1 Boeing Stratoliner
Reference pages 183-184 in "Equations of Motion"

We had just completed a test program in the Moses Lake region east of the Cascades, when Eddie Allen announced, "Here's how we did it in the old airmail days!" as he maneuvered this four-engine aircraft down into a valley at low altitude. None of us noticed that the cloud base had descended down to the ground so Allen was blocked and flew into it. Shortly after, the airspeed indicator and altimeter, required for blind flight went out when the pitot head iced up. The heater (on this experimental aircraft) had not been connected up. We did have a swiveling total head tube which Al Reed thought might not be iced over. We finally connected this to the instruments.

At that point Reed suggested we turn on the cabin pressure, forgetting that the normal door has been replaced by fabric, for this flight. In a few minutes the fabric gave way; the air rushed out in an explosive decompression, and I nearly went with it. We ultimately found ourselves over Wenatchee and landed there for the night.

This is a good example of a sequence of related accidents. But it is also an example of, "Keep trying, you may make it yet."

2 Boeing Stratoliner
Reference pages 179-188 in "Equations of Motion"

The basic airplane had fixed wing slots. Boeing's aerodynamics engineers asked for tests with the wing slots covered over. The wing had been tufted and my task was to photograph the tufts from a location back in the cabin. With the wing flaps up and engines throttled back, nothing very exciting happened. When stall was approached with rated power and flaps down, the tufts were pointing straight up or forward and the airplane rolled rapidly. I found my self standing on the cabin wall, and then on the ceiling. Crawling forward, I found the pilots with their feet on the control wheel, trying to unstall the aircraft. We wound up in an almost vertical dive, picking up speed rapidly.

Allen pulled out of the dive at the structural limit and we headed home. I found out later that the aircraft had gone through an inverted spiral and incipient spin.

This is an example of surviving only because of Allen's experience and capability; as far as I know probably unequaled in those days.

3 Boeing Stratoliner
Reference pages 189-190 in "Equations of Motion"

TWA wanted to make blind landings by descending at a specified rate (500 feet/minute) into the ground without damaging the landing gear. Boeing agreed to meet this requirement and TWA wanted it demonstrated. They sent their representative, Tommy Tomlinson, to Seattle.

Allen made the first attempt but as the aircraft approached the ground, he flared slightly. Tomlinson sensed that and said, "Try again," which Allen did with the same result. Al Reed then said, "Let me do it." Down we came at the specified rate and when we hit all hell let loose. My knees buckled; a big water bottle on the wall aft of the cockpit crashed down flooding the cockpit. The aircraft bounced back into the air and Tomlinson rushed forward yelling, "Don't do it again boys."

We believed the gear was damaged and went to some effort to check it. Finally made a landing and found the gear was unharmed.

The moral of this experience is that Boeing's very conservative structural design saved the day. Boeing depended on test more than analysis.

4 Vought XOS2U-1
Reference pages 157-161 in "Equations of Motion"

The XOS2U-1 was a short-coupled seaplane that could be catapulted from a battleship. To get a high lift coefficient it utilized a so-called "Horsefeather" flap at 50°, drooped ailerons at 35°, and a 60° spoiler forward of the flap/aileron. Wind tunnel tests and analysis predicted a high downwash and possible horizontal tail stall. Vought's test pilot, Paul Baker, was well aware of all this. On an early flight he actually experienced tail stall, flipped over and gyrated downward until the flaps/ailerons had been cranked up. A whole series of activities were initiated to understand and correct this problem, including, a "step-by-step" analysis of the motion and a flight scheme for sneaking up on the condition with a rapid recovery mechanism. Test pilot Lyman Bullard and I had much fun with this.

The final solution for service aircraft was to modify the tail airfoil and install a "blow-up" spring that reduced the flap/aileron angle.

This was an early application of the Bryan Differential Equations of Motion.

5 Curtiss-Wright Junior with 3-cylinder Szekely Engine
Reference pages 162-163 in "Equations of Motion"

On August 26, 1937, I met my brother, Cooper, at the hangar on the old Muster Field in Augusta, Maine, to fly him to Bangor. With the extra load we staggered out over the bluff with full throttle and close to stall. When Cooper would lean out to get a better view, we would lose 50 feet of altitude. Somehow we got to Bangor and then Cooper said, "It was so good of you to fly so low, I could see everything!" A day or so later, I flew it up to the hayfield in Bradley.

This is a good example of the fun one can have with a slow speed but marginal airplane. Two other examples follow:

- I flew to Mt. Holyoke in Northhampton to take a girlfriend to dinner. The only place I could see to land was on an archery court. I approached in a steep sideslip and stalled the vertical tail fin. The aircraft rotated around and landed sidewise, stopping in a very few feet. A girl from the nearby dormitory asked me, "Do you always land that way?"

- One day I took off from Brainerd Field behind the Vought Company. When the engine quit due to carburetor icing I made a downwind turn at low altitude–to avoid landing on the tobacco field with its ten foot poles. After the icing melted I tried it again with the same result.

I often wondered who could have designed such an aircraft and later found that Lloyd Child had been the project engineer. He may have been a great test pilot but was questionable as an engineer.

6 Fairchild F-22, Menasco Engine.
Reference pages 134-138 in "Equations of Motion", November 1932

Nancy Overton and I rented the aircraft at Wiggins Flight Service, Norwood, Mass., intending to fly to Bangor, Maine, to visit my folks in Old Town. Because of various delays, I realized when we were over Waterville that we could never get to Bangor and land safely before dark, so we flew back to the Muster Field in Augusta. After numerous attempts to land before darkness, we finally flipped over just short of the drop-off (Figure 6-2).

In "What Really Matters," page 139 in "Equations of Motion," we discuss a common scenario that can occur in the realm of "adventures" and why we "got away with it" in this case. We note that a bonding can occur between those who share a life-threatening adventure.

7 Night Flight with Al Reed as Pilot
Reference pages 225-227 in "Equations of Motion"

We climbed to 15,000 feet coming out in the clear above the cloud layer and flew on a triangular pattern to complete our test program. After that we started looking for a hole in the cloud layer below, to get back to Seattle. Reed was concerned since Mt. Ranier is nearly 15,000 feet and we didn't know where we were.

Reed then decided our best hope was to bail out and suggested I go first. He opened the bomb bay doors. But I hesitated–I could land in wilderness, or the freezing water of Puget Sound or the side of a building in Seattle.

Verne Hyde, the older co-pilot, well familiar with the area, looked down and observed two "lighted" areas on the cloud layer below. One must be Seattle and the other Tacoma. He suggested we line up on those and go briefly on instruments. We did and came out directly over Boeing Field.

I learned that hasty decisions are not desirable when there is time for alternatives to be considered.

8 B-17, Flat Pitch
Reference pages 224-225 in "Equations of Motion"

In our B-17 high altitude program we were approaching 30,000 feet by mid-1941. With little warning, a propeller on an inboard engine went into flat pitch. Congealed oil prohibited feathering the propeller, which was windmilling at close to the engine structural limit. We were also close to stall.

Allen took a conservative approach, maneuvering between engine overspeed and wing stall. Shuddering and buffeting we slowly mushed down. Playing with the flaps, gear, or the operating engines might have increased our problems.

9 Fairchild F-22 on my Transcontinental Flight
Reference page 258 in "Equations of Motion"

I was trying to reach Terry, Montana before dark and had just found the nearest field. But I was caught in a thunderstorm and having difficulty in finding the wind direction for a landing. In the course of milling around at 600 feet or so altitude, I suddenly saw the airspeed indicator winding down and realized a stall was imminent. I shoved the stick full forward and jammed on full throttle and averted a stall/spin by a narrow margin. Incidentally, I had flown over nine hours that day, or 600 miles.

The above story is applicable to the recent crash of Continental Flight 3407 where the pilot failed to correct for a stall and in fact created the crash, and killed all on board. All this concern about "pilot tiredness" is beside the point. The real point is that the pilot had no stall training.

10 Pressure Suit
Reference page 258 in "Equations of Motion"

The theory of our partial pressure suit is summarized in Figure 11-29, which indicates that at 50,000 feet pressure altitude in a pressure chamber the effective altitude inside the suit is about 37,000 feet, and the equivalent altitude on air is 6200 feet. Our hope was that the suit could be of simple lightweight construction that the individual could put on without external help. Unfortunately, the suggestion was made and adopted that, as a starter some tight fitting rubberized suits would be made that were tailored to specific individuals, namely Reed and myself. We would, of course be breathing pure oxygen.

For the test program, Dr. Lovelace, Dr. Boothbay and Jim Cooper (Boeing) would be present. It turned out that these tight fitting garments could only be put on with a lot of external help and could never be removed without external help. Thus I felt completely helpless, and it was scary if one had the faintest claustrophobic tendency. I survived only by, "Imposing a high level of discipline on my thinking–otherwise I could have panicked."

In the chamber, we went to 51,200 feet and stayed there for 15 minutes. I was in the suit for nearly three hours. Dr. Boothbay wanted to continue the test to even higher altitudes. However, Randy Lovelace had the ability to empathize with his subjects and knew when enough was enough.

We finally recognized that the partial pressure suit was not a good idea and the whole program was dropped. Modern pressure suits used in the moon shot are much more elaborate and costly, and far more livable.

11 Conscious vs. the Subconscious
Reference pages 261-263 in "Equations of Motion"

On the last day of my flight across the country, I approached a landing at Lehighton at much too high a speed and I had to go around again. Why would I do that? On analysis, I concluded that I had a fear of stalling. My great interest intellectually in stalling had been stored in my subconscious. As Carl Jung has pointed out, "Whatever isn't brought to consciousness can, when triggered, emerge with frightening effects." Thus with my active imagination, stalling had become a nuisance in practice.

12 XB-29 Strategic Bomber (the "Superfortress")
Reference pages 272-298 in "Equations of Motion"

The B-29 project was perhaps the biggest and most complicated thing the Americans did in WWII. It cost roughly three billion dollars (1943 dollars). I was a member of the minimum crew that flew the XB-29 No. 1 for the first six months. Most experimental aircraft are powered by production (or non-experimental) engines. This was not the case for the XB-29. It's engines, the Wright R-3350, were equally experimental and had been plagues by problems from their beginning. Most of the problems were traceable to engine cooling, high oil consumption, ignition and carburetors. Fires frequently occurred in the blower section. During that first six months we had numerous engine changes and aborted flights.

Allen called a meeting to discuss the situation. Al Reed was forceful in his opinion that we were heading for disaster and he wanted no part of it. The next morning he left for California–essentially abandoning his position at Boeing. Allen, realizing the military need for the B-29, decided to carry on. Because I had worked with Reed, Allen assumed I shared Reed's opinion (even through I had made it clear that I would go along with whatever decision was made.) So Allen demoted me and removed me from flight status. I was shocked to say the least. After agonizing for a few days, I decided to stay on and work for reinstatement.

By that time XB-29 No. 2 was under intense testing and having a host of problems including numerous engine fires. Without going into detail here, they made a flight on January 5, 1943, experienced a fire in the wing and tried to get back to Boeing Field. They never made it, flying into Frye meat packing plant and killing everyone on board as well as 20 Frye employees. I suddenly became the senior remaining member of the Flight Test Section.

Senator Harry Truman chaired the investigating committee. It was found that the XB-29 fuel system allowed fuel to be siphoned into the leading edge of the wing where it ran down and was ignited. A redesign was adopted by a number of other aircraft.

From an emotional standpoint, I felt Allen's demotion of me was unjustified, but by staying on I experienced no guilt. Apart from these tragic memories I cherish my Boeing years.

13 Avion and the XP-79
Reference pages 301-306 in "Equations of Motion"

Al Reed had obtained a job at Avion, a Northrup Aircraft subsidiary, where he became Chief of Flight Test and Aerodynamics. He offered me a position as his assistant and I accepted and drove down in my old Chevrolet. Avion was located in LA, south of Pasadena.

Avion had a Secret project for the Air Force, namely the XP-79. After meeting Avion's President, Dick Palmer and Chief Engineer, W. C. Rockefeller, I was briefed on the nature of the XP-79. It was a small flying wing interceptor in which the pilot lay down in prone position and controlled through handlebars. A rocket engine located near the pilots feet was fueled by nitric acid (oxidizer) and aniline. The structure was welded magnesium, some two inches thick at the leading edge.

The aircraft was designed to destroy high altitude bombers by literally ramming their tail surfaces.

Al and I were responsible for the flying characteristics but Jack Northrup resisted the use of fins and tail surfaces. We believed we might control it through slots and spoilers located near the training edge and obtained tunnel data at a variety of wind tunnels. We arranged to build a full scale model and a test program at NACA Langley.

Al was of course scheduled to make the first flight of the prototype. He finally refused to do that and we were both fired.

After we left, the prototype was modified by installing two Westinghouse turbojets and a stunt pilot, Harry Crosby, was hired to fly it. It finally got into a roll and crashed–Crosby was killed and Avion went out of business.

The Avion XP-79 triggered a fumdamental change in my career and led to pioneering research in flight dynamics at Cornell Aeronautical Laboratory, based on the Bryan Equations of Motion.

14 Flight Dynamics at Cornell Aero Lab, Flight Research Dept.
Reference pages 316-319 in "Equations of Motion"

I had the idea of using an autopilot to measure aircraft dynamic behavior in flight and I wanted to prove it by running an actual test. But I had no aircraft, no pilot, no autopilot and no procedure. To overcome these limitations we did the following:

a) Visited the test pilot group at Wright Field and sold them on the idea. They had funds for technique development.

b) Got an M-H autopilot from a former Boeing associate, who arranged a loan.

c) The Air Force agreed to loan us a North American B-25 and also a pilot, Glen Edwards from the Bomber Division.

d) Ira Ross at CAL suggested a "frequency response" such as used in electrical engineering.

e) Our instrumentation engineer, Walt Hirtreiter figured out a control sequence in terms of frequency and amplitude.

f) I flew as co-pilot to Edwards.

g) We picked a speed of 135 mph and later repeated at 175 mph and 215 mph.

h) The airplane was oscillated in pitch and we recorded on our oscillograph the pitch angle, normal (vertical) acceleration and control force. For years it was well known from Bryan's Equations that an airplane has two longitudinal frequencies, i.e., the "short period" and the "phugoid." We were obviously oscillating in the "short period" maneuvering mode.

i) Ed Laitone analyzed the recordings to obtain the effective spring and damping in this two-degree of freedom system and deduced the "derivatives."

j) We then published the lead article in the Journal of the Aeronautical Sciences, "Progress in Dynamic Stability and Control Research," September 1947. We completely upstaged the NACA who still thought of stability and control in a "static" sense.

k) We then went into dynamic augmentation, variable stability vehicles and related.

l) Still in the forefront, we initiated a "stalled flight" project using automatic control of an aircraft which was controllable at 12.5° into the stalled regime.

m) Using pilot opinion and variable stability we were able to develop a Flying Quality Specification.

n) Finally, we realized that conventional (ordinary) aircraft were a special case of the fully augmented aircraft of the future.

In the ten year period in which were pursuing the idea of using an autopilot in flight test we had many "close shaves" in the course of accomplishing our basic objectives

15 Lady Southern Cross
Reference pages 188-192 in "Pacific Flight" by P. G. Taylor

It had been Kingsford Smith's intention to compete in the famous England-Australia Air Race and he wanted to do it in a British-made aircraft. However the only available machine was the DeHavilland Comet but none was available with a variable pitch propeller. To be competitive Kingsford Smith decided to acquire an American aircraft and he chose a Lockheed Altair which was shipped to Australia for preparation and flight experience. It was a very fast aircraft (180 mph+), but thanks to wing flaps had a reasonable landing speed. They intended to fly the Altair to England for the start of the race when it was found that there were cracks in the NACA cowling which could not be repaired in time. They abandoned their entry in the England-Australia Air Race.

They still had to get the Altair back to the USA, sell it and pay back the folks who paid for it initially. What better way than to fly it back? So, Smithy and P. G. Taylor decided to do it, Taylor as co-pilot and navigator.

In the middle of the night at 15,000 feet altitude on instruments, the aircraft suddenly slowed down, stalled and started to spin. Neither Smithy or Taylor could figure out what was happening. Finally Smithy found that he had accidentally hit the flaps down switch.

They determined their latitude from the altitude of the Pole Star, just like the coconut-shell navigators of years ago.

This is an example of recovering from a "close shave" because Kingsford Smith methodically checked all the switches in his cockpit.

16 Southern Cross
Reference pages 264-278 in "My Flying Life," stories assembled by Geoffrey Rawson

The "Southern Cross" was flying from Australia to New Zealand on the Jubilee Air Mail flight, when the propeller on the starboard engine was struck by a piece of exhaust pipe from the center engine. The missing piece of the propeller was 9 x 12 inches and the vibration set up meant that the starboard engine had to be shut down. The aircraft was 650 miles from the Australian coast when all this occurred and their only hope was to turn back and try to reach Richmond Field on the coast of Australia.

The port engine was operating at full throttle and was using up oil fast. So the problem arose; was it possible to transfer oil to the port engine from the starboard engine. Bill Taylor in his bare feet and using a thermos flask managed to accomplish this feat some six times. As he passed through the cabin, Smitty had to change his seat and then recover aircraft trim before it hit the water.

In the event, they were forced to lighten the aircraft by jettisoning the mail, but they finally made it to Australia. They had been in the air for sixteen hours over water.

This is an example of what can be done by courageous and resourceful individuals.

17 Auto Racing

There are many examples of Close Shaves in my career in auto racing. I've picked out four examples as typical.

a. Naming Milliken's Corner, reference Chapter 18 in "Equations of Motion." This occurred in the 1948 Watkins Glen Grand Prix in my Type 35A Bugatti. I started way back in the field but had worked up to third place on the last lap. I got into the corner too fast. The brakes are non-self energizing and I had to brake with my left foot, so I lost it, spun around and rolled over.

The thing that saved me was the seat belt. Cam Argetsinger insisted on seat belts (the first time ever in racing). The corner became known as "Milliken's Corner." It was the last corner in the first Watkins Glen race where the largest crowd was.

b. After a serious accident on the original circuit, New York State prohibited racing on public roads, so the event was moved to an interim circuit (county circuit). This circuit had a long wavy downhill leg which ended with a sharp turn and no escape road. We had a four wheel drive car developed in England by Archie Butterworth (and known as the "Butterball"). This car did well on the county circuit. We would reach about 130 mph and then check the brakes. If they were marginal, we would start shifting down with the 5-speed progressive box and hope for the best.

c. Dr Scher owned a Type 54 Bugatti. In the first race I drove it for Scher (at Bridgehampton) the oil ran out of the transmission and ruined the box. The car was brought to CAL Flight Research with instructions to repair and ready the car for the 1950 Watkins Glen Grand Prix. It turned out that we finally used a Dynaflow transmission as nothing else was available. The car became known as the "Dynaflow Bug." (The installation is described on pages 438-443 in "Equations of Motion," and the performance on pages 443-446. It was the first successful installation of a torque converter in a race car.)

In the race Goldschmidt in a highly tuned Allard got out front, followed by Wacker, also on a Cad-Allard and I was running a close third. We were all lapping at over 70 mph. I decided to pass Wacker on Big Bend, but then found I was going too fast, so I resorted to a technique where I'd momentarily straighten the path (making centrifugal force zero) and hit the brakes hard. After doing that a couple of times I got into second place. I also used the transmission as a retarder by poking it into the low range at the foot of Big Bend.

As I approached Townsend Road corner, I believed I had it on the ideal line, but I lost the favorable road camber and the tail started to come around. I got in some reverse steer, but needed traction to hold the path and over did it. The front wheels hit the ditch, the car swung around, rolled over and a fire started in the engine compartment. I crawled out. I thought I should get no reaction from all this–and never did.

This is an example of favorable and unfavorable factors which enabled me to get away with it.

d. At the Palm Beach Shores race, I got into one turn in which the car was sliding sidewise toward the curb. By easing on a little throttle the sidewise movement stopped and I went around in a truly "professional" way. I'm sure I could never repeat it, but the really great drivers like Stirling Moss do it all the time.

18 Watkins Glen Permanent Circuit, the Formula Libre and US GP
Reference pages 465-467 in "Equations of Motion"

In 1955, I gave a slide show to the full board of the Watkins Glen Grand Prix under Henry Valent, suggestiong the virtue of a permanent circuit for racing and research. Cam was not there and I was not a member of the Board until 1957. To my great surprise, Henry stated they would go ahead and do it. Even more surprised when two weeks later they had acquired 550 acres of farm land and had a plan for financing the circuit.

In the fall of 1955-56, Henry, Cam and I tramped around on the site. Cam insisted that it permit a 100 mph lap. I contacted the Civil Engineering Department at Cornell University. Cam (in 1958) initiated the three Formula Libre races leading to FIA sanction for Formula 1 races. He also arranged for Stirling Moss to come over for a Formula Libre race.

In 1961, we had the first Formula 1 race. Cam was Chairman and I was the Chief Steward and we worked together for ten years. Bill and Virginia Close put together the large Timing and Scoring team and we had great help from many volunteers.

As one may imagine, there were many problems and "close shaves" that led to FIA Grand Prix racing at the Glen.

19 The Spiral Jump
Reference pages 560-562 in "Equations of Motion"

At CAL, Raymond McHenry developed an elaborate computer model called HVOSM for simulating single vehicle accidents. It had fifteen degrees of freedom, was fully nonlinear and could cope with large amplitude displacements. With it he simulated a jump, in which a vehicle took off and landed on another ramp.

He then dreamed up a still more difficult task in which the vehicle took off from a spiral ramp, barrel rolled and landed on a reverse spiral ramp. A local thrill show operator became interested; the take off and landing ramps were built and cars were towed across them. They appeared to work and a stunt man, Chick Galliano, showed up to test them. After the first manned jump his reaction was, "What the hell happened!"

The Houston Astrodome was lined up for the first public showing and a number of CAL/Calspan people went along. It was found that the run-in had to start in the dark parking lot and then run down into the lit arena. Suffice to say that a jump was finally made after a number of aborted tries.

The sequel occurred in the James Bond movie, "The Man with the Golden Gun." This was filmed in Thailand with ramps made of teak wood. The jump was perfect.

There were literally dozens of close shaves in the above.

20 Static Directional Stability and the Moment Method
Reference pages 568-571 in "Equations of Motion"

In wind tunnel testing a model is constrained and the forces and moments measured in the constraints, for various angles of attack and so on. The constraint system for an automobile where the forces and moments arise from the tires was proposed–it consists of two lateral and one fore-and-aft constraint arranged so the vehicle can still roll.

A number of Moment Method diagrams were developed with this simulation, for example, yawing moment (N) vs. lateral acceleration (Ay, in g's) for various yaw and steering angles. With our licensed technology, the MTS company developed a full-scale version, calling it the Flat-Trac Roadway Simulator. An employee of MTS attempted to patent our concept in his own name. This led to a long series of activities in which we proved they had sold a number of systems without informing us of our royalties.

This is a sad example of the problems that may arise when a small "idea" outfit has to deal with a large firm.

21 Monocycle (Roland and Haselton)
Reference page 576 in "Equations of Motion"

Doug Roland and Ted Haselton built a powered monocycle–a large loop of steel tubing and an inner frame that ran in the large loop via a series of small rollers. The rider was carried on the inner loop along with a small gasoline engine. In theory the camber thrust developed by the leaning was to balance the control force.

In actual fact, turning was impossible because of the large inertia of the heavy rim. The result was that the monocycle went off the ramp, the small rollers fell out and the machine disassembled itself.

This is an example of a theoretical concept that proved impossible in practice.