Analysis of Recorded Turnback Flight

Flown by: Ed Frye

Cessna T210L Turbo Centurion

Flown 11/24/2021

Prepared by

Rick Marshall

INFLIGHT METRICS

Contents

Introduction

The following is an analysis of the flight flown by Ed Frye in his Cessna T210L Turbo Centurion, 11/24/2021. The flight departed KTCY (Tracy Municipal Airport) on runway 30. The pilot indicated he planned on staying in the pattern as he checked out an engine that was previously overhauled. After an engine failure on takeoff at approximately 371 ft AGL, on a windless day, he was able to successfully turn back to the airport and land on the cross runway 08. The purpose of this analysis is to examine the factors that allowed the plane to successfully return.

This paper shows the results of a single turnback maneuver performed under an actual emergency. The recordings were analyzed, and the basic flight characteristics were calculated for the conditions present for that day's flight. It is important to note that the results pertain to the given conditions of the day, including the density altitude, winds, and weight of the plane. If the conditions changed, the results would change as well.

Summary

The analysis first calculates several flight parameters based on the flight recordings. These are found in the Climb Profile, Turnback Profile, Glide Profile, and Ground Effect sections of the document. Based on the flight parameters, a model of the flight is then constructed where several "what-if" questions are examined. Below is a summary of the findings.

1. The flight consisted of a straight-out departure from runway 30, followed by a loss of power at 371 feet AGL, a 1 to 2 second startle time, and a turn to the left. After the turn (approximately 205 degrees), the plane happened to be lined up with the cross runway 08, where a short glide was performed, followed by a flare using ground effect. It is important to note that the plane did not return to the reciprocal runway 12. It was fortunate that runway 08 existed as the altitude lost during the turnback was almost entirely used up in the turn. Of the 371 feet available at power out, 89 feet remained when the plane was approximately lined up with 08.

2. Climb angle vs. glide angle plays a significant role in a plane's ability to return to a runway of a given length. In this case, the plane was flown with 20 degrees of flaps throughout the flight. This probably helped in the climb angle and the altitude lost during the turn but negatively affected the glide angle. However, since the glide was so short, the flaps didn't significantly affect the glide distance of the flight.

3. The analysis shows that although the plane could return to the cross runway 08 after departing runway 30, the plane could not have returned to the reciprocal runway 12. This applies to all altitudes where power may have been lost if we assume the plane's configuration of 20 degrees flaps, the current weather conditions, and the lengths of the runway, etc. The most significant factor affecting this is the climb and glide angles. The climb angle was 6.5 degrees, and the glide angle was 7.1 degrees. Typically, the climb angle must be greater than the glide angle to enable the plane to return to a runway of 4000 feet.

4. The plane may have been able to return to the reciprocal runway 12 if sufficient altitude was reached AND the flaps were removed during the glide portion of the flight. If the glide angle could have been 6.0 degrees (as the POH of a T210N model shows), the plane could make runway 12 from a higher altitude.

5. Approximately 550 feet extra distance was gained due to the ground effect. The models used in the analysis assume the plane glides to the ground at the glide angle. However, an extra 550 feet of flight was observed when compared to the actual glide path.

6. The pilot's startle time was extremely short. It measured between 1 and 2 seconds between the time the power was lost until the plane began to turn back. This greatly contributed to the ability to return to the airport. The analysis shows that if the startle time had been 6 seconds (only 4 seconds more), the plane could not have returned to 08.

7. The altitude at which power was lost was significant. The plane lost power around 371 feet AGL. The analysis shows that if power was lost at 300 feet or below, the return to the cross runway 08 would not have been possible. It is also shown that even at a 1000 feet power loss, the plane could still return to the cross runway. Above 1000 feet, it is not likely that the plane could return (Note however that the pilot intended to stay in the pattern).

8. Some have commented that the pilot should have just glided forward and landed in the field straight ahead. The analysis shows that if the pilot chose this course, the plane would have very likely laned in the housing complex after the field. Also, once committed to the straight-ahead approach, there would be no way of correcting it since houses appear on both sides of the field.

9. Another analysis is made where the plane turns at 500 feet (assuming it didn't lose power yet) and stays in the pattern. The analysis shows that the "best option" in the event of loss of power would be runway 08 until the plane gets 2/3's down the downwind leg. Then the best option switches to runway 30.

10. Wind analysis was also performed. It shows that if there was a crosswind coming from the north at 5 knots, the plane may not have been able to make either runway 08 or 12. At 10 knots from the north, the plane would most certainly not be able to make the runways.

Inputs

Date	11/24/2021	
Email	email@edwardfrye.com	
Last Name	Frye	
First Name	Edward	
Plane		
Tail number	Unknown	
Knots / MPH	Knots	
Type aircraft	1975 Cessna T210L Turbo Centurion	
Engine type	Continental TSIO-520	
HP	310	
Mods	Full Robertson STOL Kit including Drooping Ailerons (STC # SA1525WE)	
	RAM 310 Horsepower Engine Conversion (STC # SA2689SW)	
	UVALDE Main Landing Gear Door Mod Nose and Main (STC # SA5737SW & STC SA5934SW)	
Constant-speed prop (Y/N)	Yes	
Type prop	Unknown	
Gross weight	3241	
Max Gross weight	3800	
Wing Area	175	
Airport Information		
Airport Code	KTCY	
Runway	30	
Field elevation (MSL)	194	
Magnetic Declination	13.05	East
Conditions		
Ground Winds Dir / Speed	0 knots	
Used in Model Dir / Speed	0 knots	
Density altitude	92	
Barometric pressure	30.22	
Temperature	16	C
Winds Aloft		
Airport code	Unknown	
3000 feet AGL		
6000 feet AGL		
Used in Model	Calm	
Takeoff		
Climb out IAS (knots)	78	
Heading	311	

Table 1. Inputs

Summary of Turnback Parameters

	Turnback
TAKEOFF - CLIMB	
TakeOff Distance (ft)	1173
Ave Climb Speed (KIAS)	78.3
Climb Rate (ft/min)	904
Ascent Ratio (ft forward/ft up)	8.8
Climb Angle	6.5
Dist from Liftoff to 1000 ft	9431
TURNBACK	
Altitude Lost in 180 Turn (ft)	256
Startle Time (sec)	2.0
Turn Radius	688
GLIDE	
Ave Actual Glide Speed (KIAS)	68.4
Descent Rate (ft/min)	-859
Glide Ratio (ft forward/ft down)	-8.0
Glide Angle	-7.1

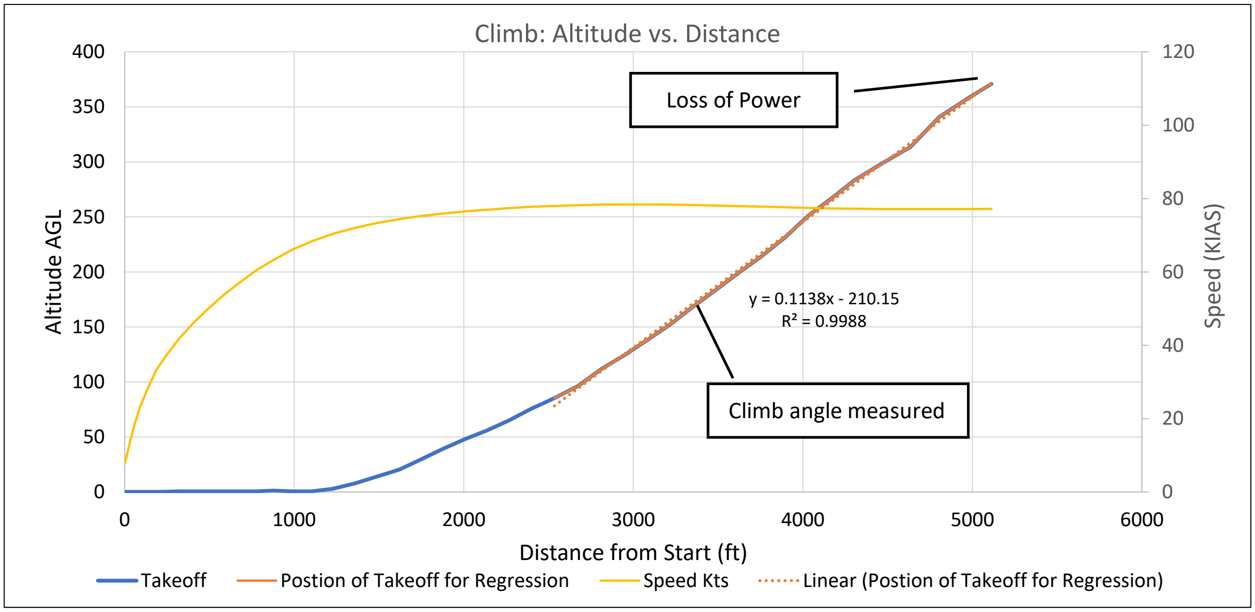
Table 2. Summary of Flight Characteristics from Turnback

CONDITIONS	
Density Altitude (ft)	92
Pressure Altitude (ft)	-106.0
Temperature (C)	16.0
Dew Point (C)	0.00
Baro Pressure (inHg)	30.22
Max Gross Weight (lbs)	3800
Weight (lbs)	3241
% Gross Weight	85.3
Gnd Wind Dir	340
Gnd Wind Kts	0
Aloft Wind Dir	340
Aloft Wind Kts	0
Takeoff Runway Heading	311.64
Align With Runway Heading	311.64
Runway Length (ft)	4001
Ground Elv (ft)	194
Power Out AGL	371

Table 3. Summary of Conditions

Climb Profile

The Climb Profile shows the takeoff and climb with a region fitted with a straight line. This region represents the most steady-state climb and is used to calculate the climb rate and angle.



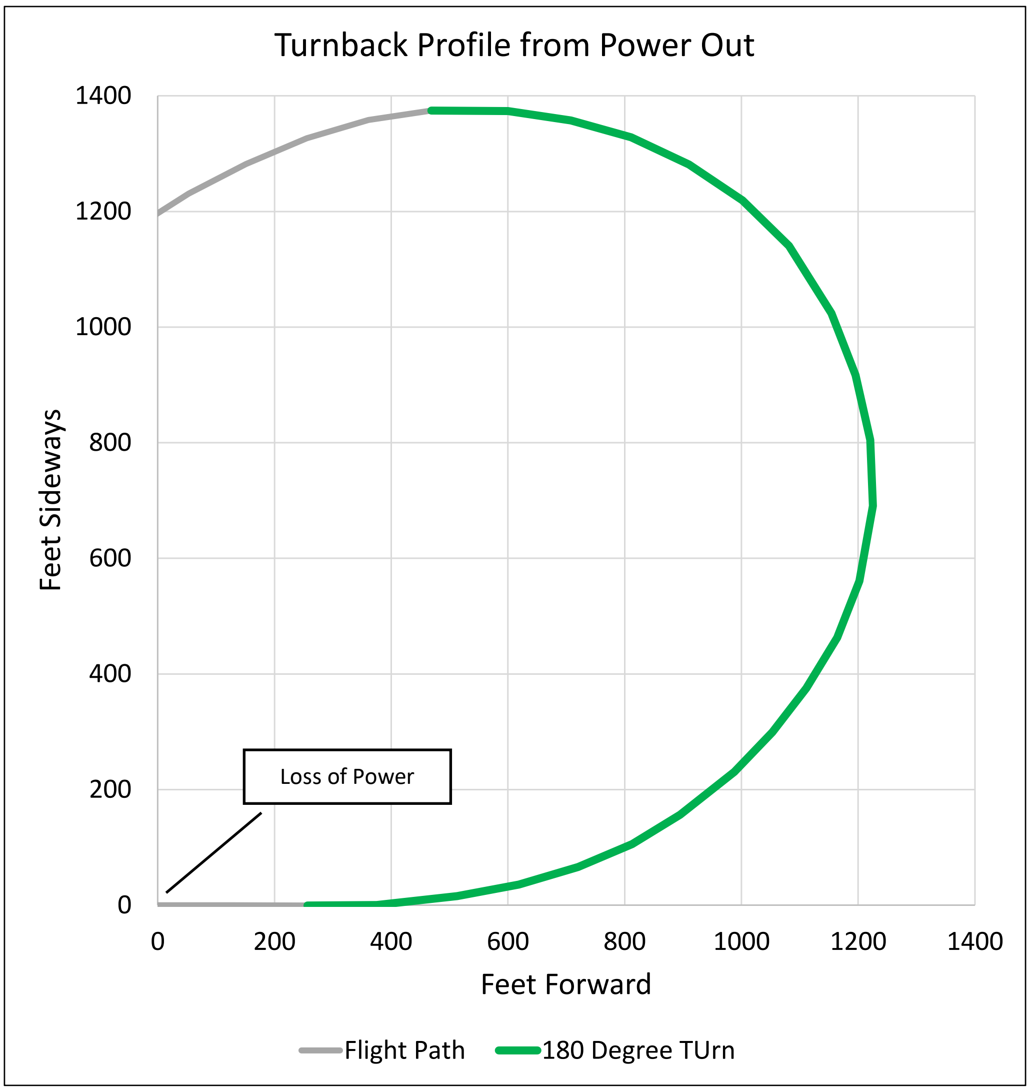
Takeoff Distance:	1173 (starting with 7.7 knot roll)
Climb Rate:	904 ft/min
Steady-state Climb Angle:	6.5 degrees
Steady-state Ascent Ratio (ft forward/ft up)	8.8
Average IAS during steady state climb	78.3 KIAS

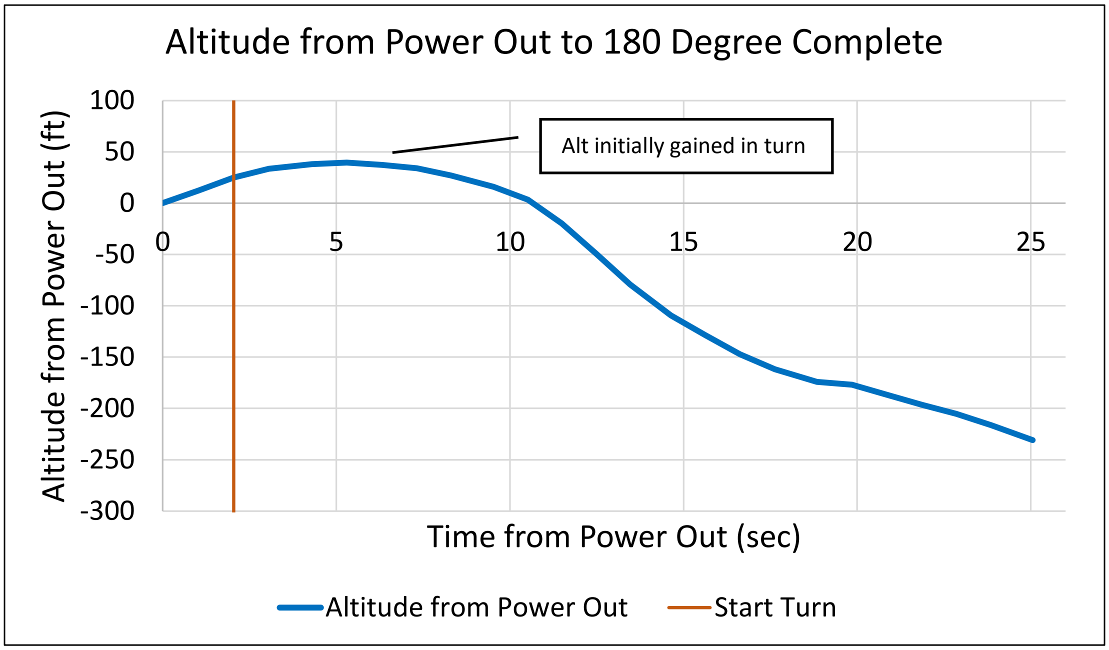
Loss of Power

Altitude	371 feet AGL (according to ForeFlight GPS data)
Distance from Start of Roll to Power Out	5112 feet
Distance from End of Runway to Power Out	1184 feet
Runway Length	4001 feet (roll started a few feet down the runway)

Turnback Profile

The Turn Profile shows the turn both in top and side views so you can visualize what the plane was doing through the startle-time and turn. The Attitude Lost in the Turn is measured from the point the plane begins to turn (after the startle), to the point it turns 180 degrees. In reality, you would need more altitude than this to aim the plane back to the runway. For the model, however, we are only interested in the 180-degree measurement. The model then uses this same "glideslope" of the altitude lost region to calculate the extra loss for various scenarios of aiming the plane back to the runway. It simply uses the 180-turn to calculate a glide slope

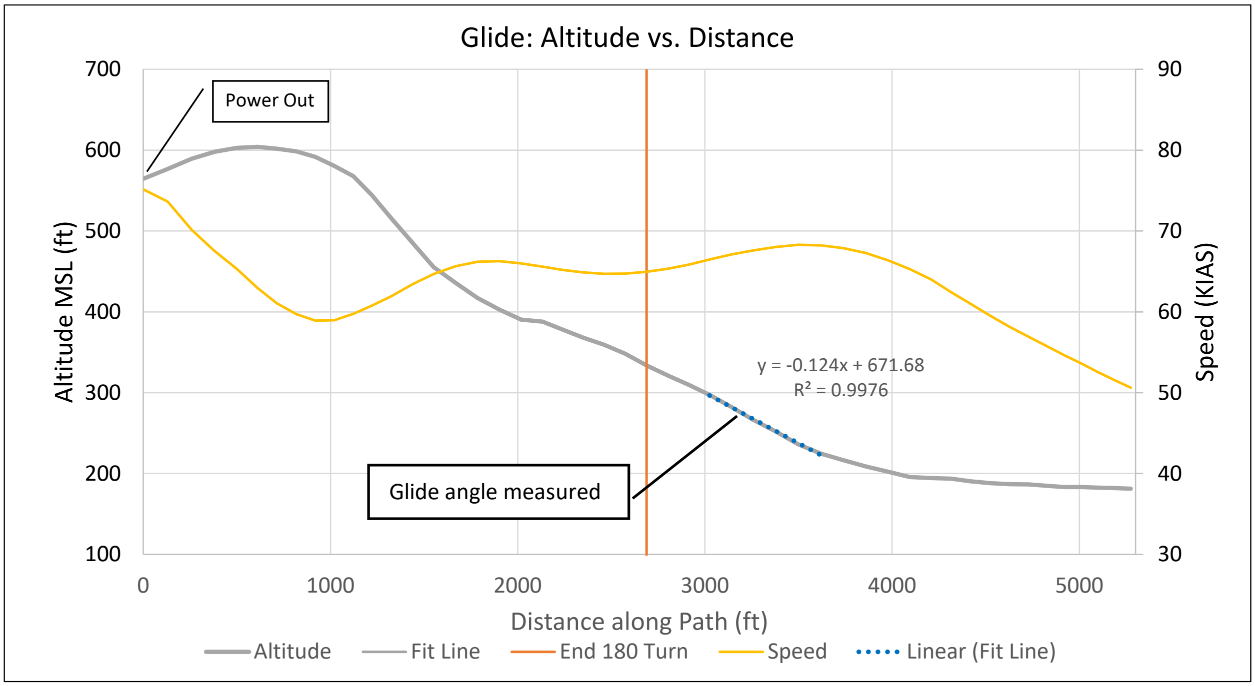




Startle Time	1 - 2 seconds (before plane begins to change track)
Altitude at Power Out	371 ft.
Altitude gained before turn starts	25 ft.
Altitude Lost in 180-degree turn	256 ft. (Note: plane gained more altitude before loss began.)
Altitude Lost in 205-degree turn	307 ft. (Approximately aligned with the runway. Roll level.)
Altitude Left After 205-degree turn	89 ft.

Glide Profile

The Glide Profile shows the complete glide paths from power out through the steady glide. The "X" axis is "Distance Along the Path". It shows the glide as if the turn was unrolled and flattened along the X-axis. The straight-line fit again represents the most steady-state glide where the glide parameters are then calculated.



Descent Rate: 859 ft/min

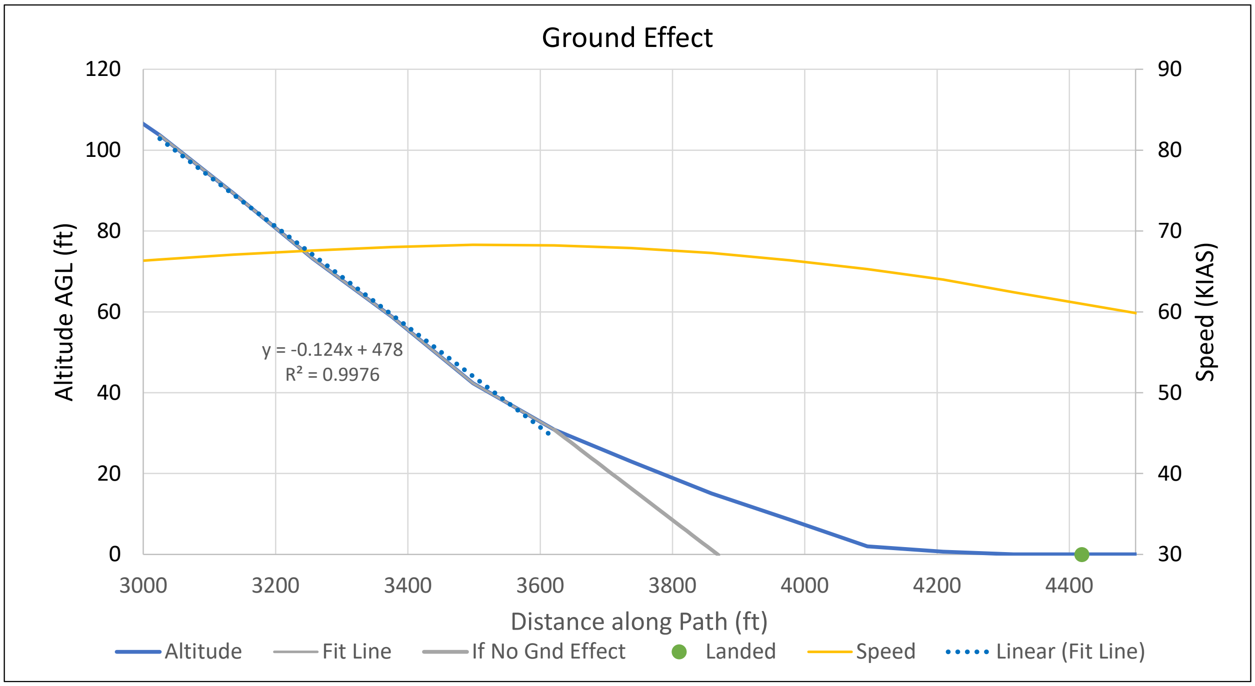
Steady-state Glide Angle 7.1 degrees (held for a brief time – see above).

Steady-state Descent Ratio (ft forward/ft down) 8.0

Average IAS during steady-state glide 68.4 KIAS

Ground Effect

By plotting the glide slope into the ground and comparing it to the actual landing location, we can calculate the extra distance gained by the ground effect. The models used in this analysis assume the plane glides into the ground with a constant glide slope. The ground effect should be added to reveal the most likely landing location.



Difference between gliding straight into the ground and where the plane landed: 550 feet

Comparing raw flight data to attempted return to reciprocal runway 12

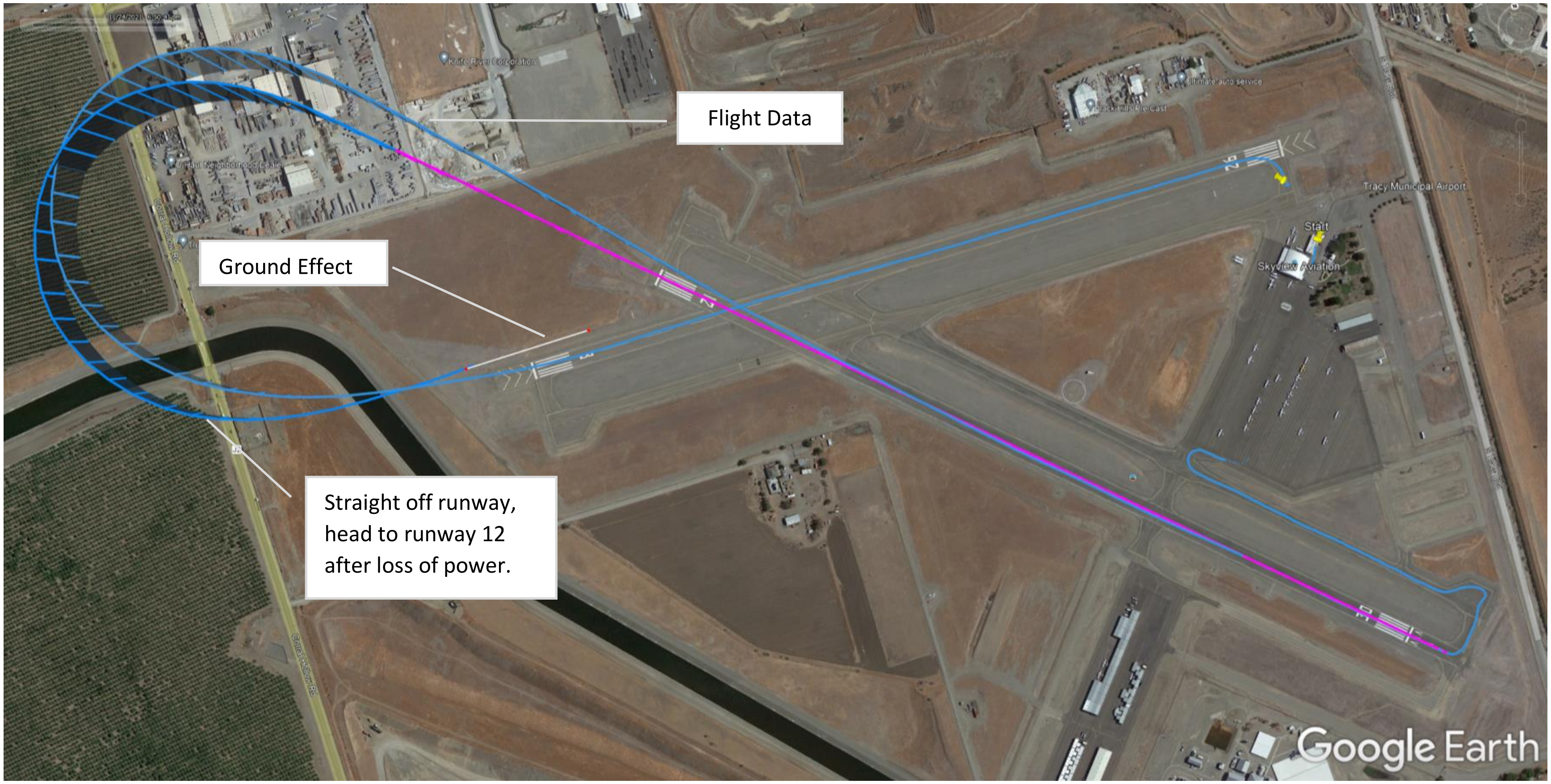


Figure 1. Takeoff and Turnback from Runway 30 at KTCY. NO WINDS. Flight data showing return to Runway 08 compared to "what-if" attempt to return to runway 12. Power out at 371 feet AGL.

Figure 1 shows two flight paths. The first is the actual flight data with the power out at 371 feet AGL, returning to runway 08. The second is a projected flight path using the measured flight parameters where the pilot tries to return to the reciprocal runway 12. The white line shows the extra ground effect distance that was experienced. Even with the extra distance of the ground effect, the plane fails to reach the reciprocal runway.

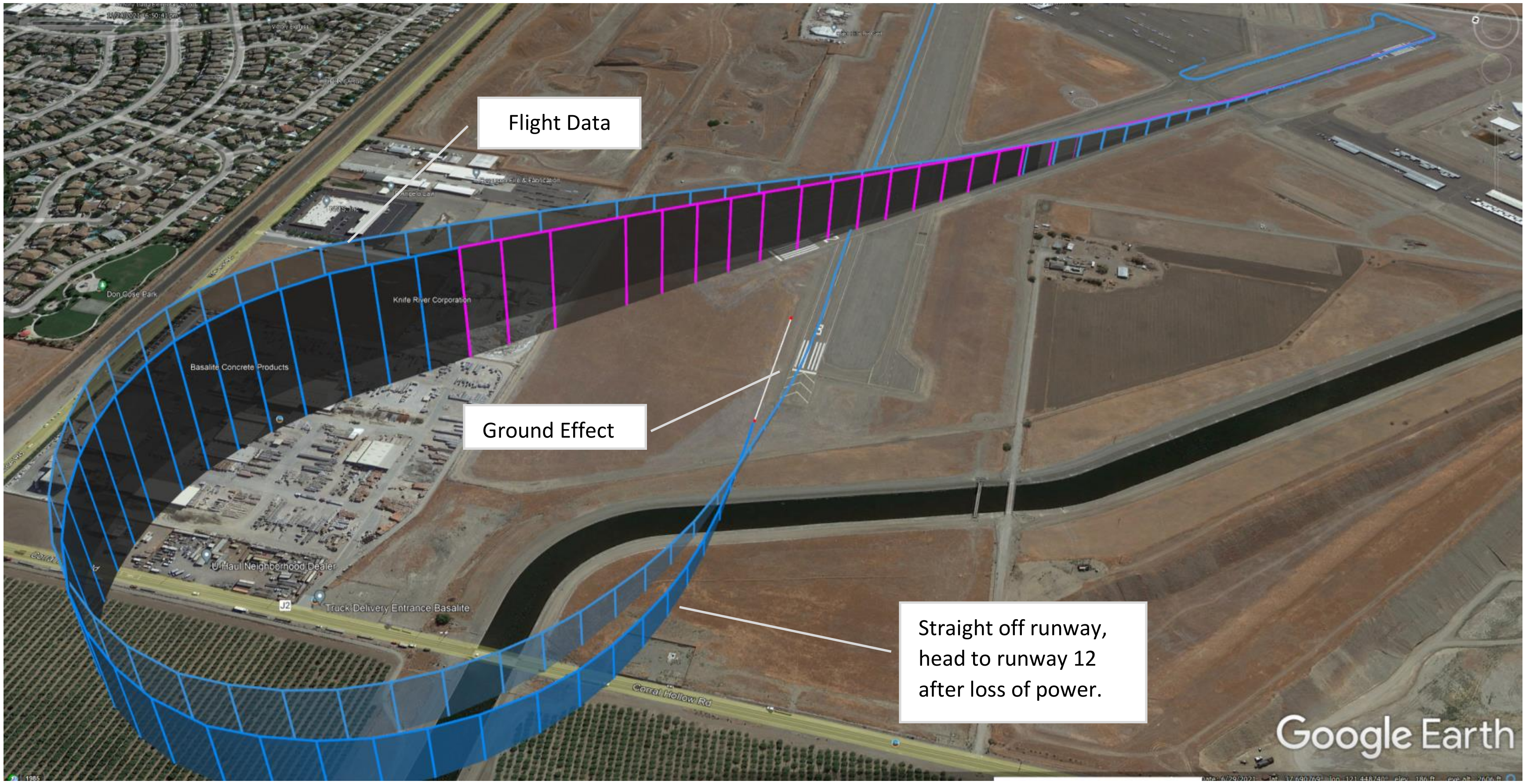


Figure 2. Same as Figure 1 but at a different vantage point.

It appears that the reason the return was possible was the existence of cross runway 08. After power was lost, the turnback consisted almost entirely of the turn back to the airport, followed by a very short glide to a runway that happened to be in the right place.

Is there an altitude when the plane could return to the reciprocal runway?

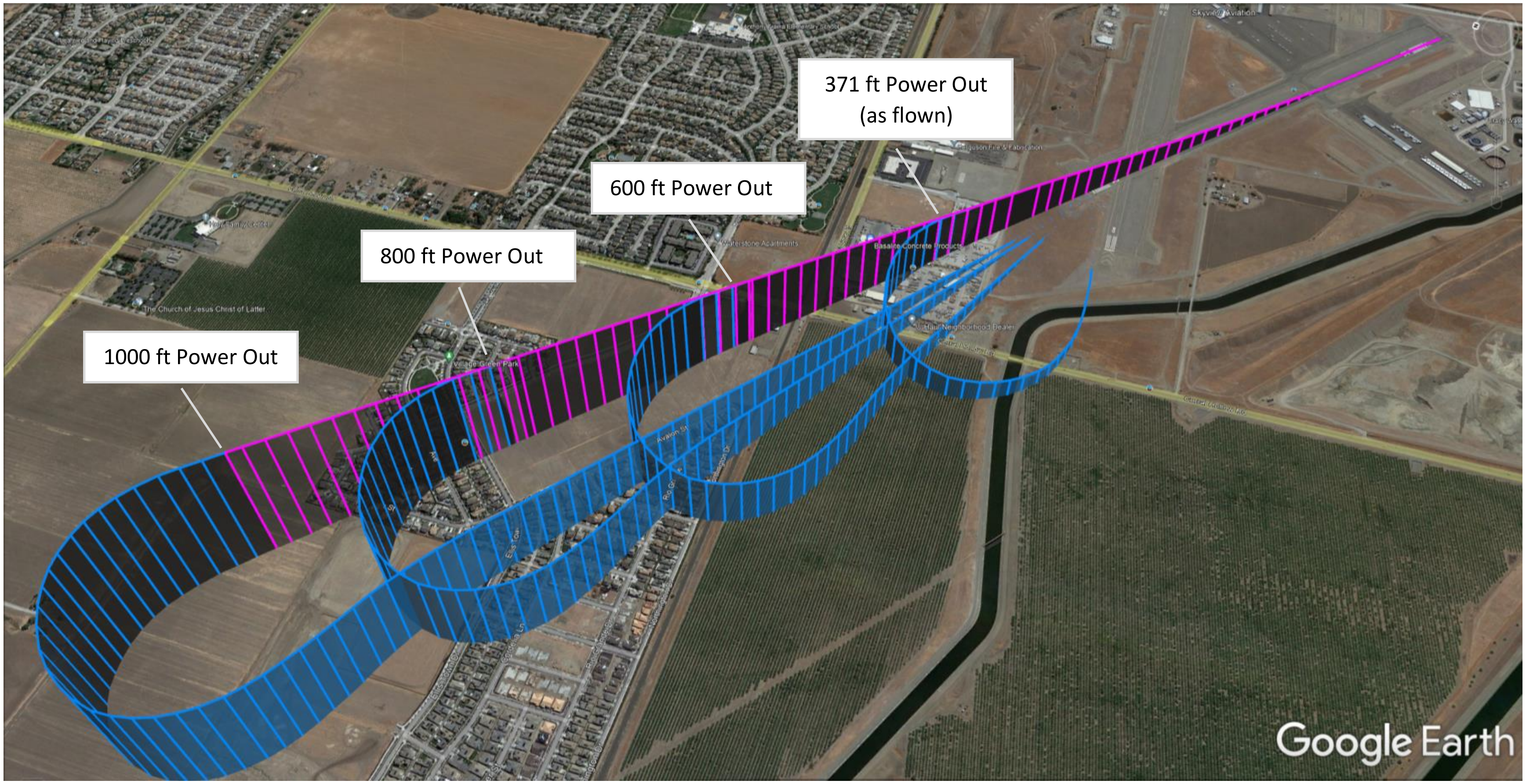


Figure 3. Turnbacks to the reciprocal runway 12 at various power-out altitudes.

Could the plane return to the reciprocal runaway 12 at a higher altitude? Figure 3 shows that the plane could not return to runway 12 at any altitude. This is essential because the measured climb angle was 6.5 degrees (for the conditions of the day, and the weight of the plane as is). The glide angle was 7.1 degrees. Thus, even with a very short startle time, and a well-executed turn back, the climb angle fails to achieve enough altitude close to the airport for the glide to be executed. The higher the plane goes, the farther away it gets from the airport, leaving an impossible glide after the turnback.

Would improving the glide angle allow for a return to the reciprocal runway?

What if the glide angle could be improved by removing the flaps during the glide portion of the flight and flying at Vg? Would this allow the pilot to return to the reciprocal runway in case a cross runway was not available? The pilot reported that the flaps were left at 20 degrees for the entire flight. If the flaps were removed during the glide portion, the POH indicates that the glide angle would be approximately 6 degrees (see Appendix. The glide angle shows 6 degrees without STOL modifications. May be different after mods, even with 0-degree flaps).

Figure 4 shows that the flight can be modeled using the basic flight characteristics (ground roll, climb angle, altitude lost in turn, glide angle, etc.). The plot shows the actual flight data, slightly modified to return to the runway (pink), vs the modeled data (blue). You can see the plane falls short of the reciprocal runway with the 7.1-degree glide angle. A power-out altitude of 1000 feet is shown.

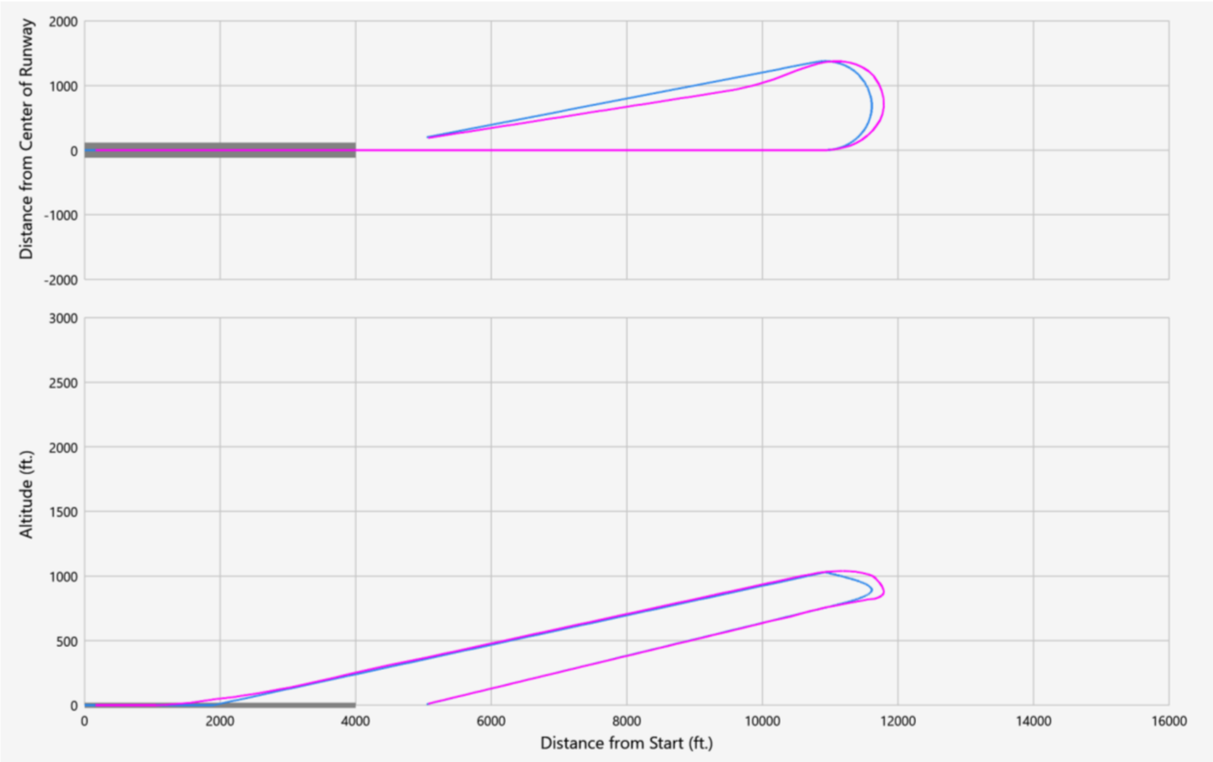


Figure 4. Actual flight data vs. modeled data.

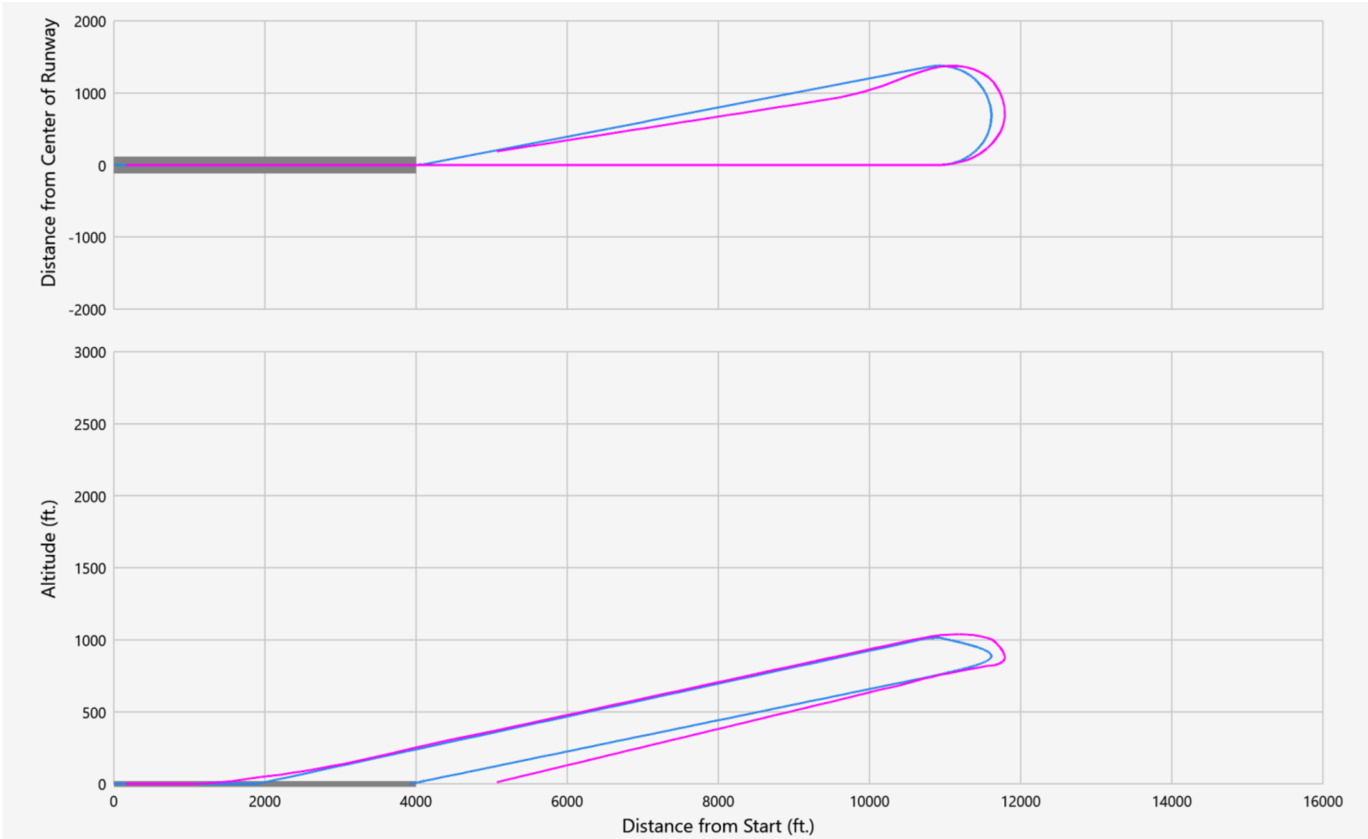


Figure 5. Modeled data showing a glide angle of 6 degrees (per POH).

Using a 6-degree glide angle, presumably accomplished by removing the flaps during the glide portion of the turnback and flying Vg, the plane would be able to make it back to the reciprocal runway. Of course, we are reminded that this works only for the climb conditions present. The climb angle is subject to changes in engine power, weight, winds, density altitude, and climb speed.

What if the startle time was longer?

The measured startle time was only 1 to 2 seconds from the time the engine quit until the plane began to turn back. This is an extremely short startle time. What if the pilot took longer to decide to act?

Figure 6 shows the same model discussed above used in an app that projects all possible glide paths back to all runways when the power is lost. Thus, it will project glide paths back to 08 and 12 for both left and right turns.

The flight path is color-coded to show approximate altitudes. The color codes are as follows:

- Blue – the altitude is between 200 and 700 AGL
- Yellow – the altitude is between 100 and 200 AGL
- Red – the altitude is between 0 and 100 AGL
- Grey – the altitude s below ground

The transition between red and grey is where the landing is predicted (minus the ground effect in the flare).

As you can see, the projected landing site, without ground effect, is close to the actual flight data. If the ground effect was applied, the plane would land just after the numbers on 08.

The other projected flight paths all fail to reach a runway.

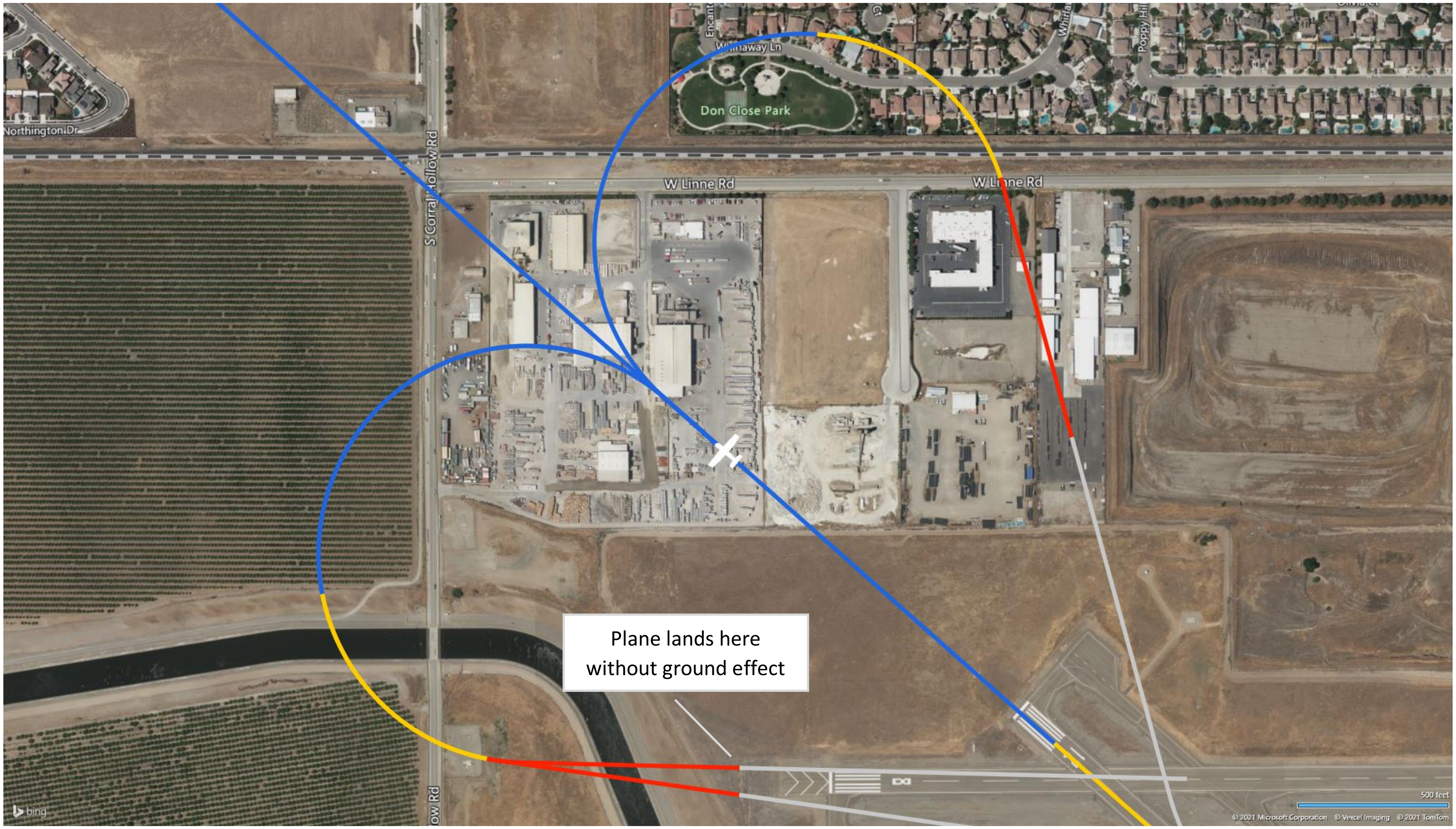


Figure 6. Loss of power at 371 ft with 2 second startle time. Projected glide paths to all runways. The plane makes runway 08.

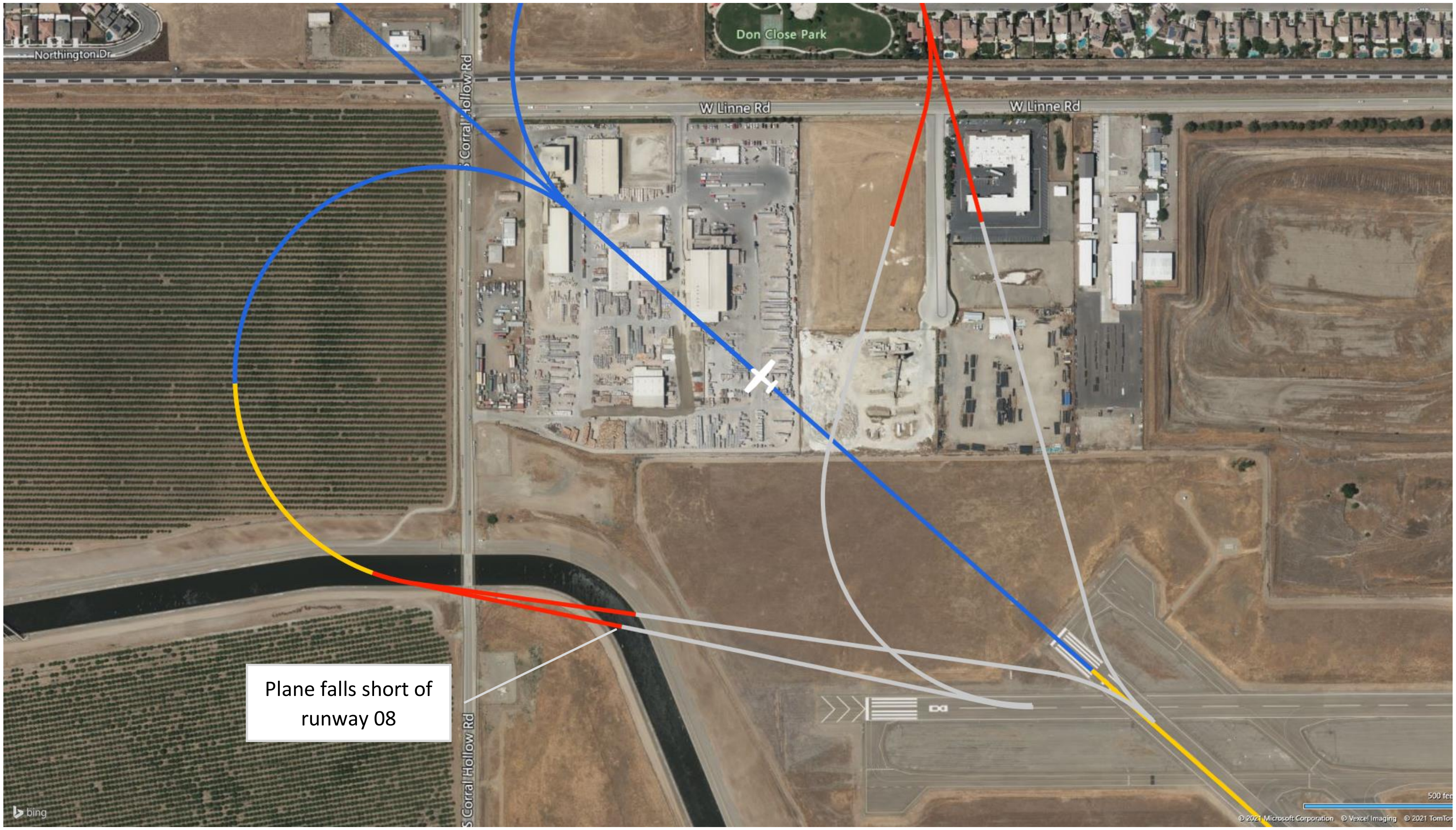


Figure 7. 6-second startle time applied at same 371 ft altitude. The plane is unable to make runway 08.

Using the same altitude for power out (371 ft AGL) but applying a 6 second startle time before the plane begins to turn shows us that the plane would not have made it back to runway 08. Even with 550 ft for the ground effect, the plane would not likely make the runway, and possibly would not have cleared the airport fencing

What altitudes could the plane lose power and still make it back to runway 08?

The plane lost power around 371 ft. AGL. What if the loss of power occurred earlier or later? Figure 6 showed that at 371 ft, the plane was turned back and landed approximately on the numbers of runway 08.

Figure 8. Loss of power occurs at 300 ft.

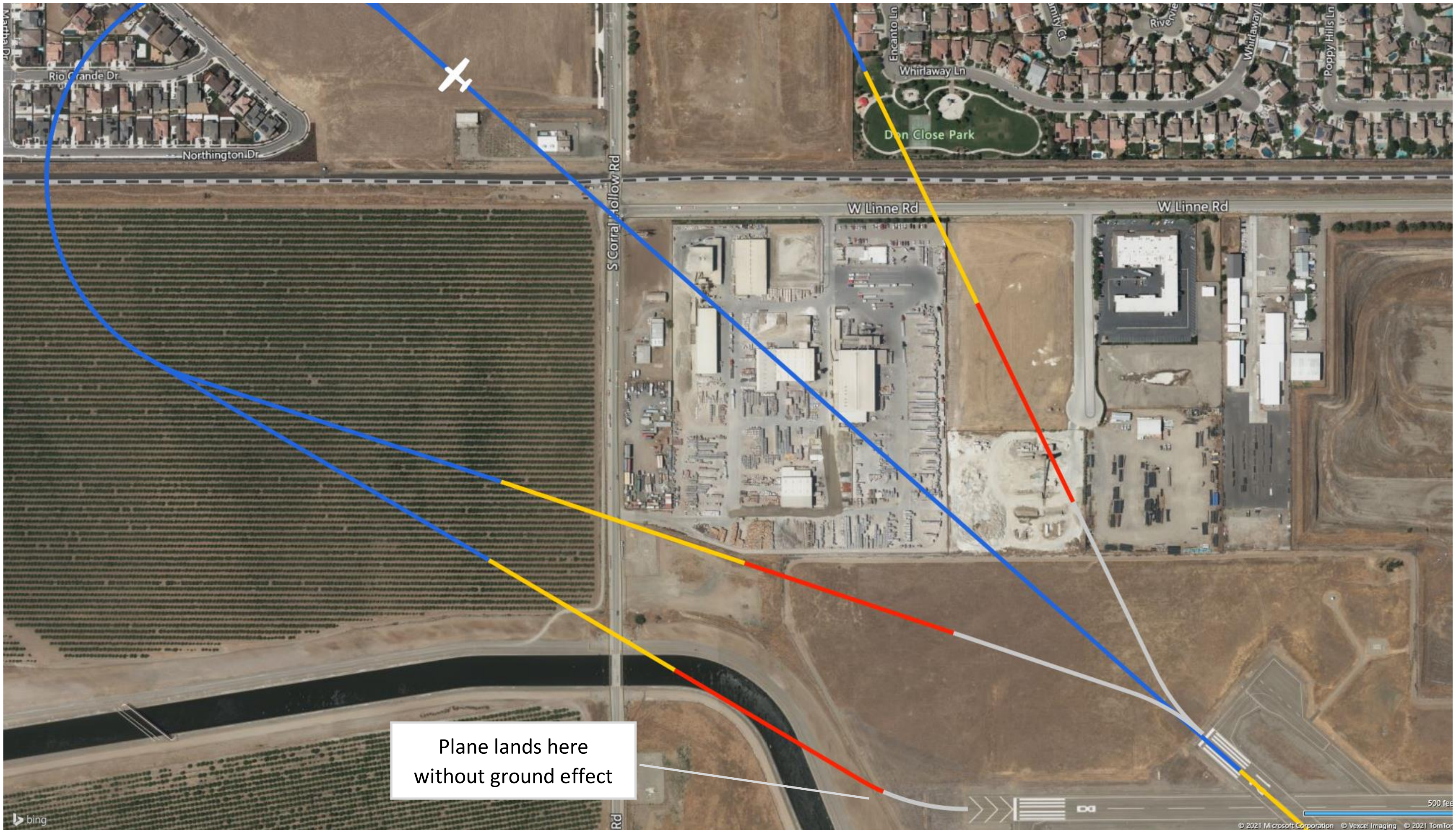


Figure 9. Loss of power occurs at 600 ft.

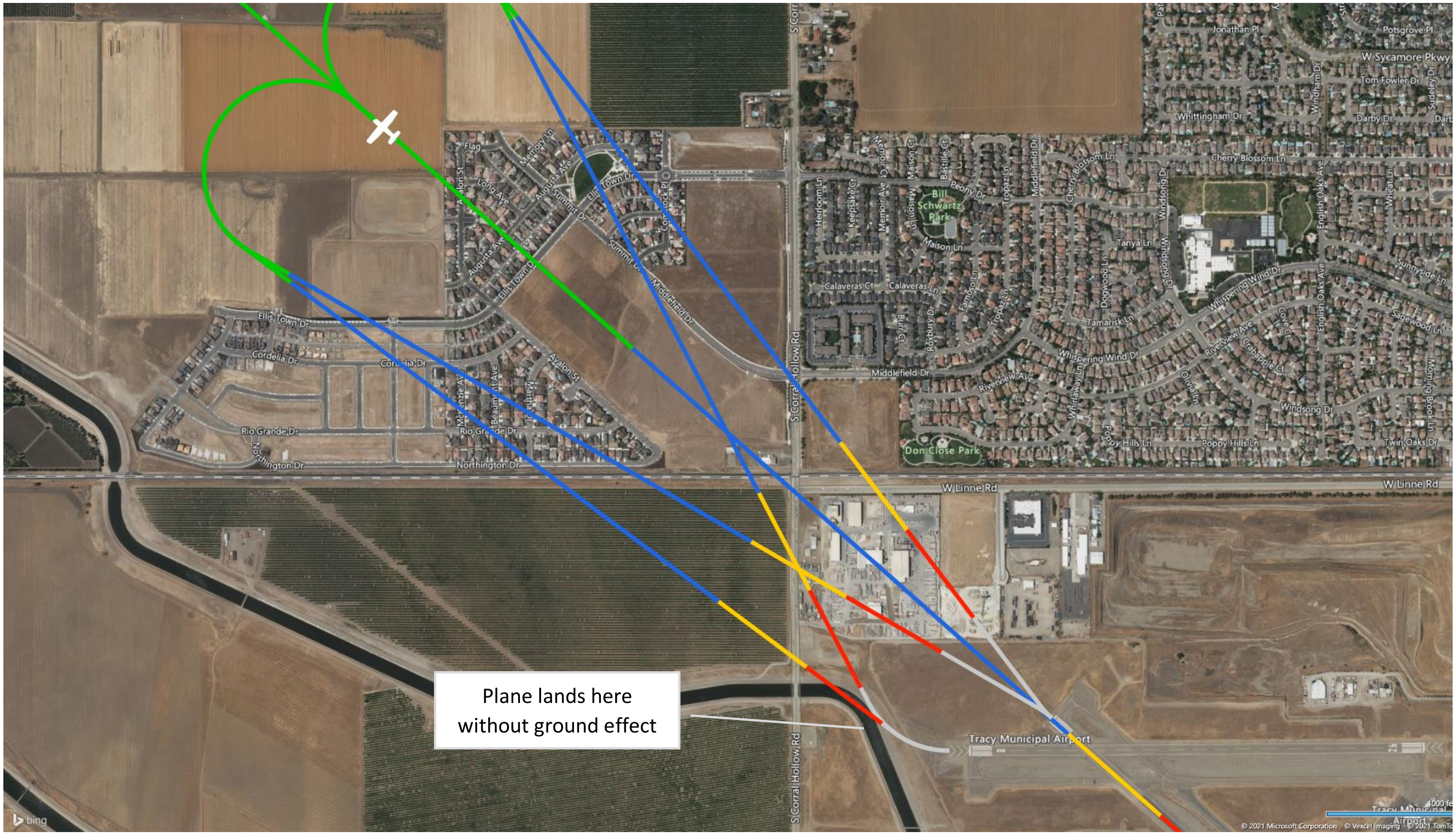


Figure 10. Loss of power occurs at 1000 ft.

Figure 8 shows that at 300 feet, the plane would not be able to make it back to runway 08.

Figure 9 shows that at 600 feet, the plane could make it back to 08 (assuming the fences could be cleared).

Figure 10 shows that at 1000 ft, the plane might barely make it back to runway 08 if it could clear the fence.

Where would the plane land if it was glided forward?

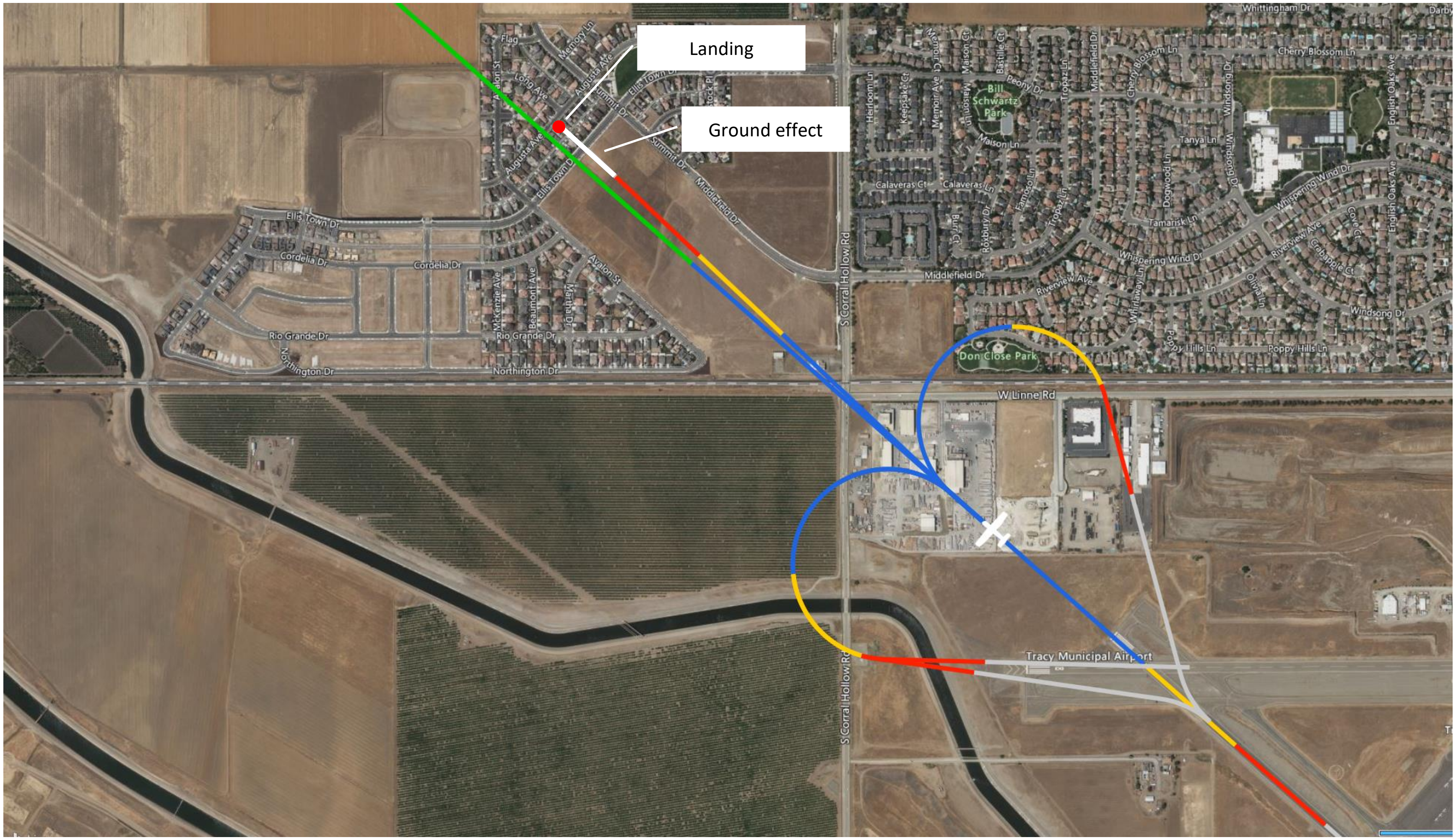


Figure 11. Path of the plane if the pilot tried to go forward. Loss of power occurs at 371 feet AGL.

Figure 11 shows that if the pilot had tied to land the plane forward (plus or minus a few degrees from straight ahead, the plane would have likely landed in the rows of houses. Further, if the pilot had not reacted to turn the plane, the “straight forward “ path could not have been abandoned for a better plan.

What if the pilot had stayed in the pattern and the failure occurred later?

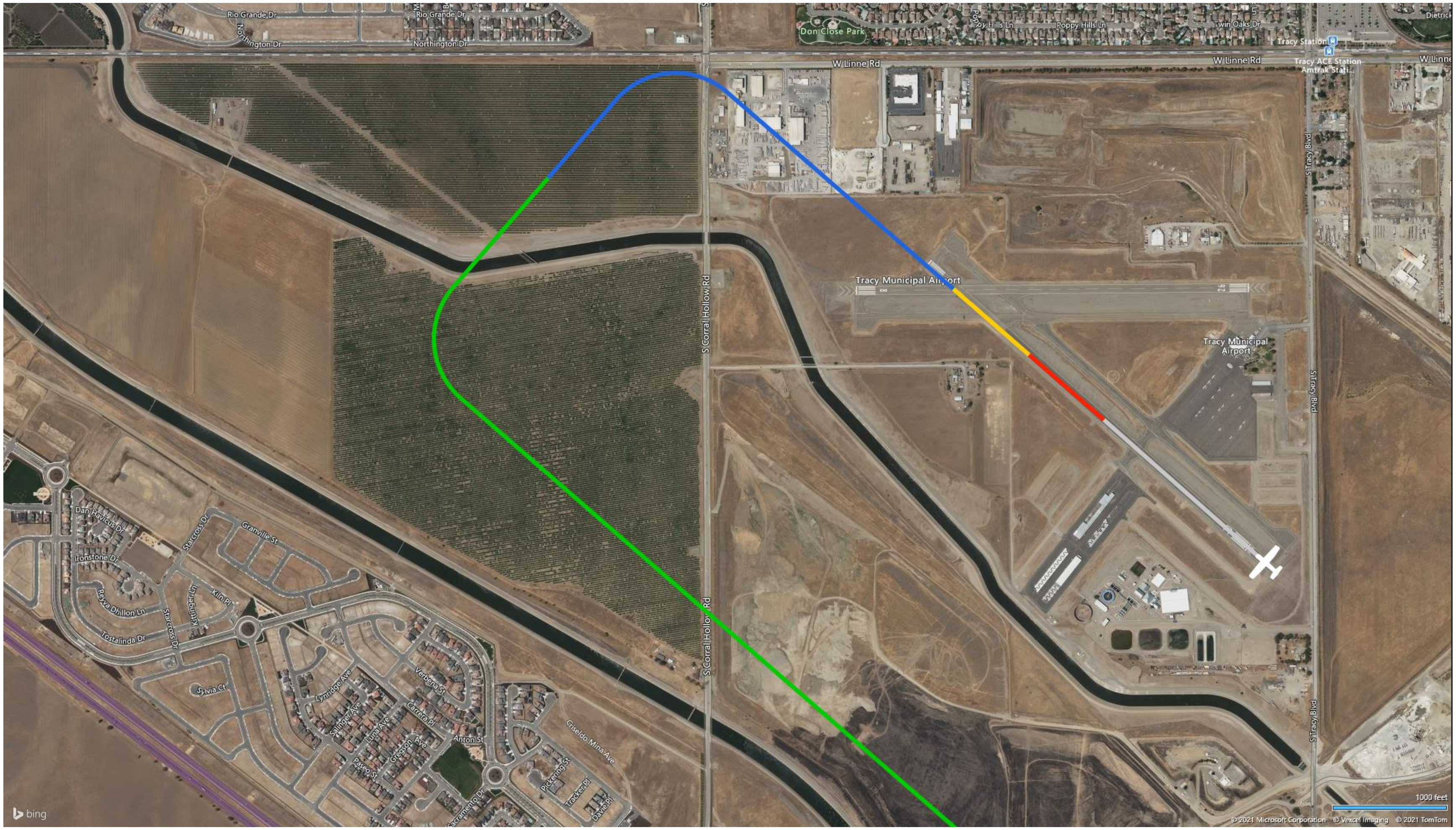


Figure 12. Path of plane staying in the pattern.

Figure 12 shows the path that the plane will be flown around the pattern. The first left turn occurs at 500 feet. Once 1000 feet is reached, the plane will fly level.

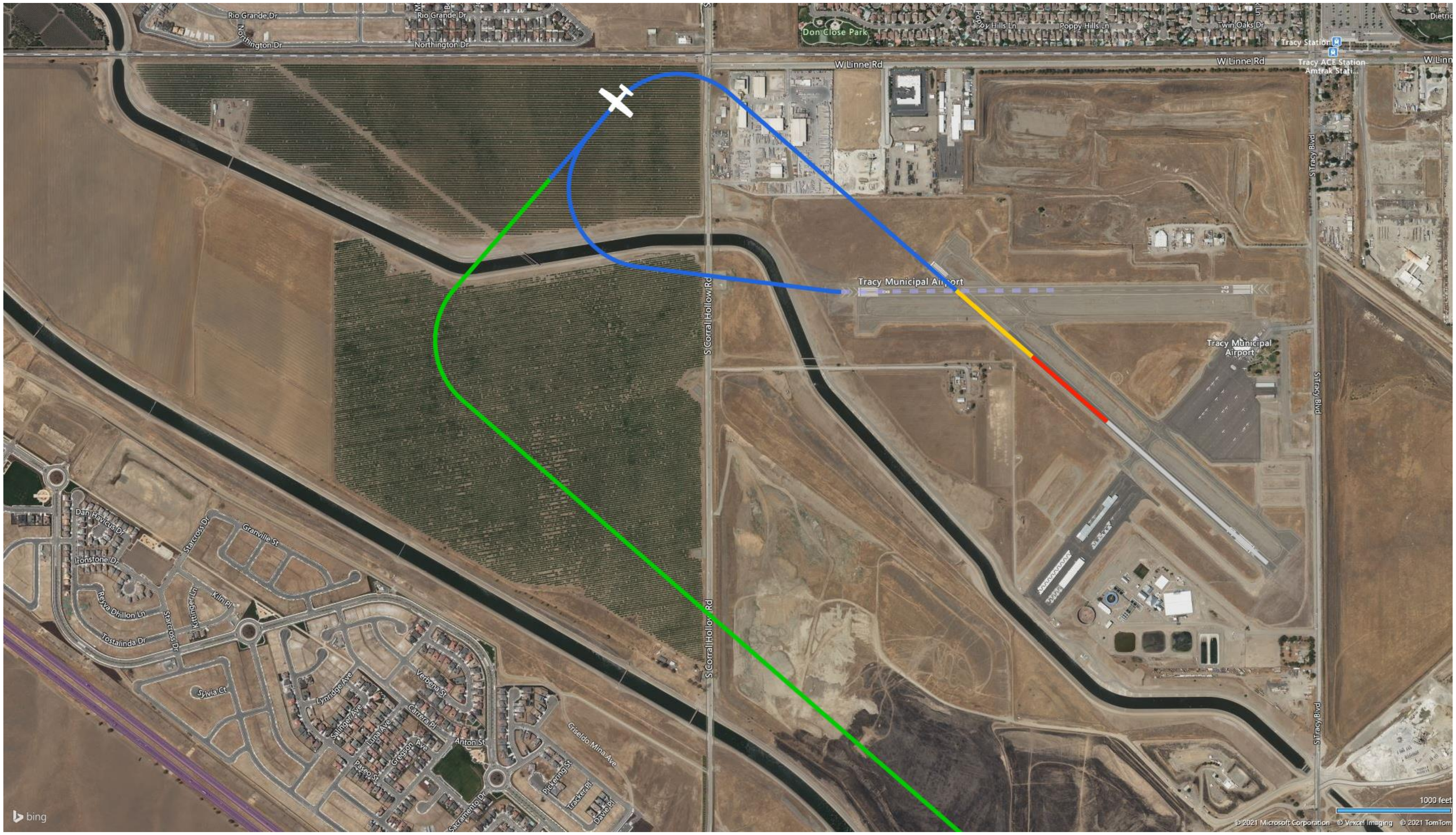


Figure 13. Path of plane staying in the pattern. Loss of power occurs at 600 feet AGL.

At 600 feet the "Best Option" is to glide the plane to runway 08, where it easily makes it.

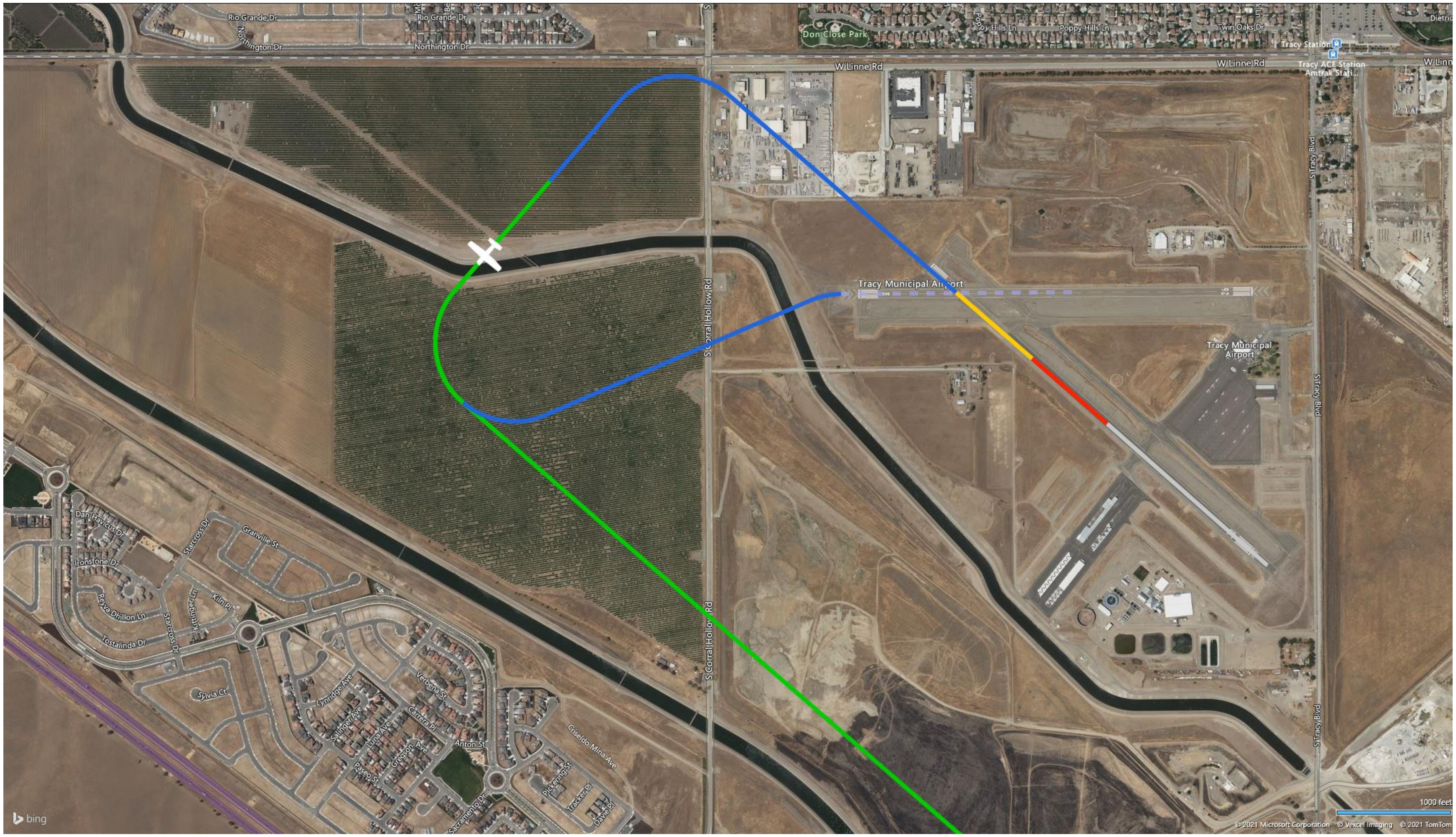


*Figure 14. Path of plane staying in the pattern. Loss of power occurs at 8*00 feet AGL.

At 800 feet the "Best Option" remains to glide the plane to runway 08, where it easily makes it.

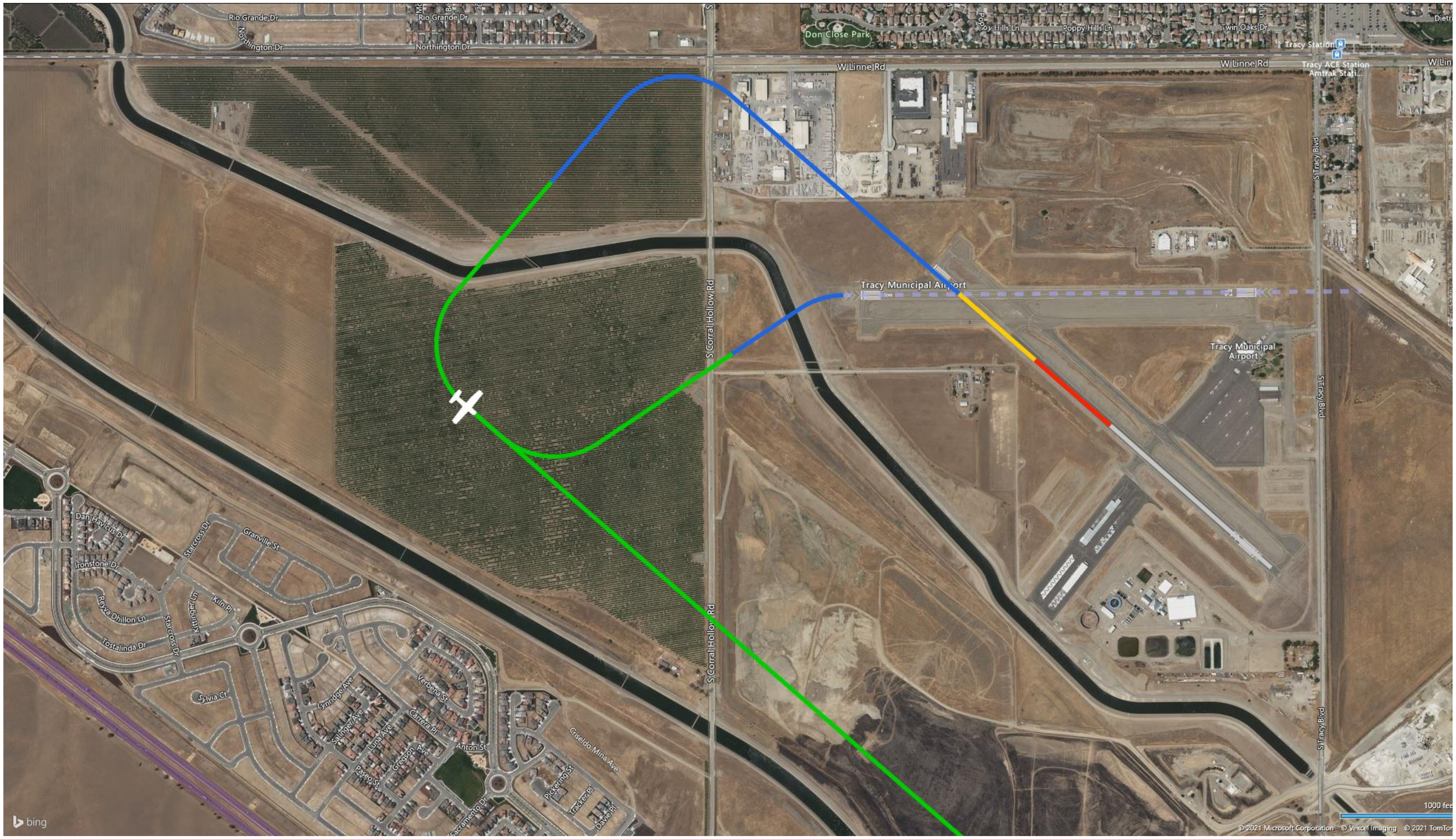


Figure 15. Path of plane staying in the pattern. Loss of power occurs at 950 feet AGL.

At 950 feet the "Best Option" remains to glide the plane to runway 08, where it easily makes it.

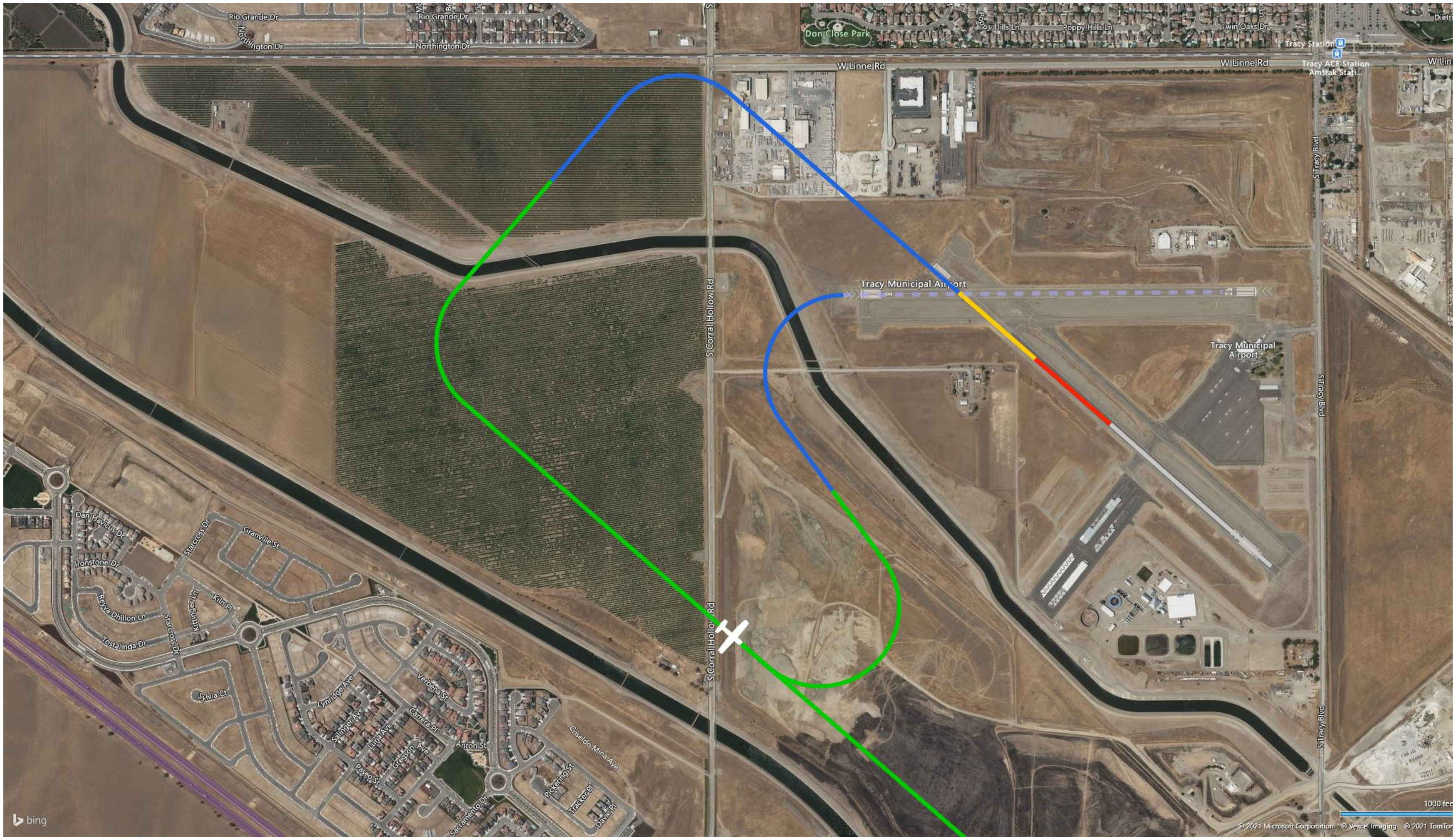


Figure 16. Path of plane staying in the pattern. Loss of power occurs at 1000 feet AGL (once 1000 feet is reached, the plane flies level).

At this point at 1000 feet the "Best Option" remains to glide the plane to runway 08, where it easily makes it. However, the next image will show a new best option.

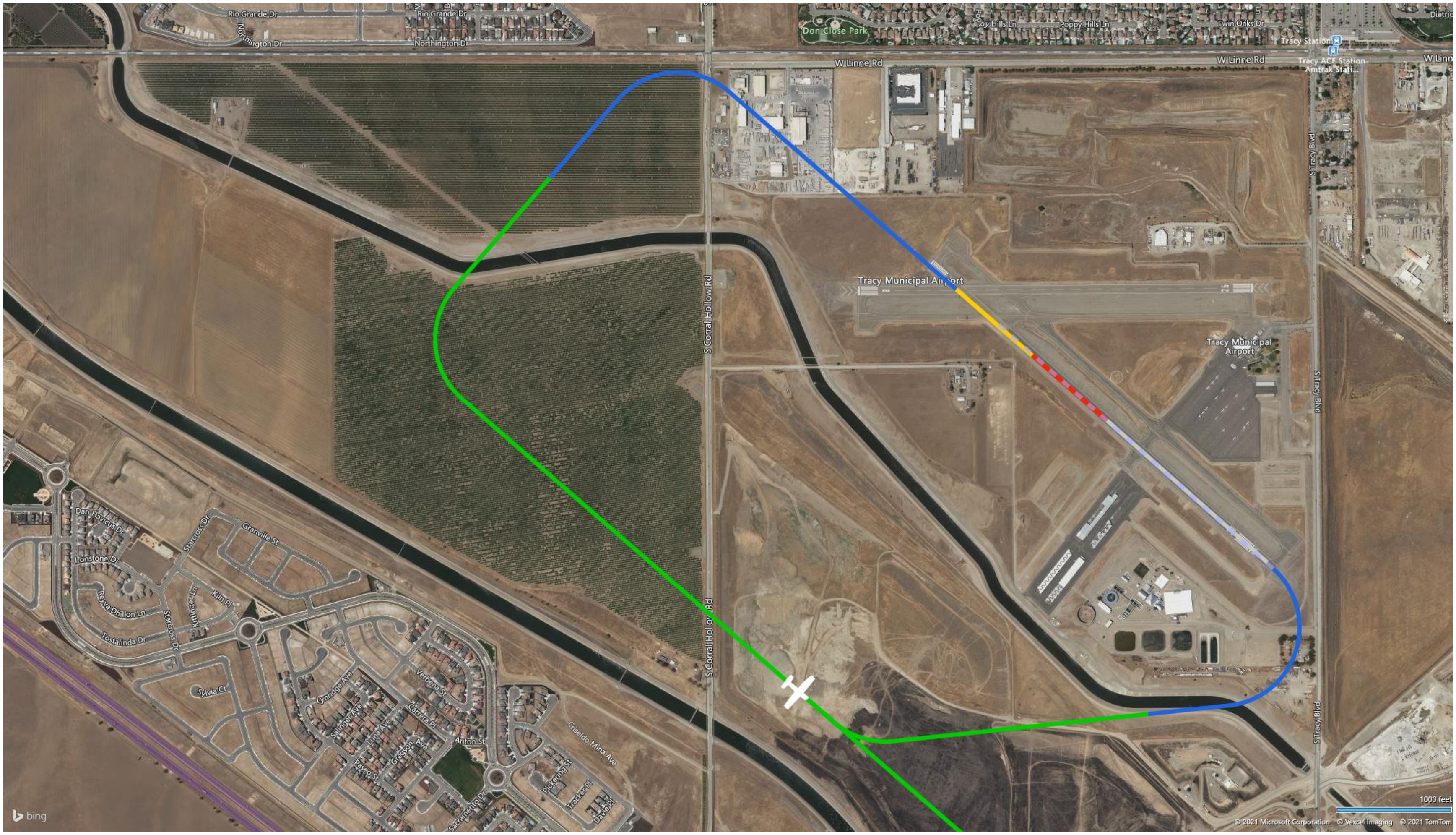


Figure 17. Path of plane staying in the pattern. Loss of power occurs at 1000 feet AGL. Best option changes to runway 30.

At this point at 1000 feet the “Best Option” switches to runway 30. The best option is defined as the highest point over the threshold, given the plane will make the threshold.

What if there was a right crosswind?

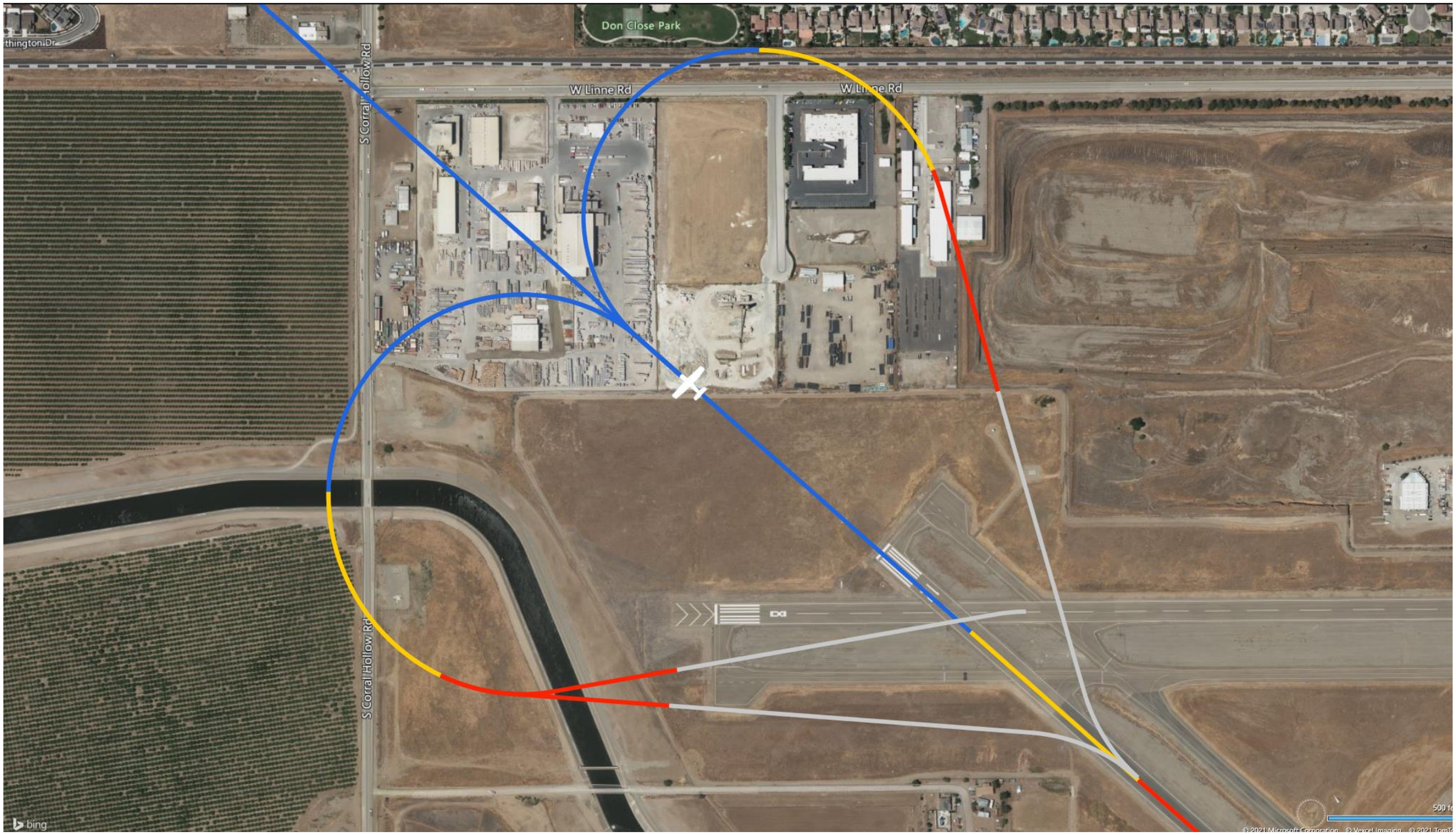


Figure 18. 5-knot wind from 0 degrees. Plane crabs into the wind to maintain track. Loss of power occurs at 371 feet AGL.

If a 5-knot wind (from 0 degrees north) had been present, the plane may not have been able to make either runway.

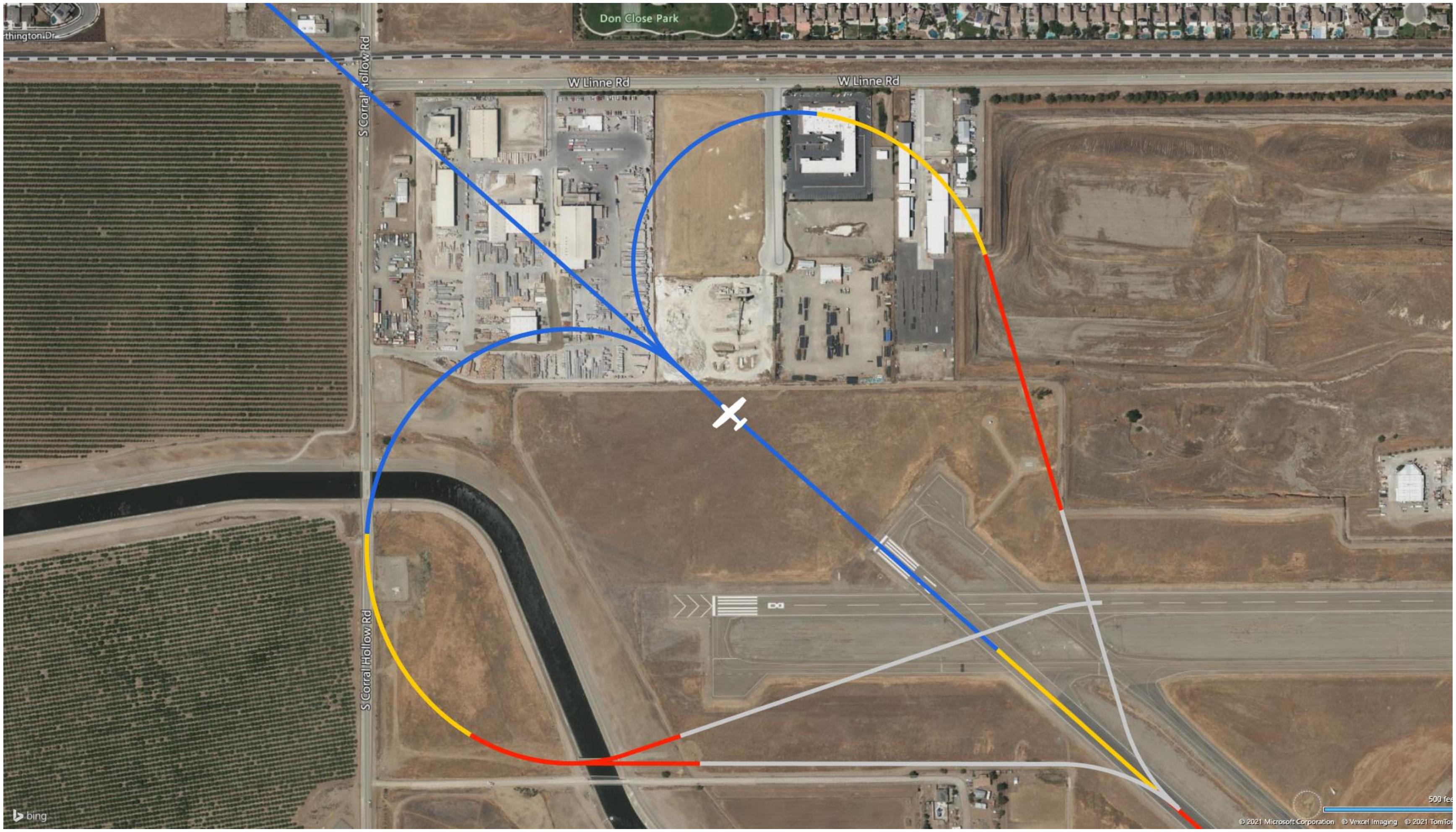


Figure 19. 10-knot wind from 0 degrees. Plane crabs into the wind to maintain track. Loss of power occurs at 371 feet AGL.

If 10-knot wind (from 0 degrees north) had been present, the plane would still not be able to make either runway. This remains the case until a 20-knot wind is introduced. Then perhaps a right turn would be possible for runway 30.

Conclusions

The success factors that made the return to the airport possible include:

1. The cool-headed skills exhibited by the pilot, including
    a. The pilot chose to turn back instead of flying straight ahead. Had he flown straight ahead the plane would likely have landed in the housing complex to the northwest after gliding past the open field.
    b. Monitoring the airspeed to ensure a stall did not occur.
    c. Application of flaps to increase the climb angle, resulting in a climb angle of 6.5 degrees.
    d. Flying the turnback at a slow speed (did not "dive" into the turn).
    e. Application of flaps during the turn to allow for a slower speed and reduced radius.
2. The existence of runway 08, allowing the plane to land on a runway right after the turn.
3. An extremely short startle time of 1-2 seconds. If the time exceeded 6 seconds, the plane likely would not have made it.
4. The loss of power occurred above 300 feet. Below 300 feet, the plane could not make the runway.
5. There were no winds. Had a crosswind of only 5 knots (from 0 degrees) been present, neither runway would likely have been made. At 10 knots, it is almost certain the runways could not be made.

Potential factors hindering the return were:

1. The bank angle was recorded at 22 degrees during the turn. Further analysis (see Appendix) shows that the bank angle was probably somewhere around 22 to 30 degrees, but not at the optimal bank angle of 45 degrees. Although the optimal bank angle for minimal loss of altitude is 45 degrees, the pilot would have to be aware of the increased risk of stalling the plane.
2. The use of flaps during the glide portion of the flight. This, however, was not a significant factor as the glide portion, in this case, was so short. For other scenarios, removal of the flaps might help.

Appendix

YouTube Videos

- Catastrophic Engine Failure after Takeoff
  https://www.youtube.com/watch?v=9FdRQiHyWQs

- Post Engine Out After Takeoff incident debrief
  https://www.youtube.com/watch?v=T3G1Y50Olls

POH Used in the Analysis

From a T210L owner's manual online at https://takeflightsandiego.com/assets/documents/1972%20Cessna%20210L%20POH.pdf

There is also a POH flight manual supplement available online at http://www.aeroelectric.com/Reference_Docs/Cessna/cessna-poh/C210L-Robertson_STOL-STC_Supplement_to_POH.pdf

Weight And Balance

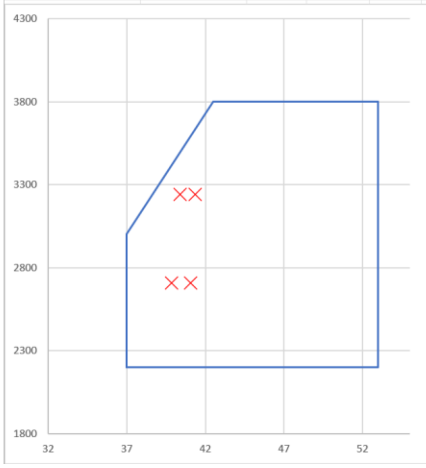
The aircraft had full tanks. The following weight and balance calculations apply.

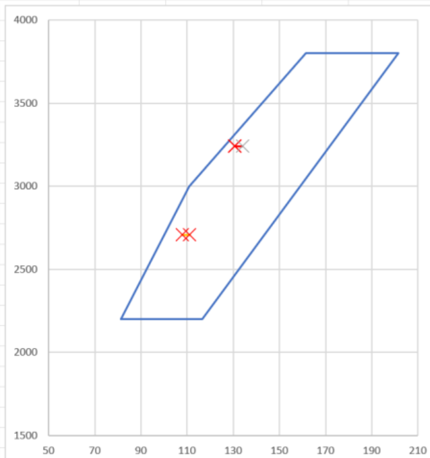
Weight & Balance for N503AT (T210L) '75

Item	Weight (lbs)	Max	Δ	Arm	Moment
Legal Empty Weight	2366.57	3800.00	1433.43	39.77	94.12
Pilot Seat	325.00			37.00	12.03
Co-Pilot Seat	0.00			37.00	0.00
Center Seats	5.00			71.00	0.36
Rear Seats	0.00			101.00	0.00
Baggage	10.00			138.00	1.38
TKS Fluid	0.00	0.00	0.00	138.00	0.00
Fuel	534.00	534.00	0.00	43.00	22.96
Total:	3240.57	3800.00	559.43	40.38	130.84
Without Fuel:	2706.57	3800.00	1093.43	39.86	107.88
Wheels up Total:	3240.57	3800.00	559.43	41.37	134.05
And W/O Fuel:	2706.57	3800.00	1093.43	41.04	111.09

	Weight	Max
Pilot	325	
Co-Pilot	0	
Center Seat 1	5	
Center Seat 2	0	
Rear Seats	0	
Cargo 2	10	50

Fuel		
Fuel Load	89	534
Tabs	65	390
Max	89	534





The Pilots Frame-By-Frame Analysis of His Video

- HH:MM:SS:FF - Video time: Hour, Minutes, Seconds, Frame 30/second
- 00:06:08:02 - Compass Starts Shaking
- 00:06:08:29 - My maximum Aileron Deflection
- 00:06:09:20 - Aircraft begins to react by pitching up and banking left, but still at a 296 heading and 9-10 degrees pitch up, I begin pushing forward
- 00:06:10:11 - I have ailerons neutral, and a 5 degrees nose up at a 295 heading
- 00:06:12:06 - I have counter ailerons to prevent over banking
- 00:06:14:06 - nose on the horizon, very slight skid (quarter bubble)
- 00:06:15:29 - you can see from the MFD, that I had turned past 260 when I start reaching for the gear
- 00:06:17:03 - I finish putting the gear handle down
- 00:06:18:08 - pushed the nose forward again

Bank Angle

ForeFlight only recorded two values for the bank angle during the turn: -20.26 and -22.45. Comparing this to the pilot's report using images of the avionics, we can conclude that the bank angle was less than the 45-degree optimal and was most likely somewhere around 30 degrees:

Pilot's report:

I did a "perspective warp" on the PFD when the turn is established is 22 degrees before I put the gear down.

Once I put the gear down, the pitch down increased and the bank angle also increased.

This looks closer to 32 degrees, but my head is in the way and there are hills in the background, so hard to be certain.