INTRODUCTORY OVERVIEW

George A. Alers
Science Center, Rockwell International
Thousand Oaks, California 91360

As previously mentioned, the ARPA program is divided into three parts. The major part devoted to defect characterization will be discussed tomorrow. The other parts are the subject of today's program and involve some major NDT problems that are not directly associated with defect characterization in a solid. They have to do with the problem of adhesive bonds, the problem of measuring residual stress and some new techniques that show great promise for failure prediction. The solution of these problems not only requires improvements in our understanding of the physical phenomena involved but they also require translation into a device for use in the field. During today's program, we will cover the four distinct areas of: 1) adhesives and composites, 2) new measurements and techniques, 3) internal stress, and 4) acoustic emission. I will begin by going over the program, pointing out the connections between each of the talks and introducing some of the ideas that tie the subjects together.

The first several talks are concerned with the very important problem of adhesives and composites. Polymers are steadily moving into more and more structural applications, especially in the aerospace industry, because weight and ease of fabrication are assuming greater importance. The adhesive bond is a method of joining metals that is very efficient because it provides the maximum amount of strength for the least amount of weight. Composites, of course, are the ultimate in structural efficiency because the strong fibers can be put in the direction of the loads thereby taking strength away from where it is not needed and putting it where it is needed. Unfortunately, these very efficient materials have not seen broad acceptance because we do not have nondestructive test techniques that will show that the completed part is reliable. We do not have a way of non-destructively testing an adhesively bonded part to assure that the bulk adhesive is at the strength level that it is supposed to have, and that it is properly stuck to the metal. Without these kinds of tests, the part has to be terribly overdesigned. In fact, standard practice appears to involve making an adhesive joint to the best of our ability and then boring a hole in it to bolt the members together.

Later in the meeting we will discuss the inspection of new materials. Not only are the composite and the polymer on the horizon as new structural materials, but ceramic materials with their high temperature capabilities will certainly need to be inspected for flaws. Here, the minute size of the critical defect will tax all of the tools that we are developing today and we shall see how important it will be to provide defect characterization capabilities at unusually high frequencies and their application to some old problems such as the measurement of internal stress. There are a lot of black magic and witchcraft methods of processing that extend the fatigue life of a part by putting compressive internal stresses into the surface. Shot peaning is the most common, but one must use the right size shot, driven at the right speed for the right length of time before the fatigue life of a metal part is extended. The only available method to insure that the processing has been done correctly is to use x-ray techniques for measuring the stresses in the surface. Unfortunately, the measurement technique is very subtle to use and very easily misinterpreted. There are many other places where residual stresses play an important role on an atomic level; the internal stresses between dislocations and between precipitates control deformation on a microscopic scale. These, in turn, determine the yield strength and the ultimate strength of a metal part. There has always been a dream among nondestructive testing workers to invent a little black box that could be used to give a meter reading of the ultimate strength or the yield strength of a metal. It is my opinion that this ultimate aim will be achieved by some of the work that is being done with nonlinear acoustics as we will hear about later.

Then, there is the field of acoustic emission. Everywhere in nondestructive testing we hear about acoustic emission as the greatest technique now being developed. It's main use so far has been in the testing of very large objects where it is economically impossible to go over every cubic inch of the structure looking for flaws. Acoustic emission has the very powerful capability of locating the flaw by detecting the direction from which the noises come. Once located, some of the defect characterization techniques can be used to assess it's criticality and a decision can be made concerning the safety of the entire structure. Unfortunately, after acoustic emission has been used for awhile, a lot of the chief engineers who were in charge of building giant structures began to view the technique with skepticism and used a line from Macbeth to describe their feelings that acoustic emission "is a tale told by an idiot; full of sound and fury but signifying nothing." It is our objective in the advanced NDE field to give some respectability to acoustic emission by learning to understand how it is that the noises are made and how to interpret them so that we can recognize the true flaws and be able to predict better how to use the technique.

Now that I have summarized the problems and payoffs that face us, I would like to go back and go over each area to tell you about our authors and how their work ties together in today's session.

In composites, the basic geometry is either a sandwich structure consisting of metal plates glued together with an adhesive, or fibers embedded in an epoxy matrix. There are always likely to be gross defects, such as disbonded areas, bubbles and porosity and there may be a subtle lack of adhesion at the joint between the polymer and the metal or between the epoxy and the fiber that ruins the adhesive strength of the interface and thus deprives the whole part of its strength. These adhesion effects may be on a very small scale, perhaps even on an atomic scale, and thus they will be very difficult to see. There may also be a chemical deficiency in the bulk of the epoxy or adhesive that causes a reduction in its cohesive strength. Our work today is to understand not only how these large defects that are relatively easily seen by x-rays and ultrasonics affect the strength of the part, but also to look at the subtle defects at the interface or in the chemistry of the adhesive itself to see how they play a role in the strength of the part.

Our first speaker, Bill Bascom, from the Naval Research Lab, will set the stage by talking about the role of gross defects as deduced from the fracture mechanics of this kind of layered structure. Then we will turn to one of the main problems with adhesive bonds and polymeric materials, which is their susceptibility to moisture. Currently, the designer can only use a fraction of the strength potential of composites and adhesives because he is not sure how water degrades strength and he doesn't have any kind of a nondestructive test tool to tell him if the water is there or if it has been there. Since this moisture problem is particularly difficult in the composite materials, Dave Kaelble and Lloyd Graham from the Rockwell Labs. will tell us about how the water gets into the graphite-epoxy composites, what it does when it gets there, how it affects the strength, and what nondestructive tests we can hope to use to detect it.

Following this discussion of fiber reinforced materials we will turn to the structure where layers of aluminum or metal are joined by an adhesive. Dr. Scott from the Naval Air Development Center will tell us about how the layered nature of the structure influences the sound waves, both for acoustic emission and for ultrasonic pulses. Then, Paul Flynn from General Dynamics and Mike Buckley of the Air Force will describe the standing wave effects that occur with a transducer in a water bath sending sound waves through the layered structure perpendicular to the interfaces. The frequencies at which the standing wave conditions arise can be used to deduce the quality and properties of the joint. I will then appear back on the podium to describe some new results obtained by sending the sound waves parallel to the adhesive layer in an attempt to allow the sound more time to interact with the defects that may be at the interface. Tom Wolfram from the University of Missouri will then tell us about the use of electron tunneling from superconductors to get an atom's eye view of what happens at that interface between the metal and the adhesive.

After we have spent the morning on adhesives and composites, the afternoon will be spent on some new NDE techniques and the NDE of new materials. Tony Evans of the Science Center is going to tell us about the problems we face with ceramics and we will get a glimpse of defect characterization. George Matzkanin of Southwest Research is going to tell us about how nuclear resonance can be used for nondestructive testing. Then Otto Buck from our Laboratories and Mr. James from Northwestern University will cover the NDE problem of measuring internal stresses.

Late in the afternoon we will get down to the fundamentals of acoustic emission with two speakers, Bill Pardee and R. Clough, who will describe theoretical approaches to the question of how to interpret emission signals and derive the most information we can from them.

I think it is important during this overview to look back over the program to see where we were two years ago, where are we now, and what we have accomplished thus far by taking a rather fundamental view of nondestructive testing and trying to get at the basic mechanisms. In the area of adhesive bonds, today's program should show that we are on the verge of having field-applicable techniques for measuring the cohesive strength of a bond. Also, we have got some pretty promising leads for measuring the adhesive strength of that interface between the polymer and the metal. It will take another year's work to provide the statistical basis to prove that these statements are true, but I think we have come from no tests at all to some very specific tests for some specific features of the adhesive bonds.

In the composites area, it was only a few years ago that it was said, "water ruins composites" and everybody had a different idea of how and why this happened. Over the past two years, we and other laboratories have figured out where the water goes, why it does what it does when it gets there and have even found some physical properties that can be used to measure, in a nondestructive way, that the water has been there or is still there or that the strength has been degraded.

In the area of ceramics, our program is very new and we are using some of the output of the defect characterization studies that you will hear about tomorrow in this type of new material where the critical defects are a few microns in size and are way outside the range of conventional ultrasonic equipment. In residual stresses, we have some new methods that utilize some unexpected techniques involving the magnetostrictive interaction to reflect the stresses that may be in a ferromagnetic material.

I am really most excited about the area of acoustic emission,which has been around for years. During the last two years, there has been a major thrust in the theoretical aspects of what generates the noise and what are its characteristics. We have coupled experimental and theoretical investigations that are already giving us information about what to look for in the frequency spectrum to tell the difference between a crack and a broken precipitate. It won't be too long into the future when we can tell the difference between a crack and the dropping of a wrench on top of a pressure vessel.

DISCUSSION

MR. MAX WILLIAMS (University of Pittsburgh): Thank you very much. The chair here is very encouraged by the fact that we also have a mechanical device in case the electronics fall apart.

Thank you very much, George Alers. As the next item on the program, we have Bill Bascom from the Navy who will discuss the Durability of Composites and Adhesives.