FAA AGING NONSTRUCTURAL SYSTEMS RESEARCH

Christopher D. Smith, Manager, Aging Nonstructural Systems Research
FAA, William J. Hughes Technical Center

Abstract

The Federal Aviation Administration's (FAA) Aging Transport Nonstructural Systems Plan describes various maintenance, training and reporting initiatives, development of advisory material, research programs, and other activities that have already started or will be undertaken by the FAA in order to address the White House Commission on Aviation Safety and Security.

This paper describes the FAA's approach to specifying and executing both near- and long-term research. Two specific initiatives, the establishment of a "validation infrastructure" and the development of arc-fault circuit interrupters, will be discussed in some detail.

In establishing the research program, the FAA has committed to the principal that a fully effective research program must be based on service data analysis and teardown evaluations. As such the program will work closely with – and draw on the findings of – the FAA's Aging Transport Systems Rulemaking Advisory Committee (ATSRAC) and the Air Transport Association's (ATA) Aging Systems Task Force (ASTF). Joint FAA-ASTF activities to assess the state of aging wiring have already been initiated.

The FAA's validation infrastructure will be used to determine the effectiveness of various technologies and techniques for mitigating nonstructural systems failures. For researchers and developers, the validation function will include services ranging from introducing researchers to aircraft systems issues to assisting developers in the transfer and commercialization of proven technology. Services to aircraft operators and manufacturers will include assistance in determining the adequacy of technology and techniques for specific applications.

Arc-fault circuit interrupter technology has the potential to mitigate the consequence of wire failure without requiring the redesign of aircraft circuitry. Plans call for a device sensitive to arc faulting and meeting all performance and design specification of existing circuit breakers.

The FAA is working closely with the aviation community, the Air Force, the Navy, and NASA to effectively specify and execute research to mitigate the hazards of aging nonstructural systems.

Introduction

In October 1998, the FAA released the Aging Transport Nonstructural Systems Plan (not to be confused with the Nonstructural Systems Research Plan (NSRP)). The intent of the Aging Transport Nonstructural Systems Plan is to evaluate the effectiveness of the current processes for design and routine inspection, maintenance, and repair of aircraft systems in mitigating the effects of aging of systems components. The evaluation will include the effectiveness of present systems in addressing environmental and accidental damage. Environmental damage is defined as degradation due to exposure to the atmosphere, damaging fluids, vibration, heat, ultraviolet exposure, and other such effects. Accidental damage includes wear and tear due to normal maintenance activities. Recommendations will be made for changes to the current processes under which systems are designed, inspected, maintained, and repaired as necessary to assure adequate consideration of systems aging effects.

The Aging Transport Nonstructural Systems Plan calls for the FAA to add six specific tasks to the Aging Aircraft Research Program. These tasks are

- To determine if a service life for airplane wire is appropriate, and – if appropriate – determine the service life for all types of wire used in transport aircraft.
- To establish the condition of aging systems wiring components and validate the adequacy of visual inspection.
- To develop nondestructive testing tools for inspection and testing of wiring systems.
- To establish aging effects on aircraft lightning and high-intensity radiated fields (HIRF) protection systems.
- To develop an arc-fault circuit interrupter for transport aircraft.
- To perform destructive testing of flight control linkages.

In establishing the NSRP the FAA has committed to the principal that a fully effective research program must be based on service data analysis and teardown evaluations. As such the NSRP will be coordinated with – and draw on the findings of – the FAA's Aging Transport Systems Rulemaking Advisory Committee and the Air Transport Association's Aging Systems Task Force.

The NSRP consists of two major research areas: electrical systems research and mechanical systems research. The planned efforts in each of these areas are described in highly structured Research Program Documents (RPDs). RPDs are used by sponsors and oversight organizations to prioritize and assess specific research programs, projects, and tasks. The NSRP RPDs were developed by the NSRP manager in response to a research request from the Technical Community Representation Group (TCRG).

Though endorsed by the Aging Transport Nonstructural Systems Plan, the support of efforts to address aging effects on aircraft lightning and HIRF protection systems is an ongoing program established by and remaining in the Atmospheric Hazards Program.

Issues

Table 1 shows a break down of airplane-related primary cause factors for serious

	Worldwide		**U.S. Operators**	
	Total	Percentage	Total	Percentage
Power plant or thrust reverser	15	3.2%	4	2.9%
Landing gear, brakes, tires	13	2.7%	3	2.1%
Flight controls	6	1.3%	2	1.4%
Electrical systems, instruments	6	1.3%	3	2.1%
Structures	4	0.8%	0	0%
Hydraulics	2	0.4%	0	0%
Passenger accommodations	2	0.4%	1	0.7%
Auxiliary power	1	0.2%	1	0.7%
Fuel systems	1	0.2%	1	0.7%
	50	10.5%	15	10.7%

Table 1: Airplane (Design Related) Primary Cause Factors – Hull Loss Accidents 1959 - 1996[1]

accidents between 1959 and 1996. The shaded areas represent items that are the subject of the NSRP.[2] Up to 3 percent of all cause factors or 30 percent of airplane-related cause factors may be attributable to nonstructural systems.[3]

Electrical Interconnect Failure

Aircraft electrical systems have been implicated in a number of recent accidents and incidents. Since 1983 there were at least 26 well investigated reports of accidents or serious incidents involving electrical interconnect system failures and preliminary findings seem to implicate such systems in the catastrophic crashes of TWA 800 in 1996 and Swiss Air 111 in 1998. While this number is small in the greater context of the over 300 million successful commercial flights in that same time period, the trend of keeping airplanes in service well past their original economic design life requires that we devote additional effort to studying the effect of aging on critical airplane systems and functions.

Still, civil aviation service and incident data – which in many cases can indicate the potential for more serious failure – is in short supply.[4] The Department of Defense (DoD) generated substantial quantitative data on the malfunctioning of electrical interconnect systems. Though civil aircraft do differ in design and operation, it is not unreasonable to use this data as guidance in focusing FAA efforts. The kinds of damage seen in the military fleet can be expected in the commercial fleet, although it would seem that the incidence of damage in the commercial fleet may be much lower due to more benign operating conditions. Table 2 shows the kinds of failure seen on a typical Air Force fighter aircraft.[5]

Broken Wire	46%
Insulation Chafing Damage	30%
Outer Layer Chafing	14%
Failure in Connector	10%

Table 2: Wire Failure Data for a Typical Fighter

The Navy's Aircraft Power & Propulsion Division at the Naval Air Warfare Center, Aircraft Division estimates that the Navy spends $10,000,000 per year on finding and replacing faulty wires. This includes more than 4800 power wire removals per year for the Navy Fleet of approximately 4670 aircraft. More serious incidents include 64 in-flight electrical fires over a 30-month period on 17 different aircraft platforms (July 1994 through January 1997) and 2 lost aircraft.

Data more specific to commercial aircraft is presented in Table 3 (and associated Figure 1).

AC Flight Hours	AC Inspected	Fleet Sample Flight Hours	50% Local Reduction of Insulation			Bare Wire Exposed Locally		
			Number of AC	Portion of Sample	Rate/10^6 Flight Hrs	Number of AC	Portion of Sample	Rate/10^6 Flight Hrs
70K+	19	1330000	6	32%	4.51	3	16%	2.26
60-70K	37	2405000	7	19%	2.91	3	8%	1.25
50-60K	73	4015000	11	15%	2.74	3	4%	0.75
40-50K	135	6075000	3	2%	0.49	0	0%	0.00
30-40K	194	6790000	2	1%	0.29	1	1%	0.15
Fleet	458	20615000	29		1.41	10		0.49

Table 3: Boeing 737 Fuel Tank Wiring[6]

Though this data is based on a very specific sample set and there was no effort to identify wire type or age, the figures are suggestive of age-related failure. The aging factors could include both wire degradation (e.g., cracking, embrittlement) and nonwire-related aircraft aging. Aging factors independent of wire degradation may include an increased frequency of collateral wire damage associated with nonwire-related maintenance actions.

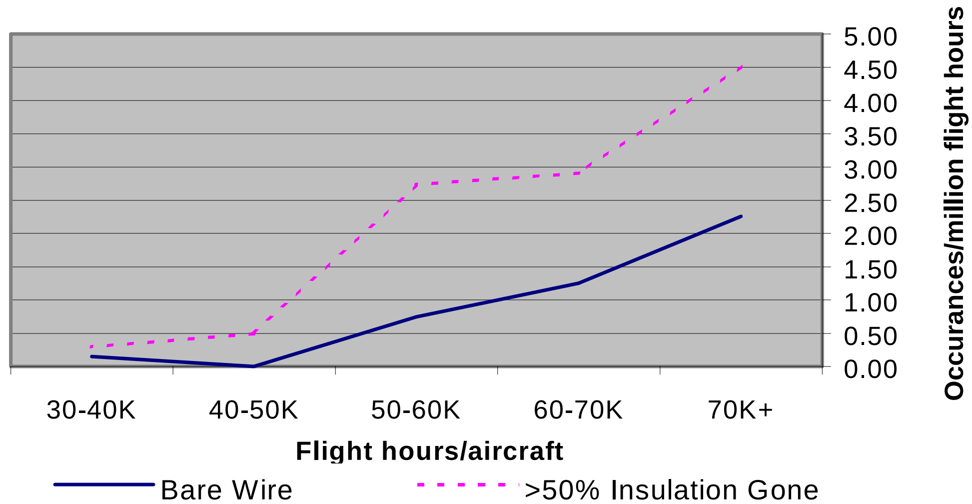


Figure 1: Age-Related Wire Failure

Electrical interconnect failure can occur in several ways.

- ***An open circuit***. Though perhaps the most benign failure mode[7], it is also the most prevalent and not always inconsequential. In 1983 a DC-10 experienced a serious autopilot failure induced by the failure of an electrical wire. Cascade effects associated with the interruption of current in one circuit – though theoretically taken into consideration by FAR 25.1309 – are hard to predict and may result in more serious failure in some other part of the electrical system.
- ***A bolted short circuit***. A bolted short circuit will generally trip the aircraft's thermal circuit breakers and prevent their reset. If, however, the circuit breaker fails – a known contributing cause of at least one DC-9 aircraft in 1987 – the consequences can be very serious.
- ***An intermittent open circuit***. Around half of the electrical components removed for cause are returned to service with no fault found (NFF). Some of these NFF incidents may be the result of intermittent electrical interconnect failures. Though the threat of any component's failure to the safety of the aircraft may be slight, a high frequency of intermittent failure may eventually lead to serious consequences either by the more critical failure of components or by a more critical failure of the interconnect system (e.g., electrical arcing).
- ***An intermittent instantaneous discharge (arcing)***. This is perhaps the most serious failure mode for electrical interconnect components. Often the shunt current is not sufficient to cause failure at the load or circuit breaker. This can result in a dangerous sparking condition in flammable environments with no means of early detection or mitigation.
- ***Degraded shielding***. Degraded shielding may result in the introduction of undesirable noise and/or electrical energy with potential adverse affects to the safety of the systems.

The causes of an open circuit may be stress related or environmental. Stress-related failures may be the result of operational or maintenance-induced distress, including frequent disconnect and reconnect of wires, displacement of wires or wire bundles during the maintenance-inspection process, and corrosion of wire grounds, connections, and splices. Most such failures are in accessible locations subject to routine maintenance.

The causes of a short circuit or degraded signal wire performance include chaffing or cut through – possibly resulting from poor installation – or environmental degradation of the insulation through excessive temperature, hydrolysis, or contamination by abrasive solids or caustic fluids. Lavatory toilet fluid and anticorrosion compounds are known to degrade may types of aircraft electrical wire. Short circuits can also occur where wire terminations are exposed to contamination by metallic and nonmetallic deposits, including metal chips or shavings from other maintenance activities.

Poor design, manufacture, or repair can aggravate the incidence of wire failure in the following ways:

- Failure to designate or install wire with the appropriate functional and environment-resistance characteristics – designated categories include fire zone, fuel quantity indicator systems, general purpose, general purpose pressurized, general purpose unpressurized, high temperature/vibration/engine, modules, power feeders, power panels, and wire wrap integration center. Appendix A contains a list of general purpose wire types and their prevalence in commercial aircraft.
- Inappropriate retrofit of wire without adherence to manufacturer's standard practice – inadequate installation of in-flight entertainment systems, for example.
- Bad splices resulting in heat buildup or moisture contamination.
- Lack of wire segregation, sags, excessive tension – often the result of wire re-installation to accommodate structural modification or repair.
- Poor circuit breaker performance in the presence of arcing faults
- Degradation of circuit breaker performance with age
- Poor segregation of electrical and mechanical systems – there have been instances of hydraulic systems and flight control linkages damaged by arcing erosion of metallic components.
- Accelerated degradation of insulation due to excessive irradiation of cross-linked polymers – possibly the result of a bundle jacket being irradiated.
- Abusive hot stamping practice which can thin, breach, or locally degrade insulation – a B-757 accident in January 1985 was the result of wet arc tracking originating from an insulation defect coincident with a hot stamp mark.
- Poor crimp connections due to wire gauge anomalies – standard wire gauge leaves room for variability in conductor mass, which has changed over time.

Once an electrical system is in a state of failure or pending failure there are several mitigating and aggravating factors:

- The flammability of electrical insulation itself. In addition to the very obvious concerns regarding flammable substances in aircraft interiors, there is the added concern that burning wire will lead to the failure of multiple critical circuits.
- Latent faults can, in certain circumstances, be found by inspection. However, the degradation of wire may not be visually detectable.
- Wire functional testing is often used by airlines to support their reliability programs. There is little, if any, application of sophisticated test equipment to address the safety

threat of degraded wire, although newer designs include reasonably capable built-in test equipment reporting to maintenance readouts on a daily basis.

The NSRP will not support initiatives into the examination of flammability requirements for wire but will require that any proposed electrical interconnect technology acknowledge these requirements.

The adequacy of visual inspection and the development of nondestructive inspection and testing tools will be subjects of the NSRP.

Mechanical System Failure

Highly complex mechanical systems are subject to failure modes which may be difficult to anticipate. Systems of large transport aircraft are certified on a fail-safe design concept that is meant to ensure that any failure with catastrophic consequence is "extremely improbable" and the failure of any system which would reduce the ability of the crew to deal with adverse operating conditions is "improbable."[8] The regulation contains provisions that require the designer take into account "the probability of multiple [dependent or independent system] failures and undetected failures."

Nevertheless such failures do occur: A DC-10 accident in 1989 was the result of the severing of all hydraulic lines in a multiple-redundant system due to an engine disk failure. Less severe accidents have occurred when electrical short circuits have damaged flight control cables and hydraulic lines.

As with aircraft wiring, many mechanical systems were assumed to have a service life greater than or equivalent to original design life limits for the aircraft itself. Within this service life, potential system failure modes may have been dismissed as extremely improbable or improbable. Because aircraft in operation today are greatly exceeding their design life limits, reconsideration of these assessments is necessary.

The gradual uniform degradation of mechanical systems presents some difficult issues. Current certification regulations require a probabilistic assessment, the simultaneous degradation of redundant or dependent systems, but do not necessarily require the specification of degradation interdependency. As such the failure probability of a backup or dependent system may be assumed as its failure probability in an undegraded state. This may be valid for inspectable systems (i.e., when the operator can periodically verify that such systems are not degraded), but some redundant systems are not inspectable. Some flight control linkages, for example, consist of concentric tubes with all surfaces except the outer surface of the outer tube being uninspectable.

Current Initiatives Program Intiatives

Development of an Aging Nonstructural Systems Test and Validation Infrastructure

One of the first initiatives of the NSRP is the development of a systems test and validation center which will take advantage of the existing inspection validation infrastructure at the Validation Center at Sandia National Labs. The Validation Center's two major aircraft (a Boeing 737 and a McDonnell Douglas DC-9) will be augmented with the acquisition of a 1971 Boeing 747 with over 100,000 hours of service. With the help of airline inspectors, the B-747 will be subject to an intensive visual inspection of its wiring systems and – where the condition of wire is suspect – destructive testing of wire insulation. In addition to this, select electrical systems on both the B-747 and DC-9 test bed aircraft will be baselined by the application of a state-of-the-art wire test system. Together these activities will provide two test bed aircraft capable of validating emerging wire test and inspection technology and valuable insight regarding the state of health of aged wiring components.

Development of Wire Testing Equipment

The FAA and US Air Force Office of Productivity, Reliability, Availability, and Maintainability (PRAM) are jointly sponsoring a short-term effort to enhance an automated wire test system. The state-of-the-art equipment will be used to help baseline the Validation Center's test aircraft and test articles and to establish a benchmark for future testing equipment developed and tested under the NSRP.

Assessment of Visual Inspection

The ASTF survey of wiring faults will provide data on physically observable faults in wiring and obvious functional failures. It cannot, unfortunately, provide data on certain latent defects and invisible degenerative conditions nor can it provide data on the degraded performance of wire and insulation (as indicated by variation from some manufacturer established or observed baseline.) This data will only be available from a complementary FAA-funded effort involving enhanced *in situ* testing and teardown.

Working in conjunction with the ATA, the Validation Center will perform supplemental nondestructive and destructive testing on interconnect system components identified by ATA inspection teams. Tests may include

- impedance spectroscopy, time domain reflectometry
- TEM, SEM, optical microscopy
- microhardness, indentation creep, abrasion and cut-through testing
- analytical chemical analysis

Development, Testing, and Validation of an Aircraft Arc Fault Circuit Breaker

The FAA is working with the US Navy's Office of Naval Research and the Naval Air System Command, Aircraft Division to develop aircraft arc-fault circuit breakers. An arc fault is the undesired, momentary discharge of current from a conductor – i.e., a spark. This type of short circuit is particularly pernicious because of the high temperature of the sparks it generates and the absence of any current excursions, which might trip standard thermal circuit breakers typically used on aircraft. Arc-fault circuit interrupter technology has the potential to mitigate the consequence of wire failure without requiring the redesign of aircraft circuitry. The execution plan for this initiative calls for a device sensitive to arc faulting while still meeting all performance and design specification of existing circuit breakers.

The joint effort will focus on the development of a specific circuit breaker for an aircraft platform with both military and civil applications. The FAA and Navy have accepted the C-9/DC-9 as this aircraft platform. Furthermore, it was agreed that the specific circuit breaker application be one that conforms to Military Specification 25017. There are at least three such applications on the C-9 (the ground support panel and two galleys). The selection of this application has at least four distinct advantages:

- Among aircraft circuit breakers, the design specification is minimally restrictive. The circuit breaker is a relatively large circuit breaker.
- The circuit breaker controls power to wires presumed susceptible to safety-hazarding arc faults. Galleys are used in flight, and the wire runs are not fire proof.

- The controlled circuits are not flight critical. Nuisance tripping – though a major concern of this effort – will not be a flight safety problem during testing.
- The applications are similar in both the military and commercial aircraft. Other civil uses of this particular circuit breaker include applications in the B-707, B-737, and B-777 aircraft.

Mechanical Systems

There are no current initiatives specifically supporting mechanical systems research. The acquisition, decommissioning, and baselining of the B-747 will be in support of both electrical and mechanical systems research.

Future Initiatives

The FAA will be proactive in identifying and addressing aging systems safety issues. Initiatives will be established when

- accidents/incident or other operational data indicate a potential safety problem whose solution may require research.
- design or operation philosophy have changed significantly since the original aircraft design or introduction into service.
- significantly more powerful design tools are available to update certification analysis.
- significantly more capable technologies or techniques are available to enhance. maintenance efficacy.

Proposed technologies, techniques, or practices which require major philosophical, organizational, or other institutional change will have to exhibit advantages which clearly outweigh the cost of implementation. Conversely, proposed technologies, techniques, or practices which do not conflict with

- existing FAA regulation and advisory material
- the ATA's Maintenance Steering Group (MSG) process for establishment of maintenance programs
- manufacturer recommended standard practice

will be favored because of their likely acceptability to the aviation community.

Assessment of Wire Service Life

The purpose of this task is to establish – if possible – a predictive technique to determine when a wire, subject to certain known conditions, will no longer be able to ensure the safe transfer of electrical current.

It is anticipated that this task will be coordinated by the Validation Center at Sandia National Labs. It will be the responsibility of the Validation Center to identify general criteria and ground rules for the assessment. These criteria and ground rules should be sufficient to ensure that (1) the process of assessment is generally acceptable to the aviation community and (2) the results of the assessment are reproducible and comparable with other analytical or empirical assessments.

Once these criteria are established, the Validation Center will supervise the execution of several assessment exercises at independent facilities. Though the criteria for the assessments will be established by the Validation Center, the details of the assessment process will be the responsibility of the participating facilities. The conduct of these exercises will be such that at least some of the wire types assessed will be similar at different facilities. In particular, each facility will

- propose specific wire types to be assessed[9],
- identify one or more specific failure criteria,
- propose an accelerated aging process, and
- design and conduct experiments to determine service life of the wire.

Upon completion of these assessment exercises, the Validation Center will attempt to correlate the results of several exercises with each other and – if possible – with service experience.

Assessment of Circuit Protection Devices

Aircraft circuit protection devices (CPDs) are typically thermal-trip breakers with assumed safe-life performance. Although circuit breakers have been repeatedly tested for their response to various circuit failures[10], the bases for all of these tests have included the assumption that circuit breaker performance is not affected by age. Though not unreasonable, this assumption must be verified.

Wire Inspection and Testing

The purpose of this task is to develop systems that determine the material or structural flaws, which may impair the safe and effective electrical transmission of power and signals. The systems may be used for infrequent comprehensive examinations or more frequent focused inspection. As such user projected capability, capital cost, and equipment costs are not pre-specified but must be established in some balance that optimally serves an identified need in the aviation community.

It is anticipated that there will be several awards in this area of research. Successful proposals will identify some inspection or testing technology or technique with sensitivity to conditions which correlate well with the degradation of electrical interconnect systems. Evaluation of system development proposals will be based on the proposed system's apparent technical merits and on evidence of endorsement and participation of aircraft manufacturers or operators.

Risk assessment

The NSRP will fund certain risk assessment tasks. Fundamentally, any risk assessment effort must be

- ***Relevant***: model assumptions cannot be brushed off as simple parameters that can be changed as necessary. A risk model has no virtue if its assumptions are unjustifiable or parameters unknown or unavailable.
- ***Practical***: The end users of the risk assessment tools developed under this program will most likely be airline maintenance organizations. The risk assessment tools will have no virtue if the end users can't embrace the tools because they are too complicated or because the tools seriously violate constraints of their operations (e.g., require unavailable data)
- ***Useful***: the tools should do more than confirm the obvious.

It is anticipated that such a tools might have particular virtue for mechanical systems subject to multiple common failure modes (e.g., jamming, breakage, wear of control linkages).

Coordination

The White House Commission on Aviation Safety and Security recommends that: *In cooperation with airlines and manufacturers*, the FAA's Aging Aircraft Program should be expanded to cover nonstructural systems. The report further endorses the expansion of the FAA-DoD-NASA cooperative research program. In response to this, the FAA has committed to work formally and informally with

- Aging Transport Systems Rulemaking Advisory Committee (ATSRAC)
- The ATA and in particular the ATA's Aging Systems Task Force
- Airframe manufacturers – either individually or through their trade organization, the Aircraft Industries Association (AIA)
- Individual aircraft operators – USAir and Airborne have been very supportive of the NSRP
- Professional organizations such as the Society of Automotive Engineers (SAE) and the National Electrical Manufacturers Association (NEMA). And in particular:
  - SAE Committee AE 8 Aerospace Electrical/Electronic Distribution Systems Committee
  - SAE Committee A 6 Aerospace Fluid Power, Actuation, & Control Technologies Committee
  - SAE Committee G 3 Aerospace Couplings, Fittings, Hose & Tubing Assemblies
  - SAE Committee S 18 Airplane Safety Assessment
- The Department of Defense (activities with the USAF PRAM Office and the Office of Naval Research are already underway)

Conclusions

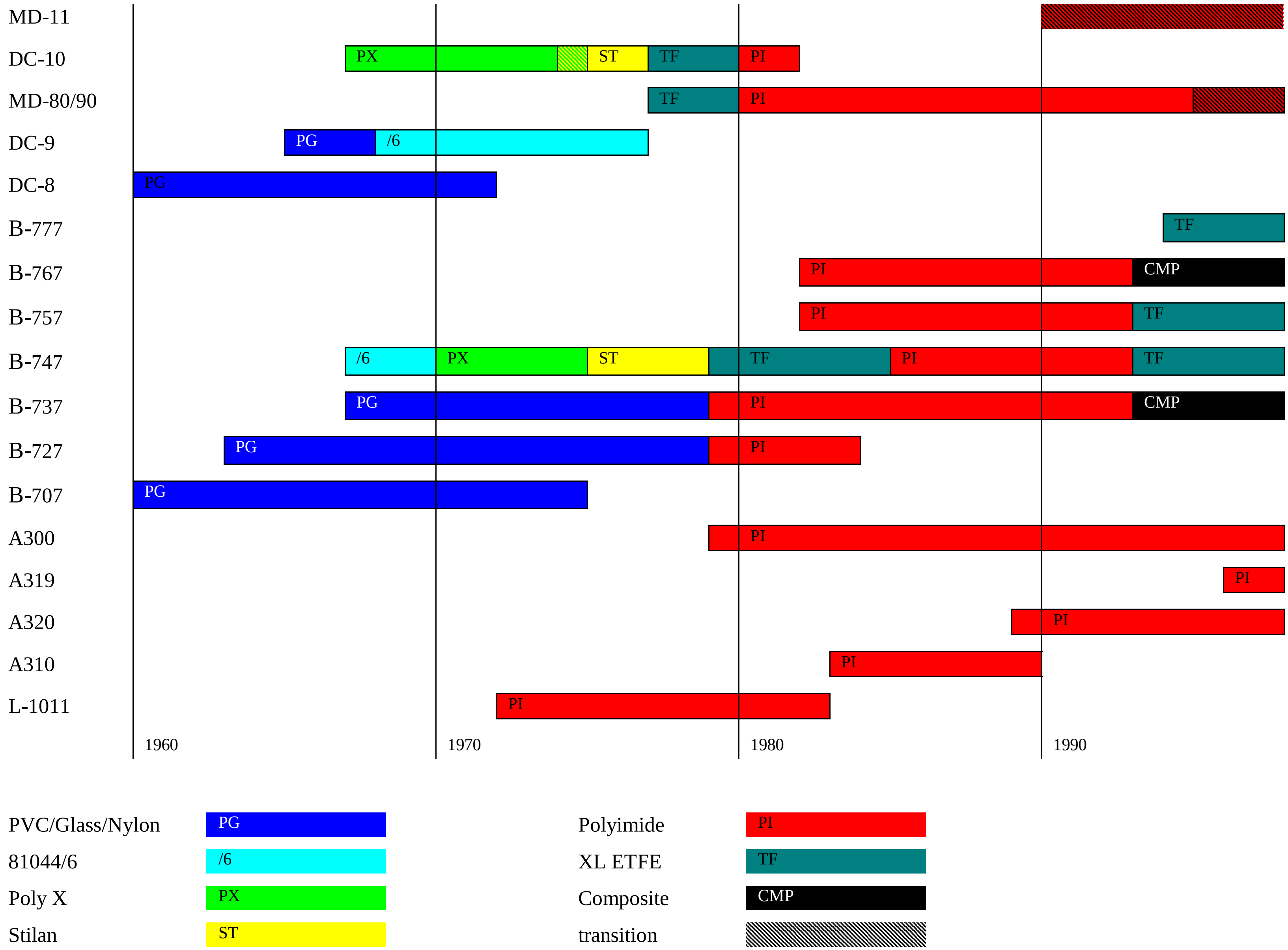
The FAA's Nonstructural Systems Research Program is fully committed to enabling and encouraging the aviation community to improve its already excellent safety record. In doing so, the FAA realizes the virtue in partnering with the aviation community including operators, airframers, and our military counterparts.

APPENDIX A: AIRCRAFT WIRE UTILIZATION

Wire Type Table

Specification Class	Constituent Polymer s	Common Designations	Aircraft	Years	Percent	Percent Fleet	Percent > 20 yrs
Mil-W-5086/1,2; BMS 13-13;	PVC/Glass/Nylon	Quad 4	DC-8	all dates		25%	68%
			DC-9	-1968			
			B-707	all dates			
			B-727	-1979			
			B-737	-1979			
Mil-W-81044/6; BMS13-38	Extruded XL- Polyalkene/PVDF	Spec 44®	DC-9	1968-77		3%	9%
			B-747	-1970			
Mil-W-81044/16, BMS13-42B	Alkane-Imide or Alaphatic Polyimide	Poly X	DC-10	1968-75		3%	8%
			B-747	1970-75			
Mil-W-81044/20; BMS13-42C&D	Polyarylene	Stilan	DC-10	1974-77		<1%	1%
			B-747	1975-79			
Mil-W-81381; BMS13-51; BXS7007;	Aromatic Polyimide	Kapton® Apical®	MD-80	1980-95		48%	5-6%
			MD-80	1995-present	30%		
			DC-10	1980 and later			
			MD-11	all	30%		
			MD-90	all dates	30%		
			B-727	1979-and later			
			B-737	1979-93			
			B-747	1985-93 †			
			B-757	-1993			
			B-767	-1993 †			
			L1011				
			Airbus	all dates‡			
Mil-W-22759/34; BMS13-48; BXS7008	Cross-Linked ETFE	XL-Tefzel®; Spec 55®	MD-80	1977-80		6%	1-2%
			DC-10	1977-80			
			B-747	1979-85, 1993-present ‡			
			B-747	79-present §			
			B-767	1982-93 §			
			B-767	1993 and later			
			B-777	all dates			
Mil-W-22759/80-92; BMS13-60	PTFE Polymide Composite	TKT Tensolite Oasis	MD-80	1995-present	70%	12-13%	0%
			MD-11	all	70%		
			MD-90	all dates	70%		
			B-737	1993-present			
			B-757	1993-present			

Aircraft General Purpose Wire Types



Wire Table Notes

This data was generated using information available in the public domain (cross checked with manufacturers proprietary data) and the FAA's tail number database. It represents the US registered fleet only. Note in particular that Airbus aircraft dates on the graph correspond to the oldest and most recently manufactured Airbus aircraft in US service, which is not necessarily equivalent to first and last date of manufacturer of those aircraft models.

Symbols used in wire type table

† pressurized only

‡ all pressurized areas

§ unpressurized areas

Wire types were first associated with aircraft by date, not serial or line number. In years where the wire type changed, I assumed half of the production to have the old wire type and half to have the new wire type. Information regarding wire type changes associated with series changes and the assumption that sister ships would have the same wire type was used to establish wire type for individual aircraft. Because these assumptions will not always hold, the numbers are approximate.

These statistics are for the "general-purpose" wire. General-purpose wire represents about 90-95 percent of wire in an aircraft but not all wire. Where a distinction between pressurized and upressurized was made, I chose to use data for pressurized.

The percentages are based on the number of aircraft having a particular general-purpose wire relative to the total fleet. Total installed length and the critically of the application are not considered.

Because of approximations, omitted wire types, and unknown types, the numbers don't necessarily add to 100.

The last column is restricted to aircraft produced before 1979.

The PVC/Glass/Nylon includes PVC/Nylon also.

Kapton and Tefzel are registered trademarks of E. I. Du Pont de Nemours and Company
Spec 44 and Spec 55 are registered trademarks of Raychem Corporation
Apical is a registered trademark of Kanegafuchi Kagaku Kogyo Kabushiki Kaisha

ENDNOTES

---

1. Industry Safety Strategy Team Presentation, October 1997.

2. Though landing gear and engines and fuel systems contain nonstructural subsystems, these systems are subject to special certification and regulation requirements. As such they are not addressed as part of the NSRP.

3. The category, electrical systems and instruments, includes avionics which are not the subject of the FAA Aging Nonstructural Systems Research.

4. In recognition of this, the Aging Transport Nonstructural Systems Plan calls for the improvement of reporting of accident/incident and maintenance actions involving wiring systems.

5. George Slenski, Aging Wire Activities and Programs Presentation.

6. FAA APA Statistics as of June 16, 1998, available on the web at www.faa.gov/apa/737iu.htm.

7. FAR 25.1309 (4) requires the safe operation of the aircraft under the assumption of this sort of failure.

8. FAR 25.1309

9. It is anticipated that wire degradation characteristics will be specific to wire type. Wire types of interest to the FAA and the aviation community include primarily aromatic polyimide, PVC/Glass/Nylon, Poly X, Polyalkene, PVDF.

10. See, for example, DOT/FAA/CT-TN94/55, Electrical Short Circuit and Current Overload Tests on Aircraft Wiring.