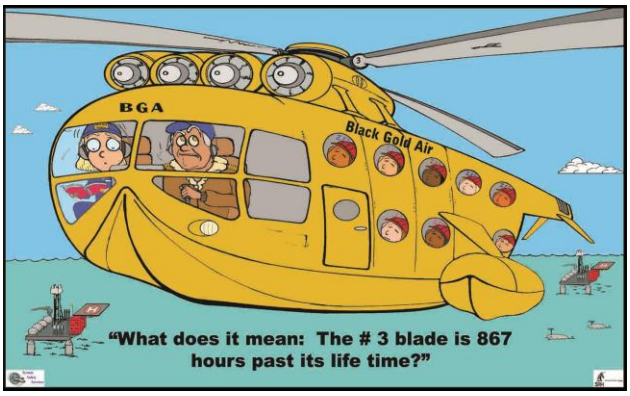


Threat and Error Management or **TEM** was developed in the 1990s and is a part of a follow-on to LOSA (**L**ine **O**perations **S**afety **A**udit. LOSA began as an audit of CRM (Crew Resource Management) to observe if the pilots were working as a team as dictated in CRM. The word Audit with its negative connotations, was later changed to **A**ssessment) which is a much better word when describing its later function in the Safety program. As LOSA is the data gathering segment of the program, let's begin there. First, one has to realize that **LOSA/TEM** is a big boy's game, but with an understanding of how it functions, you can adapt portions of it to increase your Safety margin.

- **The Big Boys Club**
- **LOSA 5,647 Flight Crew Observations in 36 Airlines**

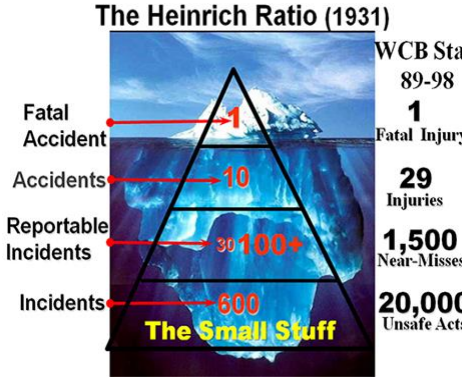
AeroMexico (61)	Frontier Airlines (57)
Asiana (83)	Horizon Air (48)
Alaska Airlines (131)	Japan Airlines (115)
Air Freight NZ (5)	JetBlue (194)
Air New Zealand (105)	LACSA (21)
Air Transat (21)	QANTAS (142)
ANA (194)	Malaysia Airlines (106)
Braathens (26)	Mexicana Airlines (68)
Cathay Pacific (133)	Mt. Cook (15)
China Airlines (76)	Regional Express (48)
Click Mexicana (24)	Singapore Airlines (105)
COPA Airlines (90)	SIA Cargo (13)
Continental (346)	Silk Air (25)
Continental Express (220)	TACA (44)
Continental Micronesia (13)	TACA Peru (8)
Delta Air Lines (737)	UNI Air (20)
Emirates (213)	US Airways (343)
EVA Air (61)	WestJet (114)

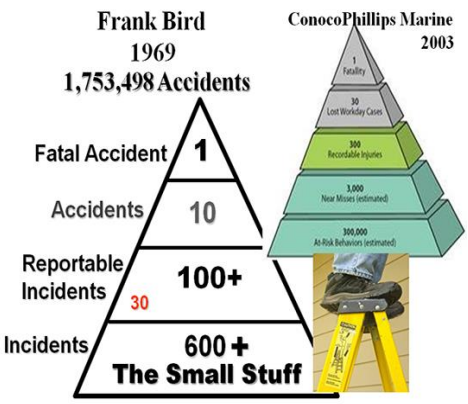
A trusted LOSA trained pilot would sit in the cockpit jump seat of an airline aircraft and quietly observe the pilots operating a flight. The observer would note any deviations to procedures and record them. Not too surprisingly, they discovered that human errors were being made on a daily basis on 93% of the flights. The majority were not serious errors, but had the potential to be. After a whopping 4,532 flights, a study of the data revealed the following statistics. There were 19,053 threats that they observed. Threats are opportunities for errors that can occur when a threat is released. 13,675 errors did occur from the threats. These errors resulted in 2,589 Undesired Aircraft States (UAS) With a UAS, Safety has been compromised and the likelihood of an incident or accident is increased.
For LOSA to change from Audit to Assurance the following steps were required.

1) Everyone had to know it was not an audit with corrective and possible punitive actions as the end result of each observation.
2) There must be a formal agreement between management and employees.
3) The agreement must spell out that there will be no punitive action taken as a result of any observations.

4) All individual data collected will remain confidential.
5) The observers must be non-management and knowledgeable of what they are observing.
6) The observer must be trusted by those being observed.
7) The observer must be trained and be a believer that Safety will be improved with the data from this project.
TEM takes these threats and trains people to:
A) Anticipate and avoid the threats .
B) Recognize and trap the errors.
C) Recover and manage the undesired states.

The **TEM** model calls anticipating threats and developing strategies to avoid them, but, when errors are still made they must be recognized and resolved or there can be consequences. We developed the same triangle model with more information on the Safety nets to use to avoid the undesired consequences.
Looking at the **TEM** triangle reminded me of a much older one that can relate to that used in the **TEM** model.
In 1931 an insurance investigator with over 30 years experience reviewed their industrial accident cases and came out with a ratio of fatalities to incidents. Note that Heinrich's original ratio indicated 30 reportable accidents but I changed that to 100 reportable for aviation as we seem to have to report everything that we can't hide. My accident diary seemed to indicate that we got a lot more reportable incidents than 30 per fatality.
Every day the CADORs (Civil Aviation Daily Occurence Report) were reporting everything from a cracked





windshield to an emergency landing due to an unruly passenger.
As Heinrich was not an academic and didn't record all the 30 years of documentation to prove his theory, many academics discarded it.
In 1969 Frank Bird spent over 4,000 hours to analyze 1,753,498 accidents and near misses to come up with basically the same numbers. Note the vast differences in other study results attached to each figure. These differences depend on just what specific subjects you analyzed. WCB (Workman's Compensation Board) accident statistics over a ten year period came up with much higher numbers for what they called unsafe acts that could result in injury. E.g. Standing at the very top of a step ladder. Heinrich on the other hand only counted incidents that, as they say, "but, for the grace of God" (luck) did not result in a reportable incident. Conoco Marine estimated their small stuff as 300,000 at-risk behaviours. I don't believe the ratios developed by Heinrich and Bird will change that much but if you are able to cut the incidents in half it will take twice as long for the fatality to occur as the ratio stays the same.
Now take their triangle and turn it 180 degrees and you have the Heinrich triangle without the ratios. The small stuff (threats) are now at the top while the undesired consequences (fatality) is at the bottom, but the overall goal of both is to; "sweat the small stuff so you never have to sweat the big stuff."
Looking back at the **TEM** model we see the small stuff called threats is at the top. As we have advocated before, it is here that we "take a minute for Safety" and anticipate just what are the threats for the particular situation? What could go wrong? What can we do to either avoid the threats or at least manage them should they occur. One threat for pilots is often the weather. I can recall when refueling our DC8s in the winter for the non-stop (we hoped) flight from Vancouver to Hawaii, the first officer would come over and ask for "a little extra for momma" when the forecast headwinds were stronger than normal. That meant that I would override the automatic fuel shut offs for each tank and fill the 2% expansion space in the tanks as well as the vent pipes. They would get about 150 extra gallons that would give them about an extra 10 minutes in the air with the fuel hungry P&W JT3-D engines. They would carefully burn that extra fuel off on taxi and with the cold winter temperatures that expansion space wasn't really needed. Safety nets need be developed in the event that one or more threats should be released. Strong headwinds to Hawaii in the winter were not that uncommon and while we never lost one into the ocean, there were a few fuel critical incidents over the years. Thus they anticipated the threat and could have avoided it by diverting to San Francisco or LA to refuel. Instead they recognized that an error in wind speeds could result in an undesired state in

which they would be able to divert to a mainland airport before the fuel got too low or declare fuel critical in order to have priority landing in Hawaii. Since that would involve paperwork the "little extra for momma" gave them that little extra for Safety. They were likely doing this before **TEM** came along but now they could see the logic in their actions which would make for a Safer operation.

In time, it was determined that the **TEM** concept would work for maintenance, ramp and others operations. United among many other airlines around the world have adapted the concept with great success.

Let's look at an accident that involved maintenance and fuel exhaustion over the Atlantic. This aircraft ran out of fuel and was able to glide over 75 miles to land on an island (Azores) airport 948 miles from Portugal. A few days before, the Airbus 330's #2 engine began to make metal. A loaner engine was obtained from Rolls Royce and the aircraft was brought in for an engine change to be done by the midnight shift with a flight schedule requirement putting pressure to get it done on time. Some of the threats not recognized at the time were the loaner engine was missing its hydraulic pump. Also, the work would be done by a midnight shift. A Service Bulletin mod (SB-RB-211_29-C626) had been carried out on the engine removed but not on the loaner engine. This mod called for a different pump and lines to reduce vibration. This SB paperwork was locked in the section of the computer that was not available to the change crew. All of these problems could be seen as threats. Completed installation resulted in the hydraulic line putting pressure on the nearby fuel line. Clearance was accomplished by taking a screwdriver, prying the hydraulic line away from the fuel line and tightening the hydraulic line B nut to hold it there. A mechanic was concerned that it didn't seem right but it was signed out to go. Vibration soon removed the gap and the hydraulic pulsations worked on the fuel line until 60 hours later a 3 inch crack appeared in the fuel line that leaked a gallon per second of fuel. The undesired aircraft state stage had been reached. The pilots were in the recovery/manage mode but first they had to recognize the problem. The flight was a red eye overnight one. Their first indication of a problem was a low oil temperature with high oil pressure indication. This was due to the leak increasing the cold fuel through the fuel/oil cooler lowering the oil temperature which increased the oil viscosity and thus pressure. They put it down to a faulty indication. Next a 6,650 lb, fuel imbalance indication appeared. Not suspecting a leak they opened the cross-feed to feed the right engine from the left side. When they carried out a fuel check they realized that they had insufficient fuel to reach their destination. They declared a Mayday and turned to the nearest land, the Azores islands. Shortly after, the

#2 engine flamed out followed by the #1 due to fuel exhaustion. They glided the remaining 75 miles and on landing likely saved 306 lives compared to trying to ditch in the ocean at night. I believe that fatigue played a role in the decision making of both maintenance and flight crew, but, to what extend we will never know. Take that moment for Safety and if it doesn't seem right it likely isn't.