



THE SURE PROJECT

 **Lockheed**
-California Company

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GO FOR THE ODDS

A SURE Lecture

by

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There he sat in his fully loaded bird. Tips and pylon tanks and the special blivet pregnantly protruding on the belly. Ruefully he gazed through the windscreen at the heatwaves dancing back and forth on the "short" 10,000 feet of runway. He wistfully remembered his transition flights with a clean Starfighter when this same 10,000 feet of pad seemed like twice as much runway as necessary. But with this temperature and a gross weight of 28,800 lbs.---unnh, unnh---it was 9000 "short" feet ahead of him to the barrier cable. From previous experience, he was intimately familiar with the difficulties of nursing this heavy muthah up into the blue. So, confidently and efficiently he completed the checklist in preparation for the takeoff. He critically checked the gages as he burst the throttle to Military power and everything registered "go". Eager to fly, he released the brakes and

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expertly stroked the throttle through the four segments of Afterburning. The tailpipe spewed out a flame-hued, conical torch as he tensed himself for the head-snapping power boost and mentally urged, "Ok baby, let's aviate". With full grunt and a rumbling roar, the Starfighter started accelerating down the runway. At the 6000 feet remaining marker, he tried to judge the instant that he barreled past the sign and simultaneously check his airspeed. Oh-oh. It looked to be right at the minimum Handbook speed of 150 knots. Now he anxiously watched the 5000 feet remaining marker sweep up and he concentrated on the blur of the sign going by and snapped his eyeballs back to one airspeed. Good. 180 knots. Just a tad above the predicted normal speed so he relaxed and smoothly pulled back on the stick as his airspeed nudged above 210. Responsively, the knife edge of the high T-tail sliced into the airstream with

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gnawing hunger until grudgingly the needle nose reared up. Continuing his back pull, the stubby, cambered wings rotated to a grasping angle of attack and voraciously clawed upward until the hurtling 14 tons lifted off terra firma. He was just 2000 feet in front of the barrier cable and the airspeed was climbing above 230 when he broke his stiff-armed grip on the throttle and reached for the landing gear handle.

Kaa-thuuunng!

Aaawhooooeee...Kaa-thuuunng!

What the hell?!?

With lightning-quick precision, his eyes flicked over the instrument panel and his brain recorded the fluctuations of the nozzle position indicator that confirmed the power surges and the thrust loss. The 104 now faltered in its sky-bound flight as gravity naggingly sucked him earthward. Making a split second decision, he reached up and jerked the

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throttle back into Military power. The engine seemed to stabilize but the bird started sinking and as he instinctively pulled further back, the stick shaker buzzed like a coiled, angry rattlesnake. Desperately, he looked ahead and saw the barrier cable looming nearer and continued retarding the throttle to idle. THAAaawhoomp!! She squatted down hard on the runway and he rapidly lowered the nose as the command of Hook! was screaming in his head. Funching the button he saw the red light flash on and wondered---

Did I make it?

Did it catch?

Dammit---she's not slowing down!

As the nosewheel hit the soft turf at the overrun edge, the cockpit pitched and bucked. Frantically, he grabbed between his legs and his hands found the D-ring. Lunging up and backward, he felt the taut cable stop his rull.

POW!

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The canopy blew and the windblast beat at him. After a heart-stopping eternity of time, he was aware of a lifting sensation--slowly, gently and then up, up---a lazy twist, a forward pitch and floating as in a dream, he saw the seat drifting away. An unfamiliar, tumbling roll and he saw the ground rising up. Fast. Too damned fast! Where's the chute? Where's the chute? Oh God, where's the chute? At a microscopic, infinitesimal point before impact, his mind mercifully went blank.

In the days following the accident, the assigned investigators diligently pored over the wreckage and delved into all possible aspects of aircraft operation. Witnesses were thoroughly questioned and they all recounted their recollections about the happening. Squadron mates silently toasted the departure of a dedicated pilot and a respected comrade.

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The Commander duly reported the loss of an aircraft and a combat ready pilot. The Flying Safety Officer was enmeshed in the volumes of paperwork required to complete the accident forms. Eventually, the accident report was finished with a massive amount of detail. It stated that the primary cause factor was a malfunction of a component in the Afterburner fuel control that caused a loss of A/B thrust. The secondary factor was a late hook extension that barely missed the barrier cable. A third factor was a delayed chute opening that resulted in the pilot fatality. Reviewing these factors, the FSO rebriefed all pilots on takeoff emergencies and abort procedures. Alertly and skillfully the pilots resumed their operational flying and in the following months there were several hundred uneventful takeoffs and successful missions. Around the bar, the accident details became ever more dim in the pilots'



memories and the accident itself was vaguely recalled as one of those incapable, unfortunate episodes of fighter aviation. Operations at the aerodrome became routine and normal until one hot, muggy day and THERE YOU SIT IN YOUR FULLY LOADED BIRD.....

Now that I've got your attention, I'd like to ask you a question. Do you know the percentage of your odds for survival during takeoff emergencies? I'm speaking of the percentage of odds that you will survive a takeoff emergency --- if you follow certain procedures. Well Ace, if you don't definitely know, I GOT A MESSAGE FOR YOU.

Reams of material and many articles have been written about the high risks attendant with takeoffs and landings. But no one, to my knowledge, has ever analyzed the odds for survival inherent with your decision to follow a certain emergency procedure. The statistics have been gathered but have they been analyzed and presented? All of us may have some firm convictions about what we think we'd do if we were faced with particular emergencies. But all too often I've found that these convictions may have emotional rather than good, analytical reasons behind them. Let me elaborate a bit as to how I came to the conclusion that some study had to be made in order to prove my personal philosophy for handling takeoff calamities with what I call the "save your bippy" procedure.

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Recently while on a foreign, classified assignment, I received a wire from "Tony" LeVier instructing me to stop on my way home and visit a NATO base in Belgium. There had been two heavyweight takeoff accidents and the Belgian Air Force had requested a SURE visit as soon as possible. Accordingly, Mr. P. K. Higgins, Lockheed's Belgian Representative, and I went to the base. Having not one evasive, political bone in my body, I opened my big fat mouth and asked the assembled Zip Drivers, "What's your problem?" Man, those Belgique Cats near ate me alive. They recounted their last heavyweight takeoff accident and proceeded to beat me around the ears with complaints about drag chute speed limitations, hook strength questions, barrier limitations, acceleration check difficulties and Handbook inadequacies. Outgunned, I gave them the best advice that I could think of and promised the Flying Group Commander that I would give their problems a lot of thought and attention. Upon arrival back at the plant, I counseled with our F-104 engineers and we were able to answer many of their questions from our barrier test data, drag chute tests and also started the procedures for instituting Handbook changes at the forthcoming review conference. Still bothered in my mind about the BAF accidents, I put on my thinking helmet and launched an in-depth analysis.

The first step was to tabulate the takeoff parameters of the configuration and conditions that are faced by the NATO F-104G strike drivers. These are:

- . Gross Weight - 28,800 lbs.
- . Runway length - 9000 feet from start of roll to barrier cable with 1000 feet of overrun.

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- . Assume sea level altitude and zero wind conditions.
- . Start with Standard Day temperature $+15^{\circ}\text{C}$ and increase in 5°C increments up to $+35^{\circ}\text{C}$.

From the Handbook plots, all of the parameters were tabulated, i.e., takeoff distance, takeoff groundspeed, distance to clear a 50 foot obstacle, refusal speed, refusal distance, refusal marker, normal speed at the go, no-go marker, abort speeds and acceleration speeds at the acceleration marker. This effort showed very graphically the expected effects of rising temperatures. Takeoff distance and distance to clear a 50 foot obstacle obviously increased with rising temperatures and the degraded performance resulted in slower accelerations. Some parameters remained constant, such as takeoff groundspeed, acceleration check marker and the go, no-go marker. While interesting, this tabulation did not give me the overall view that I wanted, so I devised a pictorial nomograph. My purpose was to present a picture that could clearly portray the areas where the odds for survival practically demand that the pilot follow a particular emergency procedure. This would help clear up any fuzziness about decision making as to which emergency procedure to follow at given stages during the takeoff. Therefore, I laid out the runway and marked off the distances at which various takeoff parameters occur. Of definite interest are refusal points, takeoff points, maximum drag chute deployment speed points and the point of minimum recommended distance for a hook extension. These points are spelled out in T.O. 1F-104G-1. Depending upon the type of egress system, I also noted the points where you encounter the minimum design speed and altitude capability for ejection. From

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the takeoff points, I extended the flight trajectory until you attain 50 feet of altitude per the Handbook plots. On the left hand side of the plot I vertically marked off a scale from 0 to 100 that I titled "Survivability Odds - %". On the right hand side I vertically scaled off Altitude/Potential Zoom Altitude in feet. Now, before we make a detailed examination of this nomograph, I'd like to briefly expound on a personal viewpoint that comes from over 23 years of fighter flying.

In the F-80 and F-84 era when I started my flying career, there were no barriers of any type. At Taegu, Korea in 1950 and 1951, we made thousands of takeoffs with each and everyone an Adrenalin-pumper. Our little F-80C's were usually loaded up with two 265 gallon underslung tip tanks along with; two 1000 lb. bombs; two napalm tanks or clusters of five inch rockets; and always our six .50 caliber machine guns had full ammunition on board. With these loads, we literally staggered off of our corrugated, pierced plank runway with its washboard surface. Our only assistance was a little extra thrust from the water-alcohol and our innate skill to help "flatten out the bumps" so that the nosewheel bouncing did not build up too much drag. During my entire tour, I remember only two accidents that were off the end of the runway following takeoff aborts. My point is that my generation of pilots did not grow up with barriers or develop any barrier philosophy in regard to late, gambling, aborted takeoffs. You might say that we grew up with no barrier hang-ups. Also, when the first barriers were introduced into the USAF, they were strictly landing barriers. However, the multiplicity and capability of our present barriers has quite

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possibly generated a school of fighter pilots that don't think about the takeoff as I do. To me, the takeoff has always comprised three phases: First, the guidance phase during the acceleration roll to achieve rotation speed. Second, the aircraft rotation phase to obtain enough lift to fly. Third, the liftoff phase at the point of takeoff. And I've always assigned two different emergency procedures for these phases. What are they? Well, let's now look at my nomograph for the answer.

Open the fold-out at the end of the lecture.

First, you will notice the various parameters that I have marked off as they occur during the takeoff. The two temperature conditions of Standard Day +15°C and Standard Day +35°C illustrates the effects of rising temperature. But let me direct your attention to the top line that I have labeled Abort Procedure. It shows that up to the refusal distance point of the takeoff, you have very high odds for survivability by following the recommended abort procedure. The Handbook defines the refusal distance as the distance required to reach refusal speed with normal acceleration. Refusal speed is the highest speed to which the aircraft can be accelerated, assuming normal acceleration, and still be stopped on the runway remaining. The refusal speeds assume maximum braking after the initial reaction time and prompt deployment of the drag chute. Therefore, the factor of maximum speed for drag chute deployment becomes important. For the Standard Day +15°C condition, the speed is reached about 600 feet before the refusal distance. In this situation, the problem of waiting until the aircraft decelerates to 180 knots becomes a handicap in properly executing the

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abort procedure. For Standard Day +35°C condition, you reach limiting drag chute deployment speed just shortly beyond the refusal distance. In any case, you are now at the point during the takeoff that the survivability odds for the abort procedure are going to be affected by system limits of the aircraft.

In order to establish the survivability odds on the nomograph for the abort procedure, I researched the statistics of barrier engagements. The Directorate of Aerospace Safety issues a report every year that is titled, "Summary of USAF Aircraft Arresting Barrier Contacts". This report documents the yearly history of barrier engagements and reveals some interesting figures. It covers USAF fighters such as the F-4, F-5, F-84, F-100, F-101, F-102, F-104, F-105, F-106, F-111 and also U.S. Navy reports. During 1969, there were 977 hook engagements attempted with 965 successful for a success rate of 98.8%. Now of the total successful engagements, an overwhelming 913 or 94.6% were made from taxiing or the pre and post landing phase. This indicates that our survivability odds on aborts, that include a barrier engagement, are at least 94.6% only so long as our aborted takeoff can basically be turned into a phase similar to a landing roll-out.

Proceeding beyond the refusal distance, you are now faced with the fact that the possibility no longer exists for aborting and stopping on the runway remaining. Any successful abort beyond the refusal distance definitely requires a barrier engagement. With normal aircraft acceleration and the passage of approximately 5.8 seconds, you will proceed from the refusal distance to the takeoff point. The takeoff groundspeed of 220 knots (for our selected



configuration) is well beyond the drag chute capability and introduces a most critical factor affecting the abort procedure survivability odds. That factor is the increasing inertia that must be stopped by the barrier. What does this mean? That the odds for survival, if you try to abort beyond the refusal distance point, must decrease. Well, in what manner do they decrease? As of now, there are just not any statistics to definitely determine the shape of the flow of odds. A guess might be a straight line descent from the intersection of the refusal distance point and the 94.6% odds point down to the zero point---one inch behind the barrier cable. But, we know that accelerations and decelerations do not follow straight lines. They are directly influenced by the non linear force of inertia. The retarding force from the barrier that is required to stop you may be represented by the equation:

$$F = ma = \frac{1}{2} \frac{W}{g} V^2$$

$$\text{or, } F_{\text{retarding}} = \text{function of } V^2$$

Therefore, I estimate that the curve beyond the refusal distance point would follow a decrease in odds that plummets downward as a function of your velocity squared. For the purpose of illustration, this curve has been drawn based on this mathematical relationship and slopes downward between the two extremes of takeoff distance points. This is because at the Standard Day +15°C takeoff point, there is still 1400 feet to the recommended hook down point and 3400 feet to the barrier cable. So, I grant you---you might---you just might be able to immediately set her back down and snatch the barrier.

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So in all probability, the odds at this point are still up there but rapidly falling. In the lower region of the curve, I've reversed the slope and flattened it out towards the barrier cable point. This is because at the Standard Day +35°C takeoff point, you are already at the recommended hook down point so the odds are not only falling---they're way down! There ain't no way for that curve to go Ace, except in the general manner that I've drawn for you. An extremely important human factor that you should consider in this problem is your available reaction time. Do you know how long it will take you from throttle retardation at the Standard Day +15°C takeoff point until you are passing over the cable? Well, a highly educated estimate gives you the thumb-twiddling, dilly-dallying time of 9.06 seconds. At the Standard Day +35°C takeoff point, you are slightly pressed by having a mere 5.6 seconds. During which, your only chores are to retard the throttle, land the aircraft (if airborne), lower the nose, jettison the stores (if desirable), extend the hook, deploy the chute (if you're slow enough) and steer the aircraft. Oh yeah--- one other thing. There are a few minor points to remember, during this exercise, like be sure to jettison pylon tanks before deploying the chute and don't jettison stores too close to the barrier (they got inertia too, you know) and all sorts of challenging imponderables to stimulate your day. Ya dig, Ace? OK, now let's go back to the beginning and examine the other emergency procedure line I've drawn on the nomograph.

You will notice that our ejection procedure line begins at zero-zero due to the design capability of the Martin-Baker ejection seat. At 60 knots and

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about 500 feet down the runway, you enter the design envelope of the C-2 ejection seats that have been modified by T.O. 980. At 120 knots and between 1500 feet to 1800 feet down the runway (depending on the temperature), you enter the design envelope of the unmodified C-2 ejection seat. Now how did I establish that 55-61% odds line? Again, back to documented statistics.

The Aerospace Safety magazine of January 1968 printed an article by Mr. J. C. Edwards of the Aeronautical Systems Division of Wright-Patterson AFB. It was titled, "EJECTION SEATS: Improving the Breed". In his article, he pointed out that about 3000 ejections had been made up to that time (Dec. 1967). Also, he pointed out that ejections below 500 feet had the greatest failure rate but had increased its success rate over the years. Further research shows that the USAF Ejection Summary Report for 1968 documents 28 rocket seat ejections below 500 feet with a success rate of 61%. The 1969 USAF Ejection Summary Report documents 20 rocket seat ejections below 500 feet with a success rate of 55%. Q.E.D. Undoubtedly, you've leaped ahead in your thinking and now thoroughly grasp my rule about Phase One of the takeoff. "Performing the proper abort procedure up to the refusal distance point guarantees the highest survival odds".

Continuing your takeoff, you next enter a grey, indeterminate area of odds in regard to the best emergency procedure. My experience has been that as you proceed beyond the refusal distance point and an emergency arises---you must decide very quickly if you want to abort. A hesitation of a few seconds (about 6) drastically lowers your survival odds for aborting. This is a classical pilot-decision area and it's all up to you. I use this transition phase to

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switch my thinking away from the abort procedure and my rule for Phase Two is, "Beyond the refusal distance point, start dismissing abort considerations and concentrate on liftoff".

As you become airborne, you're in a whole new ballgame Ace, and the nomograph shows it. We've established a 55-61% odds of success for ejection below 500 feet and those odds aren't collapsing toward a sickening zero. And a real jockey-strap grabber is that you can help those odds get better. How? Like this. Punch that Panic Button, smoothly pull back on the stick until you're riding the Stick Shaker and zoom for altitude. When you're out of climb, hold the nose up attitude with the right hand on the stick and pull the D-Ring with the left hand. My rule for Phase Three is easy as ABC to remember. It's "J-Z-E". Jettison, Zoom, Eject. Just be sure to hold that nose up attitude while you're pulling the ring. Why? To keep those odds as high as possible. You will find in your Handbook, on the ejection procedure page, a black bordered Warning that states:

DURING CRITICAL LOW ALTITUDE EJECTION INVOLVING ROLLING MANEUVERS AN ATTEMPT SHOULD BE MADE TO HOLD WINGS LEVEL OR REDUCE THE ROLLING WHILE EJECTING. THIS CAN BE ACCOMPLISHED BY FLYING THE AIRCRAFT WITH ONE HAND AND PULLING THE EJECTION RING WITH THE OTHER. EXTREME CAUTION SHOULD BE USED TO ASSURE CORRECT EJECTION POSITION WHILE STILL FLYING THE AIRCRAFT.

So the loss of ejection seat capability when ejecting from a bank angle has already been dutifully noted by the Fly-Safe gang and we've been warned. But how about pitchdown? You know, I'm sure, that when you release the control stick, the aircraft seeks a pitch attitude that is predicated upon aerodynamic

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factors. One is the trim position of the elevator. The elevator will have an effectiveness dependent upon your airspeed at the time that you release the stick. But, when you release your aft stick pull, the stick will center itself and the elevator will be at the takeoff trimmed position (assuming you haven't done any trimming during the zoom climb). With the slow speed at the top of your climb, this trim position is not adequate to hold a level pitch attitude. Another factor is your center of gravity location. A clean F-104G with a 2000 lb. centerline store has a -5% M.A.C. center of gravity location. This means that your Silver Sliver minus its external tanks but still carrying the blivet, will definitely pitchdown if you turn loose of the pole at the apex of the zoom. In the April 1970 issue of Aerospace Safety magazine on page twenty-five is an eye-opener Aerobits column titled TRIM. This column describes three severe pitchdowns at the time of ejection on three occasions during low altitude escape from the F-106. One driver had a flameout on the downwind leg and after valiant tries to relite the wick, gave up and released the control stick and reached for the ejection handles. The aircraft pitched approximately 50 degrees nose-down and he was ejected in a horizontal trajectory at about 800 to 900 feet above ground. Don't cheat yourself Ace, hold the nose up while punching.

The question you're probably pondering now, is how did I derive that odds line at the 500 foot altitude. Once more, I checked the factual statistics. The 1968 USAF Ejection Summary Report documents 98 total rocket seat ejections at 500 feet or above with 82 successful for an overall success rate of 84%.

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The 1969 USAF Ejection Summary Report documents 143 total rocket seat ejections at 500 feet or above with 119 successful for an overall success rate of 83%. The obvious message here is that if you can climb to 500 feet or higher, your overall odds for success on ejecting will increase. As Mr. J. C. Edwards has pointed out in his aforementioned article, you will be climbing toward the overall ejection success rate of around 85%. So, by keeping your cool and smoothly milking your ill bird of all the altitude capability she's got, you possibly can increase your survival odds by approximately 40%. Now I'll bet you all the San Miguel that you can drink that if you give these odds to an established expert (say a Las Vegas Croupier), he'll "jump" at these odds any chance he gets. His comment would undoubtedly be, "He who zooms and ejects away --- has greatest chance to fly another day".

Now, I'm not in the position to predict that you will be able to climb 500 feet or higher if you encounter a severe power loss on takeoff. There's just too many dynamic factors affecting the process of attaining a maximum zoom height under power limited conditions. Your Handbook (T.O. 1F-104G-1) makes a general statement that, "At 240 knots indicated airspeed, it is possible to zoom nearly 400 feet with a dead engine". I hope you recognize that the term "zoom" is a misnomer. You don't rapidly pull the stick back and pitch the nose up. If you do, you'll quickly kill off some vital airspeed without getting your desired gain in altitude. Those of you drivers who have read SURE lectures 6 and 7 are well aware of the accuracy of Lockheed's IBM computer in predicting the aerodynamic factors along F-104 flight paths. In order to give you an idea

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of the proper technique to get the maximum altitude gain, I unleashed the computer.

With the configuration that we've been discussing, the computer says that you'll break ground and fly off at a pitch angle of about 10.5 degrees. This is the pitch angle for a normal accelerating takeoff path with this load. Now let's assume that you have a power reduction problem at 250 knots with the takeoff flaps down and the landing gear up. If you immediately jettison external tanks, how much should you pull the nose up? From our computer studies, the aircraft should smoothly be rotated to an angle of attack for shaker boundary of 13 degrees. This is a pitch angle of only 20.0 degrees! So you see that it's only a small attitude change to get the most altitude. You gotta be an old smoothie in order to climb to your higher odds.

And now a final word of explanation about the curved odds lines that connect the 55-61% area to the 80-85% area. These curves are drawn in order to represent the general flow of increasing odds as your airspeed/potential zoom altitude increases during your takeoff climb path.

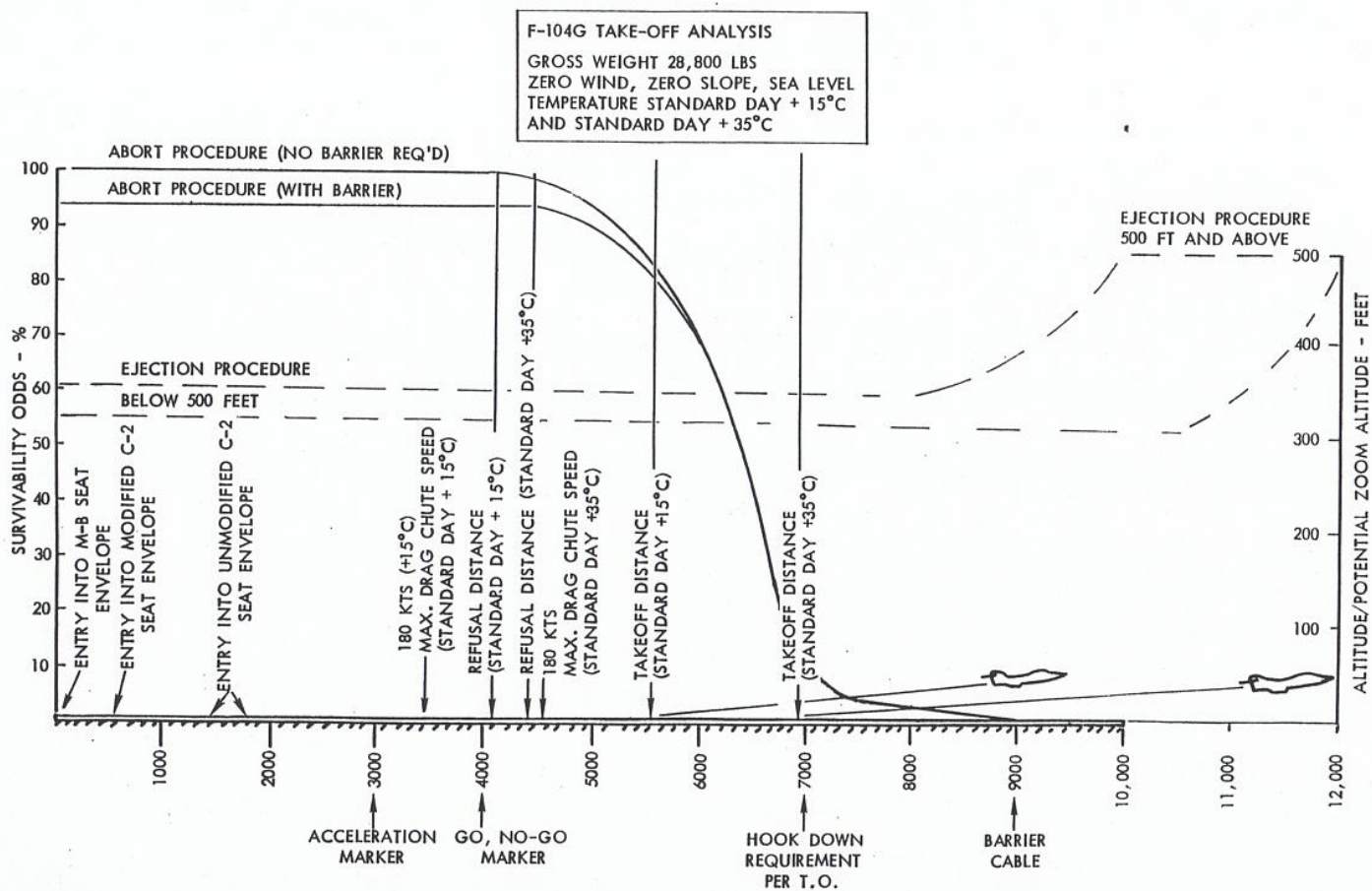
In summary, if you find yourself a few feet above the runway on takeoff with the airspeed booming around 250 knots and a major calamity occurs -- engine wheezing, FIRE lights flashing, shakers rattling, Peek 'n Panic panel all lit up --- just remember,

"Snake Sez:" Jettison, Zoom, Eject!

Go for the Odds, Ace

and

SAVE YOUR BIPPY!



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F-104G TAKEOFF CALCULATIONS

T.O. 1F-104G-1, 31 July 1969

28,800 lb., Zero wind, Sea level

9,000 foot runway to BAK-9

Figure No.	Takeoff Parameter	Standard Day +15°C	Standard Day +20°C	Standard Day +25°C	Standard Day +30°C	Standard Day +35°C
A2-5	Takeoff Distance	5600 ft.	5950 ft.	6200 ft.	6500 ft.	6900 ft.
A2-4	Takeoff Groundspeed	220 kts.	220 kts.	220 kts.	220 kts.	220 kts.
A2-10	Dist. to clear 50 ft.	9400 ft.	9900 ft.	10,600 ft.	11,350 ft.	12,100 ft.
A2-6	Refusal Speed	194 kts.	190 kts.	188 kts.	185 kts.	182 kts.
A2-8	Refusal Distance	4100 ft.	4250 ft.	4300 ft.	4300 ft.	4400 ft.
	Refusal Marker	5000 ft. remaining	same	same	same	same
A2-8	Normal speed go, no-go	192 kts.	185 kts.	182 kts.	178 kts.	173 kts.
A2-9	go, no-go speed	182 kts.	175 kts.	172 kts.	168 kts.	163 kts.
	Abort speed go, no-go	182 kts. @ 5 ^m rem.	175 kts. @ 5 ^m rem.	172 kts. @ 5 ^m rem.	168 kts. @ 5 ^m rem.	163 kts. @ 5 ^m rem.
	Acceleration Marker	6000 ft. remaining	same	same	same	same
A2-8	Normal speed Acc. marker	167 kts.	163 kts.	158 kts.	155 kts.	151 kts.