MAINTENANCE ERROR DECISION AID PROJECT

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It is a pleasure to get a chance to speak with you here this morning about some issues and some subjects that we are working on jointly with Boeing. Dave will tell you more in a few minutes about what we have been doing in terms of maintenance error analysis. He will describe in some depth the project that we have been working on with Boeing. I would be quick to point out also that Continental Airlines is not the only airline participating in this project. British Airways and United Airlines are involved as well.

We have chosen to define maintenance error for you this morning and this is a definition that we have "grappled with" amongst ourselves. We define it as an undesirable outcome of a required, planned, or unplanned maintenance event, resulting from personnel error, creating personal injury, or aircraft degradation. There are a couple of end results from error: People can get hurt, or airplanes can be degraded -- mechanically or physically. With that definition in mind, we ask "Why is maintenance error important?" Maintenance error today in the air carrier industry affects us all in one form or another. People make mistakes. Systems are designed to the best of people's ability, yet somehow, humans seem to produce failures within those systems in spite of best intentions. And that is an important issue we are trying to keep in mind. Many of you have been exposed to and are aware of our crew coordination concepts program. We have had that program within our organization for the past two years and have seen some fairly positive results in terms of effect on our organization. In that course we talk about why we make mistakes; how we communicate with each other from an interpersonal standpoint; how we solve problems and make decisions; all of the things that go toward influencing outcomes of events.

So with that definition in mind, I want to press forward. The data in **Figure 1** (provided by Boeing) shows maintenance and quality control events as the second leading cause of major aircraft accidents over that ten-year period. GE also put together some data that showed 50 percent of engine related flight delays and cancellations are caused by improper maintenance. So there is some evidence and some empirical data that says maintenance error impacts the way we do business. It impacts performance and certainly impacts people's lives in terms of injury.

Safety Issues Versus Onboard Fatalities
1982 - 1991

	Accidents	Onboard fatalities
1. Controlled flight into terrain(CFIT)	26	2,169
2. Maintenance and inspection	47	1,481
3. Loss of controll/uncontrollable	9	1,387
4. ATC system and communication	39	1,000
5. Approach and landing without CFIT	133	910
6. Postcrash survivability - smoke/fire	41	739
7. In flight - smoke/fire	6	610
8. Ground deicing/anti-icing	9	384
9. Windshear	10	381
10. Uncontained engine failure	11	199
11. Out-of-configuration takeoff	11	188
12. Airport ground operations control	23	136
13. Rejected takeoff	19	53

Some accidents are associated with more than one issue.

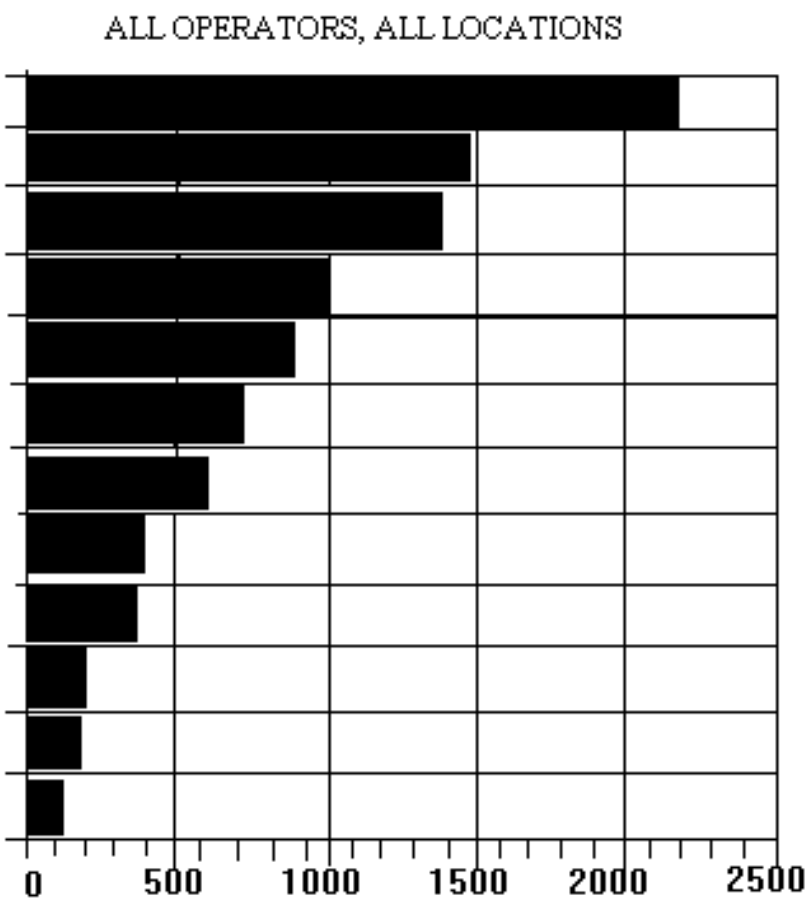

Figure 1 Leading Causes of Major Aircraft Accidents

Let us explore some of those causes a little bit closer. Table 1 lists the top eight maintenance error causes; this data comes from a U.K. civil aviation study that was done recently. Those of us who work for airlines probably hear anecdotal evidence that these problems occur every day across our systems. Yet what do we do with this data? And how does it affect our operation? I will air a bit of Continental Airline's dirty laundry. From 1988 through 1991, we had significant numbers of mishaps and incidents involving maintenance personnel (**Table 2**). There were 203 total mishaps resulting in damage to aircraft. It also includes towing, pushback, and servicing in addition to scheduled or unscheduled maintenance events -- acts of maintenance, if you will, under the FARs. These events resulted in 13,299 total hours out of service and an estimated $16,580,135 of repairs expended only on parts and labor. To factor in lost revenue multiply that figure by about four. One of the big reasons we are standing before you today is that approximately 95 percent of those errors are attributable to procedural error. Not necessarily willful error, but still procedural error. The numbers for 1992 and 1993 are not looking much better in some respects.

Table 1 Top Eight Maintenance Problems, 1992

- Incorrect Installation of Components
- Fitting of Wrong Parts
- Electrical Wiring Discrepancies
- Loose Objects Left in A/C
- Inadequate Lubrication
- Access Panels/Fairings/Cowlings Not Secured
- Fuel/Oil Caps and Fuel Panels Not Secured
- Gear Pins Not Removed Before Departure

Table 2 Ground Mishaps Involving Maintenance Personnel*

- 203 Total Mishaps Resulting in Damage to Aircraft
- 13,299 Total Hours Out-of-Service
- An Estimated $16,580,135 Repair Expended on Parts and Labor - Excluding Lost Revenue
- Approximately 95% Attributable to Procedural Error

* Includes MX, Towing, Pushback, and Servicing

Maintenance error also has a significant impact on our work force. We are presently in the midst of an on-the-job injury awareness campaign. Our objective is to raise awareness of on- the-job injuries across our system and to eventually shoot for a reduction of 50 percent. But as you can see, June 1991 to June 1992 data indicate that the actual number of injuries in our Technical Operations Division (**Figure 2**) have not decreased much. Many lives are disrupted by error, error that either results in aircraft degradation or personal injury.

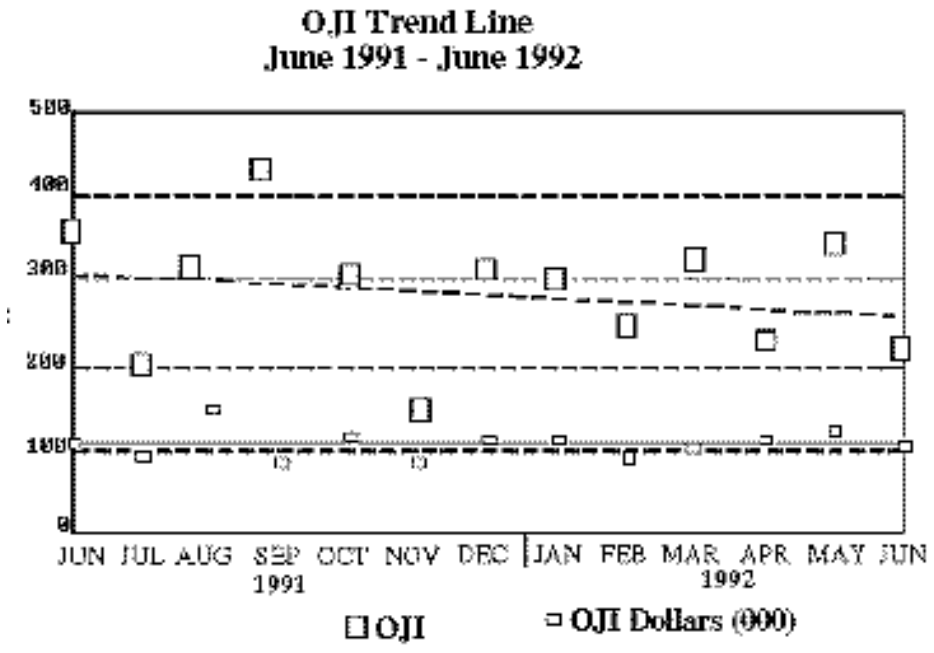

Figure 2 OJI Trend Line

I want to talk for a few minutes about how we do error analysis today in our environment. I have titled it "Turf Protection." How we do error analysis today, how do we react when we hear of a maintenance error or a damage event that is resulting from maintenance? What do we do? Well, there are a couple of levels that error analysis goes through. The nature of our operating environment today typically puts responsibility for error analysis on the front line management personnel, the supervisor, or the highest ranking member at the station. That person is given a task of doing an investigation, determining a probable cause, and in many cases mediating discipline if it is judged necessary. All within the context of having to fill out a large and cumbersome package of paperwork detailing what occurred, why it occurred and any actions taken. He must do this in addition to continuing to perform his normal duties and responsibilities, with no disruption to the operation. Filling out the paperwork is a form of punishment in itself. People do not want to have mishaps simply because they do not want to fill out the paperwork. Yet maintenance error continues to happen.

When I say error analysis today is primarily the responsibility of the front line personnel, that is depending on severity. We all can look into our own environments and see that if something minor happens, it is fine for the local supervisor to take responsibility for initiating an investigation and assuring that all the i's are dotted and t's are crossed. But what happens when something more significant happens? What happens when, for instance, a wide body airplane goes down for an extended period of time because of a maintenance error? All of a sudden it is a fairly visible event within the system. It gets on conference calls; beepers go off; yelling and screaming and gnashing of teeth is accomplished; and eventually the airplane is put back into service after repairs are accomplished and (figuratively speaking) we hang the guilty party at sunset. In extreme cases, we get a note from the FAA that says, "We'll be looking for some further information from you as to why this event occurred -- in the form of a letter of investigation; we'd like a response in about 30 days or so." That is when things really get interesting. That is when the turf protection issue really comes to the fore. We then do an "official" investigation, and we really find out what happened. Well, the jury is still out on whether or not that is truly an effective way to investigate that event. But it certainly exists today.

We think that a maintenance organization can profit from a different kind of error investigation, a different kind of error analysis. That is the reason we chose to get involved with Boeing and with our other fellow airlines on the project called MEDA (Maintenance Error Decision Aid). We want to get away from the standard blame and train scenario, where we do an investigation based on severity, elevate it to necessary levels, mediate punishment, and move on, never really learning anything from the investigation nor necessarily even having done anything profitable for the person involved.

Well, I will answer my own opening question: Do maintenance organizations profit from this type of error analysis environment? I think not, if we are honest. What is the role of a technician today in error analysis; in investigation? Does the technician investigate his own error? Not really. They are probably the most valuable source of knowledge as to why that event happened and what could possibly be done from a systemic point of view to prevent it from happening again. But they are an under-utilized resource in a lot of cases because we are intent on fixing the other potential side effects of the event such as letters of investigation or an out of service airplane. The nature of our operation dictates that we have to do that. Yet we are letting a source of valuable knowledge from a safety and investigation standpoint go untapped. This is another reason why we think participation in this project is valuable. It will begin to tap that resource. Not only can we utilize that untapped resource of the technician or the person involved directly in the mishap, but we can also apply the information to system analysis as well. So it is a win-win situation. You are able to capture the human issue within the error, but you are also able to apply it to your system to make

improvements, to help ensure that down the road somewhere the chain of events will not come together to put that person potentially at risk again.

Instead of turf protection, we would like to move toward a team approach. A team approach that says: We are not going to blame and train anymore, or we are going to at least try to avoid it. We want to get to a point where that technician's experience and voice are heard so that valuable human performance information is extracted from that event. If systemic type corrections need to be made, we can make them at that point too.

What we want to get in error investigation is what you can see on the right side of the page (**Table 3**), performance-based error analysis. Today we have the search for the guilty party, or the blame and train mentality. We want to move toward the right side where error is formally investigated; focus is on the contributing factors influencing performance; and the conclusions are objective and based on analytical, scientific method rather than someone's best guess. Hopefully the system improves with lessons learned. That's our vision. Most human factors analysis is presently done by non-human factors people, because, again, if we go back to our earliest points, we know that error analysis or investigation is typically pinned on the front line person. They are given the responsibility to do it.

Table 3 Error Investigation

Error Investigation

Today "Search for the guilty party"	Tomorrow "Performance-based"
▪ Non-existent or limited in scope	▪ Error is formally investigated
▪ Inability to assess factors contributing to error	▪ Focus on contributing factors influencing technician's performance
▪ Conclusions are subjective; mechanic is often assumed to be at fault	▪ Conclusions are objective and based on analytical assessment
▪ System performance does not improve	▪ System performance does improve

If we go on the assumption that this analysis is done by non-human factors people, another question to ask is what do the rest of us know about these maintenance events? The rest of us who sit in offices and environments and probably do not even hear of a large number of the errors that occur in our systems every day. We depend on conference calls and grapevines and informal information systems to relay this information to us. I know for a fact that I do not hear about error that occurs every day in a station that is two miles down the road from my office. Yet this knowledge is valuable, it is important, and it impacts how we operate. Our natural evolution should be to get to a point where we provide human factors-based support tools to those people who are given the responsibility of investigation so that they can consistently analyze error and develop intervention strategies without our help, literally. If that error analysis indicates that there is a system problem, then other people can be called to come in and help with those systemic type issues. At Continental we want to go even one step further than that. We want to get to a point where we do those things and make those systemic changes but we also want to assure that we have a closed loop by bringing that technician or participant in the error directly into the loop and say, "You are a valuable resource and a source of information in this event. We want your help, we want you to help us capture all these things that

led you to be involved in this error." That will allow true human factors analysis to be performed, not just the standard blame and train. It can be performed by anyone in the organization, including the front line maintenance technician.

At this point, I am going to turn it over to my colleague from Boeing and he is going to tell you what that new performance-based approach is going to look like.

Jerry has just presented why we need to improve the methodology by which we investigate maintenance error. I will address how we are planning to move to more performance-based analysis.

One year ago Boeing formed a team with Continental, United, and British Airways to develop a new "human-centered" methodology for the investigation of maintenance error. We have additionally invited the Federal Aviation Administration to join our program. The outcome of our project is what we call the Maintenance Error Decision Aid (MEDA). As the chart shows, we are building an investigation technique (**Figure 3**). I would like to point out a few key elements in our mission. First, the decision aid is event-driven. That is, it is a tool to investigate maintenance error events, whether they be actual events, or hypothetical events resulting from the awareness of some risk. It is not an audit tool, per se. Auditing and event investigation are two distinct tasks, and we felt that event analysis was the right place to start. Secondly, the goal is not simply error reduction. The goal is preventing airplanes from being dispatched with error-induced discrepancies. This is "error management." Error management encompasses the understanding that some errors may not be eliminated and that often the best strategy is to capture the error or build tolerance into the system to lessen the effects of the error.

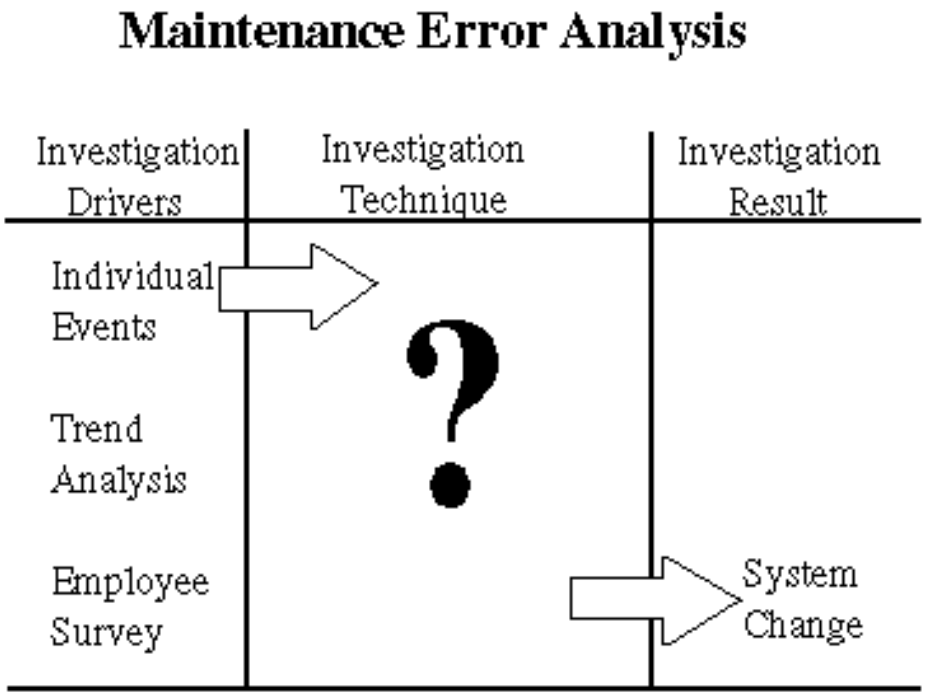

Figure 3 Maintenance Error Analysis

Before I go into the details, I would like to briefly discuss the deliverable. MEDA will be a paper-based human error investigation methodology tailored to the needs of aircraft maintenance. The deliverable will consist of two documents (Figure 4). The basic document will provide the tools for error investigation. The supplement will provide the training material required to teach MEDA analysis. You will notice the chart says "local factors analysis." The MEDA tool developed in 1994 will specifically address the needs of the maintenance manager performing what we describe as local factors analysis.

Two Levels of Error Analysis

Level	User
Local Factors:	Line Management
	Technicians
Organizational Factors:	Quality Assurance

Figure 4 Two Levels of Error Analysis

During our investigation over this last year, we found that maintenance error analysis occurs on two distinct levels (Figure 5).

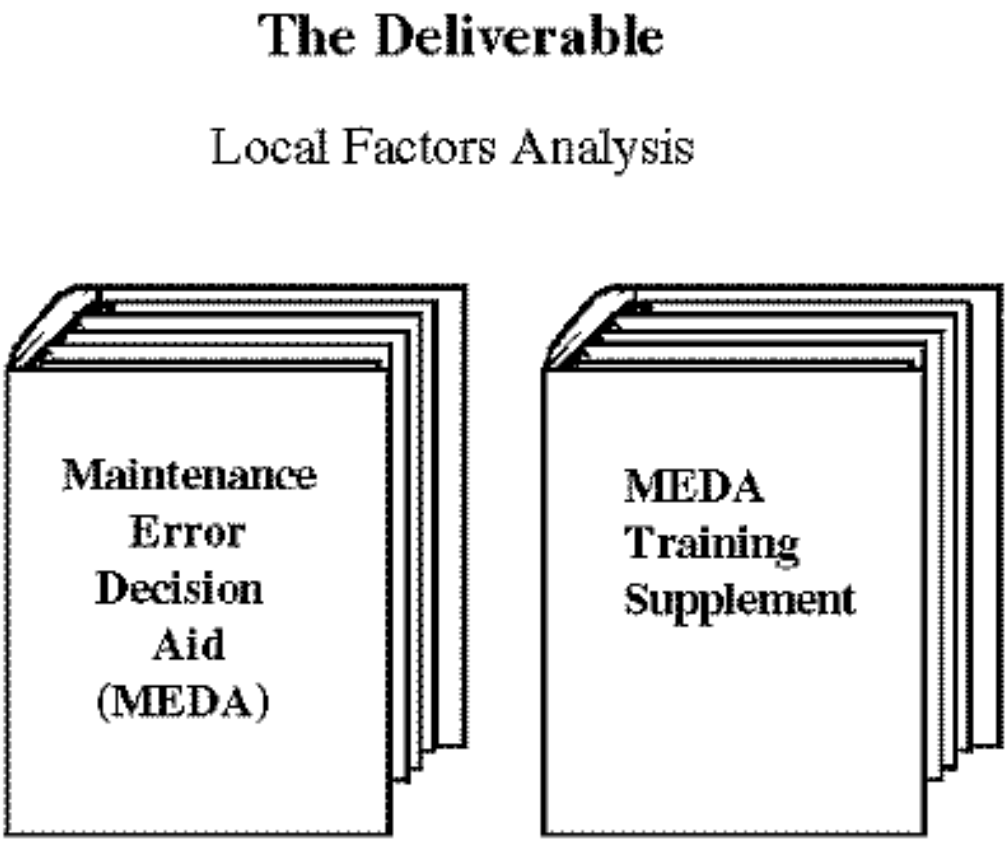

Figure 5 The Deliverable

First there is the analysis that occurs within a local area of the airline, performed primarily by the management of the technician who erred. Error analysis often remains within this level unless there is some aircraft event that raises visibility of the error beyond the local area. The second level of analysis happens at the organizational level. This analysis gets launched when the event causes a significant operational impact or the local investigators need the assistance of some outside organization such as Engineering, Quality Assurance, or Training.

I will quickly review what our development team has established as the five preferred steps in maintenance error analysis performed at the local level (**Figure 6**). The first thing a maintenance manager will do when he or she learns of an event is to determine whether it will be investigated. Today, this step in error analysis occurs almost subconsciously. If maintenance is informed by the cabin crew that the coffee maker is incorrectly installed, the crew chief or maintenance manager will quickly decide if the event is worthy of investigation. Within MEDA, we have termed this "first cut analysis." It is the quick development of an error scenario, the assessment of the potential criticality or impact of the event, and the determination of the level of investigation commensurate with the impact of the error. Within MEDA an impact decision tree is being developed to establish the relative impact of the error.

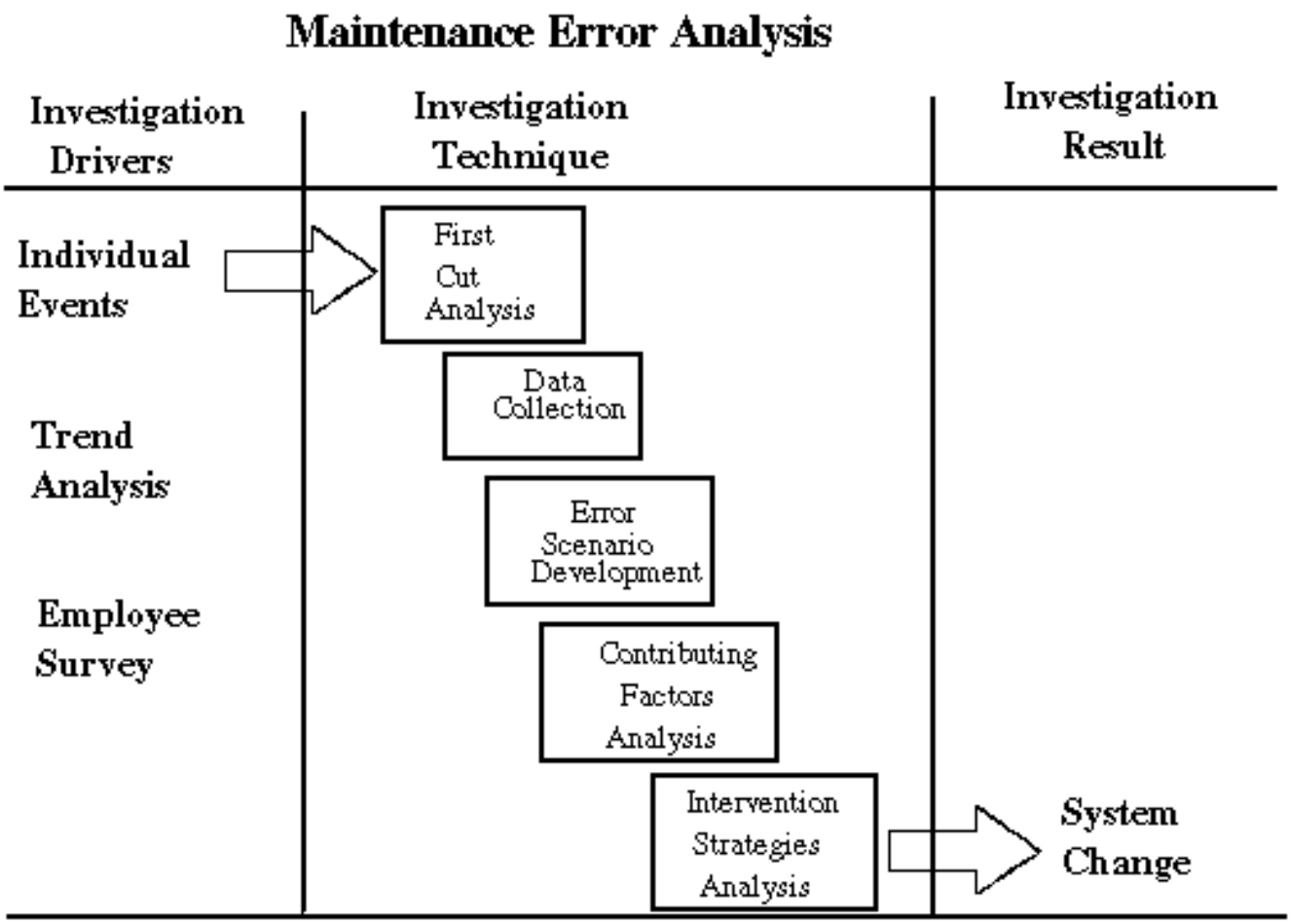

Figure 6 Maintenance Error Analysis

The second step in error analysis is data collection. Within MEDA, sample data collection forms are being developed to ensure that appropriate information is captured during the investigation. These data collection forms will be structured around the contributing factors analysis step I will discuss in a few moments.

The third step in the investigation is what we call "error scenario development." Error scenario development is designed to determine <u>what</u> happened during the event, including the identification of pertinent organization norms. Often, error occurs when the technician deviates from a particular policy or procedure. However, in some cases the system has adopted norms that have, over time, drifted away from the written procedure. In our investigation we found cases where aircraft events occurred when a technician broke from the social norm to follow a "bad" procedure. MEDA will provide event-charting techniques that will help systematically capture the actual error scenario.

The fourth and most human-factors-intensive step in error investigation is contributing factors analysis. The goal of this analysis is simply to determine why the error occurred. Within MEDA, a factors checklist will be provided to ensure that the investigator is addressing most of the contributing factors that may have contributed to the error. Additionally, supplementary assessment material will be provided for each potential contributing factor on the checklist to ensure that the investigator knows how to assess the merits of each factor within a particular error scenario. At this point, the impact decision tree used in the first cut analysis will be used to determine a revised relative ranking of the impact of the error scenario from both a safety and economic perspective.

The last step in the analysis relates to the selection of intervention strategies. Within MEDA, an intervention strategies checklist will be provided as a guide to ensure that available options for addressing contributing factors are considered. Supplementary assessment material will be provided as an extra resource of the applicability and effectiveness of different types of intervention strategies.

In addition to the investigations conducted subsequent to individual events, trend analysis must be conducted to identify common factors or links among events. When it appears there is a common factor contributing to a number of events, it is appropriate to launch an organizational level investigation. Our MEDA development team has deferred work on this level of investigation until the local factors analysis work is complete.

As an overview, the MEDA development team is working to develop methodology to improve the investigation of individual error. Our schedule for completion of this local factors analysis is to have MEDA in the field by mid 1994 and made available to all airlines by early 1995.

Many of you have seen this chart with the flying public being supported by the three legs of the stool: regulatory authorities, airlines, and manufacturers (**Figure 7**). We have been talking about how airlines can improve their analysis of maintenance error. I would like to speak briefly on what role the regulatory authorities and manufacturers must play in order for the goals of MEDA to be realized.

Figure 7 Improving Error Management Requires Teamwork

First, manufacturers must begin to better understand human performance. Over the years we have become very adept at analyzing equipment failure. When it comes to maintenance error, however, we often fall back to the search for the guilty party approach. The adding of caution notes to maintenance manuals and the subtle recommendations for your mechanics to be more careful in their work will rarely realize the performance improvement sought. We must continue to push our understanding of maintenance error so that we can design equipment and procedures that are truly less error prone and more error tolerant.

The regulatory authorities must help by putting less emphasis on punitive measures that will deter the erring individual from recommitting the error, and putting more emphasis on development of the intervention strategies that will improve overall system performance. Principal maintenance inspectors must look beyond enforcement action. They must look to why the error occurred.

With the airlines, manufacturers, and regulatory authorities working toward improved maintenance error investigation, both safety and economic improvement will undoubtedly result.