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Managing the Aging Aircraft Problem

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SUMMARY

Aging aircraft face many challenges. Certainly, one of the most costly is corrosion. The United States Air Force (USAF) spends approximately \$800 million dollars a year for corrosion detection, prevention, and repair. Another major challenge is structural fatigue cracking. This problem has significant safety implications as well as economic. Aging mechanical subsystems constitute a challenge in that they can have such a severe impact on aircraft availability. Aging wiring is also a safety and economic problem. It has not been subject to the research effort that corrosion and fatigue cracking has had in the past. Consequently, it has taken time to initiate remedial actions. Aging avionics is also a major economic burden. The problem is so severe that many of the aging aircraft are not supportable. The aging aircraft problem may be thought of as a spiral. The number of repairs increases. This causes the depot flow rates to decrease. Consequently, the maintenance burden increases. Since there is a lack of funding, the mission capable rate decreases. The problems grow larger through each turn in the spiral. This means that money for modernization of the fleet is not available. Consequently, the aging aircraft must be retained in the inventory longer than expected. Adequate funding combined with a well-conceived research and development program is essential to break the spiral.

BACKGROUND

Most aircraft operated commercially or in the military reach a state referred to as aging at sometime after entering operational service. Aging of an aircraft is not the same as it becoming obsolete. An aircraft may be obsolete before it reaches the aging state or, more typically, it reaches the state of aging before it is obsolete. A commercial aircraft is obsolete when it is no longer economically viable to keep it operational. A military aircraft is obsolete when its capabilities are no longer competitive with potential adversaries. The time when an aircraft reaches the aging state is usually much more difficult to determine. It is important to distinguish between the characteristics of the structure of a young aircraft and an aging aircraft. A young aircraft is one that continues to be airworthy with the maintenance program prescribed at the time of manufacture. The primary concern with a young aircraft is the potential for design errors that introduce unintentional high stresses in the structure that could lead to premature fatigue cracking incidents. When these are discovered the structure is modified to eliminate the problem. An aging aircraft may be characterized as one where the effects of corrosion and cracking from fatigue require modification of the maintenance program to retain adequate structural integrity. The word adequate here means that the expected number of failures would be less than one in a given fleet of aircraft. As an aircraft accumulates calendar time and flight time the effects of corrosion and cracking from fatigue, as well as accidental damage, leads to repairs on the aircraft. Cracking from fatigue can be so widespread that it degrades the integrity of the structure. When this occurs, the structure is said to be in a state of widespread fatigue damage or WFD and must undergo modifications to remove this problem. In addition, as an aircraft accumulates flight time, it may exceed its design life goal. Therefore, the maintenance program will require modification to include additional structural inspections. If the initial maintenance program requires modification from any of these events, then the aircraft may be considered to be in a state of aging.

No one should be surprised there are aircraft all over the world today in a state of aging. Economic considerations demand that aircraft be operated long beyond originally identified retirement times. One reason for keeping aircraft in the inventory is that technological advances allow currently designed aircraft to effectively perform their mission for much longer than previously possible. An aircraft, even when sold by one airline, sees extended life in another airline's operations. In the commercial sector, new aircraft tend to be evolutionary in their designs. Consequently, they are maintained in service until they are not economically viable to operate. The cost of new aircraft, particularly for the military, is enormous. Each new military aircraft is a revolutionary change from the previous model since the services must maintain combat effectiveness in an environment of ever-changing threats. Therefore, military aircraft stay in the inventory until they are operationally obsolete or they are no longer economically viable to operate. The USAF retired many F-4 aircraft because they were obsolete as a weapon system rather than being economically nonviable. In the case of the KC-135, the USAF plans to keep these aircraft operational to the year 2040 since they believe it will be economical to operate them until that time. They would likely not be obsolete in the year 2040. If the USAF can maintain these aircraft operationally until 2040, their service life will be approximately 80 years. When the USAF procured these aircraft, they planned for a service life of about 20 years.

Sustainment of an aircraft is the act of keeping it operational (i.e., airworthy). Maintenance of an aircraft (that is, the work done by mechanics in keeping it airworthy) is one aspect of sustainment. However, sustainment also includes the engineering analyses and tests needed to determine an adequate maintenance plan for the aircraft. Sustainment is life management. One task of sustainment is the determination of structural inspections based on damage tolerance principles. These inspections protect against failure from defects that could be in the structure because of manufacturing or from operational service. The approach for developing a damage tolerance derived inspection program is discussed in Section 2. Another task of sustainment is the determination of the time of onset of fatigue cracking in the structure so widespread that the structural integrity of the aircraft could be compromised. Experimental evidence shows that fatigue cracks smaller than those that could be reasonably detected by current inspection methods could constitute WFD.

Today, the primary concern with aging aircraft is the cost of their sustainment. The commercial operators buy new aircraft when it becomes economically viable for them to do so. The aging aircraft problem, however, has often made itself known to both the commercial and military operators through failures of in-service aircraft. Both operators found the maintenance programs did not adequately protect aircraft as they progressed through their service lives. The failures in both commercial and military aircraft have been the primary factor that has changed rules and specifications that are the basis of their design. In many cases, the failures have identified threats to structural integrity that were not previously identified by the certification authorities. In many cases, the commercial failures have influenced the military specifications and the military failures have influenced the commercial aircraft rules. The new rules and specifications have led to better maintenance programs that help alleviate many of the threats to failure that previously existed. However, the economic demand to fly these aircraft longer and longer has emphasized the need to re-examine these aircraft for the possibility of WFD, corrosion damage, and loss of damage tolerance capability through repairs.

It is difficult to determine the exact moment in time when an aircraft has reached the state of aging. However, all would agree that the costs associated with repairs or modifications from corrosion or cracking from fatigue would be an indicator of this condition. When these costs rise significantly, then the aircraft are certainly in that state. Chronological age is not always a good indicator of aging. However, since corrosion and fatigue are somewhat related to time in service, it does give some insight for the potential of this problem. A summary presented in July of 1997 detailed the reasons for the increase in chronological age of aircraft. In 1996, the total U.S. military fleet consisted of 20,400 aircraft. Reduced procurement budgets will prevent these aircraft from being retired since at the current rate of procurement, the time required to replace these aircraft would be approximately 100 years. The basis for this conclusion is that in 1996, the DoD budget procured only 159 new aircraft for \$5.4 billion. The estimate of the cost of replacing

the entire fleet of U.S. military aircraft is \$530 billion in 1995 dollars. Many of the aircraft in the population today are currently more than 30 years old.

Many nations are now keeping aircraft in their inventories longer than ever before. In many cases, aircraft are left in the inventory longer because they are still operationally effective; however, in most cases, they remain in the inventory because the money is not available to replace them. Aircraft, which are seeing the effects of aging through corrosion and fatigue cracking, are causing their operators to bear a significant economic burden to keep them operational with the potential for degradation of flight safety of aging aircraft if they are not maintained properly.

The United States Air Force (USAF) has maintained safety of their aircraft for the last thirty years through the application of damage tolerance principles to determine inspection intervals. This approach has on occasion been modified because of the onset of widespread fatigue damage (WFD) or the loss of material because of corrosion. In the case of WFD, the USAF has developed a modification program to alleviate the problem. In the event of corrosion damage, both modification and reduced inspection intervals have been used.

The USAF has developed a strategy for the sustainment of their aircraft starting with the identification of user needs requiring research and development efforts. The strategy is based on identifying research and development opportunities that will have a favorable return on the investment through cost savings or cost avoidance and increased aircraft availability. This has presented problems since it is difficult to determine the cost of maintaining aircraft in enough detail to determine the return on the investment accurately. To date, identified activities include improvements in nondestructive inspection capability, corrosion tracking and prevention techniques, and advances in repair of metallic structures through composite patching. In addition, improved materials for substitution and environmentally compliant coatings have been identified. The purpose of this paper is to provide a discussion of the aging concerns found in the structure of USAF aircraft and the approach the USAF is pursuing to alleviate these concerns.

STRATEGY FOR AGING AIRCRAFT

The damage tolerance approach has led to a greatly improved understanding of aircraft structures and their performance. It, when properly applied, will essentially eliminate fatigue cracking as a threat to structural integrity. Therefore, damage tolerance should be the foundation on which the structural maintenance program should rest. During the 1970's and 1980's, the USAF performed an assessment on every major weapon system using the damage tolerance approach to develop appropriate inspection/modification programs to maintain operational safety. As a result, the USAF has maintained an excellent structural failure safety record despite the ever increasing age of its' fleets.

As the aircraft grow older, the potential for fatigue cracking and corrosion increases. Many of the aging aircraft in the USAF inventory are experiencing increased maintenance costs because one or more of these problems are present. To determine the research and development actions that could be pursued relating to these problems, the USAF formed the Aging Aircraft Technologies Team (AATT). At the outset, the AATT decided they would operate under the following guidance for the researcher:

- Research and development:
 - ◆ Must be directed towards needs of USAF aircraft
 - ◆ Must be oriented towards flight safety, maintenance cost reduction, and/or enhanced availability
 - ◆ Must be output-oriented and cost-focused
 - Researcher and customer must communicate on expectations from research
 - Researcher must be able to define cost and schedule for activity

- Develop technology that can be transitioned
- Augment highest level of capability in industry or government
- The USAF laboratories must maintain organic competencies in key areas related to aging aircraft

The most difficult challenge for the AATT was to determine the return on the research and development investment for aircraft. Although the USAF has usable cost information on total cost for depot or field operations, they do not know the cost in sufficient detail to judge whether an effort on a certain component of the aircraft is justified. For example, a wing section may be subject to corrosion, but without cost data on this component, it is difficult to determine if the USAF should replace this component using a more corrosion resistant material or keep repairing the corrosion damage.

The strategy for identifying research and development programs to reduce maintenance costs can be described by six steps. These steps are

- Conduct surveys to determine problems
- Identify and prioritize solutions requiring research and development
- Establish research and development roadmaps
- Obtain management and customer approval
- Execute research and development efforts
- Transition technology to the operator

The first three steps are designed to identify the problems and develop a plan for their solution. The final three steps engage management to implement the plans and carry the research and development through to technology transition.

The first step is to conduct surveys on aging aircraft in the inventory to identify their problems in as much detail as possible. This effort includes interviews with engineers and maintenance personnel that are directly responsible for the continuing integrity of the aircraft. In addition, the AATT discussed the aging aircraft issues with the operators of the aircraft. Identification of problem areas generally requires multiple meetings with these individuals in order to get a complete understanding of the problems that may have a solution through research and development. For example, for the USAF, surveys by the AATT of approximately thirty aircraft have taken place annually four times. In most cases, the reviews required approximately one day to complete. In some cases, however, there was interest in the review by the operator because of the potential for significant funds to be expended by them for modernization of the aircraft. In these cases, the reviews required two to three days to complete. The surveys, whenever possible included laboratory personnel so that they could see the nature of the problems for themselves. In addition, the surveys included the original equipment manufacturer (OEM) since their knowledge of the aircraft is essential for a clear definition of the problem. The relationship between the USAF and the OEM for maintaining the integrity of aging aircraft has been outstanding.

The second step is to determine the potential solutions to the aging problems. The AATT makes an initial screening of the problems and makes a preliminary determination of those problems that may have potential for a research and development solution. These problems are then given the widest dissemination possible to solicit possible solutions. The potential solutions are then categorized as basic research, exploratory development, and advanced development. The last category is for technology that is ready for transition. Usually, solutions categorized as basic research require development times that are extremely long for the technology to reach maturity. However, this area cannot be overlooked since it may, in time, have significant return on the investment.

The third step is to develop "roadmaps" for the maturation of the technology for use in the aircraft. The roadmap identifies the problem, the technology to be used to solve the problem, the tasks to be performed for the solution, the schedule for completion of each of the tasks and the funding

required for completion of each task. This step requires close adherence to the AATT guiding principles.

The fourth step, which is management approval, is likely the most important in that the success of the entire program rests on the agreement of the technologists and managers that the research and development program has the greatest return on the investment. This, of course, means that the manager has an understanding of the scope of the effort required to reach the desired goals. With this step the process changes from bottom up to top down. The first three steps could be identified as "bottoms up" activity. These steps started with identification of the problems and ended with a strategy for solution.

The fifth step is execution. The strategy is not complete, however, without the implementation step. This step is "top down" in that management charges the researchers to perform to the aging aircraft roadmaps. Essential to this step is the acceptance of the technology by the logistics managers and the operators. They must demonstrate willingness to implement the technology developed to reduce their maintenance burden.

The final or sixth step is technology transition. Actually, technology transition starts with the second step since there is no solution unless the technology can be transitioned to the logistics centers. Another name for this effort that is at times more descriptive is "industrialization of the process." The first requirement for technology transition is adequate funding. The second requirement is that logistics personnel understand and are trained in the execution of the process. The final requirement is that logistics personnel are convinced that the new technology will enable them to do the job better than they are doing with existing technology.

AGING AIRCRAFT ISSUES

Funding

Funding for aging aircraft research and development activities is likely the number one problem faced by the manager. Funding of aging aircraft requirements is usually inadequate due to ever-increasing structural modification programs, safety issues, sustaining engineering needs, and responding to ever changing retirement dates. It is difficult, if not impossible; to support all identified technology areas. Consequently, there is a need to establish priorities.

In addition, justification is typically difficult for non-safety related problems since the available funding is usually consumed by safety related problems affecting the force. Care should be taken in the maintenance of non-safety related problems in that they may become safety issues through improper maintenance. An example of this is the use of inferior bonding techniques to repair honeycomb structures. Improper techniques can lead to moisture intrusion and an accelerated degradation that has the potential for loss of integrity of the component. Future funding requirements need a better understanding of return on the investment (ROI) where the ROI includes cost and availability in order to compete competitively with all the other identified requirements. Improved cost data collection procedures are needed in order to accomplish this.

In many cases, the budgets have not allowed the modernization of maintenance facilities or the upgrading of their information management systems. This has led to maintenance practices that are not state-of-the-art in that the use of information management has not become ingrained in the work force. This inadequacy is compounded by inaccurate and often-inadequate maintenance databases that lead to a misunderstanding of logistics requirements that raises costs and reduces aircraft availability. Retention of maintenance records for structural repair needs to be made a priority.

Fleet/ Depot Planning/Procedures

Another issue is the lack of support from operators for tail number tracking used to determine damage and sources of damage. Too often, since the recorder for flight loads is not flight essential

equipment, the operator fails to adequately download data or service the recorder. This has resulted in many cases where the operators were not aware that some of their practices were causing damage to aircraft that could have been avoided. The logistics community needs to communicate with operators to find operational techniques to reduce damage.

There is a concern that inadequate manning levels in both the field and at depots are causing lack of compliance with technical orders. In addition, the experience level of maintenance personnel has been steadily reducing for both the civilian and military population due to workforce downsizing. These problems are compounded by diminishing engineering resources in the manufacturing base result in increases in flow days and costs since the parts must often be fabricated through reverse engineering.

There are also many depot maintenance procedures/planning issues that cause increased costs. The maintenance planners should look at the frequency of depot maintenance visits, especially for aircraft experiencing moderate to high levels of corrosion. In some cases, the depot intervals are so long that many problems are discovered too late, resulting in more expensive and complex repairs that could have been caught earlier and remedied much easier with more depot visits. To make matters worse, many times within the same depot, there will be inconsistent maintenance practices being used from one product line to the next.

Finally, although experience shows that there are many surprises found in the maintenance of aging aircraft, there is usually a lack of planning and budgeting for these events. This leads to increased costs and a further lack of availability.

One of the most important aspects of an aging aircraft program is the quantification of the economic burden of systems in future years. This activity is necessary to support planning for retirement of existing aircraft and procurement new aircraft in the future. Without this information, the visibility is lacking to make sound judgements for aging aircraft. The process for doing this is well established for fatigue cracking. Unfortunately, for corrosion it is not as well understood.

FATIGUE CRACKING AND CORROSION

The USAF identified that the root causes for most aging related structural issues are fatigue cracking and corrosion. For each of these causes, the solutions could be obtained in one or more of the categories: nondestructive inspection (NDI), repair, modification, prevention, analysis, health, or information technology. Usually, the ultimate solution will be a combination of these categories. The discussion below covers the main efforts for both fatigue cracking and corrosion.

FATIGUE CRACKING

The introduction of damage tolerance principles by the USAF in their structural inspection program in the early seventies virtually eliminated fatigue as a safety problem in their aircraft. However, fatigue cracking of operational aircraft in the USAF is still a significant economic problem. The USAF estimates that this problem cost approximately \$250 million in 1997. The USAF attributes much of this burden to operational usage being more severe than the usage assumed for design. This occurs because as the aircraft is fielded, the operators find unique and unanticipated ways to take full advantage of the capabilities of the aircraft. This often results in more severe usage due to weight growth for new capabilities or new operational mission profiles.

Based on design processes used today, fatigue cracking in an airframe should not be a significant factor for an aircraft whose operational usage is approximately the same as its design usage. However, many of the older aging aircraft in use today were designed at a time when the effects of repeated loading was not a design consideration. Consequently, fatigue cracking is surely an economic problem and in most cases is a potential safety problem. Fatigue cracking found by inspections based on damage tolerance principles had resulted in many repairs on operational aircraft. In many cases, the cracks are repaired when found. The USAF has found that historically

this is the most economical approach and consequently, this approach is most often used until it becomes evident that the structure needs to be modified.

The certification basis on which the structure was qualified also plays a critical role in the research and development for aging aircraft. The USAF guidance for structural certification includes both slow crack growth and fail-safe structures. Although, the slow crack growth approach is most often used today, the USAF strongly advocates the use of fail-safe designs whenever practical. Designs that are fail-safe can tolerate the failure of a structural member and still maintain adequate residual strength until the failed member is discovered through inspections.

Widespread Fatigue Damage

The certification basis for many aircraft is fail-safety because it provides a good overall approach to achieve both safe and economic operation. However, when the structure develops WFD, it can cause a loss of the fail-safe capability in the airframe and drastic action is needed to restore it. Perhaps, the most famous incident of WFD is the 1988 operational failure of a Boeing 737. This event provided the motivation for the considerable emphasis by the FAA on the structural issues associated with aging aircraft. This event occurred on Boeing 737 (N73711) on 28 April 1988. On this date, cracks in the fuselage lap-splices coalesced resulting in loss of the upper fuselage from just aft of the pilot's cockpit to the wing leading edge. This was the start of the aging aircraft program for the FAA.

The effect of WFD on flight safety has long been a concern of many researchers. Most of the older USAF aircraft designs did not comply with the modern guidance for damage tolerance assessment (DTA). Consequently, there is a potential for the crack population to be so large in the structure that the application of the deterministic damage tolerance process may not protect safety. Large crack populations could also exist in monolithic structures such as the T-38 aircraft, which the USAF analyzed using probabilistic methods. The USAF refers to cracking as found in the T-38 aircraft as generalized cracking rather than WFD. The occurrence of WFD can significantly degrade the fail-safety of the structure. This problem has been evident on the KC-135, C-5A, C-141 and the E-8 aircraft. The USAF subjected these aircraft to teardown inspections. They incorporated the results of these inspections in a risk assessment to quantify the time when the probability of failure, conditioned by the fact there had been discrete source damage, becomes unacceptable.

CORROSION

Corrosion and fatigue separately have both led to serious safety as well as economic problems. Corrosion alone, in forms such as uniform corrosion (thinning) or exfoliation, may reduce the strength of aircraft and lead to failure. Both of these forms of corrosion may lead also to expensive component repair or replacement. There are many cases where corrosion alone is not significant from a safety consideration, but is a very significant economic problem. In the case of corrosion alone, one must judge the seriousness of this problem on an individual basis. Nondestructive inspections have found fatigue problems where there is essentially no influence from corrosion. Researchers have documented many cases over the years where the consequences were catastrophic. The results of fatigue cracking have caused many expensive repairs and modifications to the structure including component replacement. Fatigue often combines synergistically with corrosion. In these cases, the term corrosion fatigue is more appropriate. In most cases, corrosion, fatigue, or corrosion fatigue becomes a safety consideration only when either maintenance is not performed properly or the maintenance program is inappropriate. Experience derived from diligent maintenance has repeatedly shown that the operator need not compromise safety resulting from these problems. The purpose of this section is to describe some experiences with corrosion, fatigue, and corrosion and fatigue and to review some of the relative literature on this subject.

ASSESSMENT OF CURRENT SITUATION

Aeronautical Systems Center has created an Applied Technology Process that formalizes the relationship between the Air Force Research Laboratory, the Aging Aircraft System Program Office and the Air Logistics Centers for technology transition. This effort was enhanced when the Aging Aircraft Program Office Became the Aging Aircraft Systems Program Office on 25 Jan 2001.

The aging aircraft surveys conducted over the past four years have identified research and development needs for structures quantitatively. Solutions to these problems need to be found with cost and schedule determined. The roadmaps for solution of problems and transition of new technology should cover the next five to seven years. Any further out tends to be difficult to define adequately.

Aging aircraft surveys have identified needs for mechanical subsystems only qualitatively. There is still much work to be done to define these problems qualitatively. In the near term, emphasis needs to be placed on further development of the Functional Systems Integrity Program (FSIP) type approach. FSIP is a procedure for identifying, tracking, and taking remedial action for systems problems. In the early eighties, the USAF developed a proactive approach for subsystems called MECSIP. This concept, unfortunately, has not had needed laboratory development to make it practical for operational aircraft. Studies are needed to determine the future of MECSIP in the USAF. In its original form, MECSIP was developed using deterministic methods. Probabilistic methods in lieu of deterministic methods should be assessed to determine if they are better suited for this technology.

In an effort to understand the wiring problems in the USAF, field surveys at the Air Logistic Centers and field units served to document wiring and maintenance issues at each location as well as determining research and development needs. The Air Force Research Laboratory is currently working with the US Navy, Federal Aviation Administration, and the National Aeronautical and Space Administration to address needs. At this time, the research for this problem is immature. However, the consensus is that wiring problems can be managed.

For aging avionics, upgrading technology is the major influence. The problem is that the time period for technology change is short. Consequently, the older systems are not maintainable. Diminishing manufacturing resources is also a major problem in maintaining avionics equipment. The focus of the strategy is to develop policies/processes that create open architectures that allow future buys to be more affordable rather than by trying to maintain older technology. Many systems, such as the C-130 and the C-5 will benefit from this change in policy.

CONCLUSIONS

There is no question that research and development funding will remain a problem. It is very difficult to get adequate funding to make a real impact on the cost of operating aging aircraft. It is necessary; therefore, to place emphasis on government agency co-operation.

Quantification of maintenance costs is a problem that will continue to impede progress. There will need to be a major change in the current maintenance approaches to enable the researcher to quantify the cost of maintenance. Until this happens, it will be difficult to quantify return on research and development investment.

A related problem is parts management. The current approach leads to inefficiencies and unnecessary costs.

The USAF research and development program for aging aircraft have provided the technology base for safe and economic operation of military aircraft. This success, however, should not be used to indicate that there is no need for continued research on aging aircraft. The dangers from corrosion, fatigue or corrosion fatigue are ever present in operational aircraft. Presently, the

largest danger by a considerable margin is economic rather than flight safety. All of the collective experience from both military and commercial operations indicates this to be true. No one can foretell with any degree of accuracy what to expect as both military and commercial aircraft push further into the uncharted waters of aging. It is incumbent; however, for the researcher, the engineer and the maintenance personnel to maintain a diligent approach to the problem. They must use all available techniques such as DTA scheduled inspections, special inspections, and assessments for the onset of WFD to help ensure that they maintain the safety of future aircraft operations. Diligent use of CPC's and research into better means of corrosion detection and prevention appear to be the most promising ways to reduce the economic burden of these problems in the future. The priority for corrosion research and development needs to be given to corrosion detection and the inhibition of corrosion when found.

One of the major problems found in operations with aging aircraft is the cost associated with corrosion damage. Unfortunately, the progress made in the recent past in the control of this problem does not bode well for the future. This is especially true when one considers the impact of new environmental laws that remove many of the corrosion fighting chemicals that are currently used. Continued emphasis on research in the area of corrosion control is certainly one area that could have significant benefit.

Another major problem is WFD in primary structural elements. There will be costs incurred to establish an estimate of the time of onset of this problem. This will need to be done through the analysis of data derived from teardown inspections of fatigue test articles and/or of operational aircraft. These estimates will need to be corroborated through the use of detail inspections of suspect structural elements. Once this onset time has been reached, then there will be costs incurred by the modification of the aircraft to remove this problem.

The severity of both of these problems is made worse today because of a lack of adequate nondestructive evaluation techniques to look for corrosion damage in structural joints and to find the small cracks that would be the indicator of the onset of WFD. It appears that the current efforts in research in nondestructive evaluation will produce the technology for these problems. It remains to be seen if there is an economic motivation to transition this technology from the laboratory to inspections of operational aircraft.

Many of the aging military aircraft problems find an exact parallel in aging commercial aircraft. It is prudent, therefore, that these problems be worked through the combined talents and resources of the responsible organizations. Efforts to date indicate that this approach will be successful and most efficient in solving these complex problems.