manuals or service bulletin, and the mention of "wisp of air" does not specify a required flow amount, such as X.X CFM (Cubic Feet per Minuet). Based on the laboratory test data which took into account all the necessary factors fuse protecting these devices utilizing their recently published 2.1 amps per unit, with even at 10 amp fuse may not be adequate and could lead to future accidents if additional information is not provided to the public. The generic installation diagrams in the manual are inappropriate for most, aircraft especially pressurized aircraft which must fuse or switch protect any power source entering the passenger cockpit.

----- End of &&&&&&& Narrative -----

Discussion:

The vast majority of LSE’s customers are building one to four-place, un-pressurized airplanes with very simple electrical systems. These customers have no skill-set for (or a keen interest in) innovative designs for power distribution systems.

LSE’s instructions offered a recipe for success (See Appendix A, Figure 1) that was failure tolerant and would have performed as advertised. I agree that LSE documentation did not offer all data needed for a well considered, innovative departure from LSE recommendations. However, LSE’s documentation data was consistent with their design goal of offering a “cookie cutter” approach to safe installation of LSE products in airplanes by the most unsophisticated customers.

The narration suggests that one or more conversations with LSE were conducted to discuss matters of location and cooling. The narrative suggests no satisfying answers went to system current demands. &&&&&&&’s narrative states that a maximum current draw for an ignition module was extrapolated from a troubleshooting procedure wherein the engine was not running.

As a professional designer of electrical systems for aircraft, &&&&&&& was no doubt accustomed to easy access to any and all data required for successful integration of an accessory onto a type certificated aircraft. He was no doubt aware of a need for accurate current draw data required to accomplish a load analysis for the electrical system along with proper sizing of components.

Simple aircraft flown in fair weather environments do not benefit from sophisticated system designs. However, N811HB was specifically designed for fast, high altitude performance in unfriendly weather conditions. This airplane was particularly needful of: Failure tolerant design supported by failure mode effects analysis (FMEA). Confirmation of electrical system performance in normal and emergency conditions requires a load analysis – a detailed tabulation of current demands by all electrical accessories. System development ground or flight tests are conducted to confirm the validity of any new recipes for success.

&&&&&&&’s experience, certifications, and skill-set cited at the introduction of his narrative suggests an understanding of these practices.

Temporary flight restriction of new amateur-built aircraft offers opportunities for a system designer to confirm that design goals have been met. Uncertainty about the assumed 400 mA operating point would have been easy to resolve. Ammeter measurements in the circuits of interest during ground or flight testing would have confirmed/denied validity of the design and prompted timely correction.

Conclusion:

Studies of fact available at the time of this writing reveals the following data points of interest concerning design and fabrication of the ignition system installed on N811HB:

(1) The LSE recommendations for powering a dual ignition system were not adopted.

(2) The $$$$$$ drawing used as a basis for designing the system was not adopted. Departures from $$$$$$ recommendations include:

> **(a) power was taken from batteries as opposed to the alternator busses as illustrated.**
>
> **(b) a diode-isolated dual feed-path for critical systems was incorrectly applied to supply BOTH ignition systems as opposed to crafting separate power pathways for EACH ignition system.**
>
> **(c) moving power source from busses to batteries necessitated the ADDITION of UPSTREAM circuit protection which was not properly selected for robustness when compared with the DOWNSTREAM circuit breakers protecting each ignition system.**
>
> **(d) elimination of press-to-test features deprived the pilot of a means by which latent failures in either one of the two power pathway to ignition systems could be detected. *Conditions (a) through (d) are consistent with the LSE comment about “unusual wiring”.***
>
> **(e) The fuses were undersized for the task but even if upsized to accommodate real demands of the LSE systems, there was still risk of a single failure bringing both ignition systems down. *This condition is consistent with the LSE comment about “unfortunate selection of components”.***

In my professional opinion, this accident has root cause in a poorly crafted power system that demanded a failure tolerant architecture. Suggestions from both LSE and $$$$$$ for the powering of ignition systems were not adopted. An adaptation of philosophies from both LSE and $$$$$$ were inexpertly substituted wherein I perceive:

> **(a) a failure to establish failure tolerant design goals.**
>
> **(b) no validation of design goals by artful application of failure mode effects analysis.**

(c) no ground or flight-testing conducted to resolve hypothetical or estimated operating points.

(d) no load analysis conducted to confirm sizing of components and management of energy under various failure conditions

These are rudimentary processes common to the production aircraft industry. It is mystifying why the narrative of an experienced and certificated designer of such systems makes no suggestion of their application in design, fabrication and testing of this sophisticated aircraft.

If we had it all to do over:

Given the excellent decision to install a dual-battery/dual-alternator system in a high performance aircraft, it would have been perfectly acceptable to simply *power EACH ignition system from its own dedicated 5A breaker on the Aux Alternator Bus*. This offers the following advantages:

(1) Elimination of concerns for extending always-hot wires from the ship's battery busses.

(2) Elimination of firewall penetrations for ignition system power with a commensurate increase in reliability.

(3) Elimination of single point of failure generated by poor implementation of suggestions from the $$$$$$ and LSE drawings.

(4) The aux alternator bus has FOUR sources of power consisting of TWO alternators and TWO batteries. There is no single failure likely to bring down the aux alternator bus.

It follows the design goal for a failure-tolerant power source suggested in the $$$$$$ drawing is *already* implemented by the aux alternator bus. A diode-isolated, dual-feed path offered no significant improvement in system reliability. The architecture I've suggested offers a simple implementation with a high degree of failure tolerance.

(5) The airplane flies well on one ignition system. Striving to keep both ignition systems operating all the time stacks redundancy on top of redundancy. It offers no practical benefit.

(6) The suggested architecture eliminates press-to-test switches and pre-flight procedures to detect latent failures of the battery bus feeders.

(7) Operation of the airplane for preflight, normal and emergency conditions would be no different with regard to ignition management than for an engine fitted with magnetos. Except for two breakers on the aux alternator bus and improved engine performance, the existence of electronic ignition would be essentially transparent to the pilot.

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