Chesapeake Chapter INCOSE
International Council on Systems Engineering

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Go to Back Issues

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Feature Article

Keeping Your Balance

By George Anderson

Figure 1. Wreckage on Milam Dairy Rd, Miami, FL

System engineers often encounter superhuman resistance to recommendations that if properly followed might curtail much human misery.

In my previous article dealing with the human factors influence on the design of aircraft clocks, I included an aircraft wreckage picture as a pointer to this follow-on article. I felt that there was more to say about the consequences of poor human interfaces. Figure 1 shows the burning remains of the Fine Air DC-8 that crashed near Miami International Airport on August 7, 1997. Let the Miami Sun Sentinel introduce this tragic event:

"Maria Alvarez still has nightmares about her husband, Renato, being crushed and trapped in his burning car. He had parked in a busy warehouse district just west of Miami International Airport when a Fine Air DC-8 cargo jet dropped out of the sky. The plane crashed into a field, plowed across Milam Dairy Road, slammed into a row of computer outlet stores and Renato Alvarez's vehicle. Alvarez and the four people on board the plane were killed. 'To this day, she has sought professional help for this,' said Barry Meadow, Maria Alvarez's attorney." <Ref. 1>

The regrettable and sorrowful details of this fatal flight are readily available online from the National Transportation Safety Board web site. I wish to suggest two lessons that systems engineers can learn from the event. The first lesson is the risk management aspect of locating a number of stores within feet of the takeoff end of one of the busiest airport runways in the world. The second lesson addresses why we continue to experience fatal crashes due to improper loading.

Maria Alvarez was also present at the accident scene that day as she was working in one of the stores or buildings located within approximately 700 feet of the takeoff runway at the time her husband's car was struck by the aircraft as it skidded across Milam Dairy Road -a six lane highway at the time. While the idea of driving past an active runway may seem a small risk, working daily in a store that is in line with the runway centerline seems to be more of a risk. If the Alvarez couple had known and understood the details of what was later reported in the press about the seemingly inadequate treatment of aircraft loading by the operator, the flight crew, the FAA, and finally, the NTSB in their investigation report, they may have been less comfortable with working or driving under the flight path at Miami International Airport.

Everyone accepts risk in their lives but systems engineers study situations like this and can assign levels of risk based on two aspects. These are the probability and potential severity of the adverse event. If we assign three levels of risk for each category, I would suggest that the probability of an accident at the end of the busy Miami runway was medium on a scale of low (1), medium (2) and high (3). The corresponding severity would top the scale at high.

The numerical result of my instant analysis is shown in Figure 2. The score in each of the nine cells is the product of the associated severity and probability indicated on the horizontal and vertical scales. It places risk at the second highest out of a possible six risk levels. [The table shows risk levels of: 1, 2, 3, 4, 6 and 9.] While one can argue about my risk assignments, the direction of the analysis is clear. There is a high risk of injury or death in the vicinity where the Fine Air DC-8 crashed. This situation likely continues into the present at Miami International Airport and its runway environments. [Video: Typical crash on take off]

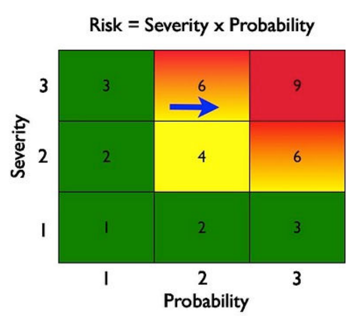

Figure 2. Risk equals Severity x Probability

What about the airplane's balance? It seems obvious that an airplane carrying 88,000 lbs of denim material on pallets needs to be properly loaded or it would not be balanced properly. The load needs to be properly secured, weighed and positioned in the aircraft to assure a safe flight. There were a lot of people who were being paid to get this right. Fine Air had contracted with another company, Aeromar, to load the airplane and they were responsible to initially calculate and provide loading data on what is termed the weight and balance form. The flight crew was responsible to check that the weight and balance form was filled out correctly and physically inspect that the cargo was loaded and secured in agreement with this form. Both groups failed completely to execute their duties and as a result the aircraft departed with a load that did not reflect the data on the signed document. Was the aircraft out of weight and balance limits for takeoff? Probably, but the NTSB

Return to Newsletter

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Matthew Hause; Chief Consulting Engineer, Atego

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investigation was unable to determine this by examining the records and could only speculate based on secondary observations.

The NTSB did discover that the loading crew was not properly supervised, the flight crew was not properly checking the loading sheet and that the true loading status of the pallets was not reflected in the loading documents. <Ref. 2>

To this day, some public reports of the accident will claim that the cargo shifted during the takeoff roll. The circumstances needed for this to be true, however, were not confirmed by the NTSB investigation. Accordingly, these reports may represent a gambit to shift blame away from the parties who were later found to be negligent. The NTSB looked at the accident documents and found a confusing process for calculating the loading of the aircraft. The process was approved by the FAA but was far from user friendly. To make matters worse, the FAA had made no attempt to standardize the loading forms or to promote a common standard method for making the calculations. While there are many ways to properly calculate an aircraft load, the one selected was unnecessarily complicated, differed from the method historically used in training and testing pilots and had no accompanying instructions. <Ref. 3>

In the aftermath of the accident, each group attempted to deemphasize their contributions to making weight and balance calculations difficult. More training was recommended, Fine Air was forced into bankruptcy, and the FAA was criticized for lagging oversight. The Airline Pilots Association (ALPA) made a weak but insincere effort to protect the pilot's professionalism but it was not credible.

For all the protestations, no one seemed to have asked the obvious question. That was, how did earlier generations of aviators manage to routinely accomplish and validate these seemingly complex loading problems?

There were many people who at one time knew the answer but their numbers and influence are growing smaller in the commercial aviation community. They are persons who have served in one of the military aviation branches. These professionals were taught and routinely applied a standard and straightforward method for calculating the weight and balance of an aircraft. To insure continued safety, they were tested at least annually on both the calculation of weight and balance and on the proper method to physically inspect loads.

The military, at some point, must have recognized that additional steps were necessary to simplify the entire process to allow for fatigue, adverse weather conditions and other emergencies associated with ground operations. In other words, training, and emphasis was not enough. Accordingly, they sought an additional backup. It appeared just prior to WWII in the form of what today is called the aircraft load adjuster. One provided by Lockheed for the C-130 aircraft is shown in Figure 3.

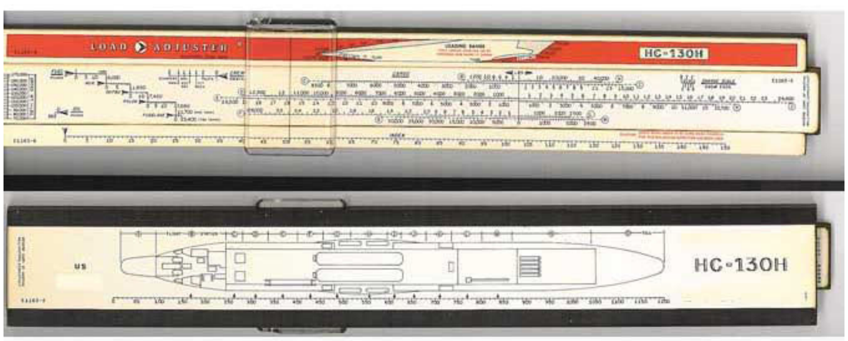

Figure 3. Aircraft Load Adjuster

The concept was that each aircraft would have its own load adjuster and the weight and balance calculations could be entered on the load adjuster by following simple instructions printed on the unit. While some understanding of the process was needed beforehand, the actual calculations were made by sliding the center section to reflect each addition or subtraction of weight based on its position along the aircraft longitudinal axis. It is not a slide rule that uses logarithmic scales to multiply and divide. Instead, it adds and subtracts the quantity known as the aircraft moment. In some ways it is similar to the Oriental abacus. See the 2007, FAA Weight and balance manual for more explanations of these terms and concepts. <Ref. 4>

A military aircraft carries fuel, cargo, and passengers as well as weapons including bombs, rockets, and ammunition. To add complexity to the calculations, one must consider that these can be expended in flight. The majority of major WWII aircraft had some form of load adjuster and today are very collectable memorabilia. Watch for them to appear at garage sales. <Ref. 5>

Why does commercial aviation, the FAA and the NTSB remain aloof from adopting the military concept so successfully demonstrated in the load adjuster? Perhaps the best answer would be the presence of the siren song of modern technology. The siren promises that yet another digital microprocessor will automate this process and remove all responsibility from everyone for the proper calculation of aircraft loading. I will not pursue that point but conclude by saying:

Thank you, Lockheed, for your wise decision to provide this simple tool for each of your aircraft. Thousands of flight crews, passengers and even innocent persons on the ground owe their lives to your foresight.

Return to Newsletter.

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Return to top.

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