



# **Engineering Ethics for Iowa Engineers: Case Study of the Goodrich Aircraft Brake Scandal**

**An Online Continuing Education Course for Engineers**

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## INTRODUCTION TO THE CASE

In June 18, 1967, the B.F. Goodrich Wheel and Brake Plant in Troy, Ohio, received a contract to supply wheels and brakes for the new Air Force light attack aircraft. Goodrich won the contract based on their competitive bid and, more importantly, their innovative technical design (that is, Goodrich was introducing a light-weight four-rotor brake). Before the Air Force could accept the brake, B.F. Goodrich had to present a report showing that the brake passed specified qualifying tests. The last two weeks of June 1968 were set aside for flight testing the brake, giving Goodrich almost a full year for design and testing.

Following brake failure at the June 1968 flight tests and the ensuing accusations by a former B.F. Goodrich employee, Kermit Vandivier, regarding qualification test report falsification and ethical misconduct on the part of specific B.F. Goodrich personnel, Senator William Proxmire (D-Wisconsin) requested a governmental inquiry into the brake qualification testing performed by the B.F. Goodrich Troy Plant. On August 13, 1969, a four-hour Congressional Hearing, chaired by Senator Proxmire, was held to determine the effect of the Air Force A7D Aircraft Brake Problem.

In 1972, Vandivier wrote a well-crafted article, “Why Should My Conscience Bother Me?” which depicted his version of the Goodrich incident. Consequently, his article formed the basis of what is now known in professional business and engineering ethics circles and the literature of whistle-blowing as “The Aircraft Brake Scandal.” As one of the most famous whistle-blowing cases in the literature, The Aircraft Brake Scandal has been hailed as a paradigm case of the courageous individual challenging an unscrupulous corporation. Whistle-blower Vandivier is treated as a hero, a man who lost his job for doing the right thing. This case study traces the history of The Aircraft Brake Scandal and presents you with the opportunity for judging whether Vandivier did the right thing.

### Ethical Issues of the Case

1. Was this a clear-cut case of ethical wrong-doing? If so, what were the wrong(s), and did they justify whistle-blowing? What are the responsibilities of the whistle-blower?
2. How did events escalate such that the only recourse was whistle-blowing? What causal forces spurred Vandivier to action? What personal, social, economic, and political considerations were involved at the time? What roles did failed technological innovation, poor communications, and erroneous qualification testing procedures play? And, could whistle-blowing have been avoided?

3. What procedures can individuals/engineering societies/businesses/government put in place to ensure whistle-blowing is not the end result?

### **An Organizational Chart of Individuals Involved in the Case**

U.S. Air force, Government Contractor

Robert L. Hartman, Chief Systems Engineer

Bruce Tremblay, Systems Group Leader, Headquarters, Aeronautical Systems Division (AFSC), Wright Patterson Air Force Base

LTV Aerospace Corporation, Prime Contractor to Air Force

B.F. Goodrich Co., Subcontractor to LTV

B.F. Goodrich Wheel and Brake Plant, Troy, Ohio

H.C. (Bud) Sunderman, Chief Engineer

Aircraft Wheel & Brake Design Section

Russell Van Horn, Section Manager

Robert L. Sink, Project Manager

John Warren, Design Engineer

Searle Lawson, Design Engineer

Technical Services Section

Russell Line, Section Manager

Ralph Gretzinger, Test Lab Supervisor

Kermit Vandivier, Technical Writer

Federal Bureau of Investigations (FBI)

Joseph Hathaway, FBI agent

United States Congress

Senator William Proxmire, Democrat-Wisconsin

General Accounting Office (GAO)

Richard W. Gutmann and staff, investigated the allegations against the B.F. Goodrich Company, and documented their findings in GAO Report B167023, "Review of the Qualification Testing of Brakes for the A7D Aircraft."

## **A CHRONOLOGY OF EVENTS IN THE GOODRICH AIRCRAFT BRAKE SCANDAL**

### **1967**

June 18: Goodrich receives Purchase Order P-237138 (for \$69,417) from LTV Aerospace Corporation. LTV orders 202 four-rotor brake assemblies from B.F. Goodrich for the new Air Force A7D light attack aircraft LTV is contracted to build for the Air Force.

LTV sets last two weeks of June 1968 aside for flight testing of the B.F. Goodrich brake assemblies. Goodrich must qualify the brake for testing prior to flight test commencement.

June 1967: B.F. Goodrich engineer, Searle Lawson, builds and tests.

### **1968**

March 1968: braking prototypes. All tests fail crucial temperature tests.

April 4: Thirteenth attempt to qualify the four-rotor brake begins. No longer any pretense of qualifying the brake to military specifications. The brake is “nursed” through the required 50 simulated stops, with fans set up to provide special cooling for the brake.

April 11: Vandivier gets involved. Vandivier, in looking over raw data from the A7D brake tests observes that many irregularities in testing methods were noted in the test logs. Vandivier queries Lawson and discovers that Lawson was instructed to deliberately miscalibrate tests, thereby ensuring the four-rotor brake qualifies to the letter of the government specification.

May 2: Fourteenth and final attempt to qualify the brake begins. Lawson is told by his superiors, Robert L. Sink and Russell Van Horn, to qualify the brake, “no matter what.”

Late May: Vandivier refuses to write a falsified qualification report, and is backed up by his immediate supervisor, Ralph Gretzinger. Despite protests, graphic portion of Qualification Report Q6031 is completed by Vandivier and Lawson (taking approximately one month). Chief Engineer Bud Sunderman informs Gretzinger that the engineering section has no time to write the qualification report, so the Technical Services section must. Vandivier is ordered to write the report. He does so, despite the fact that he knows it is a falsified report.

Late May: A few days later Lawson returns from a conference in Dallas with LTV and the Air Force, where the Air Force officials rescind their approval of Qualification Report Q-6031, and demand to see the raw data from the B.F. Goodrich testing laboratory. Vandivier tells Lawson that his attorney has advised him that both he and Lawson are guilty of conspiracy. Lawson asks Vandivier to see his attorney, and one week later Lawson is introduced to FBI agent Hathaway.

June 5: Qualification Report Q-6031 officially published by B.F. Goodrich and delivered to LTV and the Air Force.

June 12: Flight tests begin at Edwards Air Force Base in California. Lawson is present at the tests, and returns two weeks later with reports on testing incidents caused by failure of the Goodrich brake.

Late June: On hearing Lawson's story about danger to the pilot resulting from the faulty brake, Vandivier sees his attorney, who advises Vandivier that both he and Lawson might be considered part of a conspiracy to defraud the government.

Early July: Vandivier's attorney takes him to Dayton, Ohio to meet with FBI agent Joseph Hathaway, who advises Vandivier not to discuss his story, and assures Vandivier he will forward the information to his superiors in Washington.

July 27: Saturday morning conference held between Vandivier, Lawson, Sink and Warren to discuss strategies for telling LTV about the differences in "engineering" interpretation of the test results found in Qualification Report Q-6031. Sink cautions Vandivier that this is not lying; rather, it is a case of engineering "rationalization" or judgment. During the meeting, 43 discrepancies were noted. Sink deems only 3 of these worth mentioning to LTV. August: Visits between LTV and B.F. Goodrich engineering personnel.

September: Unbeknownst to Vandivier, a five-rotor brake was being designed and tested, at no additional cost to either LTV or the Air Force, as a replacement to the faulty four-rotor brake.

October 11: Lawson resigns his position at Goodrich, securing employment at LTV.

October 18: Vandivier resigns from Goodrich, making his effective date November 1. His letter contains numerous accusations of ethical misconduct at the Troy Plant over the past six months.

October 25: Sunderman calls Vandivier in and dismisses him immediately for disloyalty to Goodrich. Sunderman asks Vandivier if he will take further action. Vandivier says, "Yes." Sunderman responds, "Suit yourself."

October 27: B.F. Goodrich recalls Qualification Report Q-6031 and the four-rotor brake, and announces it will replace the brake with a new, improved, five-rotor brake at no cost to LTV.

## **1969**

May 13: Senator Proxmire requests GAO to investigate B.F. Goodrich's Qualification Report Q-6031 testing procedures.

August 13: Four-hour Congressional hearing, chaired by Senator Proxmire, held before the Subcommittee on Economy in Government to determine: (1) the accuracy of B.F. Goodrich's reported qualification test results; (2) the effect the defective brakes had on the test pilot's safety; (3) the identification of additional costs, if any, incurred by the Government to obtain an acceptable brake; and (4) the responsibilities of the Government, including Air Force actions, in the qualification testing.

August 14: Department of Defense announces changes in inspection, testing and reporting procedures.

## **AN IN-DEPTH ACCOUNT OF THE GOODRICH AIRCRAFT BRAKE SCANDAL**

The Aircraft Brake Scandal pivots on problems associated with technological innovation. In 1945 B.F. Goodrich installed a Wheel and Brake Plant in Troy, Ohio, a typical small (population approximately 15,000 in 1960) company town. Hobart Industries was Troy's dominant enterprise, and Goodrich ranked Troy's fourth largest employer. A medium-sized firm, Goodrich had an informal setting and everyone was on familiar terms with their coworkers.

As a subsidiary of the B.F. Goodrich Company, headquartered in Akron, Ohio, the Plant took over the pioneering aviation operations of the Waco Plane Company, building World War II troop gliders for the Air Force. The aerospace industry represented a fraction of Goodrich's business (approximately five percent), and while contracting work meant that many projects were underway at once, aircraft brakes were based on straightforward electro-mechanical technology and most innovations were elementary. Thus, for its first 20 years, most Troy Plant employees were trained in two-year colleges or on the floor. While a managerial hierarchy existed, no formal channels of communication were in place. As a small operation, employing 600 people (200 of whom were salaried professionals), there was little need for such elaborate procedures.

In the early 1960s, disc brakes replaced brake drums. The need for more sophisticated engineering became evident at Goodrich, and many of the Plant's earlier positions were eliminated. For example, with a background in electronics, Vandivier's expertise as an instrumentation technician was no longer part of Goodrich's vital operations; therefore, in 1965 he was reassigned as a technical writer. Other Goodrich employees suffered the same fate. Degreed engineers were hired for meeting the needs of new technologies and governmental contracting requirements. Despite Goodrich's small operation, their new, more sophisticated labor pool established a reputation for providing excellent brakes for both military and civilian aircraft. Thus, Goodrich became a strong competitor for the A7D aircraft brake contract.

On June 18, 1967, the Goodrich Troy Plant received Purchase Order P237138 from the Ling-Temco Vought (LTV) Co. of Dallas, Texas, contracting for 202 brake assemblies for the new A7D light attack aircraft. While built for the Navy, the A7D light attack bomber was procured by the Air Force; hence, the A7D was a joint Navy/Air Force program.

LTV was awarded the prime contract for the A7D, and was responsible for subcontracting to other specialists in the aircraft industry. ***LTV received four quotes from top specialists in the brake field: Goodrich, Bendix Aviation Products Division, General Tire and Rubber Co., and Goodyear Aviation Products Division. LTV awarded Goodrich the contract based on Goodrich's competitive bid and, more importantly, their innovative technical design (that is, Goodrich was introducing a light-weight four-rotor brake).***

Once discs replaced drums, the industry standard for Air Force aircraft brakes was based on a heavier five-rotor model. Because the design of the aircraft disc brake is very tough technically, and costs associated with improving it often outweigh the benefits from so doing, there was little innovation in the aircraft brake industry through the 1960s. Thus, Goodrich's proposed lighter-weight, four-rotor brake was considered state-of-the-art design in a relatively static industry. Goodrich's innovative brake design meant that the A7D light attack aircraft could carry a heavier payload (that is, munitions). Considering the cost and payload advantages, both the U.S. Navy and Air Force supported the LTV decision, and Goodrich was awarded the A7D contract.

Standard governmental qualification testing specifications and procedures were written with the five-rotor brake in mind. Qualification testing specifications were written by specialists in the aircraft brake industry, and procedures ensured that any properly designed five-rotor brake could meet, with some engineering discretion, testing qualifications to the letter of the government's specifications. With the five-rotor precedent as their guide, both the government and LTV specification documents (Military Spec MilW5013GUS Air Force and LTV Specification Document 2041637D) adopted these long-held, five-rotor standards for the Goodrich four-rotor brake. Meeting specifications was not difficult, and when brakes did not meet the intent of the specifications, compromise was commonplace. The subcontractor had license to modify procedures as necessary, provided they kept the prime contractor apprised of adjustments or problems.

A common understanding developed over time between those working within the brake industry. And while rules were not meant for breaking per se, trust was cultivated between the various specialists. With professional understandings between prime contractor LTV and subcontractor Goodrich in place, LTV set the last two weeks of June 1968 aside for flight testing. This gave Goodrich almost one full year for designing and testing the four-rotor brake.

John Warren, one of Goodrich's best engineers, designed the initial A7D four-rotor brake. In his early 30s, Warren had an excellent track record in aircraft brake design. He was involved in notable designs, including the Air Force C5A brake contracted to Lockheed and General Electric, as well as the Boeing 727 brake. After he completed the design, Warren handed off the brake so he could work on the many other brake projects in-progress at the Troy Plant.

Searle Lawson, a young and recent aeronautical and astronautical college graduate, was assigned the task of testing brake lining temperatures in Warren's design prior to building the final prototype of the A7D brake. This was Lawson's first real job working on brakes. Through March of 1968, he built and tested sundry prototypes so that appropriate lining materials could be chosen. During Lawson's laboratory test stops, however, he was alarmed by the brake's high temperature reading, as well as the fact that it glowed a bright cherry-red and threw off sparks.

***Following several simulated landings, Lawson examined the linings and noticed they had disintegrated.*** Lawson realized in December of 1967, a full six months into the project, that the A7D brake had a fundamental design flaw. From his training, Lawson understood the brake was too small and could not withstand the demands of a normal aircraft landing. "The brake would not make the required number of stops as far as [specification requirements for the] life of the brake [were concerned]. It just would not make it."

Lawson reported his findings to the design engineer, Warren, who assured him it was not a design problem. Warren said the four-rotor brake design was neither too small nor in need of more material, and he instructed Lawson to try still other lining materials. Lawson then spent much of his time in Cleveland, learning about lining materials. Trying countless materials, he continued testing the brake, but the results were always the same: the Goodrich brake could not meet the Air Force and LTV specification requirements without “nursing” the brake through the various tests.

Warren was busy with other projects in the Plant, and had disassociated himself from the A7D brake. He did not advocate misrepresenting the A7D brake; he just no longer wanted a role in the

A7D because his project segment was complete. Thus, as engineer responsible for testing the brake, the A7D was now Lawson’s exclusive domain. Unable to discuss the possible implications of the over-zealous goals of the four-rotor brake with Warren, and deciding he was still not satisfied with the designer’s recommendations, Lawson took his concerns to his immediate supervisor, Robert L. Sink, Goodrich A7D project manager. Sink told Lawson to keep testing different materials, noting that he had already assured LTV several times that the brake design was a success, and that Warren’s design would work. Sink further reminded Lawson that if the design did prove faulty, Sink would answer to Goodrich executives and LTV.

Parts began arriving at the plant and over the next few months a working model was built so that full qualification tests could begin. By late March 1968, Goodrich attempted qualifying the brake by military specifications 12 times, and each time the brake failed the specified temperature tests. At the same time, Sink continued assuring LTV that brake tests were going smoothly. As far as Lawson was concerned, however, Warren’s innovative design was a dismal failure, and the June flight testing dates were fast approaching.

On April 4, 1968, the 13th qualifying attempt was made, but again, without nursing the four-rotor brake, Goodrich qualification testing was unsuccessful. In fact, Goodrich personnel set up special cooling fans in the testing laboratory to both avoid problems with lining material and meet the specifications. On April 11, 1968, after a full year of brake qualifying tests, Kermit Vandivier found himself involved in the A7D operation when he discovered many discrepancies between the military specifications and the qualification tests carried out at Goodrich. Vandivier was then a technical writer for Goodrich. He had worked for the company for six years, the first three as an instrumentation technician, and his last three as a writer. As low man on the Goodrich totem pole, the major component of Vandivier’s work involved reading numbers off the testing strip chart and plotting the curves for inclusion in qualification reports.

The writing task was routine, and a boiler-plate format was used. Although a time-consuming effort, it did not require an engineer’s expertise. Their time was better spent on engineering design and testing. Thus, Vandivier was assigned the scripting task. After plotting the engineering curves, Vandivier wrote the appropriate documentation that would accompany the testing data in the qualification report. Yet, on seeing these recent discrepancies between the military specifications and the Goodrich four-rotor brake test results, Vandivier questioned whether he should compose a report that was so out of step with the military specifications. While not formally trained, Vandivier had worked as official scribe on enough Goodrich reports

to feel something was awry in this particular case. “All of these incidents were in clear violation of military specifications and general industry practice.”

Vandivier took his concerns to his immediate supervisor, Ralph Gretzinger, Test Lab Supervisor, who assured him that the testing laboratory would not issue a misrepresentation of the qualification tests. However, within a few days, a typewritten copy of the test logs of test T1867 [the 13th attempt] was sent to LTV in order to assure LTV that a qualified brake was almost ready for delivery.

***Virtually every entry in this so-called copy of the test logs was drastically altered. As an example, the stop time for the worn brake maximum energy stop was changed from 141 seconds to a mere 46.8 seconds.***

On hearing of the interim report, Vandivier questioned Richard Gloor, test laboratory engineer, who told him that Lawson had directed the test lab to miscalibrate the instruments, at the order of one of Lawson’s superiors. When Vandivier approached Lawson about qualification test T-1867,

Lawson confirmed Gloor’s account. Lawson told Vandivier that they were going to make a 14th attempt at qualifying the brake; however, Robert Sink, A7D project manager (Lawson’s immediate supervisor), and Russell Van Horn, manager of the Aircraft Wheel and Brake Design section, had told Lawson that, “Regardless of what the brake does on the [14th] test [conducted in May, 1968], we are going to qualify it,” and that if the 14th test failed, the report would be written based on test T1867. That said, Sink left for California on Troy Plant business. In his absence, Sink left Warren in charge of the A7D, but Warren was busy working on other design-related projects and had little time available for helping Lawson.

On May 2, 1968, the 14th attempt at qualifying the brake was made. The brake was nursed along, and little lining was left after the 45 simulated stops. While the tests were conducted, Lawson asked Vandivier to commence writing the qualification report. Vandivier was incensed and refused to write a qualification report he felt was based on falsified data. At first, Gretzinger backed Vandivier’s decision and said he would approach his own supervisor, Russell Line, manager of the technical services section, and get the matter cleared up. “He consulted Mr. Line and assured me that both had concurred in the decision not to write a qualification report.”

Meanwhile, on return from California, Sink told Lawson to start writing the report, and then Sink again left Troy on Goodrich business. When Lawson told Vandivier his predicament, Vandivier offered to help gather the test data. By the end of May 1968, Vandivier and Lawson completed the graphic portion of Qualification Report Q6031 and discussed the implications of what they were doing. Vandivier was so concerned about the implications of a falsified report that he even went above his own immediate supervisor to discuss the matter with Line. This course of action would be considered a pretty daring move in many companies today, never mind in a company operating in 1968. Goodrich had not yet developed procedures for problems like the one Vandivier found himself embroiled in; thus, going over his immediate supervisor and side-stepping discussions with Sink (because he was out of town) meant that Vandivier had already started the whistle-blowing process.

Having taken his concerns to everyone but the chief engineer, Bud Sunderman, and having the graphic portion of the report complete, Vandivier felt his involvement in Qualification Report Q6031 was at an end. This was not his fortune, however, and despite Vandivier's efforts to avoid writing the narrative portion of the report, Gretzinger told him he had no choice.

Goodrich submitted Qualification Report Q6031 to LTV on June 12, 1968, without either Vandivier or Lawson notifying Sunderman or Goodrich corporate headquarters in Akron of their misgivings. Lawson's testimony at the Congressional Hearing helps explain why this was so. "I really didn't feel there was anybody above [Sink] that I could take it to."

In mid-June, flight tests on the brake began at Edwards Air Force Base in California. On Goodrich's behalf, Lawson witnessed the tests. No members of the Air Force were present at the flight tests, as their presence was not required. And while LTV officials were present at some preliminary tests, no LTV representative attended the final flight test.

When he returned two weeks later, Lawson told Vandivier about various mishaps during flight testing. Listening to Lawson's concerns about possible dangers associated with the brake convinced Vandivier that he should contact his attorney, which he did before the day was out. "[My attorney] advised me that, while I was technically not guilty of committing a fraud, I was certainly part of a conspiracy to defraud." Vandivier's attorney also suggested that Vandivier meet with U.S. Attorney Roger Makely in Dayton.

On his return, Vandivier told Lawson that his attorney had advised him that both he and Lawson were guilty of conspiracy; not that they might be, but that they were.

Fearing conspiracy charges, Lawson asked Vandivier if he would arrange a meeting for him with Vandivier's attorney. Asked at the Congressional Hearing why he made the statements he did to the FBI, Lawson responded:

I believe my [real] feeling for going to the FBI was one of just, I guess, protecting myself. I realized from speaking with Mr. Warren, who had made statements to me to the effect that whenever something gets in trouble, referring to being at the Goodrich plant, you were on your own, don't look for your supervisors to be around, and from seeing experiences, experiencing things at Goodrich, where Mr. Sink had been involved in another incident, and somebody else was demoted, and other items like that, that I felt that I needed to talk to somebody about it, because it was a pretty serious situation, and the only person I could think of was to consult an attorney, and then he advised me to talk to the FBI.

Several days later, Lawson left on another LTV visit. While Lawson was in Dallas, Vandivier's attorney called and said that on the advice of Makely, he had arranged an interview with the Dayton office of the FBI. Vandivier's attorney arranged a meeting for him with FBI agent Joseph Hathaway in Dayton, Ohio. ***Hathaway told Vandivier not to discuss his concerns about the ethical misconduct at Goodrich's Troy Plant, and asked Vandivier if Lawson would corroborate his story. Vandivier assured him Lawson would.***

When Lawson returned, Vandivier described his visit with his attorney and what the attorney said. Lawson, taking Vandivier at his word, and without approaching anyone in the Goodrich hierarchy, met with Vandivier's attorney, and both Vandivier and Lawson met with FBI agent Hathaway. Around the same time, Mr. Bruce Tremblay, Systems Group Leader for Landing Gear in Airframe Subsystem Directorate, Aeronautical Systems Division of the Air Force Systems Command, requested the raw data for Goodrich's Qualification Report Q-6031. Goodrich declined Tremblay's request for raw data, stating that it was considered proprietary information. As noted by Tremblay, such a refusal was rare; however, Goodrich kept data in-house as a long-established policy, and gave Air Force officials the opportunity to review the raw data at the Troy Plant.

On Saturday morning, July 27, a damage control meeting took place between Vandivier, Lawson, Warren, and Sink. Sink had been away, off and on, for almost three months. He called the meeting to discuss how best to tell LTV about the discrepancies or engineering interpretations inherent in the test results of the four-rotor brake. Finances no longer mattered, for Goodrich was well over-budget given all the extra testing associated with the four-rotor brake. Lawson manned the blackboard, and together the four meeting participants compiled a list of discrepancies. Of the 43 discrepancies noted, Sink made the final decision that 40 of the discrepancies could be considered inconsequential and that only three were deemed worth mentioning.

As often happens, Vandivier, the bringer of bad news, was now alienated from day-to-day operations and openly hostile to Sink. He no longer expressed his concerns and instead relayed his suspicions to FBI agent Hathaway.

On August 26, 1968, Tremblay submitted his official letter to Robert L. Hartman, Chief Systems Engineer, Headquarters, Aeronautical Systems Division (AFSC), Wright Patterson Air Force Base. Because the Goodrich report contained no original test data, only re-plotted information, and "The method of conducting the test was highly unconventional and without suitable explanation acceptable to this office," Tremblay recommended withholding approval of Goodrich's four-rotor brake.

Meanwhile, work had already commenced at the Goodrich Troy Plant on a five-rotor brake that would replace the disqualified four-rotor model.

A number of visits took place between Goodrich Troy staff and LTV staff in Dallas throughout August and September. The activities between Air Force, LTV, and Goodrich Troy Plant personnel paralleled Vandivier's clandestine meetings with FBI agents, where he transferred sundry documents to agent Hathaway and others. From Vandivier's now limited vantage point at Goodrich, the October 8 meeting was just another forum for Sink, where Sink could ensnare others in his own prevarications. Vandivier did not attend the October 9 meeting and work continued apace on the new five-rotor brake with all indications that it was meeting standards to the letter of the military specifications. In fact, one of Lawson's initial designs had been reworked, and he was immersed in the five-rotor brake project. *As with so many whistle-blowers, Vandivier was frightened, knew he was low man on the totem pole, and was now walking alone. He found himself talking about the brake problem with anyone who would*

*listen; however, most employees were busy on other projects and preferred not getting involved.* His training was in outmoded electronics and writing, and he had a family of seven to feed. His situation looked grim at best.

In 1968 LTV sponsored a hire-a-friend program, and one of the people working on the A7D project suggested Lawson apply for a recent opening. Seeing a career opportunity, and anxious to leave Troy for an assortment of personal rather than professional reasons, Lawson applied for the position. In October he was offered a position with LTV, and when he resigned his post at Goodrich on October 11 (effective October 25, 1968), he burned no bridges and had no intentions of blowing the whistle on Goodrich. In fact, Russell Van Horn offered him reassignment to another section of the Plant, if working under Sink caused his resignation.

Lawson assured Van Horn that his reasons for terminating were personal in nature, and let him know he looked forward to working with Goodrich on the A7D and other brake projects.

Vandivier submitted his own letter of resignation on October 18, replete with accusations against Goodrich. As the Plant's chief engineer, Bud Sunderman was not always privy to day-to-day operations within the plant, instead leaving Sink and Line that task in their respective departments. Thus, it is conceivable that rumors of Vandivier's allegations had not reached him, so when he read Vandivier's letter, Sunderman was likely shocked. On October 25 Sunderman called Vandivier to his office and dismissed him immediately for disloyalty. When Sunderman asked if Vandivier would take his allegations further, Vandivier said, "Yes." Ushered out of the Troy Plant on October 18, Vandivier started working for the Troy Daily News, a local newspaper for which he had been writing local political commentary part-time since 1965.

Vandivier told his editor at the Troy Daily News about his experience at Goodrich. The editor had just received a Ford Foundation grant and passed the story to others in Washington. The story reached Senator William Proxmire (D-Wisconsin), who was receptive to Vandivier's tale of misdeeds at Goodrich. Proxmire had earned the distinction of quality assurance senator for his tough stand on government waste.

On May 13, 1969, Proxmire requested that the Government Accounting Office (GAO) review the brake qualification testing performed by the Goodrich plant in Troy. The GAO reviewed the operations at Goodrich and submitted a report to Senator Proxmire on July 3, 1969, with a follow-up letter dated July 11, 1969. On receiving the report, and without consulting Goodrich personnel, on August 4, 1969, Senator Proxmire made the first public announcement on the Senate floor, both about Vandivier's allegations against Goodrich and the GAO investigation. On August 13, 1969, a four-hour Congressional Hearing, chaired by Senator Proxmire, was held before the Subcommittee on Economy in Government. The purpose of the Congressional Hearing was to determine: (1) the accuracy of Goodrich's reported qualification test results; (2) the effect the defective brakes had on the test pilot's safety; (3) the identification of additional costs, if any, incurred by the Government to obtain an acceptable brake; and (4) the responsibilities of the Government, including Air Force actions, in the qualification testing.

GAO Report B167023, as well as the Congressional Hearing testimony presented by GAO representatives, showed that Goodrich's qualification testing procedures did not comply with

Government specifications, some of the discrepancies in the report were indeed significant, and overall Qualification Report Q6031 did not present an honest picture. In general, report findings support Vandivier's claims that the report was falsified.

In terms of the effects of the defective brakes on the test pilot's safety, Congressional Hearing testimony suggests that this point was overstated; however, in the fog of battle, no one could be sure what would happen to the pilot had the brakes failed. The consequences of design failure are not often known in advance, and in many industries seeming redundancies are used. While engineers have a deserved reputation for over-engineering, that tendency is itself a product of experience with unexpected failure (witness "the unsinkable Titanic"). Yet, while some risk always exists, Lawson testified at the Congressional Hearing that while he believed there was some danger to the test pilot, it was much less than he had once assumed.

Congressional Hearing testimony also confirmed that no additional costs were incurred by the Government in obtaining an acceptable brake, and that aircraft delivery and testing was not hindered in any way because of the Goodrich brake problem. But who would incur the additional costs, given the four-rotor brake was egregiously over budget? Perhaps not the government in this one particular instance, but surely costs were absorbed elsewhere.

This leaves us with puzzling points involving qualification testing procedures. In addition to haphazard events caused by technology-related and communications problems, the evidence supplied by witnesses at the Congressional Hearing raises other issues surrounding culpability of Goodrich, LTV, and Air Force personnel in lax qualification testing procedures. Because aircraft five-rotor brake technology had changed so little and failure seemed so remote, those concerned with the A7D brake allowed what we now perceive as slack in the qualification testing procedures.

When Proxmire questioned witnesses at the Congressional Hearing, no one other than the GAO representatives thought the testing procedures then in place were odd, even though they revealed that testing procedures were indiscriminately monitored, critical LTV and Government officials missed witnessing important flight tests, and no definite procedures were in place. At first blush, Congressional Hearing evidence points to ambiguous qualification testing procedures. But if a company can be trusted, why not cut down on supervision? Part of what contracting with professionals means is that you can avoid the additional supervision costs. Government and industry alike now often omit certain kinds of monitoring for companies that have quality control and ethics procedures in place. Yet, with increases in technological sophistication, and mounting bureaucratic layers, can any of us afford to eliminate quality control checks?

Richard W. Gutmann, deputy director of the Defense Division for the GAO, noted that Government signatures on reports seemed to carry little or no force, and that Government quality assurance seemed lacking at final testing; for example, there were no Defense Contract Administration Service (District) personnel present during any of the test flights. Gutmann stated that the deficiency in government quality assurance left the entire subcontracting responsibility with the prime contractor, LTV, a situation that seemed unacceptable in government procurement. Gutmann said that because discrepancies found in the report were significant, and that having a government presence before the final flight tests was necessary, that ". . . it is

basically the lack of participation in the qualification testing where we consider the procedures inadequate.” And Gutmann again confirmed that while a government official had signed the qualification report, it was essentially meaningless. It simply meant the official had seen it, not that he had necessarily approved it.

Finally, the Congressional Hearing lasted only four hours. This conveys the relative insignificance of the case as it was perceived by contemporary standards. Finding no “golden fleece” on which to ride, Proxmire merely wanted to confirm that the Government’s nose was clean, that the taxpayers were not being ripped off over yet another Air Force cost overrun like the C5A. No action was taken against Goodrich, and despite Vandivier’s contention that an announcement of “sweeping changes” in government contracting procedure were initiated following the Congressional Hearing, Federal government contracting procedures were constantly changed to meet the challenges of technological innovation and bureaucratic expediency.

The major change following the Goodrich incident involved governmental inspection procedures. With more people involved in fulfilling a contract, and with technological shifts, more checkpoints were enforced. Essentially, the cost of information (that is, finding out which professionals you could trust) had increased. The other change that occurred was that Goodrich, because of its blunder, was forced to deliver a redesigned, traditional five-rotor brake, so that the A7D aircraft could make its successful debut at Luke Air Force Base, Arizona, in November of 1969 without murmur of impropriety.

No one then at Goodrich lost his (there were no women involved in this particular incident) job because of the incident; however, no one ascended the corporate ladder either. Warren, Line, and Van Horn continued working for Goodrich, with the usual promotions and perks. Warren still works at the Troy Plant, and Line and Sink retired from the Troy Plant; they did not climb the Akron hierarchical ladder. And despite the claims in Vandivier’s article, Sink was not promoted. Instead, he was reassigned to the technical writing division, arguably a step down from managing technology-related projects. This is significant, for it shows that Goodrich took corrective measures with personnel-related problems in the Plant, and took remedial action where Sink was concerned.

Lawson’s superiors at LTV were most forgiving, and despite his complicity in writing a less than honest report, he remains an LTV employee to this day.

From the day of the Congressional Hearing forward, business in the aircraft brake industry continued apace, and normal practices returned. The changes made in government contracting procedures were well underway when The Aircraft Brake Scandal made its debut, and Military Specification MilW5013HUS was just another in a long series of modified procedures over time. Changes put more inspection points into contracting, but no one argued that more inspection was superfluous. The changes were neither earth shattering in terms of governmental contracting procedures, nor did they significantly affect the day-to-day operations of Air Force prime and subcontractors. It was “business as usual.”

When Lawson heard about Vandivier's chapter for the book, *In the Name of Profit*, he met with Goodrich staff and wrote Doubleday, publisher of the book, a letter disavowing Vandivier's claims. To Lawson, Vandivier was motivated (as any sane writer is) by publishing his work, and the Goodrich case provided the perfect story for launching a new career. Lawson, on the other hand, was on a successful career-track at LTV, was on good terms with staff at Goodrich, and wanted the entire aircraft brake scandal behind him.

In 1972, Doubleday published Vandivier's version of the Goodrich story, and it soon appeared in *Harper's Weekly*. Goodrich never sued Vandivier for publishing his account of the Goodrich story, in part because the costs of so doing far outweighed any benefits to the corporation.

How could they know the article would be used time and again over the next 20 years, as a case of the courageous individual battling an insensitive corporate hierarchy?

Twenty years later, Vandivier's words live on. But have those of us using his article done the Goodrich case justice? Evidence provided shows that the long-term implications of what happened at Goodrich remain unresolved. Those involved in the Goodrich case were lucky; however, our failure to learn from the past is much in evidence today—witness what happened with Challenger when pressures for fulfilling a government contract outweighed presenting an honest picture of a technology's limitations.

Was this really a case of intentional deception solely on the part of B.F. Goodrich? Does the case involve professional engineering judgment (or rationalization), negligence, incompetence, or fraud? And, if it was intentional deception (making it a legitimate case of ethical wrong-doing), who was guilty beyond Vandivier and Lawson, and was Vandivier morally justified in blowing the whistle on B.F. Goodrich? These are difficult questions to answer, mostly because life is ambiguous inside corporate America.

### **ETHICAL ISSUES OF THE CASE: POINTS FOR DISCUSSION**

Questions posed throughout the Congressional Hearing aimed at resolving the issue of whether the Air Force A7D Brake Problem case really involved ethical wrong-doing solely on the part of B.F. Goodrich and/or whether Goodrich personnel intended to deceive either LTV or the Air Force (never mind the public) by falsifying Qualification Report Q6031. There is sufficient circumstantial evidence to suggest intentional deception as a possibility; however, there is no direct evidence beyond the claims of Vandivier (and, by implication, Lawson) that the reports were intentionally falsified.

Evidence from the case exposes three significant causes for the escalation of events at Goodrich: failed technological innovation, failure to communicate full information (from the Air Force down), and lack of credible and enforceable governmental qualification testing procedures.

Failed technological innovation exposed communication and qualification testing procedural problems already in place. Then, the inability (perceived or real) to communicate concerns created an atmosphere where whistle-blowing became inevitable for Vandivier. Vandivier did not have access to counsel within the corporate hierarchy of Goodrich. The same is true of

Lawson. Goodrich personnel within the Troy Plant (specifically Sink) did not keep Vandivier within the communication loop after Vandivier voiced his concerns. Air Force and LTV personnel neither attended crucial tests, nor asked the right questions of the right people. And GAO representatives and Senator Proxmire did not follow up on puzzling points, both in the GAO report and at the Congressional Hearing, points that might have resolved the larger technical and ethical issues.

Vandivier's technical expertise remains a problem. As revealed in the Congressional Hearing, and pointed out by Fielder, Vandivier did not even complete his high school education, even though he testified that he had. He was employed as a technical writer, and despite the writer's claim to professional stature, in 1968 the term technical writer was a dubious distinction, and did not constitute the ranking of a technical professional. His technical expertise is questionable, and his charges are based on second-hand information. In addition, a boiler-plate format was used for all qualification reports, so Vandivier did not need much in the way of technical know-how for report completion. He simply fulfilled a cost-effective clerical role in the Goodrich operation.

When Proxmire asked Vandivier if this kind of thing had ever happened before, had any other technical writer for Goodrich been asked to falsify documentation, Vandivier said that, to his knowledge, this was the first time. And when Proxmire questioned him on the usual practice regarding discrepancies in testing, how Goodrich normally handled such situations, Vandivier revealed that if there were deviations in testing procedures, Goodrich put those deviations in writing and usually a compromise was reached with the contractor.

Vandivier worked at Goodrich for six years, three as an instrumentation technician and the last three as a technical writer. On whose technical authority did Vandivier base his falsification argument? It was Lawson's; however, Lawson had just graduated and was working under a designer whose specialization was the aircraft brake. Lawson had theoretical knowledge, but lacked practical experience. In addition, there were at least 30 other professionals on staff during the qualifying tests. Why was there only one person (a technical writer) willing to come forward, and only one other (an inexperienced engineer) willing to give a half-hearted corroboration of the charges?

When Proxmire questioned Lawson about the falsification of the report he prepared with Vandivier, Lawson's statement was less than accusatory. In retrospect, Lawson states that he was naive about government contracting in particular, but also about aircraft brake testing in general. He had theoretical training, but was unfamiliar with the work in practice. For example, he notes that all brakes glow a bright cherry red under similar testing, but he did not know that at the time. When he perceived intentional deception on Sink's part, he panicked, and mistrusted the advice of most of the experts around him. In addition, he feels that had he known the procedures better, he could have advised them that the four-rotor brake would have worked. This assumes, however, that other Goodrich personnel would have been straightforward about the limitations of the new technology. Receiving the benefit of increased payload meant that the four-rotor brake would have worn out sooner. It might have stopped 300 instead of 400 times (as set out in the specifications). With that knowledge, all concerned could have accessed information necessary for making a more informed decision about whether the benefits of the four-rotor brake outweighed its drawbacks.

Another former Goodrich researcher contends that in 1967 the design engineers, specifically Warren, thought they possessed the necessary technical knowledge. Brake engineering specialists at that time decided that what they deemed a small deviation in temperature was of little consequence, and because military specifications were unrealistic for the innovative four-rotor brake, they took greater liberty with engineering interpretation. As evidenced by Congressional Hearing testimony, neither Vandivier nor Lawson were aware of the extent to which specialists accommodated such procedural guidelines, until, of course, the four-rotor brake forced the issue.

At bottom, the erroneous qualification testing procedure is the most troubling point of the case. Testing procedures were lax because over time faith in proven technologies, as well as a professional trust, developed. While the procedures were discussed in the Congressional Hearing, the issue disappeared and was not of paramount concern to either Proxmire or others involved in the case. But what would have happened if the problems with qualification testing and reporting procedures had become politicized? Would all involved in the aircraft brake industry be forced to reconcile their qualification testing procedures because someone at Goodrich covered up a mistake using engineering rationalization and loose qualification testing procedures as an excuse?

Members of the Goodrich staff did not present an honest picture of what the four-rotor brake's limitations were. But the Congressional Hearing testimony also shows that those involved (from government procurement officials to subcontractors like Goodrich) were comfortable modifying reports so that their brakes would meet the requirements laid out by the military specifications.

Thus, beyond technological and communication problems, the evidence supplied at the Congressional Hearing makes testing verification procedures appear somewhat ludicrous. Written signoff meant virtually nothing, and attendance at crucial test points seemed arbitrary and optional. When Conable asked Lawson what a qualifying report meant (i.e., Was it production ready or test ready?), Lawson stated that it meant the brake was qualified for flight testing only, that it had to pass flight testing before a production brake was made for airplanes. When asked what Goodrich gained by falsifying data, Lawson stated that he felt Goodrich could gain nothing, that it was a case of certain individuals' pride, and that upper management had no idea what was going on.

There were no clearly-defined levels of accountability for the project. Lines of responsibility were blurred such that everyone's vision of the project became microscopic; hence, no one saw the aggregate implications of the A7D brake. In addition, testing procedures were no longer adequate (note: inadequate, not illegal) for meeting the challenges of innovation. But were they ethical, especially regarding the qualification testing? And who is culpable for letting such misleading qualification testing procedures persist?

Procedures were put in place because, in essence, no one ever expected that an innovative brake would cause such a stir. This meant those involved with the A7D could act out the qualification testing masquerade; hence, all involved were carrying out improper testing procedures to some degree, and this was specified by government expectations and advanced by standard industry

practice. Yet, if a certain amount of engineering interpretation is required and/or expected in meeting contracting specifications, and if these rules are implicitly understood throughout an industry, what would constitute a “falsified” report? This was certainly a concern at the time.

This raises serious questions about the qualification testing procedures as written and enforced, both during the A7D aircraft brake project and now, questions students of engineering and business ethics must tussle with. How do we reconcile innovation with meeting paradoxical testing procedures? What are the ethical implications of a procedure that forces people to compromise their professional standards from the onset? And, if government officials writing specifications are not specialists, who advises them? The same people that must in turn meet the specifications?

With each increase in engineering and technological sophistication, new problems arise, and new traps lay just beneath the surface. Perhaps the most valuable lesson of the case is that we all need to think about whether current industry practice can meet the challenges new technologies bring. And engineers and managers must be encouraged to admit when innovation falls short of its promise. There will always be risk in innovation. The trick is learning how best to minimize it.

## ANNOTATED BIBLIOGRAPHY

### The Goodrich Case: Primary Sources

Hearing before the Subcommittee on Economy in Government of the Joint Economic Committee, Congress of the United States, Ninety-First Congress, First Session, August 13, 1969. LC card 72-606996.

As the only other available primary evidence for the Goodrich case, this four-hour Congressional Hearing presents testimony from the other key actors in the brake problem incident: from Vandivier and his corroborator, Lawson, to representatives of the Air Force, Government Accounting Office (GAO) and B.F. Goodrich Co. headquarters in Akron, Ohio. The Hearing also contains the original, “falsified” qualification report (Q6031) as well as the inquiry into the Air Force A7-D brake problem. The Hearing was chaired by Senator Proxmire, the quality assurance senator, now notorious for his “Golden Fleece Awards,” handed out monthly from 1975-1980 to federal government agencies deemed most wasteful, nay reckless in their disbursement of the tax-payers’ dollars. The purpose of the Hearing was to determine: (1) the accuracy of B.F. Goodrich’s reported qualification test results; (2) the effect the defective brakes had on the test pilot’s safety; (3) the identification of additional costs, if any, incurred by the Government to obtain an acceptable brake; and (4) the responsibilities of the Government, including Air Force actions, in the qualification testing. The Hearing revealed problems not only with Goodrich’s qualification testing and reporting procedures, but with the aircraft brake industry’s procedures as a whole.

Vandivier, Kermit. “Why Should My Conscience Bother Me?” in *In The Name Of Profit*, Robert L. Heilbroner, Ed. New York: Doubleday, 1972, pp.3-31. Reprinted as “The Aircraft Brake Scandal,” *Harpers Magazine*,

244, April 1972, pp.45-52.

Vandivier, as whistle-blower at B.F. Goodrich, presented his side of the incident in this well-crafted account. The self-proclaimed ethical actor in the case, Vandivier skillfully caricatured the other central actors in the case, detailing how events at B.F. Goodrich lead inevitably to his blowing the whistle on unethical conduct surrounding qualification testing and reporting falsification at the Troy, Ohio Wheel and Brake Plant that caused possible danger to aircraft flight testing pilots. As one of the most famous cases in the literature of whistle-blowing, Vandivier's narrative is held as a paradigm example of one courageous individual challenging corporate corruption, and his account went unchallenged for nearly 20 years.

### **The Goodrich Case: Secondary Sources**

Fielder, John H. "Give Goodrich a Break," *Business and Professional Ethics Journal*, Vol. 7, No. 1, Spring 1988.

Fielder's article challenges the original assumptions of the Goodrich case, noting that Vandivier overstated the case of pilot safety. In addition, he questions why those teaching business and professional ethics courses, as well as those engaged in scholarly writing on whistle-blowing, have treated the case solely on Vandivier's version. He questions whether we have been presenting and spreading a one-sided account that is also unfair. Fielder addresses: 1) whether Vandivier's moral judgments about Goodrich were accurate and fair; 2) how academic writers have used Vandivier's version of events to attack Goodrich; and 3) why writers have uncritically accepted Vandivier's account. He concludes that it is because ". . . it so clearly fits a concept of corporate wrongdoing and individual courage that fairly obvious signs that something is wrong have been overlooked." Based on the ambiguities of the case, he questions whether it is truly useful as an applied ethics case, noting it can certainly no longer be used as a paradigm example of morally-justified whistle-blowing.

Wills, Jocelyn A. "Tough Brake for Goodrich: Qualifying the Ethical Issue," paper presented at the 1992 Phi Alpha Theta Southwest Region Historical Conference, Texas A&M University, April 1992.

Wills takes Fielder's article as her lead, and uses the Congressional Hearing and personal interviews to argue that the central ethical issue of the case pivots around problems associated with qualification testing procedures and aircraft brake industry practice. She concludes that: "A careful reading of the historical evidence shows that whistle blowing was merely a symptom of larger ethical dilemmas within both Goodrich and the aircraft brake industry as a whole from engineering responsibility regarding rationalizing ineptitude and failed innovation, the case actors' accountability for deficiencies in communications, to governmental and industry culpability in allowing erroneous qualification testing procedures to continue." Unlike Fielder, she argues that the Goodrich case remains useful for those studying applied ethics precisely because of its ambiguities and social/economic/political layers.

## The Whistle-blowing Debate

Baron, Marcia. *The Moral Status of Loyalty*. Module Series in Applied Ethics from the Center for Studies of Ethics in the Professions. Dubuque, IA: Kendall Hunt, 1984.

Baron's discussion focuses on what, if anything is good about loyalty to a corporation, and how do we decide under what circumstances it is better to be disloyal. She concludes that claims to loyalty, be they from a corporation, family or friends, must be overridden in one's duty to uphold justice.

Dandekar, Natalie. "Can Whistleblowing Be FULLY Legitimized? A Theoretical Discussion," *Business and Professional Ethics Journal*, Vol. 10, No. 1, Spring 1991, pp. 89-108.

Natalie Dandekar builds on Michael Davis' themes, and stresses the need for legislative and educational reforms to protect those who find themselves in those rare cases where they have a legitimate claim to justifiable whistle-blowing.

Davis, Michael. "Avoiding the Tragedy of Whistleblowing," *Business and Professional Ethics Journal*, Vol. 8, No. 4, Summer 1988, pp. 3-19.

Michael Davis argues that whistle-blowing need not be an inevitable outcome of ethical misconduct, and that it should be avoided at all costs because it's only real worth is as a necessary evil. He sees whistle-blowing as a tragic no-win situation, and argues that individuals should use formal as well as informal networks, and if organizational settings encouraged individuals to be the bearers of bad news and opened their lines of communications, the tragedy of whistle-blowing could be avoided.

---. "Thinking Like An Engineer: The Place of a Code of Ethics in the Practice of a Profession," *Philosophy & Public Affairs*, Vol. 20, No. 2, Spring 1991, pp. 150-167.

In this lucid essay, Davis argues that "a code of professional ethics is central to advising individual engineers how to conduct themselves, to judging their conduct, and ultimately to understanding engineering as a profession." Using the now infamous Challenger disaster as his model, Davis discusses both the evolution of engineering ethics as well as why engineers should obey their professional codes of ethics, from both a pragmatic and ethically-responsible point of view. A must read for any graduating engineering student.

De George, Richard T. *Business Ethics*. New York: Macmillan, 1982.

De George makes the distinction between when whistle-blowing is morally permissible and when it is obligatory. His criteria are as follows: 1) the company must be engaged in a practice or about to release a product which does serious harm to individuals or to society in general; and the more serious the harm, the more serious the obligation; 2) the employee should report his/her concern or complaint to his/her immediate superior; 3) if no appropriate action is taken, the employee should take the matter up the managerial line (before he/she is obliged to go public, the resources for remedy within the company should be exhausted); 4) the employee should have

documentation of the practice or defect— without adequate evidence, chances of being successful are slim; and 5) the employee must have good reason to believe that by going public he/she will be able to bring about the necessary changes. According to De George's argument, the first three criteria must be met in order for whistle-blowing to be permissible, that engineers should, whenever possible, avoid putting their jobs in jeopardy because of their personal convictions.

Goldberg, David Theo. "Tuning Into Whistleblowing," *Business and Professional Ethics Journal*, Vol. 7, No. 2, Summer 1988.

Using the Challenger disaster as his focus, David Goldberg disputes De George's distinctions between obligatory and permissible whistle-blowing, stating that when the consequences of whistle-blowing benefit the public at large, other considerations must be subordinated. He further argues that the only way we can often prevent further incidents is to expose current ethical misconduct.

James, Gene G. "In Defense of Whistle Blowing," *Business Ethics: Readings and Cases in Corporate Morality*. Ed. Michael W. Hoffman and Jennifer Moore. New York: McGraw-Hill, 1984. 315-322.

James challenges De George's views, arguing that engineers are obligated to reveal wrongdoing they are unable to prevent, because they have a duty to protect the safety and well-being of others. He offers practical considerations that can be used in deciding whether or not to blow the whistle on perceived ethical misconduct.

Much of the content in this course was adapted from materials published by the Mechanical Engineering and Philosophy Departments of Texas A&M University entitled "B.F. Goodrich Air Force A7-D Brake Problem Case and the Whistleblowing Debate." This document is provided for educational purposes only. It is intended to assist professional engineers in expanding their knowledge base for the sole purpose of attaining engineering professional development hours (PDH's). Decatur Professional Development, LLC makes no claims or warranties, express or implied, regarding the accuracy of information contained in this document or the applicability to a specific task or project. The services of an experienced, registered professional engineer should be employed before attempting to apply any content in this document to a particular task, application or project.

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