My Big Saab Jump

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The Jump

The jump I describe here occurred many years ago. It was 1967 or 1968, and I was at the young and foolish age of 24 or 25 with a heavy foot when driving. Fortunately though, the tiny 3-cylinder, 2-stroke engine of my little 1966 Saab 96 would only top out at about 85 mph on the speedometer, which is how I always drove her on the open roads of rural Ohio and how I was driving her on the night this event occurred. I had a personality quirk, and perhaps still have, that I never talked about anything that happened to me, not with anybody. I guess it's the way I grew up; I never told my parents of my problems either. But now, entering my final years, I wanted to share this traumatic event that has remained burned in my memory all these years.

I'm not the least bit religious nowadays but, in my younger years, I would occasionally attend a bible study at a friend's house. The biggest motivation for attending, however, was a chance to detour a little on the way home and drive full-throttle southbound towards Berlin Center, Ohio on Route 534 through a nice long but gentle reverse-curve (S-bend). At the time, Route 534 was a narrow, 2-lane country road running through a lightly populated, wooded area. I was approaching the S-bend at my customary 85 mph speed; that's the speed the Saab usually topped out at on a level road at full throttle. I enjoyed this particular S-bend because I could maintain full throttle and I would feel a sense of euphoria as I watched the trees stream rapidly by on either side as the little Saab leaned slightly in response to moderate g-forces. However, on this night, while exiting the final right hand curve, I noticed many large potholes, and the road was dirt instead of the asphalt I expected. I thought to myself, "No problem, I can have fun weaving around them", which I did at full throttle without having the sense to look further down the road.

I soon realized that it wasn't good to have paid so much attention to the potholes because the level road was seemingly no longer there. I couldn't see the road because my view was being blocked by a very steep and high, dirt or gravel ramp dead ahead, the ramp being much higher than the roof of the Saab, probably more than 6 feet high. If there were warning signs, I never saw them. It's funny how a high ramp, with a very steep incline, mimics a wall when coming at you at 85 mph. Death seemed imminent.

Having no time to brake, I planted both hands on the steering wheel and braced for impact. The impact was so hard that I was slammed downward into the seat and forward into the 3-point seat belt with my head pitched down so far that I saw the famous Saab airplane logo on the steering wheel's horn button directly in front of my nose. I felt like my body was being crushed through the seat to the floor of the car by an invisible elephant sitting on me. I can't put into words how horrible that felt and I remember wanting it to stop. But the crushing feeling ended abruptly as my body launched upward from the compressed seat, being stopped only by the tightly fitted 3-point seat belt. I credit the seat belt with saving me from tragedy by restraining my body from slamming head first into the roof. I remember hitting that seat belt hard as it stopped my upward momentum. Unfortunately, because Saabs of that vintage didn't have headrests, my head whipped over backwards, and I remember seeing the roof headliner directly in front of my nose. My head bobbed and thrashed about almost uncontrollably and it took great effort to stop the bobbing. Strangely, after my head stopped bobbing about, I noticed an eerie silence, and as I looked out the windshield, I saw nothing but the blackness of a dark night.

I could see that the dashboard lights were still lit, but the headlights weren't illuminating anything even as I scanned from left to right. Confused, I thought for a moment that I might have already crashed and had just awakened from unconsciousness. The thought occurred to me that the car might be lodged in a tree rather than on the ground, with the headlights smashed out. I needed to know so I leaned my head out through the door window, hoping there was enough light to see where the car rested. Looking down, I was amazed to see what appeared to be either shiny steel handrails of a bridge or new guard rails far below me, receding rapidly rearward as I flew over. I brought my head back in, and upon looking through the windshield again, I quickly realized the reason for the blackness: the headlights had been aimed skyward with nothing to illuminate, and the car was high in the air. But then, as the car started rotating nose down while still very high in the air, the headlights were starting to illuminate the road far below and trees to either side of the road, but as if I were in the treetops instead of beside them.

The car was so high in the air that I was filled with terror and I thought to myself "I want to stop and take a timeout to think about this." But I knew the brakes would have no effect, and a timeout was not possible in the real world. The road started traveling upward toward me it seemed, slowly at first, but then suddenly at a rapidly accelerating rate. As I approached the roadway with the nose of the car tipping sharply downward, and well past any ramp on the other end of whatever the Saab was jumping, I remembered watching old movies where passengers of a crashing airplane screamed as the ground raced up at them. As I descended just prior to impact, I thought to myself "So this is how I'll die, in an airplane crash!" Upon impact, I got another look at the famous Saab horn button logo with the subsequent upward relaunch of my body, and just as I got my head to stop thrashing about, there was a second hard impact. The second impact was apparently because the car had bounced off the highway and re-landed, creating a second impact not as bad as the first but I was angry that it started my head bobbing again and I couldn't see what was going on until I got my head under control again. However, I soon realized that I had lived through the ordeal, and amazingly, the Saab was still on the road, but only traveling at about 40-45 mph now, and steering a bit oddly.

In retrospect, I am glad that I latched both hands on the steering wheel very tight at the same height, approximately the 9 and 3 o'clock positions. If I had only one hand on the wheel, that hand would have jerked the wheel sharply on impact and might have steered the car into a body roll. With equal weight on each side of the steering wheel, the steering remained straight ahead, and the car jumped straight. I also like to think the free-wheeling feature unique to these little Saabs was helpful in avoiding tragedy. You see, I surely lifted off the throttle immediately after launch, and the resultant engine braking of the typical direct-connected manual transmission would surely have created a rotational torque on the body about the axis of the spinning front drive wheels, perhaps causing the car to pitch the nose dangerously low. And further, the longitudinally mounted engine could have also created a body roll torque through the engine mounts as a result of the rotating crankshaft rpm variations, causing the car to roll onto its side when landing. With the free-wheeling feature, however, the wheels were free to continue spinning as the engine returned leisurely to idle speed without any braking effect. I can't be sure how much this helped, but I was extremely lucky that the car jumped straight and true.

As the car coasted along, I contemplated stopping to examine the car but I feared that someone living nearby might have seen what happened, and I didn't want to have to explain to them or a sheriff's deputy what had happened. So I continued very slowly home on a less traveled shortcut, Palmyra Road back to Duck Creek Road, fearing that a wheel would fall off on the way. I remember an immense feeling of relief when the rented farmhouse came into view to my right as I stopped on Duck Creek Road at Route 224. That old farmhouse never looked so warm and welcoming with the light from the windows looking like a beacon for me to follow back to safety. I examined the car immediately upon arriving home to look for damage. I had apparently stretched all eight upper wishbone mounting bolts on both sides of the car because the alignment shims had fallen out, all four sets, but they were conveniently laying on the unique Saab engine area floor pan. So I stuck them back in where it looked like they belonged, without loosening the bolts further, and re-tightened the bolts. The loose floppy upper wishbones were apparently the reason for the car steering oddly because an alignment check sometime thereafter revealed still-perfect alignment!

The other damage I found included a major amount of undercoating scraped off the floor of the car for the whole length of the car because it had bellied clear down to the road surface, and the front upper and lower shock absorber mounting studs were bent away from each other, each approximately 30 degrees, because of over compressing the shock absorbers on impact. Both of the upper and lower shock absorber studs were horizontal on these cars. The front resonator (muffler) on these Saabs was mounted transversely just forward of the front wheels, tucked neatly just under the engine compartment. The 4 inch round tubular shape was now more of a D shape for its entire length, and all mounting hardware had been bent rearward, but it didn't have a noticeable effect on performance. Figure 6 further below illustrates some of the described damage areas.

A TopGear episode on Saab rally cars described early Saab cars as having a quality rare in mass produced motors: it was a hoot to drive. While that is the most notable quality of these cars, they were also well ahead of their time regarding safety and toughness. I think I may have been a fatality in any other car of the day. I'm sure, at least, that it would have been fatal to any other car. This story explains just one of the reasons I loved these old Saabs so much and why I will always love the Saab marque, and it is just one of the reasons I am sad that the brand has passed into history. I very much miss that old Saab that saved my life that night.

Looking Back

In retrospect, I wish I had gone back the next day in daylight to see what I had jumped. I might have thought to take photos of the landing spot---I'm sure I left black streaks of undercoating on the pavement. It would have given me some factual evidence of the event. Unfortunately, we moved into the city of Salem shortly thereafter, and I never had occasion to drive that section of Route 534 again, and it was a long time before I trusted the car's integrity enough to run flat out again. Plus, I was a nervous wreck for weeks thereafter. But now, late in my life, I wanted to see if I could find the spot and see what I might have jumped. It took a lot of memory searching, and a lot of online digging but I am pretty sure I have the answer.

First, I found the loop that I drove on the rare occasions that I attended the Bible study. I would leave the rented farmhouse on Route 224 and travel several hundred feet east and turn north onto Duck Creek Road. About 7 miles later, I would turn left onto Gladstone Road and arrive at the small ranch house on the left less than a half mile later. Afterwards, rather than retracing this boring trip to get back home, I would leave traveling west to Robinson Road, and then Mahoning-Trumbull County Line Road until I reached Route 534. Turning left onto 534 I would put the pedal to the metal for the fun part of the trip back home, the 7 and ¾ miles on 534 to Route 224, listening to the turbine-like sound of the little 2-stroke engine as it revved through the gears.

It was easy enough now to find the S-bend on Google Maps but I could not find any bridges over streams or an elevated section through lowlands. I had always assumed they were installing or raising a bridge because it was in a low-lying area that the jump had occurred, and I had a vague memory of a small bridge in the area. But there is no such structure today. However, I was happy to find that Mahoning County had made vintage road maps available on their website for download (http://www.mahoningcountyoh.gov/563/Highway-Maps). This jump occurred in 1967 or 1968 so I downloaded the 1966 and 1968 maps (there was no copy for 1967). To my surprise, I-80S showed as "Under Const." and "proposed" in the 1966 map and apparently completed, or at least confirmed, for the 1968 map. See Figures 1 and 2 below.

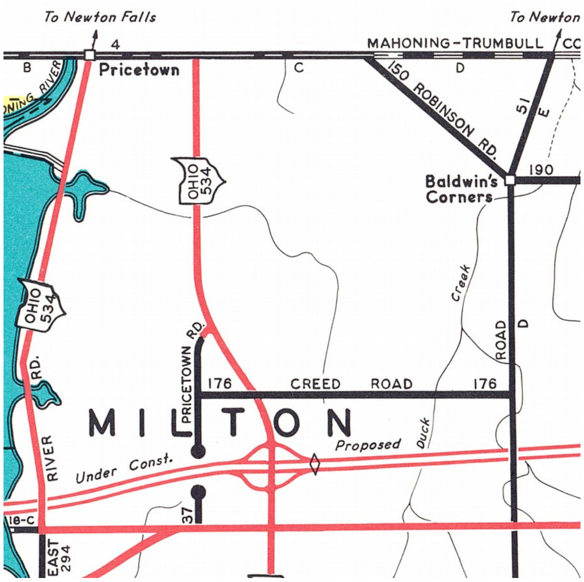


Figure 1: 1966 Map

Figure 2: 1968 Map

I had no knowledge of the new I-80S back then. As a matter of fact, although it was known as I-80S at the time, it was later renamed to I-76 around 1972. It was now obvious, however, that whatever my Saab had jumped had something to do with raising Route 534 to create an overpass over the new I-80S. To see what is there today, I turned again to Google Maps and found the following as shown in Figure 3 as viewed from westbound I-76.

Figure 3: I-76 (Formerly I-80S) Westbound at Rt 534 Today

The question now was what portion of this could the car have jumped; it had to have jumped some portion of it before Route 534 was elevated on either side to match. Using the measuring tool of Google Maps, I found that the full length of the open section, from bank to bank, is about 282 feet. The middle section above the pavement and berms, pillar to pillar, is about 163 feet. To figure how far the car might have jumped, I have done a mathematical analysis based on the original conditions which I still remember clearly. I invested a great deal of time (or you might say wasted) in doing this, but I just had to know what was feasible. As mentioned above, this event is still burned deeply into my memory like it happened yesterday; it was a traumatic event.

Trajectory Analysis

If one ignores air resistance, trajectory calculations are rather simple. However, I wanted an accurate trajectory analysis including air drag. Unfortunately, if one includes air resistance, even the simplest approximation yields second order differential equations which require a numerical solution using a program such as MATLAB®. However, free open source programs are adequate for this problem. I used FreeMat version 4.0 for all calculations herein. My FreeMat program code was developed from the theory and a basic MATLAB® program provided at: http://ratcliffe.site/USNA/EM375/labs/07Project/ProjectileTheory.pdf. For a complete understanding of the theory, please visit the above-listed reference for an excellent explanation of the theory and math involved.

However, after figuring out how to calculate a trajectory including aerodynamic drag effects, I realized even that wasn't good enough. The Saab wasn't like a simple bullet, it had a profile that creates aerodynamic lift. It's teardrop shape was especially well known to create lift because the first Saabs were designed to look like an airplane wing cross-section when viewed from the side. And, adding logic for this coefficient wasn't quite good enough; what if the car was pitched nose-up on launch, with a positive angle of attack relative to the trajectory? Well, after great effort and much research, I got it all worked out and wrote a FreeMat program to see what was possible that night. If you are interested, the gory details and derivation of the math are in the Appendix---good reading.

With the FreeMat program written and debugged, trajectories were calculated and plotted for various speeds and launch/ramp angles, with and without a positive angle of attack. The complete program is also provided in the appendix. The only input variables for each case were initial speed in mph and launch angle in degrees, and initial angle of attack with rate of change. All other values were constant. Initial height was assumed to be 2 meters (6.6 ft) at the top of the ramp; mass of the car was set to 880 kg (car plus passenger=1775lb+165lb=1940lb); frontal area was set to 1.795 square meters plus 0.039 square meters for the hanging wheels (actual Saab 96 frontal area as measured from a technical drawing using the pixel counting features of Gimp plus the wheel adjustment); drag coefficient was set to 0.32 (http://www.saabhistory.com/2007/04/01/the-aerodynamics-of-the-saab-automobiles/); gravitational constant = 9.81 m/s^2; and density of air = 1.2041 kg/m^3. Additional frontal drag area was calculated for positive attack angles as the floor turned downward into the airflow.

I knew the appropriate range of input speeds to use because I remember well how fast I was going. However, the launch angle is a different matter. That ramp looked to have an incline of at least 30 degrees but I think speed and fear exaggerated that a bit. I don't think the highway engineers would have gone that steep even with a temporary ramp. However, I think 20 degrees was quite possible, and when you add in elastic bounce from the ramp impact, the launch angle could well have been at least 25 degrees. In support of this argument, The Pittsburgh Department of Engineering and Construction recorded a grade of 37% (20°) for Canton Avenue (http://old.post-gazette.com/pg/05030/448976.stm). With the Saab's high ground clearance and short front overhang, a steep ramp would not have been a problem even at high speed. To illustrate, Figure 4 shows a Saab 96 approaching a ramp of 25 degrees (That's not my Saab but my Saab was red just like the one shown). Figure 5 shows a Saab 96 landing at various angles. The front muffler is the little round brown spot just lower than the bumper and just forward of the wheels. That's what took on the D shape but the bumper was not damaged.

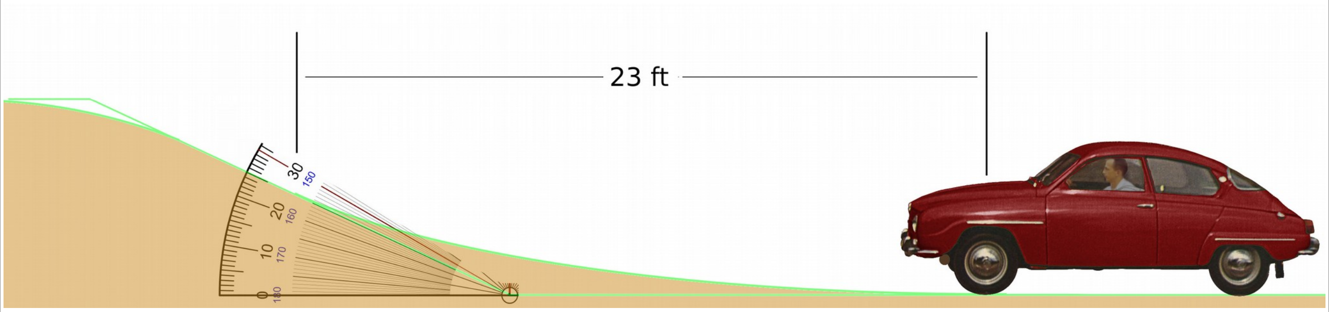


Figure 4: Saab 96 Approaching a 25 Degree Ramp

Figure 5: Saab 96 Landing at Various Angles

For those readers who don't think a positive angle of attack would have aided the Saab in its flight, I have provided an underside view from a vintage Saab brochure in Figure 6 (ignore the red and blue arrows). You can see here that the floor is completely flat and clear of obstructions except for the exhaust which runs longitudinally, with the rear muffler tucked neatly up into the right, rear wheel well. There is no exposed frame. Nor is there a gas tank or any fuel or brake lines; those are all inside the car body. Even the rear axle is tucked up into a cavity, above the airflow. All of the reinforcing corrugations run parallel to the airflow---obviously designed by aircraft engineers. And finally, the floor extends almost bumper to bumper; there is no rear valence hanging down to catch air; the Saab's back extends down smoothly and uninterrupted to the floor.

I previously described the most obvious damage to the car. Those areas are highlighted in light blue. The upper wishbone mounting bolts that were stretched are highlighted in yellow.

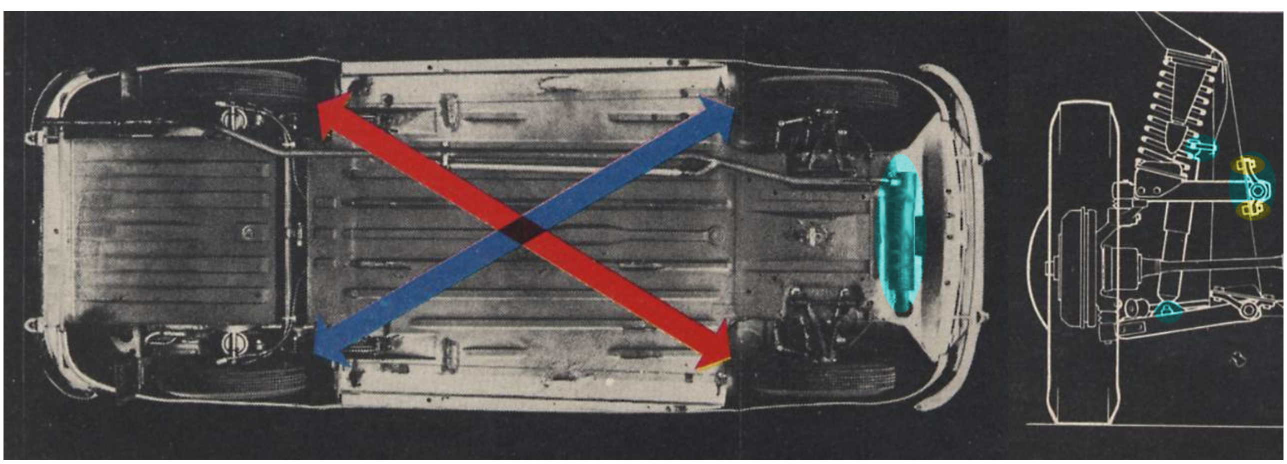


Figure 6: Saab 96 Floor and Front Suspension

As a side note in support of the above floor discussion, the CRC HANDBOOK of tables for APPLIED ENGINEERING SCIENCE, 2nd Edition, on page 517 under AUTOMOBILE DRAG COEFFICIENT ESTIMATES, specifically credits the Saab 96 along with the Porsche coupe and Citroen DS19 with having an "integral, flush floor, little projecting mechanism" in drag class (1).

With knowledge of the range of speeds and realistic ramp angles, or rather launch angles, it was now just a matter of plugging various combinations of speed and angle parameters into the FreeMat program and seeing what came out. I find plots more interesting than data so I have provided the plots first in Figures 7-9 below. The plots include a simple schematic of the overpass and true-to-scale representations of the Saab to give a visual impression of the distances involved. The launch velocity at the beginning of the overpass is the entry velocity minus an adjustment for energy lost during ascent of the ramp. See the appendix for a full discussion.

In the figures, there are blue trajectories, magenta trajectories and red trajectories. The blue trajectories are for a zero angle of attack (think "as an arrow flies"). The magenta trajectories are for an initial positive angle of attack of 6 degrees which remains constant throughout the jump. The red trajectories are for an initial positive angle of attack of 12 degrees, dropping at a rate of 3 degrees per second as the car rotates back toward a zero angle of attack. For a given velocity and launch angle, the plotted trajectories give an idea of the range of possible trajectories depending on the angle of attack.

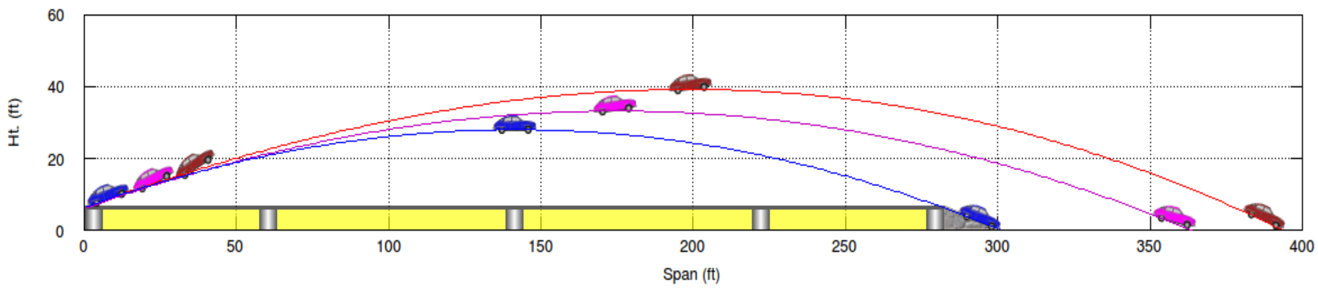


Figure 7: Case 1, 83.6 mph, 16.7 Degree Launch

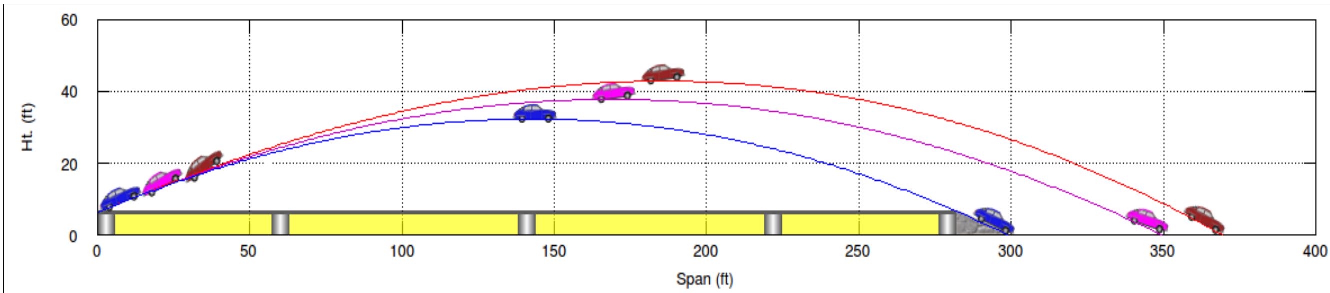


Figure 8: Case 2, 78.57 mph, 19.9 Degree Launch

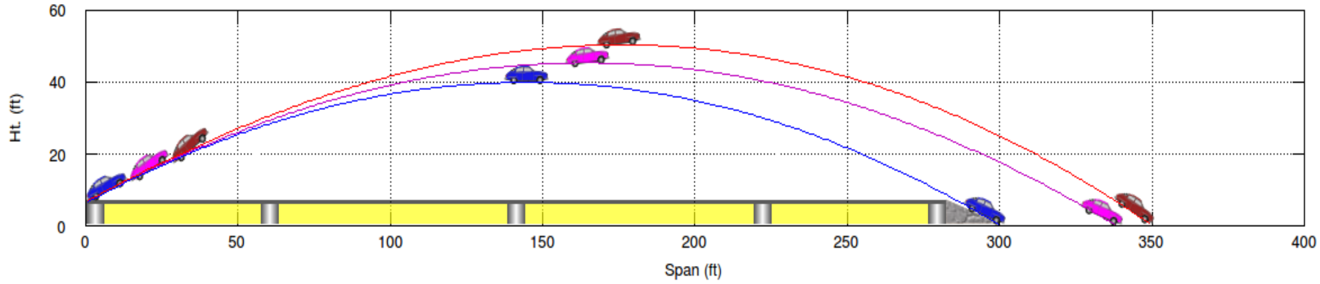


Figure 9: Case 3, 73.53 mph, 24.5 Degree Launch

In each of the three trajectory plots above, a combination of speed and launch angle were chosen to provide a trajectory of at least 300 ft. I chose 300 ft. because I was trying to determine if I could have jumped the entire overpass of 282 ft and the opposing temporary ramp, thus an extra 18 ft. At the highest entry speed possible in the Saab, 85 mph, it would have been possible with a launch angle (ramp angle plus bounce angle) of only 16.7 degrees. However, the ramp appeared to be noticeably steeper than this. At the other end of the scale with a launch angle of 24.5 degrees, the car could have attained 300 ft. at an entry speed of only 75 mph but with a very high jump. Based on my recollection of the event, the actual speed and launch angle was closest to Case 2, with a speed near 80 mph and a launch angle near 20 degrees. The plots confirm that such a jump was indeed possible.

The question remains, however, could my body and the car have withstood the g-forces of such a jump?

Estimation of g-forces

There are three g-forces that I have attempted to make crude estimations of: landing g-forces on the driver (me), landing g-forces on the car itself, and driver g-forces on ramp impact at launch.

First, for landing g-forces on the driver, I make made the following assumptions:

1. the car was rotated downward approximately 30 degrees on impact;
2. the distance from the front axle to the front seat cushion was approximately 48" (4 ft);
3. the Saab had approximately 10" (0.833 ft) car floor-to-ground clearance; and
4. the foam cushioned seats could sustain approximately 6 inches (0.5 ft) of seat crush.

I should note that I chose 30 degrees based on my memory of how far the car had turned nose down. The car's rotation was independent of the trajectory, i.e., not parallel to the trajectory. Anyway, the best I could hope for here are ballpark figures. From the above assumptions, the approximate deceleration distance (Dy) for the driver would be:

$$Dy = \sin(30) * 4 + 0.833 + 0.5 = 3.333\,\mathrm{ft} = 1.0\,\mathrm{m}.$$

Further, I only looked at the vertical component of velocity because that is what suddenly went to zero. Knowing the vertical velocity, it was a simple matter to compute the vertical energy, and because energy equals force times distance, and force equals mass times acceleration, the two can be equated as follows:

$$Ey = \frac{1}{2} m * Vy^2 = m * Ay * Dy\,.$$

The average g-force on the driver would therefore be:

$$Ay = 0.5 * (Vy * 0.44704)^2 / Dy / g$$

where V_y is the vertical speed in mph, and where 0.44704 is the conversion factor to convert mph to m/s, and g=9.81 for conversion to g-force.

The calculation of g-forces on the car itself is identical to the above except that the seat crush is absent. Thus, for the car, Dy=2.833 ft=0.8635 m.

For driver g-forces on initial ramp impact, things are a bit more complicated because there would have been a circular easement onto the straight ramp. I chose to ignore the easement for simplicity, and because it was very small, and so I used the same calculation as above but I used the component of velocity perpendicular to the ramp as the landing speed. This ignored the softening effect of any circular arc easement from the roadway to the ramp which means my calculated g-forces may be on the high side. On ramp impact, however, the car's angle was equal to the ramp angle.

With the above equations, g-force calculations were made for the three cases shown above, and the results are shown in Table 1 along with other pertinent trajectory calculations.

All of the g-force estimations are rather tame compared to what the average human body can withstand. For example, the maximum for a human on a rocket sled is 46.2 g, and humans can handle at least 20 g for less than 10 seconds in the horizontal direction (https://en.wikipedia.org/wiki/G-force#Human_tolerance). Because I was wearing a tightly-adjusted 3-point seat belt, my biggest risk of injury was probably risk to my spine due to compression and my head thrashing about. By the way, by 1968, Saab was using headrests as standard equipment.

As a side note, the calculated final horizontal velocity is consistent with my memory of still rolling at about 40-45 mph. The crushed muffler, and the floor pan undercoating removal would have slowed the car significantly.

	Case 1			**Case 2**			**Case 3**		
Entry mph	**85.00**			**80.00**			**75.00**		
Launch mph	**83.60**			**78.57**			**73.53**		
Launch Angle	**16.70**			**19.90**			**24.50**		
Sub-Case	**(1.1)**	**(1.2)**	**(1.3)**	**(2.1)**	**(2.2)**	**(2.3)**	**(3.1)**	**(3.2)**	**(3.3)**
Attack Angle	**0.00**	**6.00**	**12.00**	**0.00**	**6.00**	**12.00**	**0.00**	**6.00**	**12.00**
Attack deg/sec	**0.00**	**0.00**	**-3.00**	**0.00**	**0.00**	**-3.00**	**0.00**	**0.00**	**-3.00**
Air Time sec	**2.620**	**3.240**	**3.560**	**2.840**	**3.380**	**3.630**	**3.140**	**3.610**	**3.800**
Distance ft	**300.93**	**365.45**	**394.50**	**300.69**	**351.25**	**370.51**	**300.59**	**338.65**	**349.63**
Height ft	**28.01**	**33.58**	**39.23**	**32.68**	**38.13**	**43.23**	**39.91**	**45.34**	**49.97**
Final X mph	**77.26**	**76.08**	**74.18**	**71.28**	**70.33**	**68.48**	**64.53**	**63.79**	**61.86**
Final Y mph	**-27.19**	**-26.72**	**-30.77**	**-29.75**	**-29.26**	**-32.80**	**-33.07**	**-32.69**	**-36.00**
Launch G	**8.03**	**8.03**	**8.03**	**9.20**	**9.20**	**9.20**	**10.81**	**10.81**	**10.81**
Landing G	**7.41**	**7.16**	**9.49**	**8.87**	**8.58**	**10.79**	**10.97**	**10.72**	**12.99**
Car Landing G	**8.72**	**8.42**	**11.17**	**10.44**	**10.10**	**12.69**	**12.90**	**12.61**	**15.28**

Table 1: Trajectory Data (All Angles in Degrees)

I was a little surprised by the short calculated air times in the table. I was asked some years ago when I mentioned this jump how long I was in the air. After running the event through my head, I answered about 7 seconds which I admit is ludicrous and impossible. I imagine some "slow motion effect" was occurring because of how traumatic the event was. To reconcile my memory of the event with the calculated times, I sat in one of my old Saabs and timed some of the motions with a stopwatch. Time zero in the plots starts at launch from the ramp, and I assume that I had already rebounded out of the seat and that I was starting to get my head under control at that time. So, I timed a quick look at the dash, scanning the windshield from left to right, looking downward out of the window, and bringing my head back in to look through the windshield again. Doing this as fast as possible always took at least 2.5 seconds. Because I was still terrifyingly high in the air after the above actions, with at least a second more of air time, I am sure that I was in the air for at least 3.5 seconds. My timing experiment didn’t include any time for thought because I’m sure I was thinking very fast at the time.

Based on my memory of events and the timing experiment, I believe Cases 2.2 and 2.3 in the table are closest to what really happened that night. Both of these cases require some positive angle of attack. I mentioned above how the Saab’s free-wheeling feature helped prevent the nose from dipping down to a negative angle, allowing bounce off the ramp to possibly provide some positive angle of attack. Additionally, because I never moved my foot to the brake pedal, I am sure that my foot momentarily floored the throttle during ramp impact due to the large g-forces on my body. If the throttle remained floored for a bit of time after launch, spinning the front wheels would have induced a nose-up rotation to add additional angle of attack. And, the Saab’s 58/42 front/rear weight distribution would have helped maintain a stable attitude.

With regard to g-forces and survivability again, I would like to point out that I know personally about high g-forces from a head-on collision with a behemoth-like 1971 Chrysler New Yorker in our mid-size 1982 Pontiac Grand Am. The Chrysler suddenly turned left towards a driveway as we were traveling a little above 55 mph. Ohio State Police said my skid marks were about 39 ft. The end result is shown below in Figure 10. I felt fine that night, but by morning, I could barely hold my head up straight. The Chrysler was still drivable, and the uninsured driver skipped town and fled back to their home in North Dakota. And, by the way, I felt worse during the Saab’s launch and landing than in this crash, although this was partly due to the length of the event.

Figure 10: Another High g-force Experience

Figure 11: Ford Escort After 60 Foot Drop

Damage Expectations

Fortunately, my Saab didn’t look like the Pontiac above, but that begs the question of whether it could have survived with only the damage I described above, i.e., bent shock absorber mounts, stretched upper wishbone bolts, crushed muffler, and scrubbed floor pan. After all, the table above shows trajectory heights varying from 28 ft to 50 ft depending on launch speed, launch angle, and angle of attack, and that is quite a drop although that is how it looked to me as I wished for a timeout when the car turned nose down.

It didn't take me long to find proof that the Saab could manage such a high drop with minimal damage. I found an example of a car being dropped 60 ft (some articles said 65 ft) onto the concrete roof of a Silo Eco-Home for the purpose of demonstrating the safety of the home [Hart, Catherine (2009, April 9). Car Drop a Smashing Success. GREENSBURG GreenTown. Retrieved from http://greensburggreentown.org]. See also https://youtu.be/xf1y3PRav4w. They apparently obtained a junkyard Ford Escort for the drop. From the video, it appeared that all the tires were flat beforehand. Amazingly, the first 60 ft drop onto the flat portion of the roof did little apparent damage as shown in Figure 11. It took a second drop onto the raised sidewall of the silo to destroy the car. You can see what happened in the video. My low mileage Saab certainly had better structural integrity than a junkyard Ford Escort with deflated tires (or even a new Escort with fully inflated tires). Remember, these Saabs were designed for dirt roads and were famous for their jumping ability in the many rallies that they dominated. They also had a very large ground clearance with generous vertical wheel travel. And finally, a car dropped from a stationary position will fall a bit faster than a car with a large horizontal velocity due to the coefficient of lift. I am not the least bit surprised that my Saab survived a much smaller drop. I am a bit surprised that I survived without injury.

Conclusion – Countering Some Arguments in Advance

Some readers may look up specs for the Saab 96 model and claim that it only had a top speed of 75 mph and that my claimed speeds are too high. But those specs are for the initial 1960 model year when the car had only 38 hp and a 3-speed transmission. By 1966, the car had 46 hp (42 DIN) with triple carbs and a higher compression ratio, and it had a 4-speed transmission. Comparison of drive-wheel traction (torque) vs. speed curves in the official Saab service manuals for 1960 vs. 1965 (still single carb with 2 fewer horsepower than 1966) confirms the car would have had the extra drive-wheel torque to achieve 85 mph. I could not find updated curves for the 1966 model year. I drove many thousands of miles at 85 mph and sometimes as high as 90 on a good day with a tailwind.

Some will say I wasn't really in the air for over 3 seconds, that time seems to slow down during a traumatic event. I know about this phenomenon from the head-on crash with the Pontiac. The 39 foot skid marks were created in less than half a second but it seemed so long that I thought the brakes weren't working. However, none of the moments in the Saab jump were of the sort to trigger much of a time-slowing phenomenon, except possibly the time from when I wished for the timeout until the crash landing. Mostly, I was just confused, trying to figure out what was going on. In fact, considering just real physical possibilities as discussed above, noticing the dash lights working but no headlights, scanning the dark view from left to right, and then taking the time to look down out of the window and bring my head back inside could not have been accomplished in less than 2.5 seconds, and I was still terrifyingly high with at least another second of air time when I wished for that time out. Throw in some head thrashing time and 3.5 seconds seems too short.

Others will say the damage to the Saab would have been greater than what I describe. I would like to add, in addition to the example of the Ford Escort, that with the monocoque construction of the Saab, the unitized frame rails were above the floor pan. In fact, the gas tank, brake lines, fuel lines, and pretty much everything except the exhaust and suspension were above the floor pan (see Figure 6 above). These Saabs had a very high ground clearance, almost like today's SUVs. Quite a bit of energy could have been absorbed before bottoming the floor pan onto the highway.

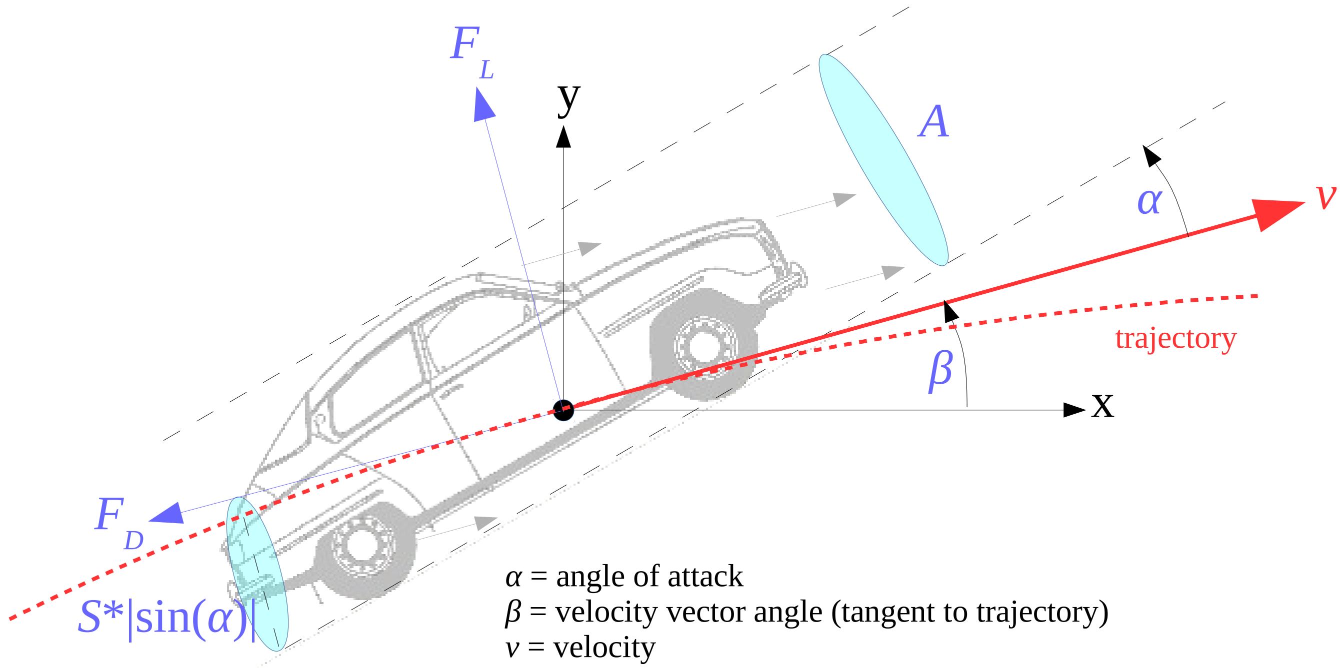
And finally, I call your attention to the laws of physics. I remember well my speed, the steep angle of the ramp and its height well above the top of the car. The laws of physics determine what happens thereafter in such an event, and the laws of physics cannot be denied. Just for kicks, if you want to see what a long jump looks like, check out this video of a record breaking Red Bull truck jump of 379 ft: https://www.youtube.com/watch?v=febbQ4dvjUk. I would have appreciated the gentle approach ramp and the enormous suspension travel of the purpose-modified truck.

Call me crazy if you will, but I am confident that my little Saab jumped as far as I claimed above. I'm glad I'm still here to tell the story.

So, that's my big Saab jump story and I'm sticking to it.

Appendix

1. Reference Drawing for Trajectory Mathematics Below:



α = angle of attack
β = velocity vector angle (tangent to trajectory)
v = velocity
A = front silhouette drag area
S = floor area
$S*|\sin(\alpha)|$ = exposed floor drag area due to angle of attack
F_L = lift force (perpendicular to velocity vector)
F_D = drag force (parallel to velocity vector)

2. Trajectory Mathematics:

When a car is traveling on a highway, the car's body is parallel to the velocity vector. However, when a car is in the air during a jump, the body may be rotated either nose-up or nose-down with respect to the velocity vector. This deviation is referred to herein as angle of attack as shown above. A moving car normally experiences drag forces which are proportional to the frontal silhouette area, shown as *A* above. When the car is angled nose-up (positive attack angle) with respect to the trajectory (flight path), the floor area *S* creates additional frontal drag area as shown. The frontal area *A*, however, is treated as constant herein because small changes in attack angle have a negligible effect on the area. The shaded blue ellipses rather loosely represent the two drag creating areas. It would be difficult to illustrate the areas accurately but it shouldn't be hard to understand the concept. The sum total of drag forces is shown as vector F_D.

Most, if not all, passenger cars have a positive coefficient of lift meaning that there are positive lifting forces on the car. The teardrop shape of the Saab is well known to have substantial lift, especially so for the Saab since the first Saab was designed to resemble an aircraft wing cross section. Generally, fastback shaped passenger cars have a coefficient of lift greater than 0.3, and this is the number used herein for the described jump (http://hpwizard.com/aerodynamics.html). When a car is angled nose-up with positive angle of attack, the coefficient of lift increases because of the additional pressure created on the floor and the additional vacuum created on the topside of the car, just as when an aircraft files in a nose-up attitude to gain lifting force. Since the Cessna 172 has a similar coefficient of lift at a zero attack angle, I assumed a similar rate of increase for the Saab, increasing to approximately 1.6 for a 15 degree attack angle (http://www.aerospaceweb.org/question/aerodynamics/q0184.shtml). However, even on an aircraft wing, turbulence occurs on the top surface when 15 degrees attack is exceeded, causing loss of lift. So I used 12 degrees as the maximum possible attack angle at launch for the car.

In the numerical solution described below, the trajectory calculation starts at the top of the ramp when some velocity has already been lost due to the height and length of the ramp. Assuming an elastic impact with the ramp (I didn't hear any crash on entry, only on landing), there are two components of energy loss while the car is on the ramp, kinetic energy loss equal to the potential energy at the height of the ramp and kinetic energy loss due to drag forces. The kinetic energy lost in attaining the height of the ramp is given by $E_{loss1}=mgy_0$ where y_0 is the height of the ramp. The energy loss due to the aerodynamic drag force can be approximated based on the fact that force times distance equals energy. In this case, that loss is $E_{loss2}=(0.5*C_D*A*\rho*v_0^2)*(y_0/\sin(\beta_0))$. The calculated drag energy loss will be insignificantly high because of assuming a constant force. The remaining energy at the top of the ramp for launch is $E_L=\frac{1}{2}mV_0^2-E_{loss1}-E_{loss2}$ where uppercase V_0 is the entry velocity when hitting the base of the ramp and lowercase v_0 is the velocity at the top of the ramp at trajectory time zero. The trajectory time zero velocity is thus $v_0=\sqrt{(\frac{2E_L}{m})}$.

Based on the above information and the drawing, the flight path trajectory can be calculated numerically from the top of the ramp using the following derivation:

Given that the aerodynamic drag and lift force magnitudes are given respectively by:

$$F_D=\frac{C_D A_{(t)}\rho_a v_t^2}{2} \qquad F_L=\frac{C_{L(t)} S\rho_a v_t^2}{2}$$

where C_D is the coefficient of drag;
$C_{L(t)}$ is the coefficient of lift at time t;
$A_{(t)}$ is the frontal drag area at time t;
S is the floor area;
ρ_a is the density of air; and
v_t is the velocity at time t,

the total aerodynamic forces acting on the car in the x and y directions are, respectively:

$$F_x=-F_D\cos(\beta)-F_L\sin(\beta) \qquad F_y=-mg-F_D\sin(\beta)+F_L\cos(\beta)$$

where m is the mass of the car; and
g is the gravitational constant.

And now, using the notation $\dot{x}=dx/dt$, and keeping in mind the following:

$$v_t^2=(\dot{x}^2+\dot{y}^2)$$

$$\dot{x}=v_t\cos(\beta) \qquad \dot{y}=v_t\sin(\beta)$$

$$\cos(\beta)=\frac{\dot{x}}{\sqrt{\dot{x}^2+\dot{y}^2}} \qquad \sin(\beta)=\frac{\dot{y}}{\sqrt{\dot{x}^2+\dot{y}^2}} ,$$

we can find accelerations in the x and y axes as follows:

$$\ddot{x}=\frac{-C_D A_{(t)}\rho_a}{2m}v_t^2\cos(\beta)-\frac{C_{L(t)}S\rho_a}{2m}v_t^2\sin(\beta) \qquad \ddot{y}=-g-\frac{C_D A_{(t)}\rho_a}{2m}v_t^2\sin(\beta)+\frac{C_{L(t)}S\rho_a}{2m}v_t^2\cos(\beta)$$

$$=\frac{-C_D A_{(t)}\rho_a}{2m}\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}-\frac{C_{L(t)}S\rho_a}{2m}\dot{y}\sqrt{\dot{x}^2+\dot{y}^2} \qquad =-g-\frac{C_D A_{(t)}\rho_a}{2m}\dot{y}\sqrt{\dot{x}^2+\dot{y}^2}+\frac{C_{L(t)}S\rho_a}{2m}\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}$$

which gives us all that we need for the FreeMat ode45 function to obtain a numerical trajectory solution. Since the parameter input order to ode45 is of the form $(x),(\dot{x}),(y),(\dot{y})$, we expect input from ode45 to the user-written, second order ODE function (MySaab96JumpODE) to be:

$$p=\begin{bmatrix} p_1=x \\ p_2=\dot{x} \\ p_3=y \\ p_4=\dot{y} \end{bmatrix}$$

and for output from the user-written MySaab96JumpODE which is returned to ode45, we have:

$$Fout=\begin{bmatrix} Fout_1=\dot{p}_1=p_2 \\ Fout_2=\dot{p}_2=\ddot{x} \\ Fout_3=\dot{p}_3=p_4 \\ Fout_4=\dot{p}_4=\ddot{y} \end{bmatrix}$$

where:

$$\alpha_{(t)}=\alpha_0+\alpha_{rate}*t \quad \text{(current attack angle)}$$

$$A_{(t)}=A_{front}+S*|\sin(\alpha_{(t)})| \quad \text{(current frontal drag area)}$$

$$C_{L(t)}=C_{L(0)}+C_{L(slope)}*\alpha_{(t)} \quad \text{(current coefficient of lift)}$$

$$\ddot{x}=\frac{-C_D A_{(t)}\rho_a}{2m}\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}-\frac{C_{L(t)}S\rho_a}{2m}\dot{y}\sqrt{\dot{x}^2+\dot{y}^2} \qquad \ddot{y}=-g-\frac{C_D A_{(t)}\rho_a}{2m}\dot{y}\sqrt{\dot{x}^2+\dot{y}^2}+\frac{C_{L(t)}S\rho_a}{2m}\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}\ .$$

3. FreeMat Program for Trajectory Calculations:

```
%% MySaab96Jump.m
% Based on Matlab program written by Colin Ratcliffe discussed in...
% http://ratcliffe.site/USNA/EM375/labs/07Project/ProjectileTheory.pdf
% assumed units: metres, seconds, Newtons, kg, radians
% This program runs successfully on FreeMat v4.0
% It most likely runs on Matlab as well, but will need modifications
% for Scilab. I don't know about Octave.
%
% Modified 2/28/2018 to include aerodynamic lift
clear;clc
global Cd Cl0 Clslope rho A S m Pa Pr g
CaseName='';
 while isempty(CaseName)
    CaseName = input('Enter name:','s');
 end
%
V0str='';
 while isempty(V0str)
    V0str = input('Enter V0 in mph:','s'); % Workaround for bug in Freemat V4
 end
V0mph=eval(V0str); % entry speed mph
V0=V0mph*0.44704; % entry speed mph m/s
```

```
   %
   theta0str='';
    while isempty(theta0str)
       theta0str = input('Enter launch angle in deg:','s'); % Workaround for bug
in Freemat V4
    end
   theta0deg=eval(theta0str); % initial launch angle in degrees
   theta0=theta0deg*pi/180; % radians
   %
   PaStr='';
    while isempty(PaStr)
       PaStr = input('Enter attack angle in deg (0-15):','s'); % Workaround for
bug in Freemat V4
    end
   PaDeg=eval(PaStr); % Initial angle angle degrees (different than launch angle)
   Pa=PaDeg*pi/180;
   %
   PrStr='';
    while isempty(PrStr)
       PrStr = input('Enter attack angle rate in deg/sec (usually minus):','s'); %
Workaround for bug in Freemat V4
    end
   PrDeg=eval(PrStr); % attack angle rate degrees/sec
   Pr=PrDeg*pi/180;
   %
   Y0=2; % Initial height (m)
   m=880; % mass of Saab 96, kg (car+passenger 1775lb+165lb)
   A=1.795+0.039; % front silhouette area plus extra for hanging wheels, m^2
   S=4.146; % surface area of floor, m^2 (approx 44.625 sq ft)
   Cd=0.32; % most commonly cited figure
   Cl0=0.3; % coefficient of lift at attack angle=0
   Clslope=(1.6-Cl0)/(15*pi/180); % coefficient of lift increase per radian (1.6
at 15 degrees)
   g=9.81; % m/s^2
   rho=1.2041; % density of air, kg/m^3
   %% calculate launch velocity based on ramp energy loss of mgh
   E0=0.5*m*V0^2; % entry energy
   Eloss1=m*g*Y0; % ramp height energy loss
   %% Further reduce launch energy for drag force acting through length of slope
   %% This is a slight overestimate of energy loss because it assumes constant
speed
   Lslope=Y0/sin(theta0); % Length of slope assuming ramp angle is launch angle
   Eloss2=(0.5*Cd*A*rho*V0^2)*Lslope; % energy loss due to drag while on slope
   EL=E0-Eloss1-Eloss2; % adjusted launch energy
   VL=sqrt(2*EL/m); % launch velocity mps based on launch energy
   VLmph=VL/0.44704; % launch velocity mph
   %% perform projectile calcs
   tmax=8; % do calculations for 8 seconds of flight time
   tspan = [0 tmax];
   % initial conditions as [x0, vx0, y0, vy0]
   IC = [0; VL*cos(theta0); Y0; VL*sin(theta0)];
   SOL = ode45(@MySaab96JumpODE, tspan, IC);
   xt = linspace(0,8.0,801); % For 8 seconds at .01 sec interval
```

```
    yt = deval(SOL,xt);
    n = 1;
     while yt(3,n) >= 0
        x(n) = yt(1,n)*3.281; % x position from column 1 (m => ft)
        vx(n) = yt(2,n)/0.44704; % x velocity from column 2 (m/s => mph)
        y(n) = yt(3,n)*3.281; % y position from column 3 (m => ft)
        vy(n) = yt(4,n)/0.44704; % y velocity from column 4 (m/s => mph)
        n = n+1;
     end
    x(n) = yt(1,n)*3.281; % final values after crossing y=0
    vx(n) = yt(2,n)/0.44704;
    y(n) = yt(3,n)*3.281;
    vy(n) = yt(4,n)/0.44704;
    Tn = xt(n) % landing time
    Xn = x(n) % final x (jump span)
    Vxn = vx(n) % final Vx
    Yn = y(n) % final y
    Vyn = vy(n) % final Vy
    Pan=(Pa+Pr*Tn)*180/pi % landing attack angle deg
    Vn = (Vxn^2+Vyn^2)^0.5 % final velocity
    Ymax = max(y) % height of jump
    thetan=atan(Vyn/Vxn)*180/pi % landing trajectory angle deg
    Dy=(sin(30*pi/180)*4+0.833+0.5)*0.3048 % Occupant vertical stopping distance
    Gocc=0.5*(Vyn*0.44704)^2/Dy/g % (Vyn mph=>m/s)
    Dy=(sin(30*pi/180)*4+0.833)*0.3048 % Car vertical stopping distance
    Gcar=0.5*(Vyn*0.44704)^2/Dy/g % (Vyn mph=>m/s)
    Dy=(sin(theta0)*4+0.833+0.5)*0.3048 % Launch perp-to-ramp stopping distance
    Vyl=V0*sin(theta0) % velocity perpendicular to ramp m/s
    Glaunch=0.5*(Vyl)^2/Dy/g % (Vyl mph=>m/s)
    figure(1);clf;
    str=sprintf('%s, V0=%6.2f mph, VL=%6.2f mph, Angle=%4.1f deg, Attack=%4.1f,
Attack rate=%4.1f, Y0=%5.2f
ft',CaseName,V0mph,VLmph,theta0deg,PaDeg,PrDeg,Y0*3.281);
    if ((PaDeg == 0) & (PrDeg == 0))
      plot(x,y,'b-'); % blue plot if no angle of attack
    elseif (PrDeg == 0)
      plot(x,y,'m-'); % magenta plot if constant angle of attack
    else
      plot(x,y,'r-'); % red plot if variable angle of attack
    end
    % NOTE: The following axis statement is optional and is of the form axis([xmin
xmax ymin ymax zmin zmax])
    % NOTE: Use it only if you want all plots to be of exactly the same scale and
axis limits
    axis([0 400 0 60 0 0]);
    % The following axis equal statement makes sure x and y are spaced equally to
give an undistorted plot
    axis equal;
    grid on;
    title(str)
    xlabel('Span (ft)')
    ylabel('Ht. (ft)')
    % NOTE: The following sizefig is optional and sets the plot resolution...
```

```
    sizefig(1354,320)
    PlotPng=sprintf('%s.png',CaseName);
    print(PlotPng)
    FileName=sprintf('%s.txt',CaseName);
    str=sprintf('V0:\t\t%6.2f\nVL:\t\t%6.2f\nTheta0:\t\t%6.2f\nPaDeg:\t\t
%6.2f\nPrDeg:\t\t%6.2f\nTn:\t\t%6.3f\nXn:\t\t%6.2f\nYmax:\t\t%6.2f\nVxn:\t\t
%6.2f\nVyn:\t\t%6.2f\nGlaunch:\t\t%6.2f\nGocc:\t\t%6.2f\nGcar:\t\t%6.2f\nVn:\t\t
%6.2f\nPaFinal:\t\t%6.2f\nThetaFinal:\t\t%6.2f\nYn:\t\t%6.2f\nY0:\t\t
%6.2f\n',V0mph,VLmph,theta0deg,PaDeg,PrDeg,Tn,Xn,Ymax,Vxn,Vyn,Glaunch,Gocc,Gcar,Vn
,Pan,thetan,Yn,Y0*3.281);
    fp = fopen(FileName,'w');
    fprintf(fp,'%s',str);
    fclose(fp);
```

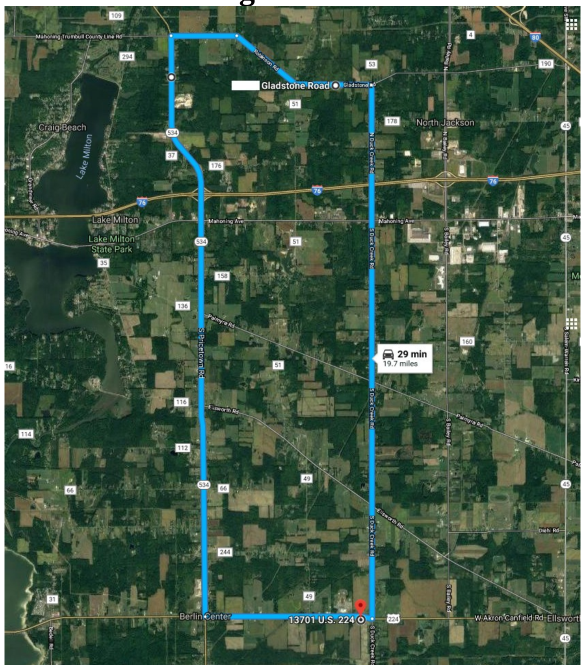
4. User-Written ODE Function for Above FreeMat Program:

```
    function [ Fout ] = MySaab96JumpODE( t, p )
    %% simultaneous second order differentials for projectile
    % motion with air resistance and aerodynamic lift
    % modified 2/28/2018 to include aerodynamic lift
    % output vector Fout has the four differential outputs x', x'', y', y''
    % assumed units: metres, seconds, Newtons, kg, radians
    global Cd Cl0 Clslope rho A S m Pa Pr g % these are defined globally so they
can be changed
    % outside the function - means this function doesn't need editing
    % for different projectiles
    % Cdrag=Cd*Afront*rho/2/m drag force constant (Afront varies with attack angle)
    % Clift=Cl*Afloor*rho/2/m lift force constant (Cl varies with attack angle)
    %
    Pat=Pa+Pr*t; % current attack angle
    Afront=A+S*abs(sin(Pat)); % current frontal area includes floor projection due
to attack angle
    Cdrag=Cd*Afront*rho/2/m;
    Cl=Cl0+Clslope*Pat; % current coefficient of lift
    Clift=Cl*S*rho/2/m;
    Fout = zeros(4,1); % initialize space
    Fout(1) = p(2);
    Fout(2) = -Cdrag*sqrt(p(2)^2 + p(4)^2)* p(2) - Clift*sqrt(p(2)^2 + p(4)^2)*
p(4);
    Fout(3) = p(4);
    Fout(4) = -g -Cdrag*sqrt(p(2)^2 + p(4)^2)* p(4) + Clift*sqrt(p(2)^2 + p(4)^2)*
p(2);
    end
```

5. The Old Farmhouse is Still There Pretty Much Unchanged Except for the Barns:

6. The Welcoming Farmhouse View as I Neared Home (Daylight View):

7. The Loop I Intended to Drive That Night:



8. Google Measurement of Route 534 Overpass Over I-76: