

MANAGEMENT OF RELIABILITY AND MAINTAINABILITY;
A DISCIPLINED APPROACH TO FLEET READINESS

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It certainly is my pleasure to be here at Goddard again. It has been a number of years since I have been here. I was at NASA for a number of years in the past, but I recall a remark of my very own that came to me as I was listening to the introduction.

When Apollo was over, I said to the Administrator of NASA that I want \$10 and a new suit. I don't know whether you understand that expression or not, but when you get out of jail the first thing they give you is \$10 and a new suit.

Apollo was over. I said, I am through with reliability, we have done a job, I don't want anything more to do with it. I came from a systems engineering group and I said, I want to get back into that business and get out of this game called reliability.

Well, the \$10 and a new suit didn't last long because I was thrown into the Navy to see if we could manage to turn around a trend in the Navy which was very detrimental; the lack of operating life in Naval equipment.

Now, I use the term operating life. That is what I grew up with and the Navy calls it reliability. Whatever you want to call it, it is all the same thing.

Today you are here to learn, listen and talk a lot on the subject of precision time. I think also you should put the word precision in your mind very carefully because that is really what reliability and what the quality assurance world is all about. It is really the precision of how you do something.

What we learned in Apollo was that nothing in the terms of operating life happens by accident and that you can have reliable systems without redundancy. As a matter of fact we had many systems that were very important and that were not redundant, although we did have quite a bit of redundancy.

When you don't have redundancy, such as the military has a great lack of, then you must depend on how you design your systems and you must depend on how you manufacture your systems. So today what I would like to hold in front of you is the term "precision," because that is what it is all about. We are going to talk a little bit about the experience, what has happened in the Navy in the past years, where we have been and where we think the program is really paying off.

I think there is quite a bit of excitement in terms of our own contractors and ourselves as to what we see being introduced to the fleet, which has a primary job to do.

If you notice, in the Figure 1 we didn't put in reliability and quality assurance and that is for a very good reason. For a number of years, I think most people have become mesmerized with the word "reliability" and "quality" and there is a little story about the runner who went out to see how the war went and the runner came back and said, "the war doesn't go too well, Emperor." And the Emperor says, "shoot the runner."

That is really what I found happening, when I came to the Navy. We had reliability people standing up, answering questions that should have been properly addressed to the designer and we had people standing up in quality assurance circles trying to answer questions which really belonged to the manufacturing community. So we have decided to focus where it is important and put our hands around the throat of the guy who is really doing it to us; the designer and the manufacturer.

The reliability and quality organizations have a purpose and a point; and we are not in any way circumventing their role, but what we are trying to do is make sure that we focus on where the culprit is and that is the designer and the manufacturer. You will see very little discussion about reliability and quality itself, but you will see it more centered around the design arena and around the manufacturing arena, which is where it all takes place.

I think the thing that is important is the word "mandate", in Figure 2. On Apollo we had a mandate and that was to land three men on the moon and bring them back safely within the decade.

That mandate means a lot. The Navy decided back in the mid-'70's that the fleet was not doing well and that parts and people were not the answer to bad equipment. And they really put a mandate out and this is how I got involved.

They said, we want to change the way the Navy operates in terms of the equipment operating life and these are the three commands that are involved: the Air Command, the Elex Command and the Sea Command.

In Figure 3 is shown how the mandate carried itself out. On the slide you can see the office I now hold (06). It is a responsible role along with the logistics community and the acquisition community. The three operations report directly to the Chief of Naval Material. So that means we have recognized the mandate and the organizational structure which is, of course, very important.

A little bit in terms of motivation. I saw Figure 4 in the Patent Office on documents that I was reading not too long ago. It is a plow in combination with a gun. I am sure that the designer of this machine, back in the time period when that plow was made, was doing it for protection, but I couldn't help but think what a great motivation that would be if you were the mule who was pulling the plow.

Of course what we want to talk about is the management of a disciplined approach. The whole secret to this business of precision is a matter of discipline (see Figure 5), how you go about it and how your understanding takes place during the course of that discipline.

Now normally speaking this is what you would find yourself dealing with in terms of reliability and what I saw the Navy dealing with back in the mid-'70's is their version of reliability. It has been charted for simple understanding, but it is what I refer to as the game of random nines.

Figure 6 is a chart that portrays how the acquisition cost (A) increases as the reliability is increased. The support cost (S) decreases as the reliability is increased.

This chart was supposed to tell you that for some Delta increase in reliability here, that there is a point on the acquisition cost curve where it would be too expensive to continue to develop the equipment in terms of placing it into a higher reliability category.

And, of course, this chart is absolutely true if you are intending to manage your reliability by a test program. If you are intending to test your reliability into your program then, of course, this is the kind of a curve you would see in terms of the acquisition costs, because you would be spending so much money for time, equipment, test chambers and it would be very late in the program, it would be a very costly kind of an operation.

And I have seen these type of curves run before on equipment and they are referred to as cost drivers. And in any program where you run into reliability as a cost driver, what you will find most times is that you are dealing with a program where the test philosophy is reigning supreme, rather than the design philosophy.

So this is the game that I got involved with when I first came to NASA back in the mid-'60's. And there was a group called PSAC that was looking over Apollo and they wanted us to do a predictive kind of analysis and to do a reliability program in what I call the game of random nines. In other words, they were trying to get us involved in the mathematical aspects of reliability rather than design and manufacturing.

Very fortunately for NASA they didn't listen to PSAC and went on and did what was right.

In Figure 7 is shown what we replaced the game of random nines with. There is nothing that we can't do in terms of acquisition fundamentals that defines the program reliability that aren't under these categories.

Actually when we were with the Apollo program there were quite a few more analytical activities than this that we could perform in order to understand reliability of our equipment while it was in the design process. But for the military application we picked these categories and said they are the ones we want to use, they are the ones that we are going to focus on and if we understand these, we are sure that we can design and build reliable devices.

There is one secret to reliability that you have to understand and it comes out very clearly in this chart and that is, reliability is a function of stress. If you understand the stress on your hardware, you understand its reliability. If you are overstressed, you are not very reliable. If your equipment is overstressed it is not reliable. These are simple analytical tools, but very powerful analytical tools that if used properly can give you as much confidence as a very complex test program.

They have the advantage of being done up front while the design is still on the paper, they have the advantage of not using a lot of capital resource and inventory and yet giving you the confidence that you need to understand whether your equipment is going to hack it or not in terms of the stress that is being put on it.

For instance, the mission profile definition is very important. You have to understand where it is going to be used, how it is going to be used and what environment it is going to be used in. Of course, that is one where we have fallen down on our swords many times because we have just inadequately defined the environment, sometimes out of ignorance and sometimes because we were just careless.

If it is something we don't know and it is perfectly understandable, we will learn what the mission really turns out to be later.

But all of these tools are designed to produce analysis and in the Navy most of our contractors have generated the necessary algorithms in the Cad and Cam work in terms of getting the analysis into the automation system such that the engineer doesn't have to do it in the long, time-consuming way.

This is a very important analysis that Apollo spent a lot of time on and as far as an analysis goes in terms of understanding stress, that is probably the most important one; the most powerful one there is, up and down the board.

The only problem was that it wasn't known outside of Apollo circles. Today it is getting the emphasis I think that it needs in industry. I think the jury is still out though as to how important it is to military systems that have not a high reliability requirement. It may come as a shock to you but in most cases military equipment doesn't demand high reliability. It demands what we call a median kind of a reliability somewhere in the 80 to 90 percent category, not like the Apollo reliability where failures were just ordained not to be, which demanded very precise design and very precise understanding of the design.

The question of sneak circuit analysis came in as whether or not it would be a type of analysis that would be valuable to the military. It turns out that it is, I think, but the jury is still out voting and the jury is really the industry. As they use it, become more familiar with it, we are finding out how cost effective it is and whether or not it is really paying its own way in terms of an analysis activity.

Next I am going to talk about design experience.

What we have here is a series of figures that show you some of the involvement of the design and what it really means in the early stages.

When I first came to the Navy we asked some very simple questions about what was the policy of say junction temperatures in the design of electronic equipment. We couldn't find any policy written.

We also went out in the fleet and did some measurements to see what typical junction temperature were in equipment and we found they were operating somewhere in the 150 to 140 degree C category.

We also know from our experience with Bell Labs that this is the temperature that they like to design in for the majority of their equipment and they have had a lot of experience with those kind of temperatures and we know what reliability we can get out of them.

If you put those numbers together what you see in Figure 8 is a difference of 900 times the reliability of the equipment depending on just simply what junction temperature you pick. We, in the Navy picked

the 100 degree standard because we couldn't afford the luxury of the weight, the extra copper that goes into designs of these very cool systems at the bottom of the chart, but we also couldn't afford the failures that we were seeing at these high temperatures. As a matter of fact, we set 100 degrees as a standard and it has turned out now that we are probably designing more in the 100 to 90 degree C region.

Our contractor has come back and told us that they really think they can probably design fairly comfortably at 110° to 120°. But we set the 110°C standard back in 1975 and we are probably going to move it very shortly into a lower temperature category since we seem to do it with a relative amount of ease.

But as you can see, even within the bandwidth of 120 to 110, we are still talking 12 times the reliability. So you can see the sensitivity of the precision of reliability requirements to just one little element, which is called junction temperature.

Also embodied in another chart, which I didn't bring today, is the electronic stress on the devices. You have two kinds of things you should look at in semi-conductors which are very important, one is junction temperature and the other is electronic stresses. I have just highlighted this one because it is very significant and easy to see.

Figure 9 is a chart that I think really portrays for people who have difficulty understanding what the relationship is between dollars, temperature and MTBF. We have collected this on a fleet of aircraft, 200 to be exact, and what we are looking at was the impact of operating temperature on MTBF and on the operating cost of the airplane. I think this is a very, very, important chart, at least it is for the Navy because it is the first time we have been able to quantify MTBF with temperature and with the dollars.

And what the chart portrays is what we did. We took a 200 fleet of airplanes and we lowered the cabinet temperatures from 110 down to 90, which is a 20 degree drop in the cabinet temperature.

And when we did that we almost doubled the MTBF. It went from about 2.7 to 4, but we found also that when we did this 20 degree drop in temperature of the box, we found that the annual operating costs decreased \$42 million for every year for those 200 airplanes. And now we find that if we can drop it another five degrees in those cabinets, we can have an annual savings of \$8.5 million a year on those 200 airplanes.

So you see, reliability has a very direct connection with the economy of how we operate, how we bill, how we buy. And in this day of inflated dollars, where we are buying less and less with the same amount of money, we have to understand more and more of these relationships and we have several other families of charts that show the economic impact of just a few degrees of temperature on the subtlety of reliability.

We have always known these numbers, like you could lower the temperature and the MTBF's would change by these amounts. Those are relatively known factors, but what we had not known is the impact of operating costs on airplanes when we just lowered it those 20 degrees.

So it shows you that for every degree you lower the temperature, you are not only dealing with MTBF, but you are dealing with operating costs.

Figure 10 is a very significant chart in terms of just the design and understanding of temperature and the design of a piece of equipment. This is a signal processor. We call it an ASP and the interesting thing about this chart is when we first looked at this program a number of years ago, the reliability it was achieving, was right around the 200 hour level, against a specified level of somewhere between 500 and 700 hours. We did a design analysis of that particular piece of equipment and we found most of the devices were running too hot. We didn't have a whole lot of money on this program, so what we told the designer of this equipment, which was IBM, that what we wanted them to do was to relocate the components on the boards and not do any new design. So essentially we went in and changed the printed circuit board only. All of the components went back on that were on there before. The electrical circuits were exactly the same. Only this time we did a sort of a regression analysis, thermal regression analysis, we put the components where they would best receive their cooling. In other words, the very hot ones were near the edge of the boards and those who needed less cooling progressively went towards the center of the boards.

We made a thermal adjustment of the parts on the board. When we put it back into service, 750 hours MTBF is the equipment reliability that we got. Now you see, to me that is very powerful. This is very inspiring for a designer to understand that the only difference between the old failure rate and the new was the fact that he relocated components.

We didn't change the design. We didn't do anything except just relocate the components on the board. Then what we noticed, when we got it out in the field was that we were still not achieving the reliability that I thought we ought to be achieving. So we took some more looks at that piece of equipment and we found that the field failures were about 50-50 parts and workmanship. In other words, the design stresses were within the limits that we wanted to be in, but parts and workmanship were a problem.

So in the next version, the initial production, we pulled that design back into the factory and changed the manufacturing process. When we fielded this piece of equipment, Figure 10 shows that the reliability went up to 1000 hours MTBF.

We looked in the field and saw that we were seeing some kind of categories that were lower than these numbers, but still a problem in the area of workmanship. We have instituted a screening program which improved the reliability prediction. We haven't fielded these units yet.

We are now putting our equipment through a vibration thermal cycle before we put it into the field and when that is completed we expect to see the reliability go up again.

I think the message of this chart is that this is a manageable process. There is nothing mystical about reliability. It has nothing to do with mathematics. I hate to tell you that, but E to the minus, Lambda to the t is a dead duck in the Navy.

Figure 11 is a "show and tell" about where all of this leads if you properly follow it.

When we were getting ready to put an INS, Inertial Navigation System, into the F-18 program we found we needed five to nine times the reliability of any current system in order for the airplane to meet its design requirements.

At that time when we went into the design phase of the F-18 INS system, Litton was the primary builder of these systems and everyone of these, with the exception of the A-7 had been built by the Litton Company and, as you can notice, the best that they had in terms of MTBF on any INS they had ever built from the 1960's through the 1974 time frame, was somewhere around 90 hours MTBF. And, yet, we had to have somewhere around 500 to 700 hours MTBF on an INS system if our F-18 was going to fly the way we wanted it to fly.

So we initiated those design parameters that we talked about earlier, what we call design fundamentals, and put in the manufacturing disciplines that we wanted on the program and today that program is flying in 22 test airplanes and is demonstrating somewhere between 500 and 700 hours MTBF.

The thing that is interesting about this chart is that the same manufacturer who from 1960 to the 1972 time frame couldn't make an INS system with any more than 90 hours MTBF in it for all of those airplanes. And yet we changed the design standards, changed his manufacturing standards and today we regularly get this kind of thing out of that manufacturing operation.

So once again, I am trying to show you that it is a discipline process, it has design capability in it, it doesn't have to be mathematically driven. We simply look at our design, understand the stresses and see to it that it is built to print, which of course is a big problem.

If you look at our general industry's response to all of the initiatives that I have just talked about, in Figure 12 is shown the top 10 people who spend most of the Navy's money in terms of delivering systems to the Navy. And these are the kinds of evaluations that we have put on the industry.

As you can see, there is still some red (R) with some companies as they gradually understand the transition design and the biggest one, of course, is motivation which we are working on this year, which I think is very important.

You know, Patton once said years ago, "You can't push a wet noodle." And that is a very true statement. So what we have done is gone to the corporate people and said, we are now demanding that you ask that your equipment be reliable, that you make that first in your company.

There is no point in building equipment, no matter how well, no matter how precisioned, such as your time equipment. You know, if you build very precisioned time equipment, but it doesn't do the job, it quit on you when you want it the most, then there is really not much point in having that design. You know, let's not be infatuated with just the performance aspects of equipment.

The Japanese have shown us what happens when you become infatuated with a total equation, not only the design of the equipment, but the manufacturing and the understanding of the stress of the equipment. You know, the Japanese are just about to put us out of business electronically and that is because they have understood the equation. I think it is high time we, as Americans, understand what that equation looks like also.

So we have been working diligently in that area and it won't be long before I think that the chart is going from all red in 1975 to have it all green (G) in 1985. And I think with our top 10 contractors we will have that happen.

As I said earlier, understanding design stress is really the main part of the equation for the design aspect. But now you still have to build it to print. No matter how well the design has been carried out, no matter how well you understood the stress on the equipment and no matter how well you did your design, if the guy out there on the floor doesn't put it together the way the design is supposed to go together, then you have shot it all.

So what we are involved in Figure 13 is a heavy emphasis on the manufacturing of equipment, or what we like to refer to as build to print.

We are going to talk about today in two areas: parts and workmanship (see Figure 14). The only parts that I am going to bring up with

you today, which are occupying probably 90 percent of our problem areas, is semi-conductors. And the other thing we will talk about is workmanship. But I will first talk about the parts problem, what we see in the parts area and what I think you should be very attentive to in your precision time work in terms of semi-conductors.

Back in the late '70's we did a study, shown in Figure 15, which became very significant to us. I became aware that parts and semi-conductors were giving us an unusual amount of trouble in the fleet and we were buying mil-standard parts, high reliability parts, JANTX and JANTX-B parts, which are supposed to be the top of the line, the cream of the crop.

But we began to see equipment with these mil-standard parts in them that weren't performing the way that we thought they should. So we went out and bought a dozen part types in quantities of about 100 or 1000, I have forgotten how many were in these lots now, but we bought 12 different types of semi-conductor devices with what was referred to as a statistical quantity and then we put them in tests at one of our labs. And what you are seeing here is the summary of one part type of which the other eleven looked exactly alike.

But what I want to go into is to show you what really happens in this world that began to open our eyes.

If you go to Radio Shack to buy a given part it will cost you 59¢ for that part. If you buy the same part commercial screened, such as the FAA, or other people buy, that same part will cost you \$1.99. If you buy the part with high-rel standards, such as NASA buys, that will cost you \$3.10. If you buy the same part under what is referred to as a mil-spec the part will cost you \$12.50.

Now what we found out in this study, if you notice there is only one thing changing in this chart that you can see and that is the amount of paper you buy.

If you buy your part at Radio Shack there is no more than your receipt. You get a little more data at each higher priced part and when you get the mil-spec part you have bought a trainload full of information and it is supposed to guarantee you that you have now bought the part quality that you want.

Well, what we found in this study is that that wasn't true! What we really saw is that there was quite a difference in terms of the reliability between the first two categories. And we saw there was a lot of difference in the quality between the next two. But the significant part that came out in all 12 part types was that we could see no discernable difference between the mil-spec and commercial screened parts.

Now, why is that? We began to study it and we thought we knew the answer, and since Fairchild has blown the lid off everything we now know the answer. But at that time we were speculating.

You see, commercial screened parts is where 99 percent of the parts are sold commercially. We in government only buy three to four percent of the industry's output and what is happening is, when they run short of mil-spec parts they are just dipping in the box and getting us these commercial screened, unburned-in parts. And that is the reason we could not see the difference. They just look alike.

You know, we wrote a great mil-spec, but we just aren't able to police it or enforce it.

So that began to open our eyes. I got a couple more pieces of data here that I am going to show you. Here are six of the leading semi-conductor manufacturers in Figure 16; we took their names off to protect the guilty, but I never have quite figured out why I wanted to protect them, but nevertheless every name that you know is on this list.

In one major program it became a real eye opener for us, it was a mining program where we were having trouble with some of the semi-conductor devices.

We decided that we would go in and do our own pre-cap visual. The manufacturer had been doing it for us now for three years and we were having trouble with this particular device. So we said, we are going to see if anything is different. We are going to send our own people into the factory and we are going to sit down with the guy who does the pre-cap visual and we are going to do it right along with him.

When our man arrived at each one of these six plants the reject rate that showed up is shown in Figure 16. Now mind you, they had been delivering them to us all along. And, as a matter of fact, these two fellows, number three and four, came to the Navy and said that they had a 72 percent rejection when we were sitting there with them and that they previously had only a 6 to 5 percent rejection.

Those two fellows said to us, if you really want a mil-spec part we can't supply it to you and they disqualified themselves and they had been sending them to us for three years.

Now these other fellows who had still unusually high numbers, at least agreed to clean up their lines, and they began to deliver us quality semi-conductor devices.

Well what we found out is there is gross cheating going on in the semi-conductor world; gross cheating.

A typical example is shown in Figure 17. We screened, we took a family of them and you can see the number of parts. I won't go into it here for time reasons. But when we did the exact same test, we took mil-spec parts that had already been delivered to us and we put them through the mil-spec test again. We just sent them to an independent tester, and we said what we want you to do is submit these to a mil-spec standard test requirement just as though you were the manufacturer and do exactly the same thing he is supposed to do when he ships them to us. And that is what the column represents in Figure 17.

And when that guy was finished with testing, I think it was 20,000 parts, we found 14 percent rejection of transistors, 14 percent rejection of IC's and about 11 percent rejection of diodes.

What we are seeing consistently, in the Navy in the mil-standard world of military parts, in the semi-conductor world, is somewhere between 10 and say 17 percent rejection of mil-standard parts. Now those are parts that, you know, we are paying the \$12.00 for. They are not the Radio Shack part. They are the part that is supposed to be tested, burned-in and are supposed to be high quality devices. That has changed our whole way of doing business once we learned this.

Now here is an example of what happens. We call it the manufacturing burden.

Figure 18 is a chart I showed the industry just to show them how stupid this whole thing really is. But here is a case where a guy delivered 425 pieces of which 243 were found bad. When they were taken apart, they found they didn't even have the same die in them. Figure 18 is a picture of two different dies in the devices. What had happened is; he had just put the wrong dies into the devices. Now mind you, not only does he have the wrong quality on the die, but he also has the wrong die in the semi-conductor. Now that doesn't bother me nearly as much as the statement down on the bottom. An alert was put out, everybody was told, the manufacturer, which is National Semi-Conductor, responded to the alert in this way. And this is what was written on the alert; It says: "This situation of mixed parts does not constitute a reliability problem". It has got the wrong die in each one, but that is not a reliability problem!! They say: "All of the incorrect devices would have been detected at the users incoming, receiving testing board level checkout". In other words, "Buyers beware."

You will find that somewhere along the line at your cost and at your expense, but we don't consider that a problem. And that is the kind of thing we are dealing with in semi-conductors.

Now, of course, there was one that has really hit the street lately. I am not going to spend a lot of time on it, but as you know Schoenberg took over Fairchild in a stock option bit and when Schoenberg came into

that plant and began to do an audit of what they had bought, and my own version of this is they get what they deserve because I don't like people that do these stock option takeovers, but at any rate they now found out that they have a disaster on their hands.

You know, Schoenberg came to the Navy and came to DESEE and says, hey we don't quite understand what is happening in the Fairchild plant. We put out approximately 2 million semi-conductor devices a day -- on the military line -- and yet we don't find but 500 sockets in which we can burn them in and we don't understand how they are doing that.

Of course everybody rushed into the plant to see what it was all about and what you really found out is that they weren't burning in at all.

For the last five years Fairchild has been shipping mil-standard, high reliability devices unburned-in. And those are in all of your equipment right now. You see, what I am saying to you is you are really -- "Buyer beware."

Now the Navy has established its own programs with screening. Most all of our major vendors have bought what is referred to as "century equipment". It is a temperature screening device that we rescreen all semi-conductors. We just don't use any semi-conductor that isn't rescreened. It is just a disaster. I am sure in your precision world you should take very great note of this because I think it is very important that you recognize that just because you bought a mil-spec part doesn't mean you have got anything at all. You have got to determine what you have got yourselves.

Shown in Figure 19 is a program for which we had specified an MTBF allocation. I picked it because it was a fairly high number in terms of Navy equipment and the thing that is interesting about this curve is if you look at the JAN world, you see the mil-burned-in part is required, the thing Fairchild didn't do for us and let me just stop right here a minute.

If you think the scandal going on with Fairchild is only with Fairchild, it is just because you haven't visited the other plants yet. Don't you believe for a minute Fairchild is the only one delivering unburned-in parts. You just have to understand how semi-conductors are made, you have to understand what the volume is and having been around these plants for awhile you have to understand the term called "ship for revenue".

At the end of every month a payroll has to go out in a semi-conductor plant. And when they get near the end of the month, if they haven't sold enough devices to meet their payroll, anything that is on the shelf gets sold. That is called "shipping for revenue" and that goes on across the whole industry.

Now what this chart shows you is that there really is a break point at which the cost begins to go up, but the MTBF doesn't meet the same cost rise. And really is there sufficient reason to use the mil-burned-in part for military equipment, or should we really look at the 883 screen parts, which is where the cost cross over point is.

We are looking for cost effective reasons, does the JANTX part really pay for itself, or should we buy a couple of levels down, do our own screening and see if that isn't the most cost effective way to put the semi-conductor into military equipment.

If you think the problem is bad, Figure 20 just says you haven't seen anything yet. Because when you go to the outer circle, which is the '80's, what you are going to find out is that in the past, the outlook for the semi-conductor industry was market emphasis and then sales were sort of the thing they were interested in but in the '80's you are going to find that profitability is the only thing industrial sources are interested in.

As foreign companies come in and take over the semi-conductor houses (I will make you a prediction that within 10 years there will be no semi-conductor house in the United States that isn't owned by a foreign interest) and buy up this industry what they are going to be interested in is only word, "profitability." And you are going to have a devil of a time knowing what you have got and believing what you got unless you have some way of screening your own parts.

Figure 21 shows there is a lot going on in the semi-conductor world that I think is good. What I have said is a bad picture, but actually any place we have seen the Japanese take over the semi-conductor industry and work with the semi-conductor world, what we find immediately is the part type quality goes up.

There are all kinds of laws saying don't buy overseas, don't buy offshore, all of this kind of stuff, but it is primarily nonsense because in actual fact the Japanese build a better device. And the reason they do is because they spend more money in the design process.

You know, our manufacturers have known for years that the quality of the device would go up if they just spend more money on the masking process, just for example. They spend over twice the amount of money we do for masking their devices and, of course, they get a better device when they mask it.

So if you look into the process what you find is that the Japanese are really moving and you can look at the curve and see that. The reason is they have understood what it is that they are looking for that makes real profitability; a dependable device.

Figure 22 is a little parts story. The other part of it is workmanship. We have recognized that workmanship also is a problem, loose wires, improper manufacturing procedures, et cetera. So we instituted about a year ago, a year time frame, we instituted this screening program which is really just a matter of known literature that we put into a document. We used it on the Apollo program. It has been used in space programs and probably is nothing new to you all.

But the point is, we said, hey on all of our equipment from now on we want to see random vibration, 6G, no less than 10 minutes, no more than maybe 20 minutes, but somewhere in that time frame. And we said we also want to see thermal cycling and we want to see that thermal cycling is a function of complexity and there is a family of curves in this book that shows it. We have given this book to all of our industry and particularly the corporate people because what we want them to understand is that, it decreases corporate costs.

If you can understand what it is in your manufacturing cycle that is giving you trouble, then you can correct it and you can build the product better and better at a cheaper and cheaper cost.

So this document was sent out to the industry. It has very good response. We are now thinking about turning this into a NAVMAT publication, or maybe even a mil-standard, or I don't know what to do with it exactly. But at any rate, it has served its purpose in industry now. It has called attention to the fact that if you really want to improve your profitability of your company, as well as delivering more reliable equipment, you must do some type of manufacturing screening and that is the screen we picked that came mostly out of NASA literature and if you have seen it I am sure you are familiar with it. That is working well for us.

Between the emphasis on semi-conductors, rescreening, between doing this kind of manufacturing screening, we are seeing equipments now go out into the fleet that are sometimes two, three, and as much as five times greater MTBF then we have ever seen before and this is because we put the focus on design and manufacturing and I think that is the point I really want to make with you.

Don't play mathematical games. Don't get involved with E to the minus Lambda t. Those are interesting things and I am sure they have some design predictive nature, but look at the part that is really important in this whole equation and that is understanding the stress in your design and being able to build it to print.

If you can guarantee yourselves those two areas are under control, you will be building precision time equipment that just will be very dependable. And, after all, that is really what we are looking for is dependable equipment.

Figure 23 just says we haven't made quite the progress with the transition in manufacturing as we have with the transition in design, but this is because we got on it a little bit later, we got on it in the late '70 time frame recognizing these kinds of problems. There is still very little green (G) on the chart and I guess the main message in that building to print is very, very, difficult and we are working very hard to get industry standards set such that we all can have a baseline for manufacturing that we understand.

What we see is a great deal of volatility in the manufacturing process. Some companies do it one way, some companies do it another way and nobody really knows why they do it either way.

So what we are doing now is setting a family of standards for manufacturing that we are going to send out very shortly and we are going to say, now this is what we expect you to do as a minimum; if you want to do any more than that, fine. But we feel by doing that we can set a baseline in this manufacturing where we come closer to building to print within the economics of the design. So that is really what we are looking towards.

Let me just say to you in closing that, this has been a very fascinating area for me in the military. Coming from the NASA Apollo program, I really didn't think there was an achievement that I could make that could really top putting men on the moon and bringing them home.

But having been with the Navy now a number of years and working in transition with them to try to bring more reliable equipment into the fleet, try to decrease the fleet burden in terms of OMN costs, what we found is what I think is a very exciting program.

I think the Navy in the next few years will be routinely delivering reliable equipment to their fleet. It will be equipment that just like the INS system for the F-18, it will have five to nine times more reliability in it than we have ever seen in the past and we will be doing it for less dollars. That is very important. We will be doing it for less dollars.

As the inflation goes up, we just have to do more and more with less and less dollars. And by resorting more and more to the analytical understanding of reliability, rather than to the testing understanding of reliability, we find the economics that we are really looking for in this whole business.

I think the Navy is making great strides in this. As a matter of fact, I think the Air Force is moving along with it. We have spent a great deal of time with Al Slay on this matter and I think you are going to see the FSC Command begin to be very much engaged in this business. It is really quite exciting.

The thing that you will have to keep in mind is that it is very fragile. Until we can get it down to where it has some solid base under it, it is fragile. We have had programs that were doing well, we left them alone for about a year, came back and they weren't doing too well. We found that various disciplines had been dropped. The emphasis hadn't been carried through. So what we found is that right now, at least, we just can't drop any program. We have to keep them all under our visibility in order to keep them moving because they are a little fragile.

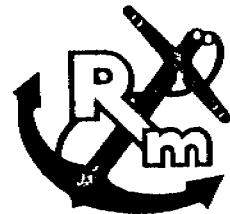
But I think as time goes by we will see it harden more and more and we will find less of this fragile business. So that is the main message I have and thank you very much.



30

DESIGN AND MANUFACTURING WHAT THEY MEAN TO FLEET READINESS

Figure 1



THE RELIABILITY MANDATE

31

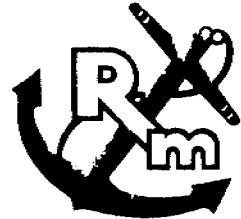
NAVAIR

NAVELEX

NAVSEA

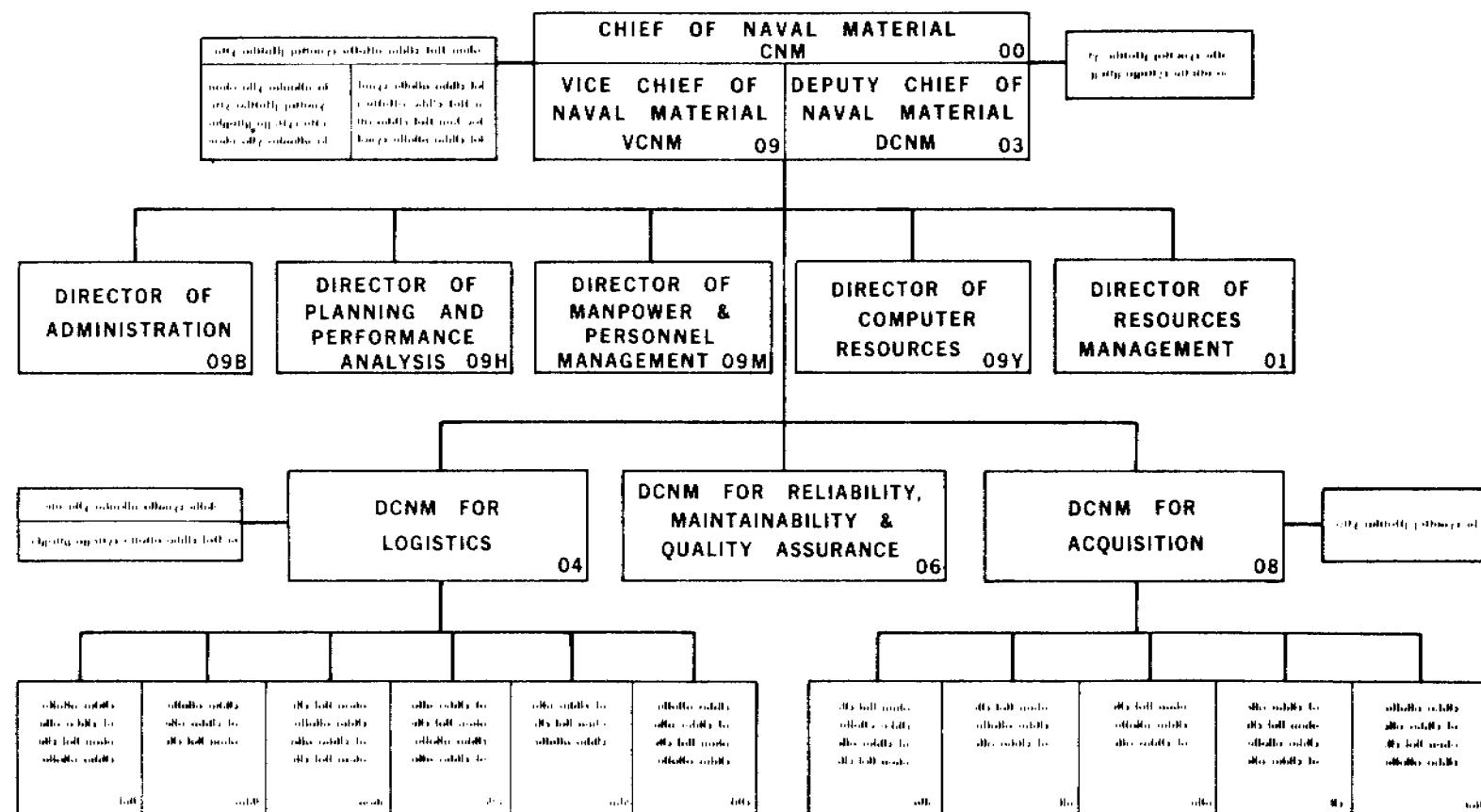
NAVAL MATERIAL COMMAND — NAVMAT

Figure 2



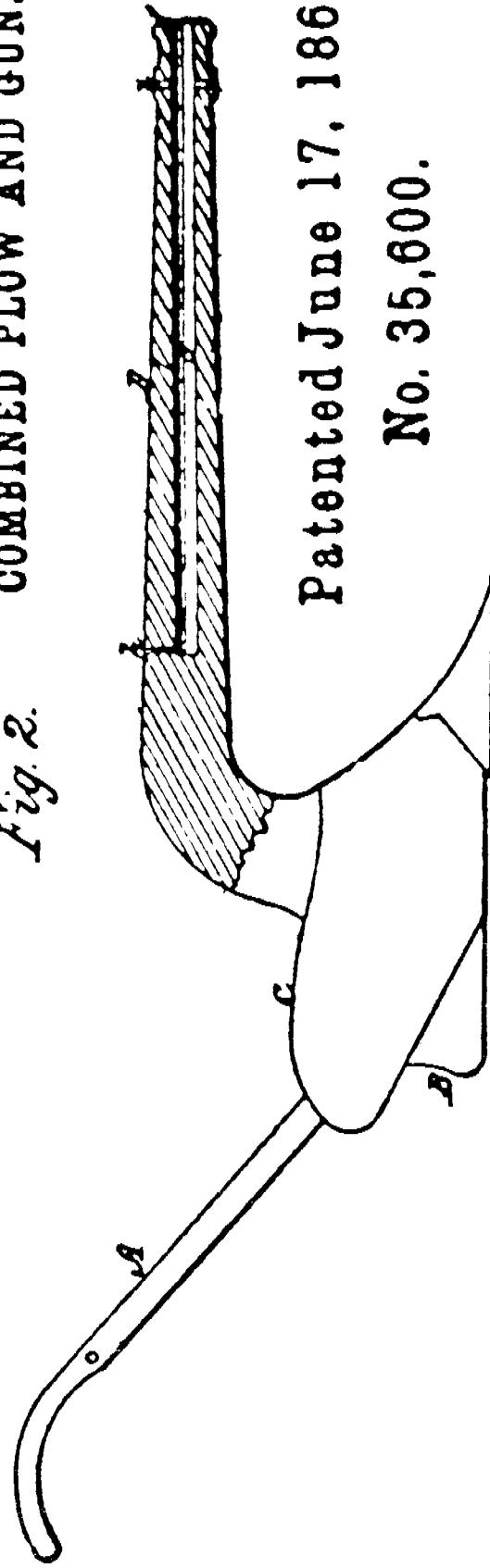
ORGANIZATIONAL STRATEGY 1980

HEADQUARTERS NAVAL MATERIAL COMMAND



PR
m

Fig. 2. COMBINED PLOW AND GUN.

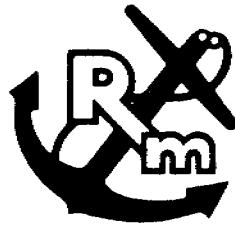


33

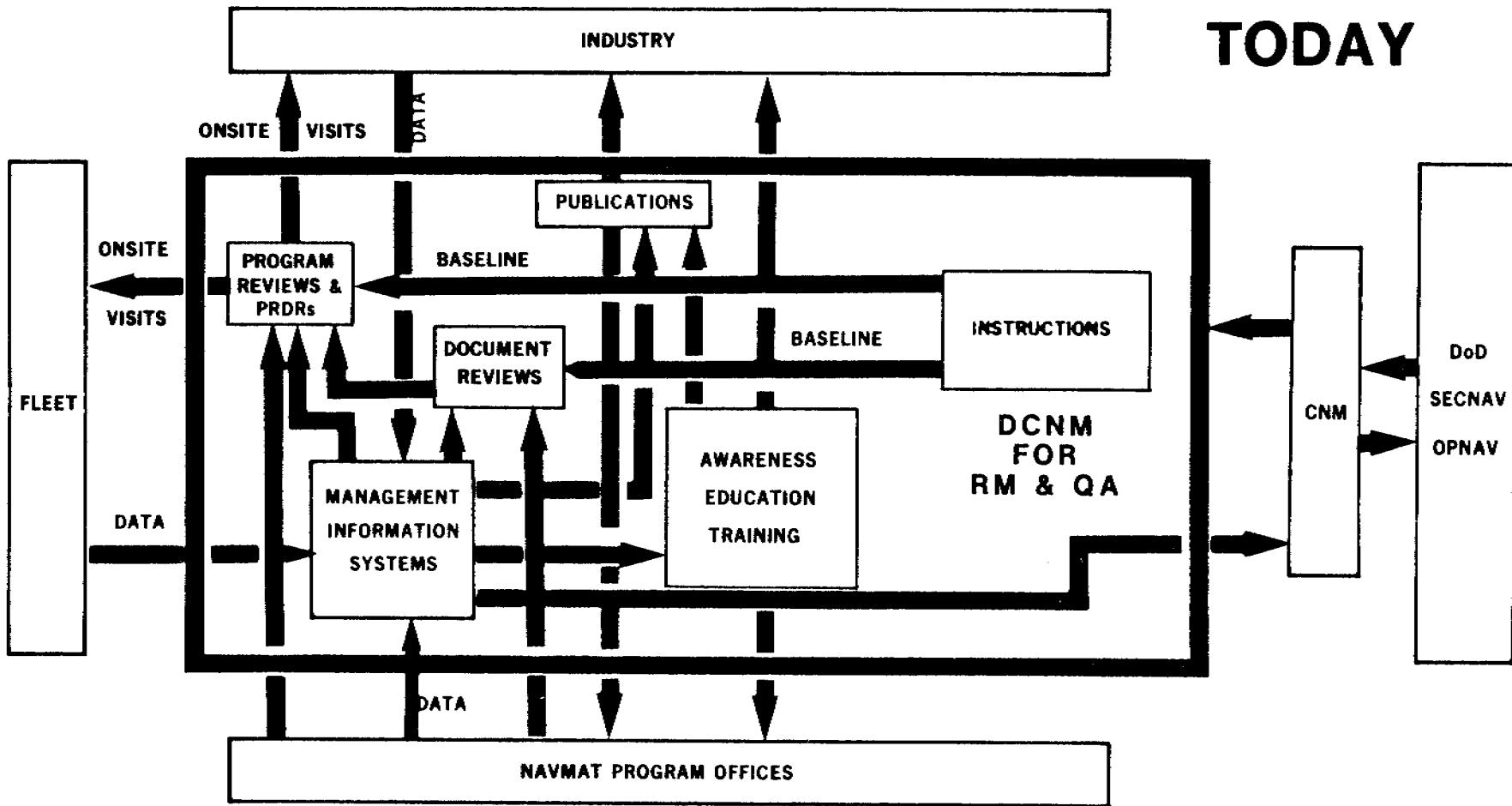
Patented June 17, 1862
No. 35,600.

MOTIVATION

Figure 4



MAJOR ORGANIZATION FUNCTIONS AND INTERFACES



- NEW OBJECTIVES UNDERSTOOD -- NEED FOR POLICING DIMINISHING
- INITIATED INSTRUCTIONS, MANAGEMENT INFOSYSTEM, AWARENESS PUBLICATIONS
- INITIATED PRE-PRODUCTION RELIABILITY DESIGN REVIEWS

Figure 5

~~R^m~~

GAME OF RANDOM NINES

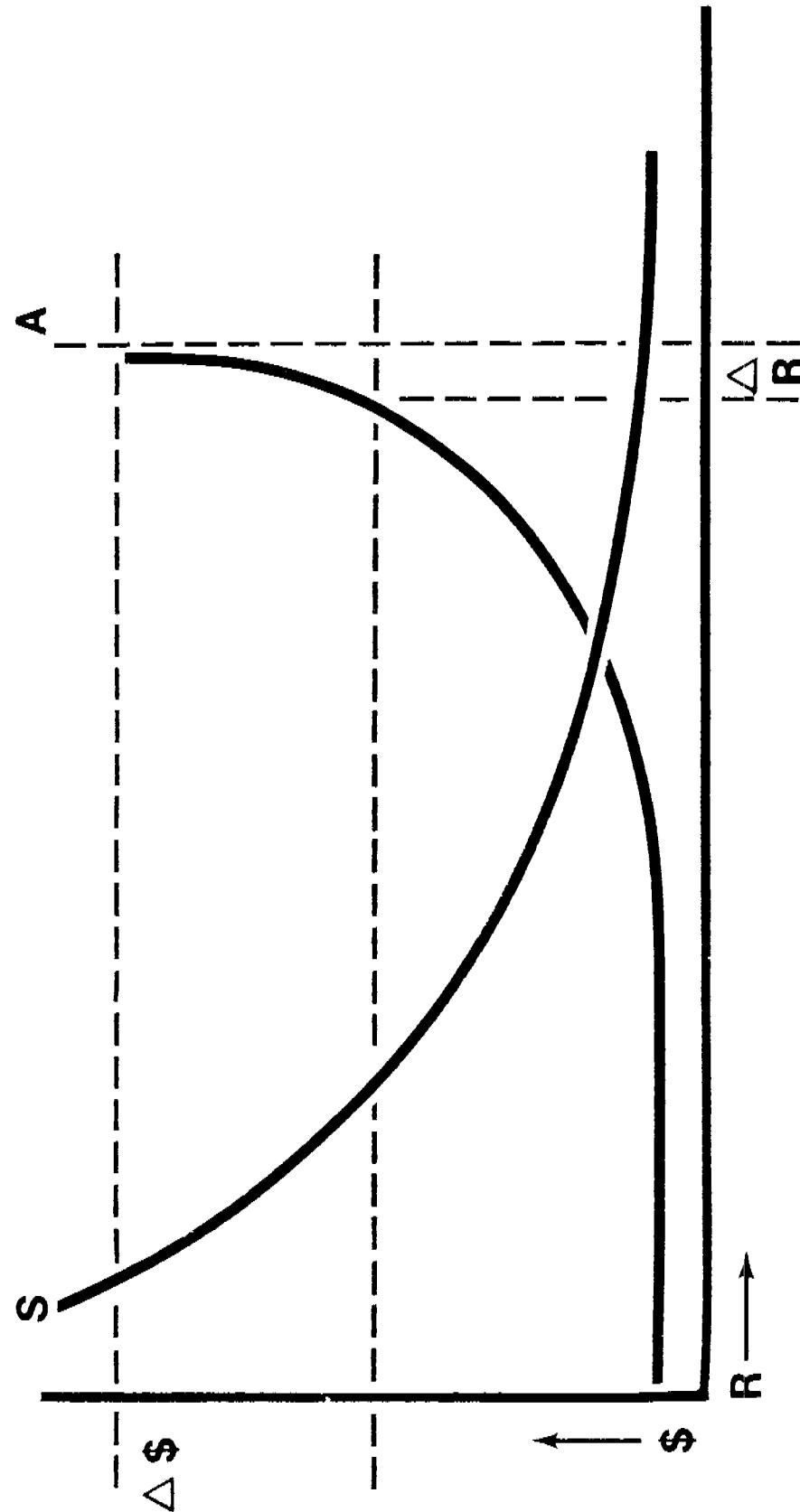


Figure 6

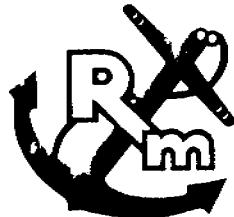


MATERIAL ACQUISITION FUNDAMENTALS

96

- MISSION PROFILE DEFINITION
- STRESS ANALYSIS
- DERATING CRITERIA
- WORST CASE ANALYSIS
- SNEAK CIRCUIT ANALYSIS
- PREDICTION/ALLOCATIONS
- FAILURE MODES & EFFECTS ANALYSIS
- TEST, ANALYZE, & FIX WITH CLOSED LOOP REPORTING
- DESIGN REVIEWS
- MISSION PROFILE QUALIFICATION TEST

Figure 7



JUNCTION TEMPERATURE IMPACT ON SEMICONDUCTOR RELIABILITY

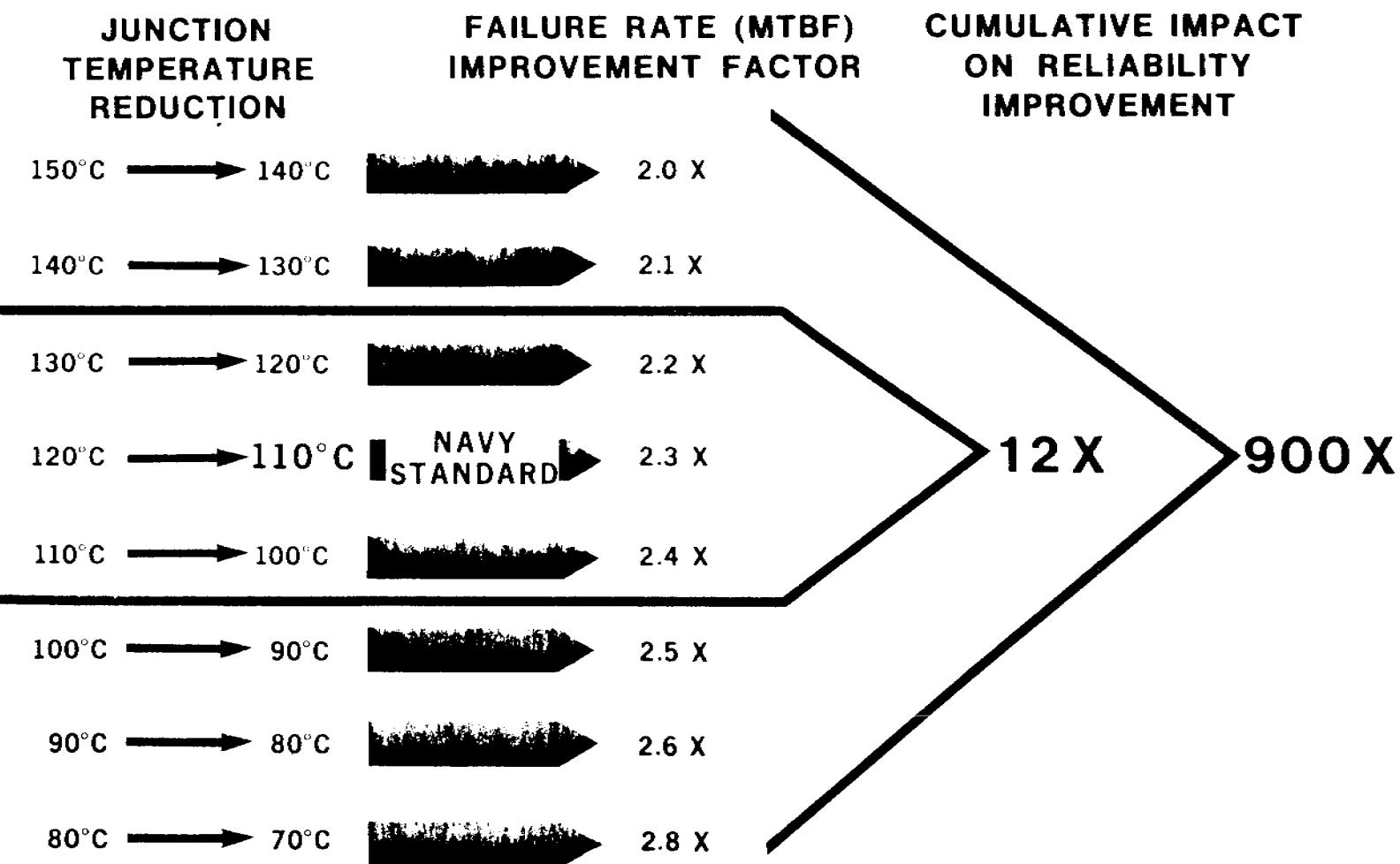


Figure 8



OPERATING TEMPERATURE IMPACT

IMPACT OF OPERATING TEMPERATURE ON ANNUAL OPERATING COST AND MTBF
(BASED ON 200 AIRCRAFT)

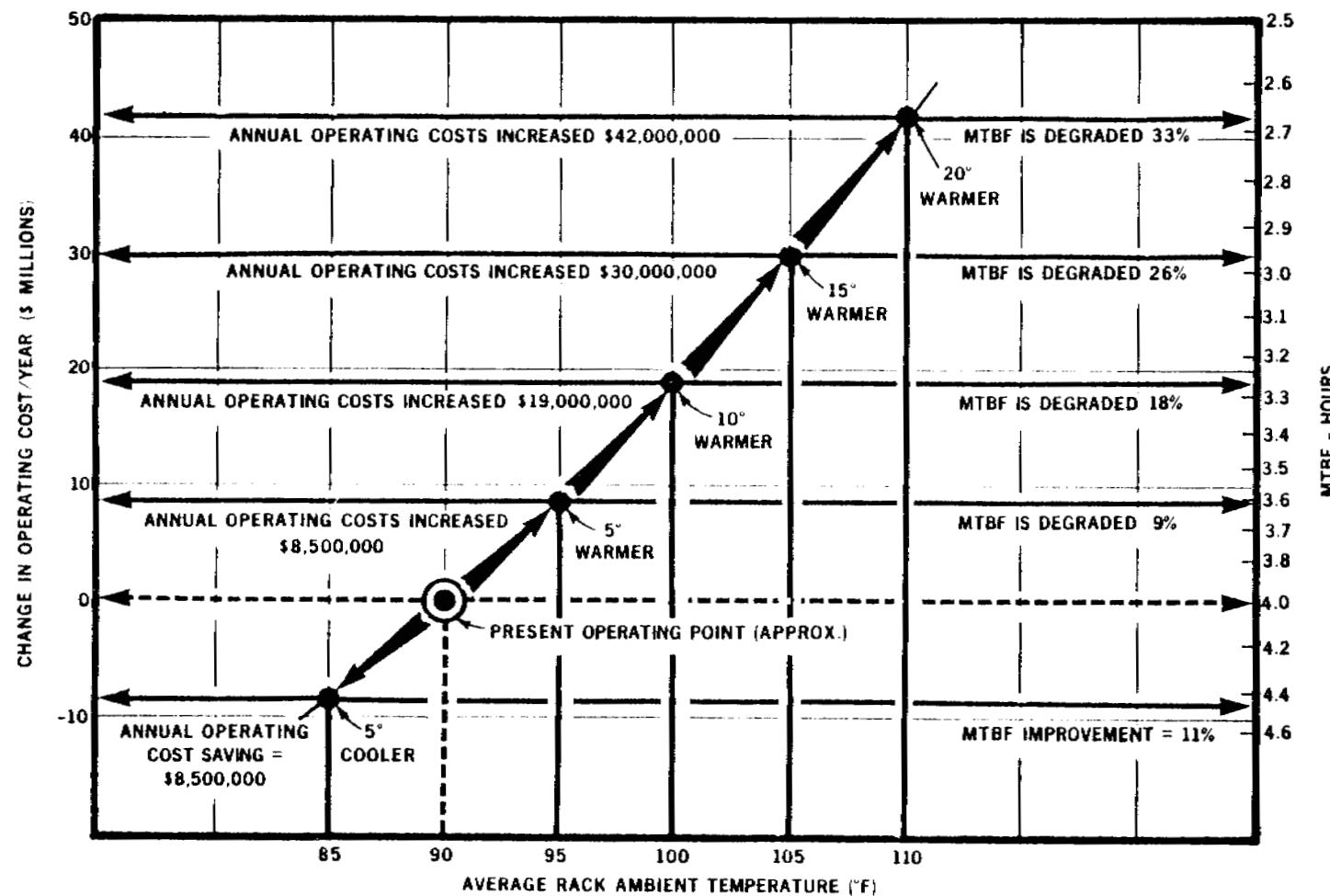


Figure 9



AN/UY-1 ANALYZER UNIT RELIABILITY PERFORMANCE IN SERVICE USE

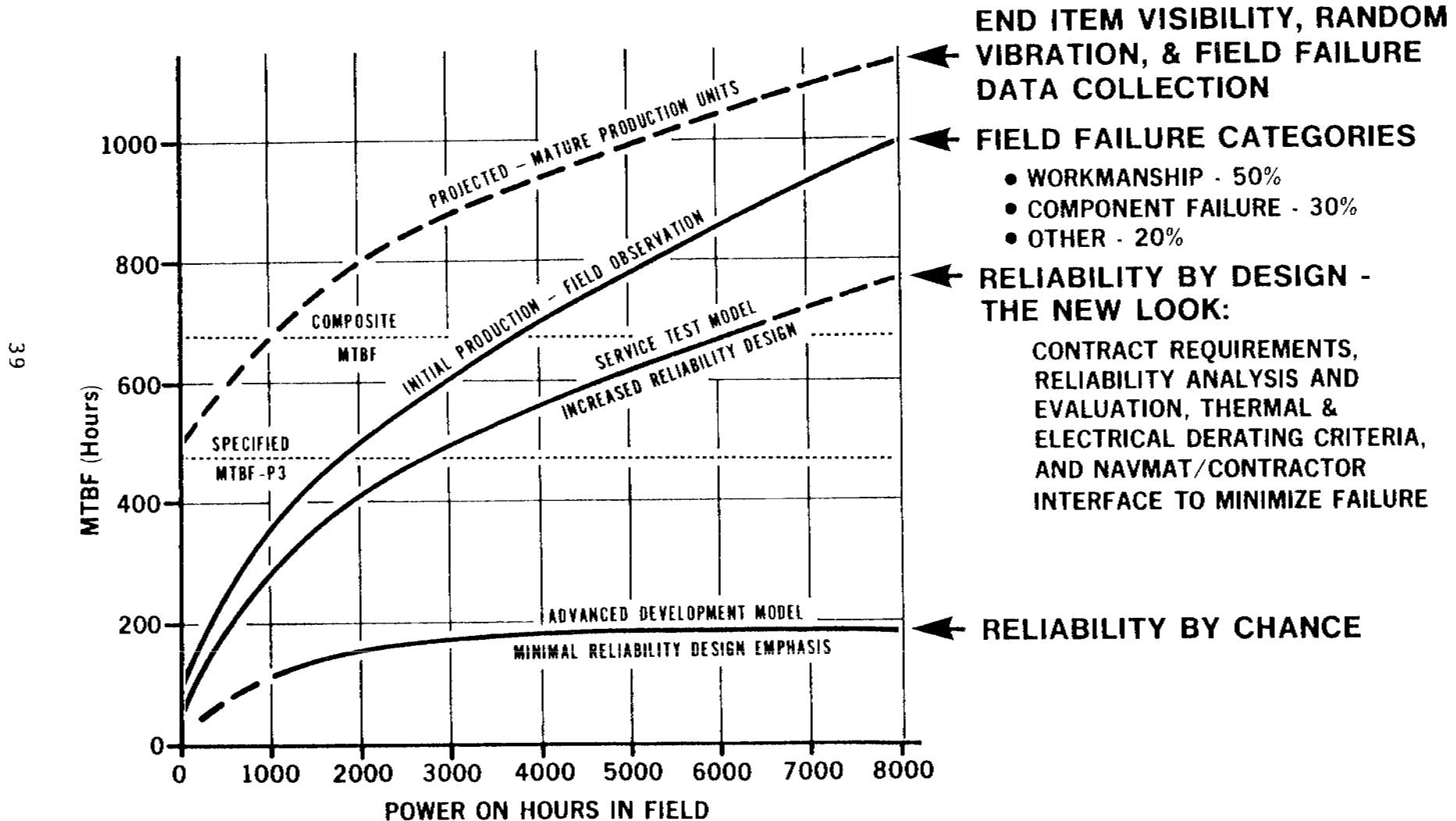
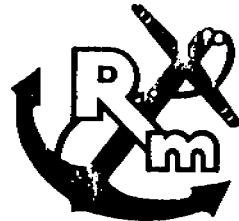
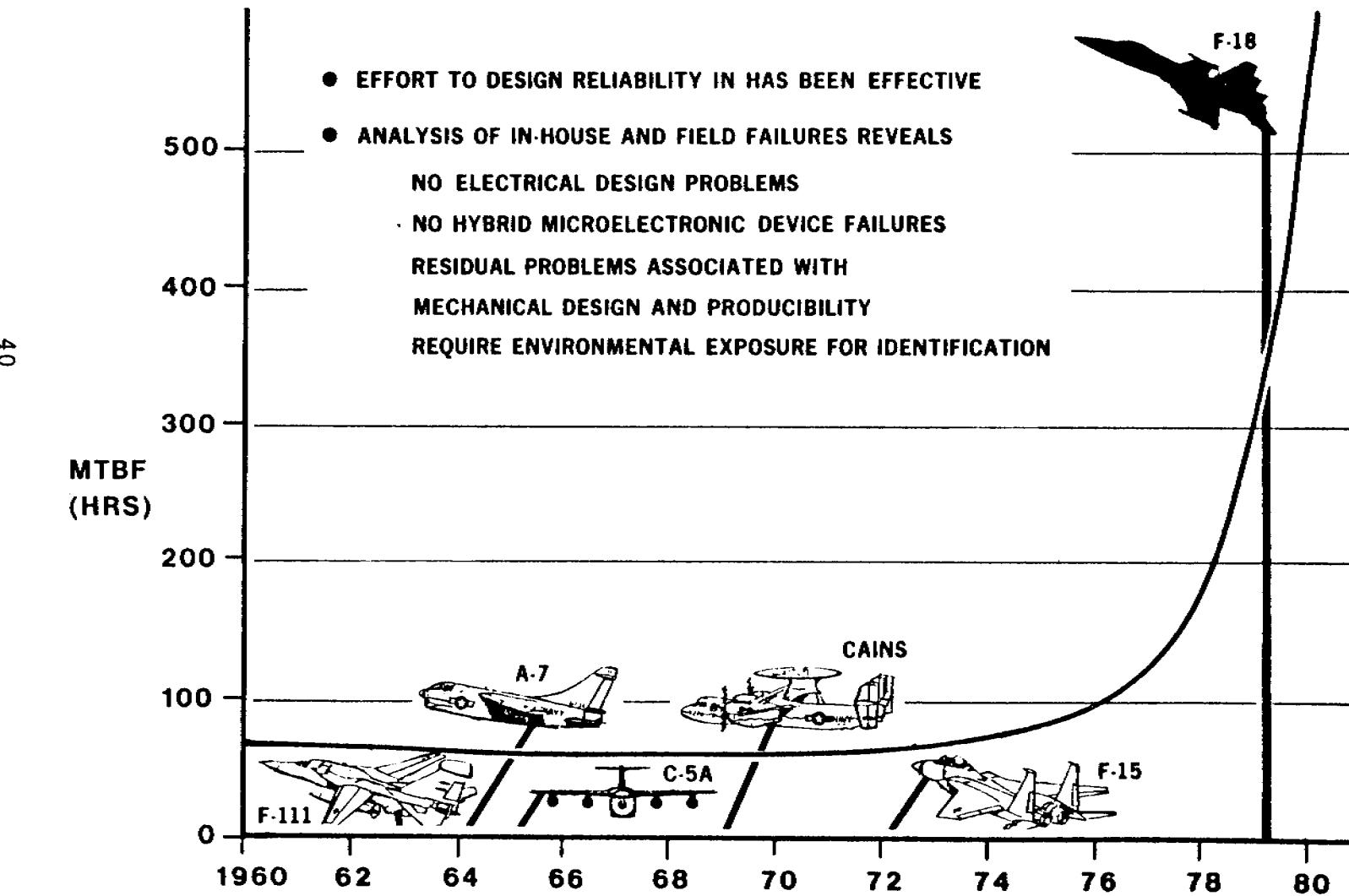


Figure 10



F-18 INS DESIGN EXPERIENCE





INDUSTRY IN TRANSITION DESIGN

R 1975

G 1985

REPRESENTATIVE CONTRACTORS

	1	2	3	4	5	6	7	8	9	10
POLICY IMPORTANCE OF DESIGNING RELIABLE EQUIPMENT REFLECTED IN CORPORATE STATEMENTS	Y	G	G	Y	G	G	G	G	R	G
ATTITUDES RECOGNIZES THE NEED TO IMPROVE RELIABILITY DESIGN EFFORTS	G	G	G	G	G	G	G	G	G	G
AWARENESS RECOGNIZES THE IMPORTANCE OF DESIGNING IN RELIABILITY	R	G	G	G	G	G	G	G	R	G
STANDARDS FORMAL BODY OF CONSERVATIVE AND PROVEN RELIABILITY DESIGN PRACTICES	R	G	G	G	G	G	G	Y	G	G
MOTIVATION FORMAL PROGRAM FOR ACHIEVEMENT AND RECOGNITION	R	R	R	R	R	R	R	R	R	R

R ACTION REQUIRED

Y IN PROCESS

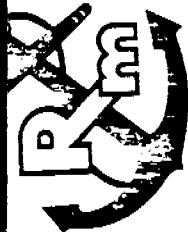
G ACHIEVED

Figure 17



MANUFACTURING

BUILD TO PRINT



MANUFACTURING END ITEM VISIBILITY

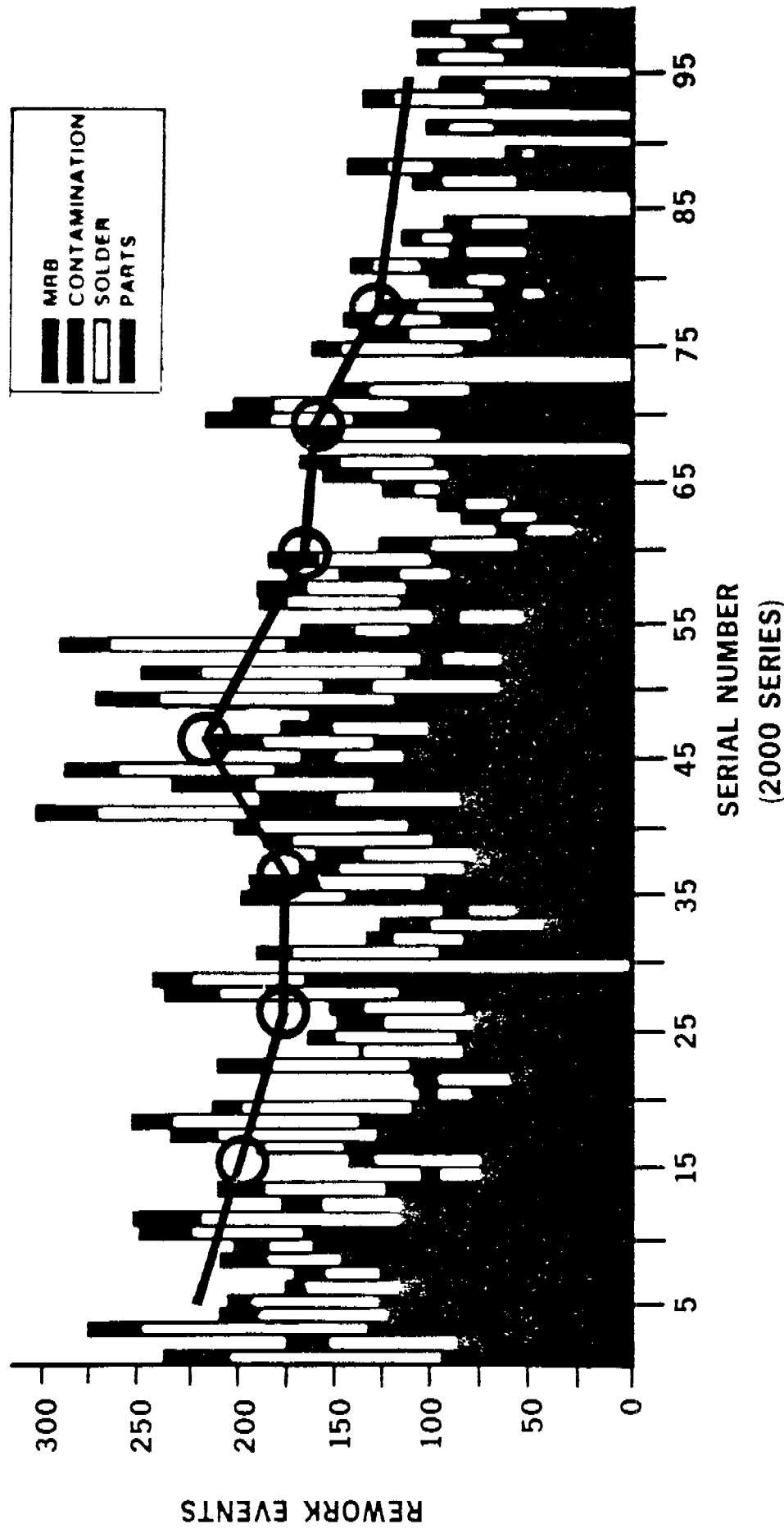


Figure 14



THE COST OF QUALITY

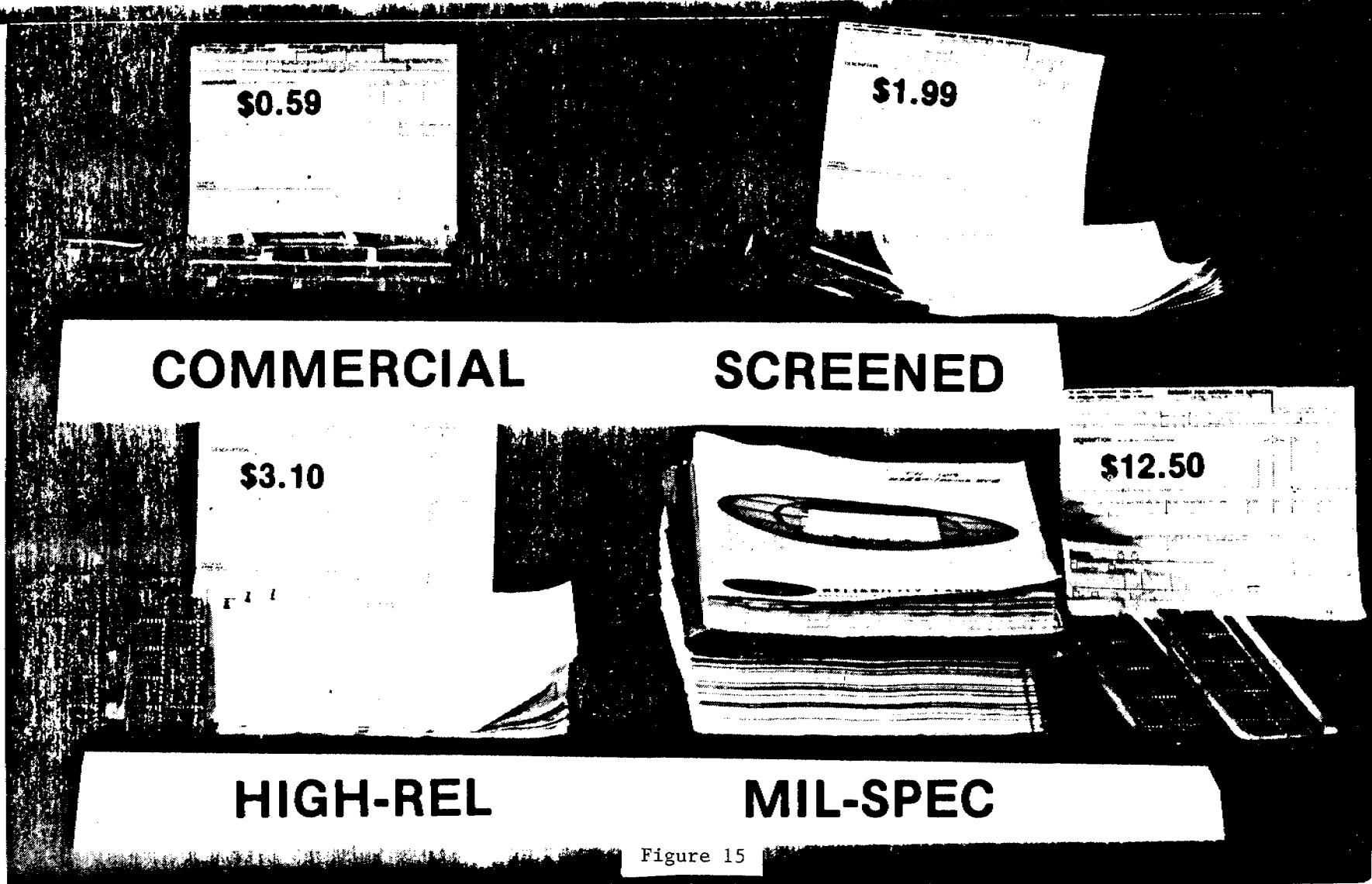


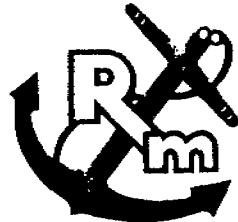
Figure 15



INTEGRATED CIRCUITS

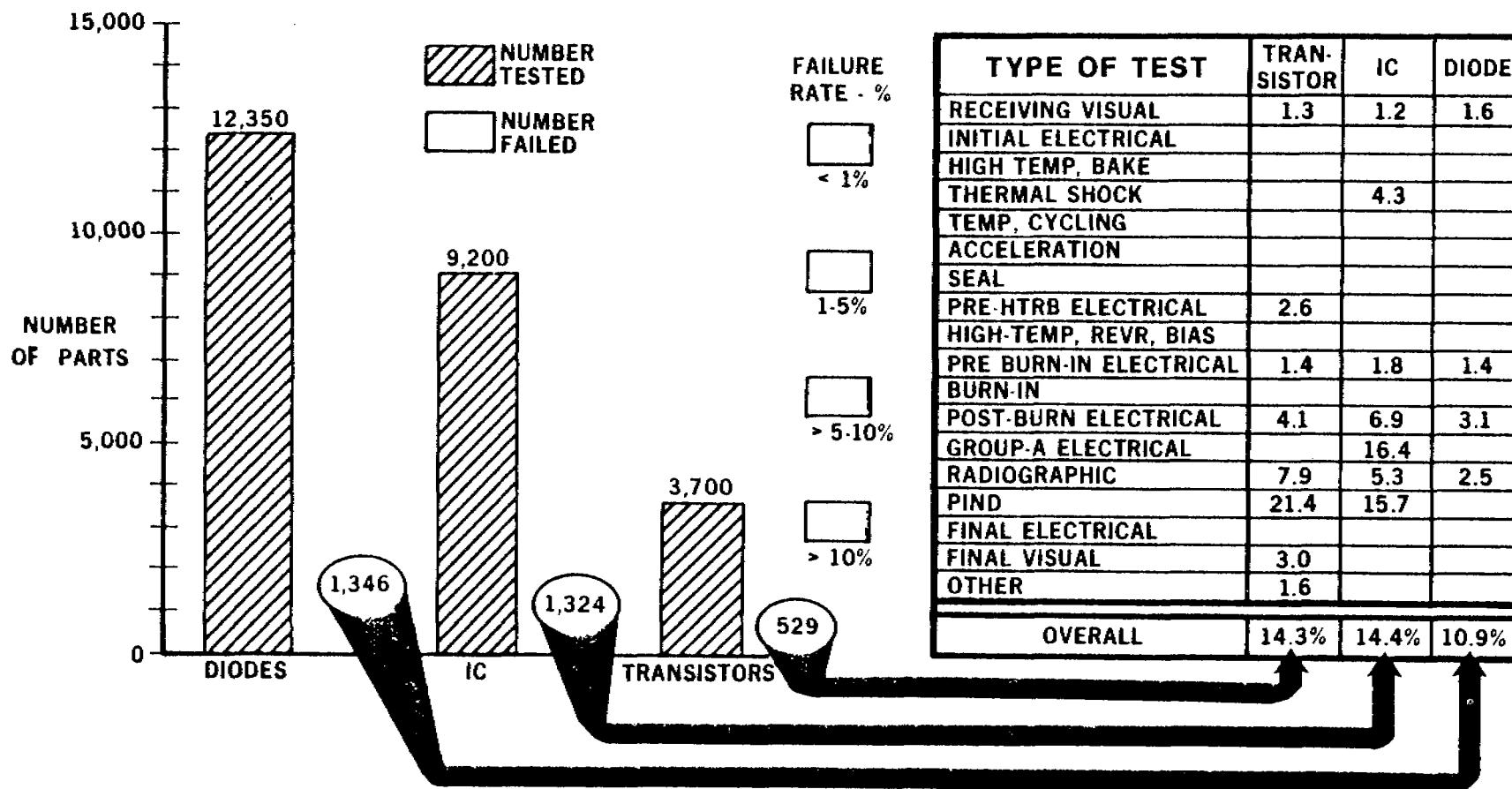
PRE-CAP VISUAL SOURCE INSPECTION RESULTS

MFG	ACCEPTED	REJECTED	% REJECTED
1	33,000	15,200	32
2	38,000	12,700	25
3	1,389	3,597	72
4	1,219	2,268	65
5	2,804	448	14
6	446	95	18



PART SCREENING RESULTS

MIL-SPEC PARTS





MANUFACTURING BURDEN

ALERT: (T3-A-79-06)

243 DEVICES OUT OF A LOT OF 425 PIECES FAILED INCOMING INSPECTION FUNCTIONAL TEST AT ROOM AMBIENT TEMPERATURE, ON SITEK 3200 TESTER. INTERNAL VISUAL (DECAP) INSPECTION REVEALED TWO DIFFERENT DIES IN PACKAGES WITH IDENTICAL JAN MARKING. FIGURE 1 SHOWS DIE FOR UNITS THAT PASSED, AND FIGURE 2 SHOWS THE DIE FOR UNITS THAT FAILED TEST.

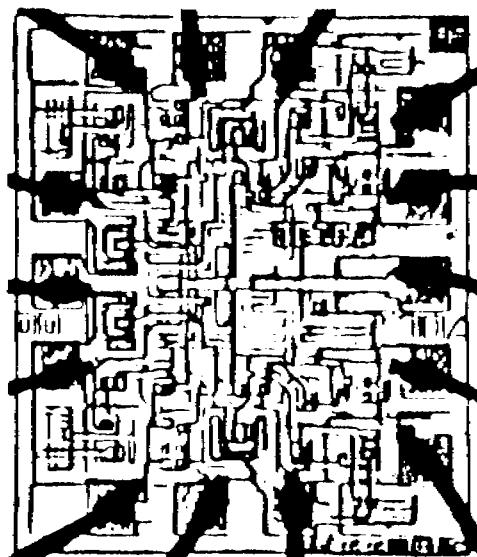


FIGURE 1 - GOOD PARTS

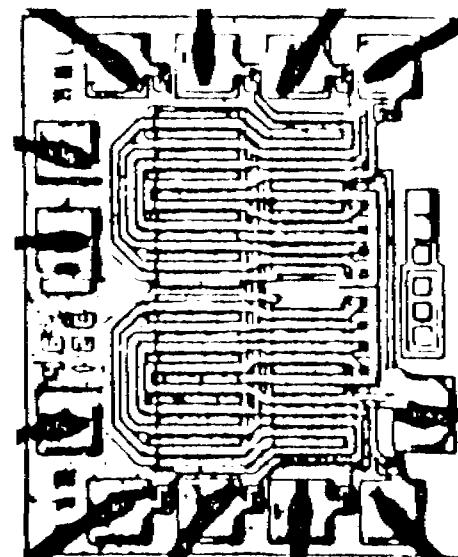


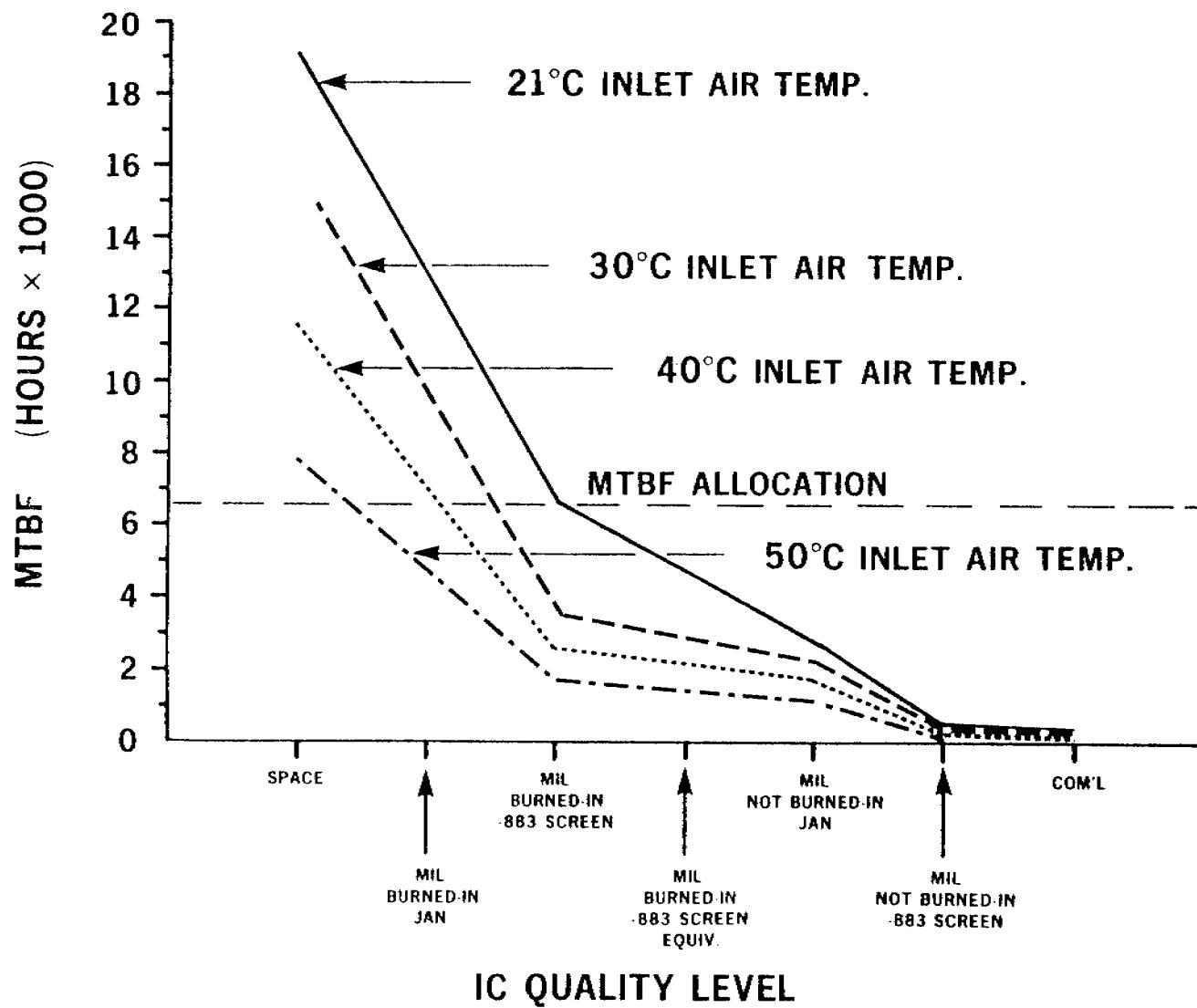
FIGURE 2 - NON-CONFORMING PARTS

MANUFACTURING RESPONSE: "THIS SITUATION OF MIXED PARTS DOES NOT CONSTITUTE A RELIABILITY PROBLEM. ALL OF THE INCORRECT DEVICES WOULD BE DETECTED AT A USER'S INCOMING TESTING OR AT BOARD LEVEL CHECKOUT."



SYSTEM RELIABILITY VS. QUALITY GRADE & TEMPERATURE

48





SEMICONDUCTOR INDUSTRY

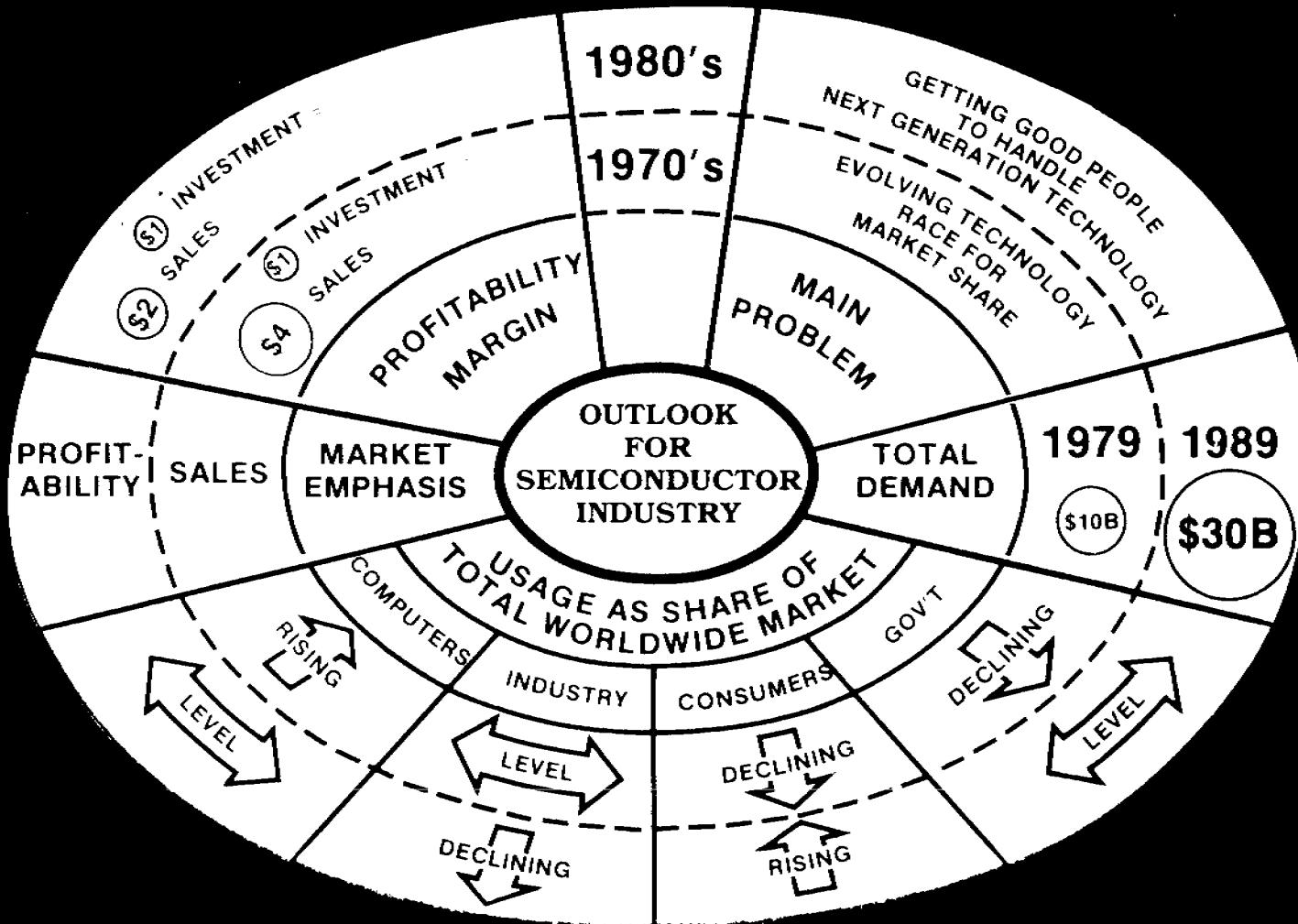


Figure 20



JAPAN'S PENCHANT FOR RELIABILITY

JAPAN PRODUCES RELIABLE SEMICONDUCTORS
BY DESIGN, NOT BY CHANCE:
DEFECT PREVENTION, NOT DEFECT DETECTION

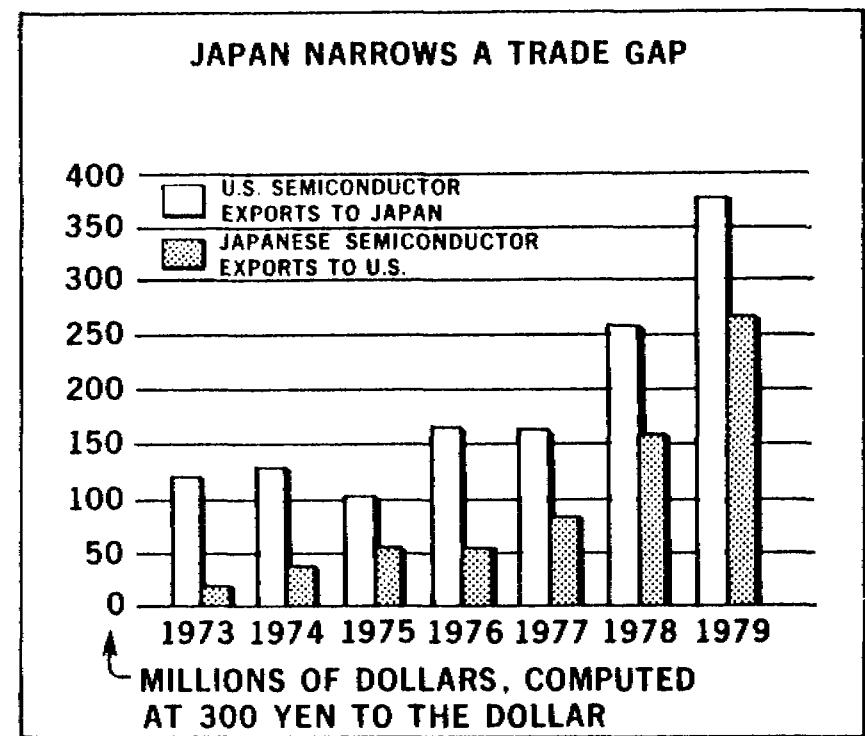
EXAMPLE: BETTER, MORE EXPENSIVE
PRODUCTION MASKS FOR CHIPS

65

RESULT: JAPANESE REJECTION RATES
ONE-HALF TO ONE-TENTH U.S. RATES

CONCLUSION: UNWILLINGNESS OF SOME
U.S. VENDORS TO PRODUCE RELIABLE
SEMICONDUCTORS IS COSTING THEM
NOT ONLY LOSS OF MILITARY BUSINESS
BUT POTENTIALLY OTHER CUSTOMERS
AS WELL

- EVIDENCE:



- SOURCE: BUSINESS WEEK, 3 DECEMBER 1979



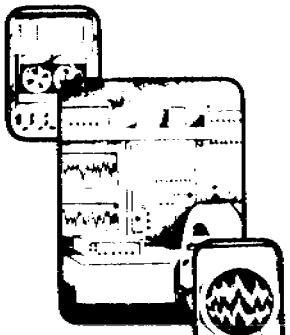
NAVY MANUFACTURING SCREENING PROGRAM (P-9492)

TS

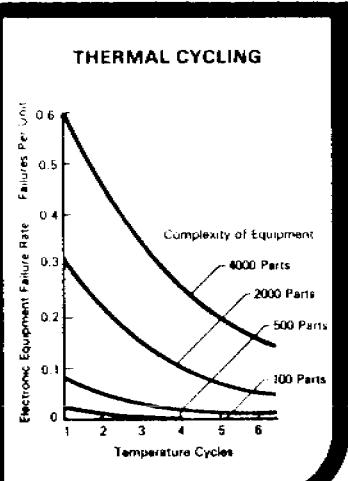
**NAVY
MANUFACTURING
SCREENING PROGRAM**

DECREASE CORPORATE COSTS
INCREASE FLEET READINESS

RANDOM VIBRATION



THERMAL CYCLING



Temperature Cycles	100 Parts	500 Parts	1000 Parts	2000 Parts	4000 Parts
1	0.6	0.5	0.4	0.3	0.2
2	0.3	0.2	0.15	0.1	0.05
3	0.15	0.1	0.05	0.02	0.01
4	0.08	0.04	0.02	0.01	0.005
5	0.04	0.02	0.01	0.005	0.002
6	0.02	0.01	0.005	0.002	0.001

NAVMAT P-9492



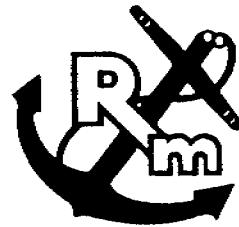
- NAVMAT PUBLISHED P-9492 AND DISTRIBUTED TO 83 TOP CORPORATE OFFICIALS (CHAIRMEN OF BOARDS THROUGH DIVISION VICE PRESIDENTS)
- RESPONSES ENDORSE P-9492 THRUST ENTHUSIASTICALLY
- SOME CONTRACTORS HAVE ALREADY BEEN USING P-9492 TYPE SCREENING AT THEIR OWN EXPENSE BECAUSE OF ITS OVERALL COST IMPROVEMENT

- OTHERS PROPOSE TO SCHEDULE ONTO EXISTING TEST EQUIPMENT, SINCE TEST TIME SO SHORT, IF CONTRACTS REQUIRE
- RESPONSES INDICATE EVEN MORE STRINGENT TESTING OF LATEST COMPLEX ELECTRONIC SYSTEMS, AND TESTING AT LOWER LEVELS OF ASSEMBLY SHOULD BE REQUIRED
- GENUINELY COOPERATIVE, CONSTRUCTIVE RAPPORT DEVELOPING BETWEEN NAVMAT AND INDUSTRY WITH REGARD TO NEED FOR MANUFACTURING IMPROVEMENT

DEPARTMENT OF THE NAVY

MAY 1978

Figure 22



INDUSTRY IN TRANSITION MANUFACTURING

R 1975

1985

G

REPRESENTATIVE CONTRACTORS

	1	2	3	4	5	6	7	8	9	10
POLICY CORPORATE STATEMENT THAT MANUFACTURING QUALITY IS OF PRIME IMPORTANCE	R	R	R	R	R	R	R	R	R	R
ATTITUDES SELF-DISCIPLINE SHOWN IN QUALITY OF MANUFACTURING OPERATIONS	R	Y	R	Y	G	Y	Y	Y	R	G
AWARENESS RELIABILITY IN MANUFACTURING IS 'BUILDING TO PRINT'	G	G	Y	Y	Y	Y	Y	Y	Y	G
STANDARDS MANUFACTURING PRACTICES REFLECT DISCIPLINED QUALITY APPROACH	R	Y	R	Y	G	Y	R	Y	R	G
MOTIVATION FORMAL PROGRAM FOR ACHIEVEMENT AND RECOGNITION	R	R	R	R	R	R	R	R	R	R

R ACTION REQUIRED

Y IN PROCESS

G ACHIEVED

QUESTIONS AND ANSWERS

DR. WINKLER:

Thank you very much for a most interesting and challenging presentation. Let me add to your quote of Patton. I don't think you can put screws in the General ever.

And that is what it amounts to in some of these things. Well, if gear is to be there, then of course it is up to us to insist on quality.

There is one thing I wanted to ask you, however, and that is your comment about military systems reliability in general is not required to be so very great.

I would suggest that there are cases such as for instance in our case in precise timing in which we provide a commodity, precision timing, on which many operations depend. That in this case I think you have to insist on much higher reliability. The reliabilities that we are talking about in timing equipment is on the order of 20 to 50,000 hours MTBF. In this case we have an entirely different proposition. It has become uneconomical, for instance, to have maintenance people trained in some equipment because they will never see equipment fail. Or if it fails you will never have one experienced man around.

But it was certainly an extremely challenging and interesting speech. I wish we could all read it after it has become available in printed form, at least once a month on a Monday morning.

Do we have any questions?

DR. MCCOUBREY:

I wonder if values of parameters, such as junction temperature, are included in procurement specifications now?

MR. WILLOUGHBY:

You mean in ours or in yours?

DR. MCCOUBREY:

In the Navy procurement.

MR. WILLOUGHBY:

That list of what we call fundamentals up there goes into most of the Navy procurements now and we set 110 degrees as the max temperature that we will accept.

Now, I won't lie to you and say that we have accepted any temperatures with more than 110. We do, on an engineering basis, make some exceptions to that. But it is with judgement and consideration that we allow that temperature to go more than 110 degrees, which is the important point.

We know the risks we are taking and then we will let it go higher. But we are finding that we have to make less and less of those judgements.

Early in the program we had a lot of people asking for exceptions on the 110 degree. Now we find almost nobody asking for it. As a matter of fact, as I said, we are running more like 90 to 100.

It has been put into standard specs, which I think is important.

MR. RUEGER, The Johns Hopkins University, Applied Physics Laboratory

I understand that when reliability gets to a high enough number the Navy has a philosophy about not buying spare parts. Then when a failure occurs there is a long recovery cycle to get the instrument back in service.

MR. WILLOUGHBY:

Yes. You have hit on part of a problem. It has to do with mathematics once again. The Navy, in terms of sparing its equipment, uses algorithms as to certain numbers of times that the equipment has to be worked on during a years time, or during six months time. And there is a very flukey little algorithm that they use that does quantify exactly what you said.

And as the MTBF goes up, what they will do, if you follow this algorithm, you will find yourself with less and less spare parts.

See, what this has caused to happen, I will get into in just a minute. But what this has caused to happen, we have doubled, tripled and quadrupled the reliability of some equipments only to find that it is the most unavailable in the fleet in terms of availability.

The reason is from the way the sparing system is put together. We ran into an anomaly in the sparing system. That is what it amounts to. It is a logistics world. But the logistics community

is now re-looking the way they provision equipment because what they were doing was shooting themselves in the head with this particular algorithm.

And it is just simply said, significance of failure has nothing to do with it. It is only quantity. For instance, we had one piece of equipment we tripled the reliability on and the availability of the equipment went down to a mean time to repair of 13 months because they didn't even order a spare transformer for it. They had to order one at the first failure of a transformer and have it wound.

But that is a problem that is very unique to the military and let's hope nobody else does dumb things like that.

