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Tin Whiskers – A Long Term RoHS Reliability Problem

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Tin whiskers grow in the absence of lead in solder and pose a serious reliability risk to electronic assemblies. Tin whiskers have caused system failures in earth and space-based applications as well as missile systems. At least three tin whisker-induced short circuits resulted in complete failure of in-orbit commercial satellites.

Ignorance of the Problem

"It's not what you don't know; it's the things you know, that are not so, that really get you."

Ignorance of the scope and of the seriousness of the tin whiskering problem is the simple, sad answer as to why it took the NASA Goddard Space Flight Center (GFSC) until the 1990's to act on what Bell Labs had clearly published in the 1950's and '60's.

GFSC scientist Dr. Henning Leidecker stated that "We were taught the seriousness of this problem by a contractor in 1998, and have continued learning about it since then, and have been sharing what we have collected and otherwise learned."

Here is a partial listing of "Publicly" Reported Whisker Failures listed at GFSC's website on tin whiskers (http://nepp.nasa.gov/WHISKER/).

1942-43 - Aircraft Radio Corporation Electrical Problems - The first recognition of electrical problems caused by metal whiskering appears to have happened in 1942-43 in aircraft radios made by Aircraft Radio Corporation in Boonton, New Jersey.

Air-spaced variable capacitors were cadmium plated to retard corrosion, and the cadmium plating whiskered, and these whiskers dropped the Q of the tuned circuits to unusable low values. This company's radios included those used to land under conditions of zero visibility. How many died as a result of these whiskers? As this was during the war, perhaps there were reports, classified at the time, and now perhaps declassified since more than 50 years have passed, but NASA has not found them. There is an article "Cadmium Whiskers" from a paper by Howard L. Cobb, Branch Librarian of the Aircraft Radio Corporation, in The Monthly Review of the American Electroplaters' Society (January 1946, volume 28). The beginning of this article says about the same things as all the following articles.

The growth of needle-like crystals on cadmium deposits has caused considerable annoyance in the radio industry. These crystals are known as "whiskers". They grow between condenser plates of variable condensers, and, being electrical conductors, actually short circuit the plates, thereby putting the radio set out of operation.

Not much is known about the cause of the growth of these crystals, and a moderate search of pertinent literature reveals very little. In the paper, figure 2 shows cadmium whiskers growing "between ten-year old condenser plates": which would date to ~1936. The plate gap is 80 mils (2.0 mm), and these plates could have started shorting within one to three years of being plated, say 1937--9. (Cobb does not hint at when problems caused by whiskers were noticed, or in what specific radios.) It seems to have taken the special circumstances of WWII to identify a systematic problem, and the cause of this problem. This adventure is documented in "Filamentary Growths On Metal Surfaces --- Whiskers" by K. G. Compton, A. Mendizza, and S. M. Arnold, a paper presented at the Seventh Annual Conference and Exhibition of the National Association of Corrosion Engineers, New York, N.Y., 13 -- 16 March 1951. The abstract includes:

... The growths are of the same character as those known as "whiskers" and which developed between the leaves of cadmium plated variable air condensers, causing considerable trouble in military equipment during the early part of World War II.
... one thousand test specimens of different metals...

1946 – American Electroplaters' Society, The Monthly Review

1951 – Conference of the National Association of Corrosion Engineers

1956 – Convention of American Electroplaters Society S. M. Arnold (Technical Proceedings of the 43rd Annual Convention of American Electroplaters Society, p. 26 (1956)):

That the growth of whiskers is not a new phenomenon may be concluded from the examination of undisturbed old equipment. For example, a number of zinc plated details installed in a telephone central office in 1912 were recently removed for study. Surfaces which had been protected from cleaning operations and from excessive air circulation had numerous whiskers present. The Introduction states that Bell Labs learned during the early part of 1948 that "channel filters", used in carrier telephone systems, were failing, and that Bell eventually traced the problem to whiskers growing from zinc plated steel. (Note: not tin plating was the cause in this case).

This article mentions the high degree of difficulty in identifying the cause of the shorting: in some cases, the whisker that caused the short disappeared, and the fault could not be reproduced in the lab. Even when the whisker was still present and shorting, its diameter is less than that of a human hair, and can easily escape attention, even to a careful inspector. But they were good, and eventually "nailed" this problem. Bell carried out a research program, alloying tin with each member of the periodic table that they could figure out how to get into a plating bath. In the mid-1950's, they showed that the addition of 1% to 5% lead to plated tin quenched whiskering.

Other studies showed that as little as 0.5% lead was effective. And these have been repeated with the same findings. Since many plating shops do not hit the target of lead concentration with high precision, specifications often call for 2% or even 3%, in order to increase confidence that one will get at least 0.5%.

• 1974 – 20 Years of Observation – Trans. Inst. Of Metal Finishing
• 1986 – Pacemaker FDA Class 1 Recall - Total Failure Crystal Oscillator Short
• 1989 – Phoenix Air-to-Air Missile Failures
• 1991 – Raytheon Patriot Missile Intermittent Misfire Problems
• 1998 – Galaxy IV & VII (PanAmSat)
• 2002 – Northrop Grumman Relay Failures - Military Aircraft -- approximately 10 years old -- failed. Rated at 25 amps/115 Vac/3 phase
• 2005 – Millstone Unit 3 Nuclear Reactor Shutdown: Dominion Learns Big Lesson
• 2006 – Galaxy IIIR (PanAmSat)

A nuclear reactor shutdown is a particularly disturbing event. During the first 24 hours of a sudden nuclear reactor shutdown at Millstone Power Station this spring, technicians zeroing in on a computer malfunction as the culprit were stumped. One of the technicians picked up a magnifying glass and took a closer look. “They saw something different,” Reyher said, “and they asked themselves, ‘What can this be? A piece of solder? Something’s there. Let’s take a picture.’”

Within a few hours, under a high-powered microscope, they spotted a thin filament of metal, barely visible to the naked eye, spanning the card’s surface and bridging a line of conductive material, called a trace. That metal fragment, they soon learned, had singlehandedly caused the electrical short that gave a false low-pressure reading and forced an unplanned shutdown. The tin whisker that shorted out at Millstone's Unit 3 reactor on April 17 triggered an automatic shutdown designed to protect the reactor, but that is not what worries the Nuclear Regulatory Commission. Rather it is that the tin whisker could prevent a safety system from working properly, said NRC spokesman Neil Sheehan, whose agency is responsible for overseeing safe operations in the industry.

NASA found a problem with the Space Shuttle. GSFC has rules prohibiting the use of pure tin coatings, and also zinc and cadmium coatings, but applied these universally only since the early 1990’s. Unfortunately, there were no Shuttle Program specifications prohibiting the use of (pure) tin plating on sensitive electronics. The original Shuttle Program had some rules prohibiting pure tin, but not universal rules, applying across all procurements, including fasteners used near electrical circuits. The first batch of Shuttles was made using card guides plated with leaded-tin (in 2007, these guides were examined for whiskering, and only a few whiskers were seen, and all were shorter than a few mils in length.)

The space shuttle Challenger exploded in 1986, tragically killing its crew. Congress supplied NASA with the funding for a replacement shuttle: OV-105, Endeavor.

NASA started building Endeavor in 1986, almost a decade after the first batch. And later, when OV-105 was constructed, at least one waver was granted at the request of a manufacturer. During that decade, OSHA had made it more expensive to dispose of tin plating baths that had some lead in them. The contractor that had won the bidding to make the electronics, Honeywell (Clearwater, FL) – the same group that had built the first batch of electronics – proposed to NASA that Honeywell “go green” and provide pure tin plated card guides. NASA said: “Sure, go green. Of course, the pure tin coating presents the possibility of whiskering. But that is only theoretical.”

Not words you should choose to be remembered by.

During 2006, NASA found some 100 to 300 million tin whiskers growing on these card guides. These whiskers had lengths between 0.2 mm and 25 mm. The wildly ironic thing is that these card guides are beryllium copper, and never needed any tin plating to protect them from corrosion! They found a guide that was uncoated, and it was perfectly free of any corrosion at all.

The pure tin coatings on the card guides were there to prevent corrosion (although they were not needed for this, since the Be-Cu metal does not corrode under the use of these guides), and not to present a risk of problems by peeling (i.e., shedding conductive chunks of tin onto the electronics). These coatings grew whiskers, and these did present a threat of causing short circuits. Clearly, the tin coating failed to satisfy the requirement: no production of conductive debris.

NASA Goddard scientists believe that there was a shorting event induced by a tin whisker --- an electronics box made for use in OV-105 but not installed in OV-105, shorted while undergoing ground testing. So that box failed, and the cause of the failure, ergo, was a tin whisker.

When using the term "failure", one needs to write in such a way that the readers are clear as to what system failed, and in what way it violated its "work requirement". Violating a work requirement is just as serious a situation as a failure, in the case of critical systems such as the space shuttles, nuclear power plants, weapon systems and medical devices; ost people would agree. To be clear, the Shuttle Endeavor (OV-105) works fine, and so *that* system did not fail.

Why did this happen? Why did this NASA approver not know about tin whiskers?

The decision, to use pure tin, and regard whiskering as “only theoretical,” was a mistake based on ignorance of the actual threat of whiskering. The NASA approver and contractor were not generally ignorant; rather, they were distinguished professionals with long experience in space systems. But they had one bit of ignorance about something they thought they knew about – that tin coatings can grow whiskers, but that this would be rare, and that any damage would be even rarer.

Perhaps they were correct in this last estimate: none of the Shuttles are known to have encountered a whisker-induced problem in flight. And there is another reason too: NASA requirements echo the style of requirements used by the military and by many areas of aerospace: these are directive --- “do this; do not do that" --- with no explanations as to what happens if these are contradicted. And, alas, no references back to the literature (if any) that generated these requirements. NASA has requirements that say, "Use 3% lead in the tin coating", but they have no pointers to (say) those Bell Labs words that say: "Pure tin coatings have caused entire product lines to fail in service."

So the NASA rep allowed a waver when asked for it by the manufacturer who wished to "optimize" his process by using pure tin coatings; probably, the NASA rep had not had experience with tin whisker damage, and did not recognize how very real this possibility was. This style of directing, without any references to reasons, has cost NASA dearly!

Why are so many people ignorant of tin whisker risks? Most people think, "If it hasn’t happened to me, then I don't care about it" not realizing that it is happening to them. Most people address problems that they know they have had before. They do not recognize a steady drizzle of problems caused by metal whiskers. It’s hard to "see" whiskers even when whiskers are present.

Do all tin, zinc or cadmium coatings produce whiskers? Not all of these coatings produce whiskers within the time of use of the equipment. For example, NASA Goddard’s Jay Brusse has what he terms a 'busy box' with a number of tin-plated soldering lugs, each bolted down tightly so there is stress present on part of the lug: only 20% are showing any whiskering at all.

Another example: NASA inspected 100 walnut-sized tin plated relays, stored for at least 5 years (no contacting that might rub off whiskers). About 20% were growing whiskers.

No one yet understands how to predict the whiskering proclivities of a given tin coating. The distribution of lengths is close to log-normal, and it is the median value of length that grows at a rate of 0.5 mm to 1.0 mm per year --- Leidecker has gotten these values from a number of different reports on experiments dating from the 1950s onward to 2005 (and later). When the coating does grow whiskers --- not all do. And some grow only wimpy ones.

There are a number of reports on experiments that track individual whiskers. Some of these grow linearly, but the length need not extrapolate back to "zero length at plating time"; rather, the "time at which length back-extrapolates to zero" may be months to years --- this is called the 'latency time'. Some whiskers grow (at least roughly) linearly for some time, but then switch to a different growth rate, ranging from zero growth rate, to faster than before. The median growth rate is more stable, and increases roughly linearly with time.

Consider an object with a property Q, measured with a scalar value. Consider an ensemble of clones, showing a stable distribution of values of Q, and suppose this is a log-normal. Then each sample of size N drawn from that population will have a maximum value, and this will show very large scatter as you look from sample to sample, and there is NO maximum limit short of infinity. The Shuttle Endeavor whiskers showed an example that was 25 mm long, after growing for 19 years --- this critter was exceeding the 1.0 mm/yr seen for the median values, and why not? The maximum values are not the median values.

The distribution of lengths is log-normal, and this means that the growth rates of individual whiskers will also show a distribution, and that one possible distribution for the growth rates is also log-normal --- and not well-described with a single number, or even a small range of values.

Some whiskers grow faster, some slower. Surface compressive stress seems to play a role, and humidity definitely does. For every datum that is known about tin whisker growth, there seem to emerge two more that are not. Sort of like a hydra...

There is a general consensus of opinion amongst the scientific community that temperature cycling greatly promotes growth, especially cycling above and below the 13.2ºC phase-transition temperature of tin. All other things equal, they probably grow faster in warmer conditions. Tin pest is an autocatalytic, allotropic transformation of the element tin, which causes deterioration of tin objects at low temperatures. Tin pest has also been called tin disease, or tin leprosy.

It was observed in medieval Europe that the pipes of church pipe organs were affected in cool climates. As soon as the tin began decomposing, the process sped up, and seemed to feed on itself.

At 13.2 ºC (about 56 ºF) and below, pure tin transforms from the (silvery, ductile) allotrope of β-modification white tin to brittle, α-modification *grey tin*. Eventually it decomposes into powder, hence the name tin pest.

The decomposition will catalyze itself, which is why the reaction seems to speed up once it starts; the mere presence of tin pest leads to more tin pest. Tin objects at low temperatures will simply disintegrate.

The tin crystal has anisotropic coefficients of expansion, so any temperature change generates a compressive stress somewhere, and that drives tin atoms to walk form here to there...and drop into the lower energy state of a crystal. Read Woodrow's paper http://nepp.nasa.gov/whisker/reference/tech_papers/2006-Woodrow-Paper-Tin-Tracer-Diffusion.pdf on isotope diffusion, on the NASA website. Tin atoms are itinerant at room temperature, even left to themselves!

More papers on the subject are at http://nepp.nasa.gov/whisker/reference/reference.html

Whisker containment is not done with rigid things. Parylene lasts a few years and then a tin eruption blows out a divot of it. Elastomers stretch a bit, then crack and tear. Containment depends in part on inducing Euler buckling. See Kadesh and Leidecker, http://nepp.nasa.gov/whisker/reference/tech_papers/kadesch2000-paper-effects-of-conformal-coat-on-tin-whisker-growth.pdf

To complicate matters, not all whiskered surfaces cause circuit malfunctions. A malfunction will occur if there is a bridge to another conductor at a different voltage. A low voltage melts the whisker open, escaping logged fault. The event may be able to latch an enduring fault. ~1V, evaporates the entire whisker. >15V, metal vapor plume forms plasma arc. ≥50V, at ≥30A, post-identification damage is obvious.

Size and geometry can increase risk more than six orders of magnitude. The whisker has to bridge to another conductor at a different electrical potential; this potential has to be high enough to break down the insulation presented by the tin oxide coating (at least 20 mV, usually 100 mV to 2 V, and sometimes as much as 15 to 40 V (!)); and then the whisker's conduction has to create a circuit problem. When more than about 100 mV is applied across the metal part of the whisker (i.e., after the tin oxide layer is dielectrically ruptured), then enough current will flow to melt the whisker open, usually within a millisecond or less --- sometimes, this current event is so brief that it escapes being logged as a fault. Other times, the event is able to "latch" an enduring fault (as in alarm circuits), and then the trouble-shooter has a really hard job: finding where the now opened whisker was, which is a challenge!

When the potential difference placed across the metal part of the whisker exceeds about a volt, then the whisker evaporates along essentially all of its length --- these events are really hard to identify later. Sometimes the presence of a number of un-shorting whiskers in the area points circumstantially to what has happened. When the potential difference is larger than about 15 volts, then the metal vapor plume from the suddenly evaporated whisker can be ignited into a plasma, forming an arc. The arc will endure if the gap is less than roughly a mil (25 um) and the available current is more than roughly 300 mA, and new metal can be evaporated rapidly enough from the cathode to keep the plasma tube dense. Things get more exciting when 50 volts or more, at 30 A or more, is available --- enough damage is left so that post-identification is easier.

Besides the above potential difference and tin oxide skin issues, there are also issues of simple "real estate" and geometry: the risk of whisker shorting increases with the area that is coated, and the area of the other conductor, and the distance between these areas is reduced (and the general "shape" can matter too). These factors accumulate to a range in shorting risks of over more than six orders of magnitude for situations I've examined, and this makes an important difference. Not all tin plated electronics are equally at risk!

Not all whisker-induced failures can be identified. Very few analysts correctly identify whisker-induced problems. A professional failure analysis can run between $300 and $3,000 per job. Almost no broken commercial equipment is ever put through any such analysis; rather, the failed unit is junked or refurbished without any assignment of the fault. It is characteristically only equipment used in tasks of high importance that gets any analytic attention. And, sadly, only a very few analysts are able to correctly recognize whisker induced problems!

Does commercial-grade equipment have this problem? It is typically only the military and space communities that carry out the analysis that is necessary to locate the source of the damage. And then, only a few of the folks making these analyses are perceptive as to the real cause.

Not all cases of whisker-induced failures are reported! NASA has logged, in 5 years, 3 to 5 reports a month of tin whisker infestation that required urgent help.

Very few have allowed NASA to document their problems in detail or share results publicly. Fear of lost sales, warranty claims, punitive damages, injuries, embarrassment and no desire to share solutions to problems with competitors. For the last five years or so, NASA is logging from three to five calls a month from folks who have spoken with them about tin-whisker infestations at their companies – infestations so bad that urgent attention was needed and eventually produced a correct identification, often with our help – and then these folks have requested confidentiality.

To a good approximation, NO ONE has allowed NASA to log their problem(s) in an explicit manner. Their reasons are clear enough: these include fear that sales will drop, and fear of a run of warranty claims and even claims for damages and injuries, and fear of embarrassment at being caught in bad practices. So, to protect themselves, they forbid their problem from being listed. Sometimes, the argument is that: "OK, now we have learned about this; darned if we will share this learning with our competitors: let them figure out why this stuff is failing!"

"Problem of the Commons"

There is the story of a room filled with people, and also a dead stinking horse. Each person has a personal reason for silence, and so no one mentions the rotting carcass. Thus, the group does not work together to improve the living conditions, and soon all succumb to the poisonous gases and corruption.

“The hundreds of cases we have documented scale to roughly a few million to a few hundred million cases of whiskering problems over the last fifty years --- this seems about right to me.” stated NASA’s Leidecker. He suspects that about 3% to 30% of electronics systems that are using pure tin plating are growing whiskers, and that about 0.5% to 5% of the total are having shorts caused by these whiskers, and that about 0.005% to 0.5% of the total are having the cause of these shorts correctly identified, and then about 0.000.01% to 0.01% of the total are being publicly named.

So the hundreds of cases they have documented scale to roughly a few million to a few hundred million cases of whiskering problems over the last fifty years --- this seems about right to him. But the public perception is that there are only a few cases, and that these have happened "to other folks". A man operated a computer room in which "75% of the computers blew the fuses in their power supplies in the space of a few hours. It took him several months to trace the cause to zinc whiskers”. The whiskers probably had been growing for years beneath the room's raised floor, but hadn't created trouble until a water spill occurred, Leidecker says. Air blown into the space between the tiles and the sub floor to dry up the water dislodged the whiskers, which then wafted into the computers through vents in the floor.

Get the word out — whiskers are a real problem.

Texts that teach newcomers about ways to make systems more reliable do not mention the dangers of whiskering as strongly as they should. A few allude to whiskering, usually as "rare" without distinguishing between "rarely happening" and "rarely publicly documented". There are few repositories of these horrors: who would pay to maintain them --- the manufacturers?

GIDEP (Government-Industry Data Exchange Program) http://www.gidep.org/ is a cooperative activity between government and industry participants seeking to reduce or eliminate expenditures of resources by sharing technical information essential during research, design, development, production and operational phases of the life cycle of systems, facilities and equipment. GIDEP files are locked except to the few GIDEP members, and not publicly available.

Aerospace Corporation locks their extensive files even tighter. Only CALCE and GSFC are publicly accessible (so long as the year-by-year funding holds out). And so knowledge of each of the relatively few identified cases quickly fades, in most venues. New folks can even suppose that whiskering was maybe once a problem, but that it doesn't happen any more.

"We WILL use pure tin, and we WILL NOT examine the evidence of problems" is an important reason for the continued "living with denial" of the problem. It would certainly be expensive to add the lead back in or to use some other corrosion protection, and most folks hope that they can continue to use pure tin without "getting caught" in a public problem.

Thus, a typical company, selling parts with pure tin coatings, that are occasionally causing a short, will continue this practice. They will promptly replace any one of their parts that the customer can show has shorted as a result of a whisker. And buyers of these parts will point to this "prompt replace" policy, and to the lack of a publicly documented problem with the use of pure tin coatings, to support the choice of purchasing these relatively inexpensive parts in favor of more expensive parts with whisker-free coatings. And no one is charged with tracking injuries or deaths that result from this practice.

Do suppliers give us what you order? If you specify 3% leaded-tin coating, will you be certain that you receive it? NASA found “pure tin coatings” 1.5 to 3% of the time (month to month) even when the contract and Certificate of Compliance says “contains X% lead”

Believing the "Certificate of Compliance" contributed to a multi-billion dollar event (not to NASA; rather, to a commercial fleet) caused by whiskering-induced shutdowns in spacecraft. Suppose our agreement with a manufacturer calls for all plating to be leaded-tin coating (with, say, 3% by weight of lead). Can NASA be certain that this is what they will get? No. There are a small number of customers (including GSFC) who have become very picky about knowing that the coatings they are supplied, actually meet the specified lead-content. So NASA is carrying out assays.

NASA has found "pure tin coatings" at the rate of 1.5% to 3.0%, month after month, even when both the contract and the supplied "Certificate of Compliance" says "contains x% lead" (where "x%" is the requested fraction, usually 2% or 3%. This rate has been stable for several years. Except for one eye-brow raising run of 70% pure-tin deliveries, when leaded-tin was requested and certified to have been delivered.

Blindly believing that the "Certificate of Compliance" was a correct statement of the lead-content, contributed to a multi-billion dollar event (not to NASA; rather, to a commercial fleet) caused by whiskering-induced shutdowns in spacecraft. So, “picky” customers continue to check, even though this assaying is expensive. This is not really different from other compliances (but it is a new cost burden). NASA has always found that a small but hugely-important fraction of supplied stuff does NOT meet their specifications, even when delivered with a "Certificate of Compliance".

Especially in recent years, NASA is being told to "believe the supplier; they are in partnership with us, and can be depended on to fulfill their part of the contract". Most do the right thing. On the other hand, Mars has a new crater on it, memorializing an example of a supplier who did not. And there are many other examples. So "Trust But Verify" is a wise approach.

Can we model the risk of whisker-induced shorting? Even the very first reports in the literature, as well as all the following ones, remark on the variability of whiskering.

Many attempts have been made to deal with this, including controlling aspects of the plating materials and methods, the details of the metallurgy of the substrate, the temperature and humidity of the environment during growth.

There is no prescription for reliably predicting which plated surfaces will grow whiskers and which will not. Whisker growth is a random event: it is stochastic. Perhaps someday we will lean the controlling parameter(s), and will then be able to apply coatings that are reliably whisker free.

Right now, the best policy is to add more than 0.5% lead, or not use these coatings at all. That having been said, some statistical control is possible. It is within sight to estimate "probable risk of damage by whisker-induced shorting". The density of whiskers, longer than a threshold length, has been shown to follow a Poisson distribution. This is fully characterized by a single parameter: the average density (whiskers/area). This is typically near 10,000 to 15,000 whiskers per square centimeter for "bright tin" on brass, down to 500 to 1,000 whiskers per square centimeter for "matte tin on copper". But this also depends on the thickness of the coating (dropping as coatings get thinner or thicker than the roughly 1 to 3 um thickness producing the above densities).

The length of a mature field of whiskers has been shown to be usefully modeled using a log-normal distribution: there are two parameters: the median length (which goes roughly as 0.5 to 1.0 mm per year, and has some other roughly known dependences on coating details and substrate details and environment details) and the (dimensionless) standard deviation of the log of the length; this latter parameter is usually near 0.8 to 1.0 (when "log to the base 'e' is used). There is also a decently measured probability density for the angle at which the whisker grows from the substrate.

There is no accepted probability density for the thickness-measure of whiskers. Observations show most whiskers are in the range 0.1 to 10 um, with about 1 to 3 um being most likely; however, the distribution of thicknesses has not been reported. Also, there is a possibility of a correlation of thickness with length: suitable data have not been reported, nor estimates of this correlation. Hence, we are not able to compute the distribution of electrical resistances (R ~ rho * length / area of cross section); rather, we have to measure it (and we have the beginnings of a measured distribution). The eventual hope is that we will be able to develop a community-consensus as to the above stochastic treatment of whiskering.

And then when a community-consensus has been obtained, combine that stochastic treatment of whiskering with the knowledge of the geometry (size and shape) of the electrical circuits containing the potentially whiskering tin-plated surfaces, compute an estimate of the distribution of whiskers that make mechanical contact with surfaces at different potentials. And finally combine this with the knowledge of the electrical behavior of the circuits to estimate the probability that each mechanical contact will produce an electrical contact that results in a detectable circuit-event.

We are, of course, especially interested in those events that would "kill" the circuit's functioning. Then we could be in a position to foretell if an electrical system is likely to host "A Perfect Storm", and join the gallery of famous catastrophes, like the Aircraft Radio Corporation's radios using cadmium-plated air spaced capacitors, or like the Western Electric frequency-multiplexed phone line equipment. Or whether the electrical system is likely to be a "Perfect Harbor" providing safe operations for many years, even with pure tin coatings.

We are not there yet. But we are close enough to begin making broad classifications. For example, if inspection shows only a few square millimeters of pure tin, with no whiskers presently visible, and no conductors with a different potential within centimeters, and these provide enough voltage to promptly clear any whisker without launching a sustaining arc, and the mission life requirement is 3 years; then, the risk of tin-whisker induced failure is very low.

Are there mitigations?

Conformal electrical insulating coatings to block any loose whiskers from shorting. A whisker-tough coating (there is none yet) which contains whisker growth. When an appropriate coating is used, and is correctly applied everywhere (and does not introduce its own damages), then the risk of shorting can be substantially lowered.

Re-plate with tin-lead solder which dissolves any pure tin plating. www.corfin.com Corfin Industries, Salem NH, implanted a robotic hot solder dip (RHSD) – for tin whisker mitigation. It is a US Navy-qualified process.

BGA Reballing for conversion to Tin-Lead flushes all balls and alloy residue on the pads and replaces balls with tin/lead solder balls.

XRF – X-Ray Fluorescence Analysis – Used to determine Lead (Pb) content of Termination Finishes and Plating Thickness.

Summary

For high reliability electronics, such as for NASA, military, aerospace or medical, specify "no pure tin, or zinc, or cadmium plating" on your equipment or at least try to mitigate whiskers with conformal coatings. Check your incoming materials at the document-level and use explicit assays. NASA strongly prefers "no pure tin, or zinc, or cadmium" on their equipment. Their rules forbid the use of these materials. And they check their incoming materials at the document-level and using explicit assays. But they sometimes find that they have one or more of these forbidden materials anyway, despite their rules and checks.

Then, they have to decide whether to scrap the delivered equipment, or to take it apart and rebuild it, or to "fly as is". NASA is working to develop science-based methods for aiding the managers who must make these decisions. They are not there yet in all cases; but, they are there for a few clear-cut ones. And they can hope to improve.

For more information visit:
http://nepp.nasa.gov/whisker/
http://www.RoHSUSA.com
http://www.hlinstruments.com/RoHS_articles/

There is now a LISTSERV called tinwhiskers@freelists.org**.** Users can subscribe to the list by sending email to tinwhiskers-request@freelists.org with 'subscribe' in the Subject field. You can subscribe at this website http://www.freelists.org/list/tinwhiskers. To post to the mailing list, simply send email to tinwhiskers@freelists.org**.** To see prior postings go to http://www.freelists.org/archives/tinwhiskers/

NOTE: The Boston Reliability Society Chapter has just initiated a project titled RoHS6 Pushback. High level overview: RoHS6 is technologically feasible for simple boards with simple electronic parts. As the complexity increases, the risks become large and the long term reliability is not assured. The issues and risks need to be quantified and shared.