Root Cause Analysis of Precursors

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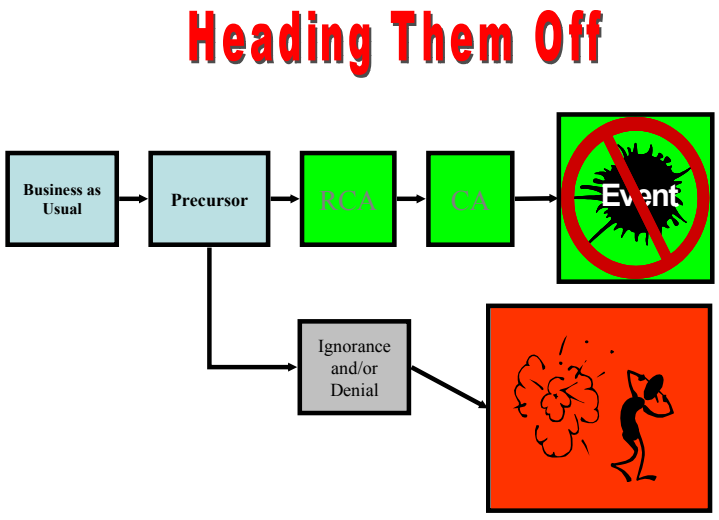
Abstract: In discussions of consequential adverse events a "precursor" is a situation that has some, but usually not all, of the ingredients of a more highly undesirable situation. The root cause analysis that includes the consideration of precursors differs from other root cause analysis in that one wishes to explore what kept it from being worse. The challenge is to select the precursors that point to the greatest fragility or precariousness.

Background:

This discussion is about precursors to highly consequential events. It is not about "error precursors[1]", per se.

Wouldn't it be nice to identify precursors before the disasters that they "precursed"? With great retro visual acuity experts and lay people alike identify precursors to "Challenger"[2], "Concorde"[3], Three Mile Island[4], Davis-Besse 2002[5], and other consequential adverse events.



An old cattle attendant might ask, "Why not head them off at the pass?" That is to say, "Why not identify and analyze the precursors and take corrective action to prevent the downstream consequential adverse event?"

A Precursor?:

The National Academy of Engineering workshop[6] definition is: "Accident Precursors" are being defined as any event or group of events that must occur for an accident to occur under a given scenario.

A dictionary[7] definition of "precursor" is "one that precedes and indicates the approach of another."

In discussions of consequential adverse events a "precursor" is a situation that has some, but not all, of the ingredients of a more highly undesirable situation. In other words, a

precursor is an event or situation that, if it had included (or not included) some other small set of behaviors or conditions, a consequential adverse event would have occurred. Of course, former similar events are also regarded as precursors even though they don't quite fit that definition.

Thus, here is a comprehensive definition of precursor[8] that will work for safety discussion purposes:

> A precursor is a previous similar situation with severe consequences and/or an event or situation that, if it had included (or not included) some other small set of behaviors or conditions, a consequential adverse event would have occurred.

To be specific, let us consider the space shuttle "Challenger". We now know that every shuttle launch that included O-ring blow-by before "Challenger" was a precursor to "Challenger", in that if the pre-launch ambient temperature had been sufficiently low the O-rings would have failed and the vehicle would have been lost.

In the case of the supersonic transport "Concorde" an examination of the accident history[9] indicates roughly a half-dozen recorded precursors to the fatal foreign object encounter. These involve either foreign object encounters or tire blowouts or both. But what about the unrecorded precursors, e.g., the times that a Concorde aircraft took off uneventfully from a runway on which there was a foreign object?

In the case of Three Mile Island (TMI) Unit 2, we now know that every one of the cases of stuck open power operated relief valves (PORV) before the famous partial meltdown was a precursor to a core damaging accident. But this is a bit more of a stretch than "Challenger", in that the missing ingredients included not recognizing that the valve was stuck open and, to make matters worse, reducing make-up flow to the stricken reactor.

Before the accident at TMI few, if any, nuclear reactor engineers would have believed that operators would fail to recognize the symptoms of a stuck open relief valve, nor would they have believed that operators would reduce make-up flow in the face of symptoms of inadequate coolant inventory.

In the case of Bhopal[10], we now know that many routine cleaning operations using water were precursors to the chemical slaughter of the neighbors. The missing ingredient was a blank flange separating the water cleaning operation from the reactive chemical. However, even if the installed mitigating systems had been in good service condition there would have been a major consequential event, but limited to the facility site.

Has there ever been a serious consequential adverse event that did not have precursors? Or would sufficient access to the history of the stricken victim reveal precursors, that, had they been recognized and attended to, would have resulted in averting the event?

Chernobyl apparently came out of the blue, but did it? One of the drawbacks of keeping problems secret is that there is no external pressure to attend to precursors.

Has there ever been a consequential event, near miss, compromise, or infraction/deviation that was not a precursor? In some sense of the word "precursor", probably not.

What Keeps a Precursor From Being a " Real McCoy"?

A "Real McCoy" in this case is, of course, a highly consequential adverse event. When less than a Real McCoy happens, the Real McCoy did not occur because: 1) an exacerbating factor was missing ("Challenger") or 2) a mitigating factor was effective (operator action in the pre-TMI PORV stick-opens), or 3) both (Davis-Besse 2002 (no high pressure transient, detection of degradation)).

To express these ideas as equations that will come in handy later, we have the following:

Equation 1.

{Real McCoy} = {Precursor} + {Exacerbating Factor(s)}

Equation 1 just says that if the next occurrence of the precursor situation includes things that make the situation worse enough a consequential event will result.

Equation 2.

{Real McCoy} = {Precursor} – {Mitigating Factor(s)}

Equation 2 just says that if the next occurrence of the precursor situation does not include important defenses, barriers, or other mitigative measures that the precursor situation did include a consequential event will result.

Equation 3.

{Real McCoy} = {Precursor} + {Exacerbating Factor(s)} – {Mitigating Factor(s)}

Equation 3 just combines the thoughts of Equations 1 and 2.

Moreover, as repeat similar events teach, a Real McCoy consequential event can be a precursor, too, as was recently illustrated. In Connecticut's St. Raphael Hospital not too long ago a woman was killed in an operating room when she was given nitrous oxide instead of oxygen[11]. A week later another woman was killed in the same operating room in the same way, thus providing a tragic example of not learning from experience.

The St Raphael case gives us:

Equation 4

$\{\text{Real McCoy}\}_{(N+1)} = \{\text{Real McCoy}\}_{(N)} + \{\text{Nothing}\} + \{\text{Time}\}$

All this says is that if an adverse event is not effectively investigated with appropriate corrective action, the causes of it may continue to exist. If the causes continue to exist another similar event may occur.

Notice that Equation 4 does fit our text boxed definition. Furthermore, this does seem to endorse the dictionary definition except for the part about indicating the approach of another.

And that's a serious issue. If precursors really did indicate the approach of the downstream "Real McCoy" prudent people would take action to "head them off at the pass". Wouldn't they?

The partial loss of the crew of USS *Squalus* [12](SS-192) was a precursor to the complete loss of the crew of USS *Thresher* [13](SSN-593). The Real McCoy and the precursor are related by both Equation 4 (both submarine sinkings due to loss of hull integrity) and Equation 2 (*Squalus* did her test dive in relatively shallow water.). Unfortunately, *Squalus* did not result in restrictions on depth of water for test dives. But, why not?

This gives:

Equation 4(a)

$\{\text{Worse Real McCoy}\}_{(N+1)} = \{\text{Real McCoy}\}_{(N)} + \{\text{Nothing}\} + \{\text{Time}\} + \{\text{Exacerbating Factor(s)}\}$

At Tokaimura[14] every processing of a batch of low enrichment material using the management-approved short-cuts was a precursor to the criticality accident, but none of them really did indicate the approach of the downstream "Real McCoy" criticality accident. But, why not?

Near Misses

A near miss is a special case precursor. There seems to be some agreement that near misses should get investigative attention commensurate with the corresponding averted consequential event.

When the necessary exacerbating factors are highly likely the precursor is often called " a near miss". For example, running a red light in a busy intersections without a collision. The exacerbating factor would have been a crossing vehicle in the intersection.

Similarly, one would expect a precursor to be called a near miss if the mitigating factors were unlikely or not robust. For example a high energy line break that resulted in no injuries because the workers happened to be at lunch when it happened.

In general, we think of a near miss as a precursor whose ingredients differ in only minor or non-robust ways from those necessary for a consequential event. (Some people like to say "near hit" for the same concept.) The "near miss" concept suggests the following:

Equation 5

{Real McCoy} = {Near Miss} +/- {Not Much}

With this insight many of the shuttle launches prior to "Challenger" were "secret" near misses. And some of the Concorde accidents before the fatal one were also "secret" near misses. Why do managers and program people not ask questions such as, "What kept this one from being worse?" and "How close are we to a Real McCoy?"?

Secret Precursors?

The problem apparently is not the precursors as defined by the dictionary. When a precursor effectively indicates the approach of a Real McCoy people do something about it and the next Real McCoy is averted. This is almost a tautology, but it needs to be said.

But, alas, safety reporting is not like ice hockey reporting. The "saves" and "close shots on goal" are not counted, publicized, and interpreted. Thus, many instances of precursors that should indicate the approach of a Real McCoy remain unheralded. For example, Concorde program personnel kept records of the accidents involving Concorde aircraft, but apparently did not "connect the dots" to envision a take-off encounter with a foreign object destroying an aircraft.

The problem seems to be the secret precursors, the ones that don't overtly indicate the approach of the Real McCoy. They also remain unheralded as precursors, to the detriment of victims and other stakeholders, such as the second St. Raphael fatality.

Notice that all of the "postcursor" Real McCoys mentioned above followed precursors that did not effectively indicate their approach. However, events and situations are not capable of implying anything. It takes people to make inferences from events and situations. People can unveil the secret precursors, if they know how to.

"Unveiling" the Secret Precursors

To unveil something is to reveal its true nature. It is clear that lives, pain, assets, and careers could be saved if organizations could unveil secret precursors. One approach

would be to make inferences systematically from events and situations to reveal their true nature as precursors.

A popular term for a systematic method of making inferences from events and situations is "root cause analysis[15]". Not all methods of "root cause analysis" deliver "root causes". It's just a popular shorthand for "a systematic method of making inferences from events and situations".

The two questions before us now are:

1. How does one select events and situations to do root cause analysis (for the purpose of determining their precursorship)? And
2. How does one do root cause analysis to determine precursorship?

Selecting Events and Situations for Root Cause Analysis

It goes without saying that consequential events such as *Squalus* and the first St. Raphael fatality, both mentioned above, should be subjected to root cause analyses that include consideration of precursorship. This obvious lesson to be learned has clearly not been learned.

In the case of *Squalus* the investigation did not sufficiently dwell on what kept the consequences from being worse. Understandably so. *Squalus* was the first actual use of the submarine rescue system that is the basis for today's submarine rescue systems. The investigation, however, did not result in advising submarine commanders to choose test sites that are sufficiently deep to achieve test objectives, but shallow enough to avoid collapsing unflooded compartments[16].

Most root cause analysis approaches do not include the examination of precursorship explicitly. Most of them do include considerations of preventing repetition of the same event. Few ask the question, "What kept the consequences from being worse?" or equivalent.

Thus we have one easy part of the answer to the first question:

All consequential events should be investigated for precursorship.

The precursorships to be tested would those of Equations 1 through 4(a).

> (Occasionally there is a highly consequential event that may not merit much investigation. For example, the Hurricane Andrew destruction[17] of the non-vital portions of the Turkey Point Nuclear Plant, which had no unexpected adverse effects on nuclear safety-related systems, structures, and components.)

Another easy part of the answer to the first question is:

All near misses should be investigated for precursorship.

The more difficult parts are tied up in the dilemma of how to recognize milder events and situations that could be precursors without doing a root cause analysis of them. A partial answer would certainly involve mental models of how the event or situation could involve a precursor.

Unfortunately the cultures that produce the secret precursors seem to include aspects that prevent unveiling them. Cases to be considered in this regard are:

- Davis-Besse 2002 (recent near miss Loss-of-Coolant accident mentioned above),
- Davis-Besse 1977 (stuck open PORV as a TMI-2 precursor[18]),
- "Challenger" (O-ring blow-by on launches before the disaster), and
- Millstone Point regulatory shutdown (2-CH-442[19] and the Unit 1 reactor vessel draindown[20] as precursors to the lengthy regulatory shutdown).
- Tokaimura and Davis-Besse 2002 (undetected regulatory infractions as precursors)

A Necessary Skill for Unveiling Secret Precursors

Before one unveils a secret precursor it must be recognized. At the core of precursorship is the quality of being an ingredient, part of a recipe. A precursor is an ingredient of a recipe for dire consequences. If today's anomaly or today's usual practice cannot be envisioned as an ingredient of a recipe there is no hope that it will be unveiled. Envisioning an anomaly as an ingredient of a recipe for dire consequences is sometimes called "connecting the dots" or "seeing the anomaly as part of a picture".

For example, before the Davis-Besse 2002 incident no one apparently was able to recognize that not doing a bare metal inspection of the reactor vessel head was an ingredient of the recipe for a career-killing shutdown, but it was. In hindsight, if the bare metal inspection had been done as specified the reactor vessel head degradation would undoubtedly have been discovered at such an early stage that it would have been handled as the fairly routine matter that it should have been, like the leakage at V. C. Summer[21]. Of course, at V.C. Summer the leakage did not have to be sought out as at Davis-Besse.

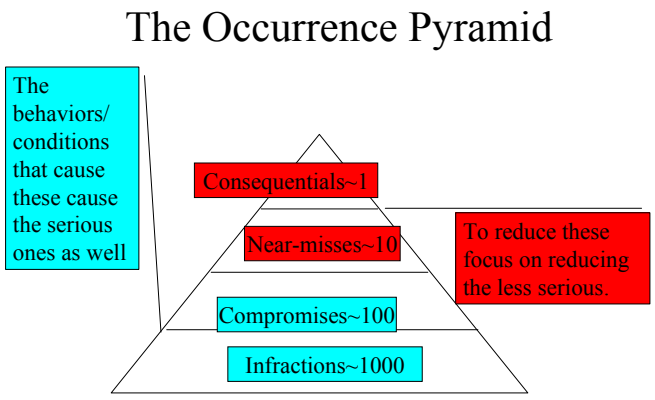
At Davis-Besse there were dozens of anomalies that, in retrospect, were ingredients of a recipe for an extended shutdown. When one anomaly is not recognized as a precursor the failure can be explained as a narrow knowledge gap. But when dozens of anomalies are not recognized as ingredients one begins to wonder about programs, processes, organizations, interfaces, yes, and of course, safety culture.

The recipe for the extended shutdown at Davis-Besse included the following major ingredients, any one of which could be called a precursor by a purist, and the progressive accumulation of them would be called a precursor by the most hard-to-convince:

- Leaky control rod drive mechanism joints that encouraged tolerance of leakage
- Some boric acid deposits in the reactor vessel head area from the above leaks
- Alloy 600, which is subject to cracking
- Time, temperature, and stress
- Ignored NRC criticism of the boric acid corrosion control program
- Industry group predictions that cracks at Davis-Besse were likely
- Small cracks opening (not knowable directly)
- Boric acid issuing from the small cracks (not knowable directly)
- Difficulties doing reactor vessel head inspections because of the design
- Truncated inspections
- Disapproval of proposed changes to facilitate the inspections
- News of other Alloy 600 cracks in similar plants
- Increased appearance of rust-colored boric acid deposits
- Clogging of radiation monitor system filters
- Fouling of containment air cooler heat transfer surfaces
- Failure to do root cause analyses of above anomalies
- Gullible or falsified auditing of the boric acid corrosion control program
- Unaware regulatory and industry oversight (not knowable directly)

The point is that there are varieties of precursorship. And precursors accumulate. Precursors may be grouped in four levels of severity:

1. Consequential events (like the first St. Raphael fatality)
2. Near misses (like Davis-Besse- with respect to a loss of coolant accident (LOCA))[22]
3. Compromises (latent barrier vulnerabilities)
4. Infractions and deviations (anomalies and vulnerabilities at a low level)



Anecdotal experience suggests that there is roughly a power of ten difference in the occurrence rates between the levels of severity. Root cause analysis experience indicates that, as a general rule, the causes of compromises, infractions, and deviations include the causes of near misses and consequential events. And the investigation of consequential events and near misses shows that these higher severity events have an accumulation of lower level events as causes.

Doing Root Cause Analysis to Determine Precursorship

A root cause analysis to determine precursorship is much like other root cause analyses. In fact, one of the auxiliary objectives of any root cause analysis should be to determine those influences on the consequences that are precursors.

A valid root cause analysis is based on evidence, includes tightly linked chains of influence, includes generic implications of causes and effects, and goes deep enough to reveal important underlying issues. The following eight questions[23] are helpful:

Questions about impact:

1. What were/are/will be the consequences?
2. What is the significance?

Questions about influences:

3. What set the stage for the consequences?
4. What triggered/initiated the chain of events?
5. What made/makes/will make the consequences so bad?
6. What kept/ is keeping/will keep the consequences from being worse?

Questions about close-out:

7. What should be learned from the event?
8. What should be done about it?

The discussion of root cause analysis will, as far as possible, be restricted to aspects relevant to precursors. It is by no means exhaustive.

Consequences: Question 1: Consequences are adverse outcomes of the event. Equation 4 above suggests that if nothing is done the event in question is a precursor to a future similar event with similar consequences. Consequences of interest are actual consequences that have accrued to date, expected consequences that are in the pipeline, and potential consequences that have been averted by the absence of exacerbating factors and/or the presence of mitigating factors, as indicated by Equation 3 above.

Significance: Question 2: Significance is what the event means (signifies) to the victims and other stakeholders. One important part of significance is potential consequences as mentioned above. Another is the generic implications question[24], "If this happened/existed, what else should/could/would one expect?" This directs one to another source of insight into precursorship.

Influences: Questions 3-6: In looking for precursorship we do not restrict ourselves to causes of consequences, but rather open our eyes to influences. Influences include all causes and also include all factors that limited, controlled, or restricted the consequences, as well.

Vulnerability: Question 3: If the situation had not been set up for the event, it could not have happened. The set up is a vital ingredient of the recipe for the consequences and thus includes precursorship considerations.

Trigger: Question 4: Vulnerability alone does not cause consequences. It takes a trigger or initiating action. What were the triggers for "Concorde"? One might say that it was a previous aircraft dropping a foreign object on the runway. Others might say it was the take-off roll-out itself that was the trigger. Some triggering actions can be considered to be precursors in and of themselves.

Exacerbation: Question 5: In some cases, such as the Davis-Besse 2002 extended shutdown, the vulnerability (Alloy 600 with stresses plus the corrodible carbon steel) and the trigger (time at temperature) do not cause the consequences of interest. It takes something to exacerbate the situation, i.e., make it worse, amplify the adverse effects, continue the damaging mechanism, or the like. These factors can be precursors.

Mitigation: Question 6: In the vast majority of consequential events and in all near misses there were factors that limited, controlled, or restricted the consequences. For example, the 2002 Davis-Besse situation was prevented from becoming a loss-of-coolant accident (LOCA) by the discovery of the reactor vessel head degradation pursuant to repairing a nozzle crack. Thus the consideration of the mitigating factors yields insights into the precursorship of the event.

Closeout: Questions 7 & 8: The closeout is where the real value is. The value cannot be accessed, however without the investment involved in answering the previous questions.

Learning: Question 7: In answering this question the team captures the lessons to be learned, the factual basis of each lesson to be learned, and who should learn each one. A

natural lesson to be learned from deep reflection on the details of events involving precursors is that the recognition of precursors is a skill that enhances safety.

Corrective Action: Question 8: In order to avert the consequences of the Real McCoys indicated, suggested, or announced by precursors corrective actions must include not only controlling the precursor behaviors and conditions, but also controlling the processes that produces them, and by improving the processes that should have detected the precursors at an earlier, more economical stage.

How to Get the Answers to Questions 3 Through 6

The answers must be based on solid evidence to be worthwhile. But evidence alone does not give the answers. Here is a "kitchen-tested" set of utensils[25] for converting evidence into answers.

Organizing the data: Use a Comparative TimeLine © (CTL) to organize your data. When used resourcefully the precursor information will almost leap off the page at you. For graphically-oriented teams the Event and Causal Factors Chart (E&CFC) will work. If the E&CFC is selected, it helps to include notes about what should have been.

Establishing Chains of Influence: Use Why Staircase Trees, but adhere to a few cautionary rules, including:

1. Start at the top with a consequence (actual, expected, or averted).
2. Make every set of boxes constitute a complete explanation of the box to which the set is connected.
3. Make tight causal linkages. Do not omit layers of explanation.
4. Continue until the last layer is, at least in the opinion of the team, less significant to understanding precursorship than the item that it explains.

Utensils for Closeout

Determining What Should be Learned:

Use tables and matrices to make sense of influences. Be prepared to refine what has been done in accordance with instructions given above. Some useful utensils include:

1. The Missed Opportunity Matrix
2. The Barrier Analysis Matrix
3. The Cause-Consequence Matrix
4. The Lessons to be Learned Matrix
5. The Regulatory Infraction Matrix

Determining What to Fix:

At a minimum, one needs to interrupt the chains of causation, i.e., those parts of the Why Staircase Trees that relate to a) what set up the situation, b) what triggered the event, and 3) what made it as bad as it was. But one should also consider what existing defenses could be enhanced to provide the desired protection.

Specifically one needs:

1. Interim compensatory actions to stabilize the situation and prevent further harm while more complete actions are pending.
2. Corrective actions for adverse effects (consequences).
3. Corrective actions for causes at all levels.
4. Corrective actions for the generic implications (including "extent of condition") of effects and causes.
5. Corrective actions for self-assessment deficiencies not included in the above.
6. Corrective actions for independent assessment deficiencies not included in the above.

Caution: In most cases the corrective actions will not have been included in the annual budget. Thus corrective actions require reallocation of resources. This can cause precursors.

Generic Implications

Clearly the most important consideration of precursors is their unveiling. Unless the precursor nature of a behavior or condition is known it is not likely to get the attention it deserves. Close behind the unveiling is the recognition of the generic implications. Identifying the generic implications is answering the question, "If this happened (or existed), what else should/could/would one expect?"

This question can be broken down into more focused questions that include:

1. What effects could this precursor cause?
2. What deeper precursors could cause it?
3. What are the similar precursor behaviors/conditions?
4. What are the processes, programs, interfaces, barriers, etc. similar to the ones that caused the precursor and could be causing others?

Reflection

Severe adverse events "from out of the blue", i.e., without precursors seem to be rare. One might suspect that the adverse events that seem to come "from out of the blue" are events whose precursors were not recognized. Thus, the ability to recognize precursors and to respond appropriately would seem to be a very valuable organizational skill.

On the other hand, the better people get at recognizing anomalies and envisioning them as indications of ingredients of recipes for dire consequences, the more precursors are

reported for disposition. An organization needs to prioritize the precursors to be addressed. Some precursors are departures from regulatory requirements and must be given high priority to be addressed. Others may constitute immediate threats to life or health and must be attended to promptly. Still others may be ingredients of complex recipes whose ingredients other than the known precursors are known to be unlikely. Suffice to say, the question of prioritizing precursors is non-trivial.

Clearly it would be helpful for adverse events and to be reported transparently so that the implied fragility (precariousness) of the situation implied by the cumulative precursors could be understood. Three Mile Island, "Challenger", "Concorde", Davis-Besse 2002, the Millstone regulatory shutdown and other events may well have been averted if the fragility (precariousness) of the situation had been known to accountable individuals. Do current processes conceal the fragility (precariousness)? Do publicized green (good) performance indicators distract attention from precursors?

Conclusions

Many adverse events that have been investigated in detail have been "precursed", i.e., they have been preceded by behaviors and conditions that were ingredients of the recipe for the adverse consequences. However, it was the secret precursors that were the unaddressed opportunities for reducing or averting the consequences.

A practical definition of "precursor" is given above and illustrated.

A framework for investigating actual and potential precursors is provided in terms of eight questions for investigation teams.

A tool kit for investigating precursors is described.

Finally a reflection provides a challenge for future considerations of precursors.

References and Notes

[1] Institute of Nuclear Power Operations, "Human Performance Fundamentals Course Reference", Atlanta, GA (December 2002)
[2] http://history.nasa.gov/sts51l.html
[3] http://www.concordesst.com/accident/accidentindex.html
[4] http://www.wowpage.com/tmi/
[5] http://groups.yahoo.com/group/DBRVH_LTBL/ provides internet access to other links related to this case.
[6] This definition is from an information sheet called "FAQ on Accident Precursors", but more is available at http://www.nae.edu/precursors
[7] http://www.m-w.com/cgi-bin/dictionary?book=Dictionary&va=precursor
[8] Let the reader beware that other definitions abound, e.g., at http://saphire.inel.gov/pdf/MIT-NED-EDF-2000-01.pdf, Apostolakis, et al, give "By "precursor" we mean any off-normal situation that could occur at a NPP that approaches but does not reach core damage."
[9] http://www.concordesst.com/accident/accidentindex.html
[10] http://www.american.edu/TED/BHOPAL.HTM
[11] http://www.yaledailynews.com/article.asp?AID=17653
[12] Maas, Peter, "The Terrible Hours", HarperCollins, NY (1999)
[13] http://www.subnet.com/fleet/ssn593.htm
[14] http://www.aip.org/pt/dec99/toka2.htm
[15] http://groups.yahoo.com/group/Root_Cause_State_of_the_Practice/ provides internet access to a large community of root cause analysis practitioners as well as links, files, database tables, and other resources.
[16] This is a special case of an important safety principle that tells us not to take risks in excess of those for which there is some benefit. For an extensive list of these principles see "The Firebird Forum", Vol. V, No. 7, of October, 2002, W. R. Corcoran, Ed. Posted at http://groups.yahoo.com/group/Root_Cause_State_of_the_Practice/
[17] http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1993/in93053s1.html
[18] http://www.wowpage.com/tmi/pri.html
[19] http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1993/in93090.html
[20] USNRC Information Notice 94-52: Inadvertent Containment Spray and Reactor Vessel Draindown at Millstone Unit 1, July 15, 1994
[21] http://www.nrc.gov/reactors/operating/ops-experience/alloy600/vcsummer.html
[22] There was at least one other significant precursor at Davis-Besse. It is described by Apostolakis, et al at http://saphire.inel.gov/pdf/MIT-NED-EDF-2000-01.pdf
[23] Corcoran, W. R., "The Phoenix Handbook", Nuclear Safety Review Concepts Corporation, Windsor, CT (2003)
[24] Corcoran, W. R., "The Firebird Forum", Vol. 6, No. 1, January, 2003
[25] These are described in "The Phoenix Handbook" and in issues of "The Firebird Forum", which are cited above.