Connecting Industry to Mathematics Instruction

NSF ATE Award # 1954291

Threat Assessment

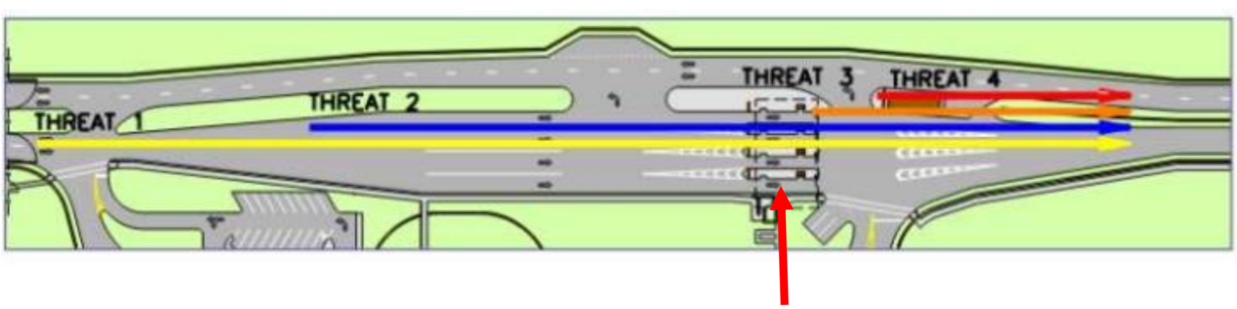
Stantec, an engineering company with an office in Raleigh, has hired you to help make Kirtland Military Base safer. When a vehicle enters a military base, they must pass through the Entry Control Facility (ECF or guard stand) and show ID. It is the job of the guard to allow or deny access to the base. The Department of Defense has identified 4 possible scenarios (threats) in which unauthorized vehicles attempt to enter the base. The four threats are outlined below:

In partnership with

Scenario	Action
Threat 1	Vehicle approaches the ECF in the inbound or outbound lanes at a moderate or high rate of speed
Threat 2	Vehicle enters the ECF in the inbound or outbound lanes at or under the posted speed limit and then accelerates at some point farther in the approach zone, after an advance speed detector
Threat 3	Vehicle appears legitimate until the ID check area
Threat 4	Vehicle is rejected or directed to proceed to the inspection area; however, once away from the guard, attempts to enter the installation

Source: UFC 4-022-01

A threat 1 vehicle approaches the base quickly and enters the base without stopping at the ID check. A threat 2 vehicle speeds up at some point before the ID check and enters the base without stopping at the ID check. A threat 3 vehicle appears legitimate and will begin to slow down for the ID check but then at the point of the ID check, speeds up and enters the base. A threat 4 vehicle stops, has their ID checked, gets denied, but instead of turning around and leaving or pulling into the rejection area, they will instead step on the gas and enter the base. An illustration of the starting location of each threat in relation to the ID check are pictured below.



ID Check

Your job is to determine the placement of an active vehicle barrier (AVB) on the base. The goal is to place the barrier in a location that will successfully stop all four threats. An AVB is an automated barrier that comes up from the ground to stop any unauthorized vehicles attempting to enter the base.

Initial thought questions:

1. Describe at least two or three things the base will need to consider before installing the AVB?

2. Where do you think the AVB should go? Why?

Determine the placement of an Active Vehicle Barrier

Response time is the key to the location of the AVB. Response time is the sum of the guard reaction time, time for the barrier safety system to warn other traffic, and barrier deployment time. The minimum requirements for these are as follows:

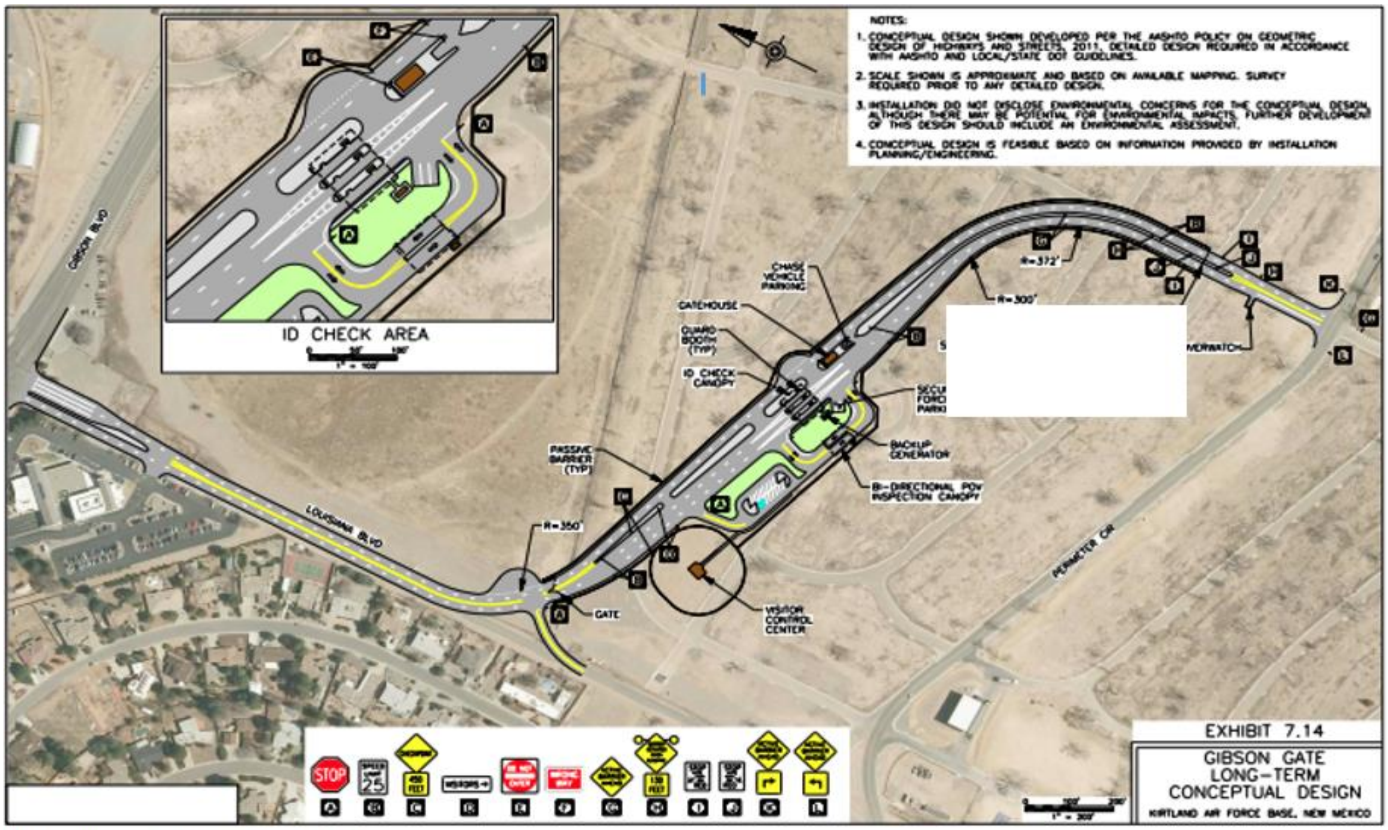
Guard reaction time - the time it takes the guard to realize there is a threat on the base. Minimum guard reaction time for threat scenarios 1-3 is 3 seconds and for threat scenario 4, is 1 seconds.

Barrier safety system - the system put in place to alert authorized vehicles that there is a threat on the base and the AVB is about to deploy. The minimum time for this is 4 seconds.

Barrier deployment time - time it takes for the AVB to be in place. The minimum time is 2 seconds.

1. What is the minimum time required for this sequence of events?
2. Why do you suppose there is a difference in guard reaction time for threats 1-3 and threat 4?
3. Why must these three things happen in sequence instead of simultaneously?
4. For the purposes of this problem, we are going to use the minimum time of 9 seconds. However, what are some reasons that a military base might want to increase the time required to deploy the AVB?

The image below is an aerial view of entry to Kirtland Military Base in New Mexico (Military Surface Deployment and Distribution Command Transportation Engineering Agency, 2019).



Background Image Source: Google Earth

Military Surface Deployment and Distribution Command Transportation Engineering Agency. (2019). Traffic and Safety Engineering for Better Entry Control Facilities (SDDCTEA Pamphlet 55-15). Retrieved from https://www.sddc.army.mil/sites/TEA/Functions/SpecialAssistant/TrafficEngineeringBranch/Pamphlets/SDDCTEA_Pamphlet_55-15.pdf

5. Notice that along Louisiana Blvd, the road curves before it straightens out. Does the curve in the road impact any of the threat scenarios? If so, which one? Explain your reasoning.

Be aware there are two categories of route segments: tangents (constant acceleration) and curves (limited acceleration).

Tangents (Constant Acceleration) In this instance, the term tangent refers to both straight travel lines, which are not affected by variables such as friction, superelevation, or gravity (for the sake of this computation), and large sweeping curves where the vehicle does not reach its skidding velocity and may accelerate through the curve.

Curves (Limited Acceleration) are influenced by friction (between the tire and road surface) and super elevation (the slope/tilt of the road with, or against, the curve). A vehicle traveling through a curve is limited to how fast if can go before it will start skidding out of control. If the vehicle reaches its skidding velocity while traveling through the curve, it is no longer permitted to accelerate through the curve and must remain at constant velocity until it enters a straightaway (Tangent).

For this exercise, we will assume the following constants:

acceleration (a) = 11.3 ft/s^2
coefficient of friction (f) = 1.0
super elevation (e) = 0%
acceleration due to gravity (g) = 32.2 ft/s^2
maximum vehicle velocity (V_{max}) = 130 mph
vehicle weight = 4,630 lbs

6. Why might we assume that the maximum velocity is 130 miles per hour?

7. Research super elevation and explain what it is using complete sentences (hint: NASCAR relies heavily on this).

8. Why does assuming a super elevation of 0% in the curves provide a more conservative result?

The formulas you will use throughout this activity are given below.

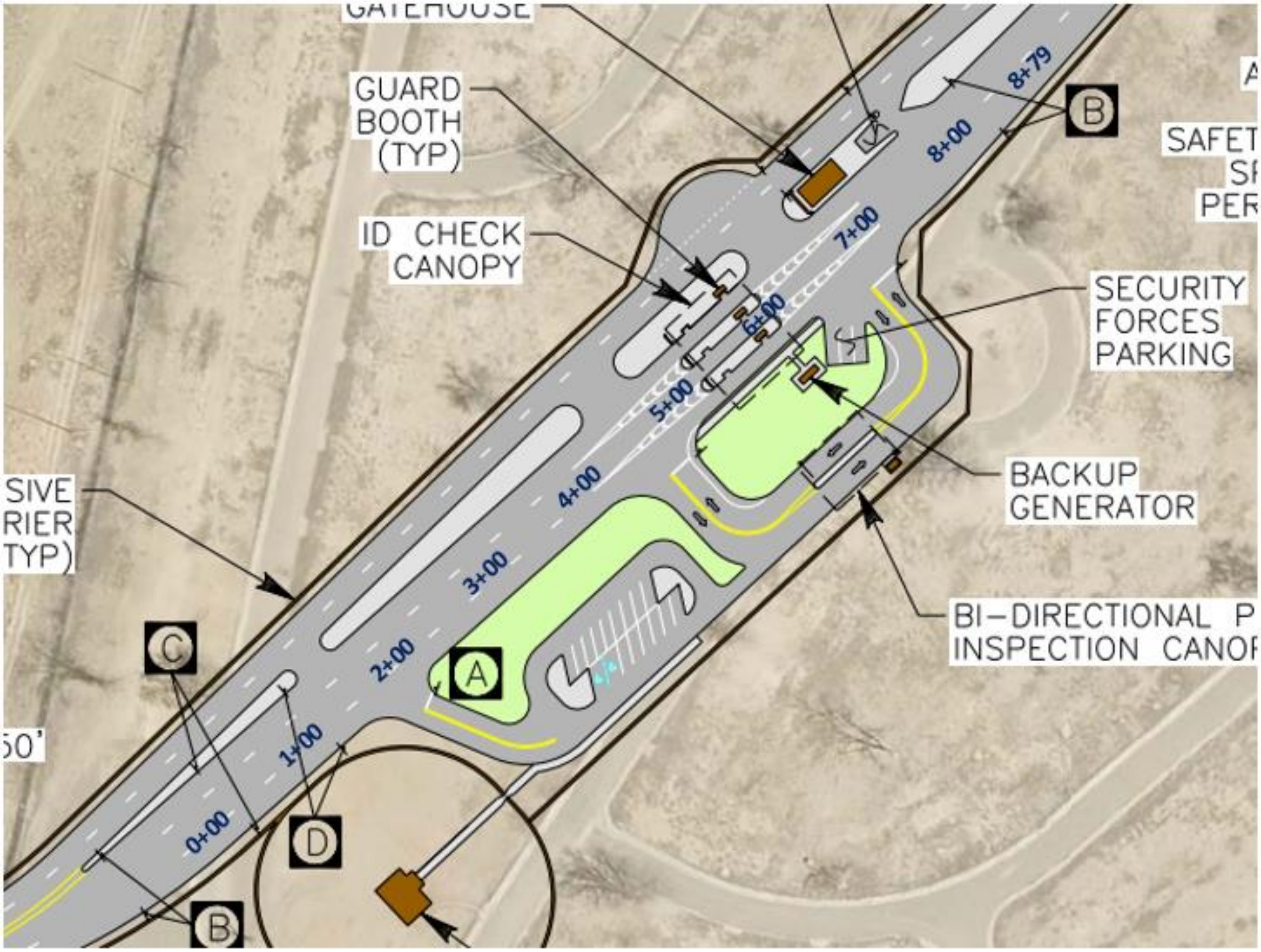
Formulas for Calculating Velocity	
For Tangents and Curves (Constant Acceleration)	**For Curves (Limited Acceleration)**
$V_f = \sqrt{V_o{}^2 + 2aL}$	$\boldsymbol{V_s = \sqrt{(f+e)gR}}$
Formulas for Calculating Time	
$T = \frac{2L}{V_f + V_o}$ (Constant acceleration)	$\boldsymbol{T = \frac{L}{V_s}}$ (Constant velocity)
V_f = Final Velocity V_o = Initial Velocity a = acceleration L = Distance T = Time	V_s = Skidding Velocity f = coefficient of friction e = super elevation (%) g = gravity coefficient R = radius of horizontal curvature

Note that the Curve (Limited Acceleration) equation does not actually compute the final velocity of the vehicle in the curve, it only defines the maximum speed a vehicle can travel without losing control. Therefore, the Tangent (Constant Acceleration) equation may still need to be utilized to compute time in curve segments.

As you begin to work through the 4 threats on the following pages, you will work through the four threats in the following order: Threat 2, Threat 3, Threat 4, and then Threat 1 at the end.

Scenario 1: A Threat 2 Example

The vehicle approaches the facility at the posted speed limit of 15 mph. The vehicle suddenly and aggressively accelerates to 25 mph before the guard sees this on security cameras, located at station 0+00, and reacts.



Threat 2 begins at station 0+00 and does not encompass the initial curve on Louisiana Blvd. Because the curve is not included, we won't need any of the formulas for the curve equation to determine where the vehicle is located after 9 seconds.

Questions 9 – 15 relate to Scenario 1: A Threat 2 Example

9. The initial velocity of the vehicle is 25 mph because this is the speed the car is traveling when the guard realizes that the vehicle is not intending to stop at the guard station. What is the initial velocity in feet per second?

10. Open an Excel Spreadsheet and create a table with the following headings in row 1:

    a. Curve or tangent
    b. V_o (initial velocity)
    c. L (distance)
    d. R (radius of horizontal curve)
    e. V_f (final velocity)
    f. V_s (skidding velocity)
    g. T (time)

11. Each of these headings fall into one of three categories:
    a. *Known:* We either have a word (curve or tangent) to describe what's happening or we know the value and can substitute the known value into the table. For this example, what headings do we know?

    b. *Unknown:* A value is unknown if it is what we are trying to find or if we don't have an exact value, but we have an equation. For this example, what headings are unknown?

    c. *Does not apply*: Consider the type of road you have as not all cells will be full. For this example, what headings do not apply?

12. Fill in row 2 of the excel spreadsheet with the values and words that are known and the equations that are unknown. Leave blank anything we are trying to solve for and anything that does not apply to this problem.

13. Use goal seek to determine how far vehicle 2 travels in 9 seconds.

14. What is the final velocity of the vehicle for this scenario? Did the vehicle stay under the maximum velocity? If not, how can you adjust to make sure the vehicle doesn't go too fast?

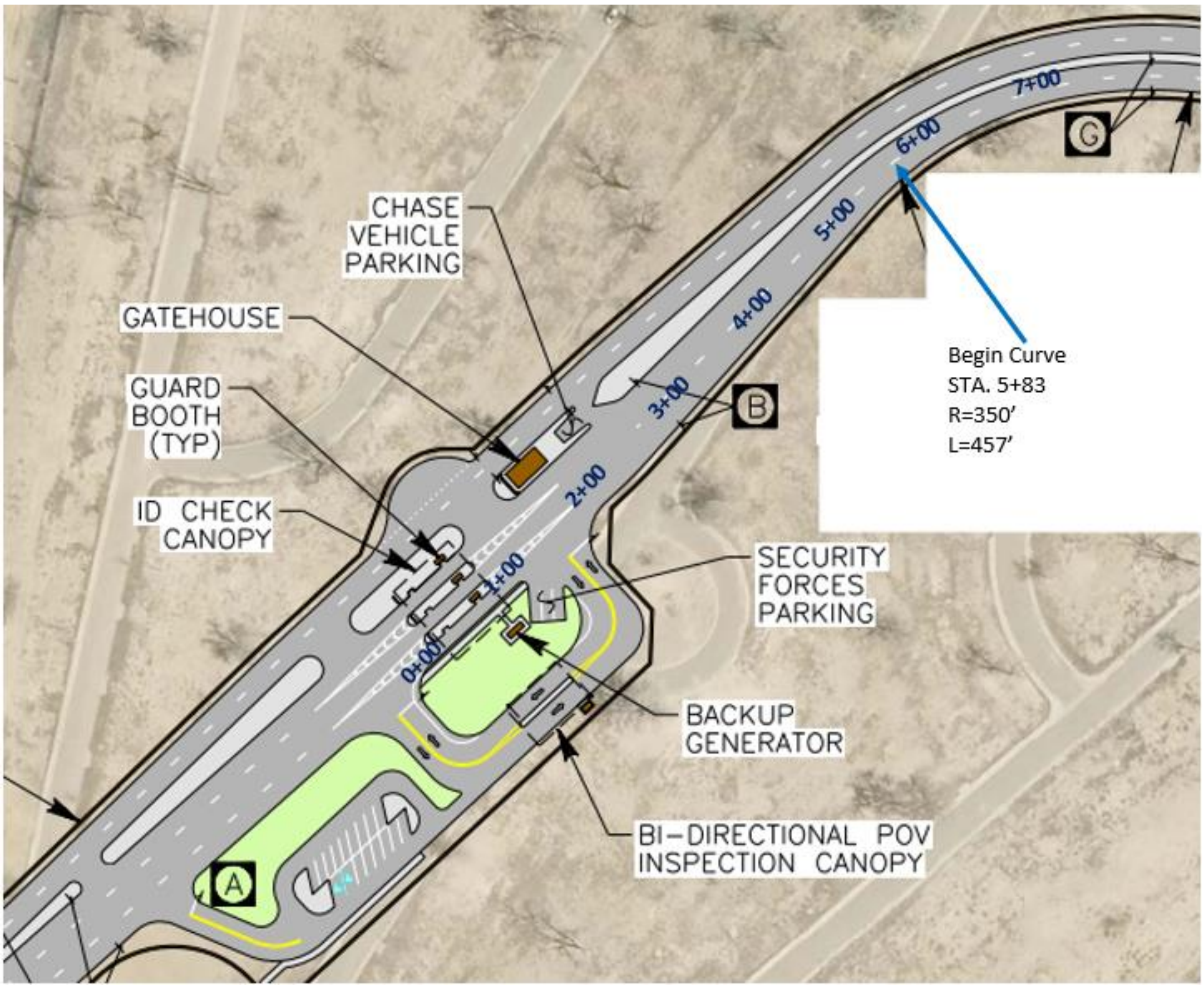
15. Mark the location of the vehicle in threat 2 after 9 seconds on the map on the last page of this activity.

Scenario 2: A Threat 3 Example

The vehicle slowly approaches the guard booth at 10 mph. The vehicle suddenly and aggressively accelerates just before the ID check at station 0+00.

16. Using the same process as before but using row 3 of your Excel document, determine the location of the vehicle in threat 3 after 9 seconds.

17. Mark the location of the vehicle in threat 3 after 9 seconds on the map on the last page of the activity.

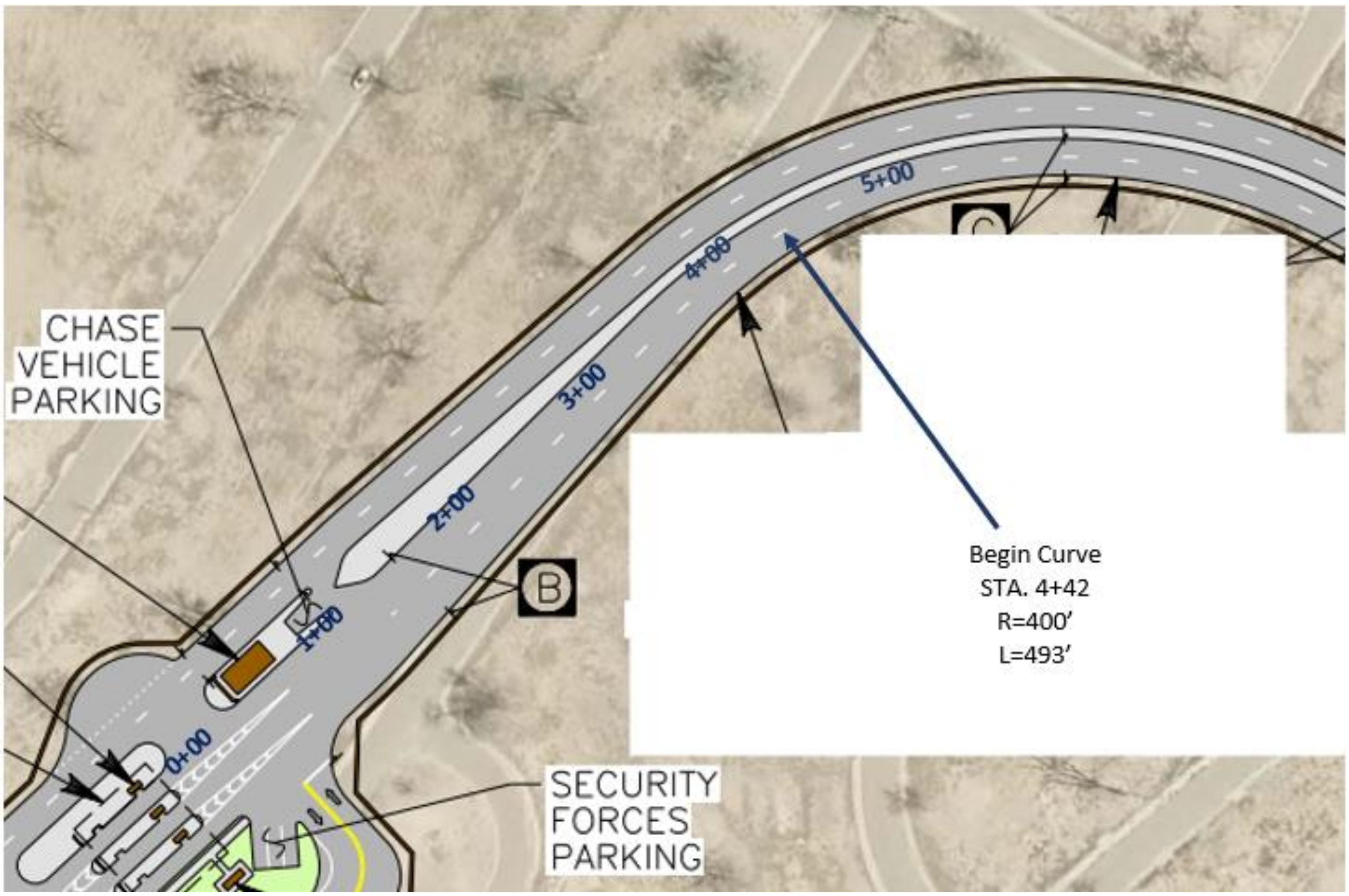


Scenario 3: A Threat 4 Example

The vehicle's driver does not have proper ID and is told to turn at the rejection lane. The vehicle stops at 0+00, as if to follow the guard's order, and then suddenly and aggressively accelerates onto the facility.

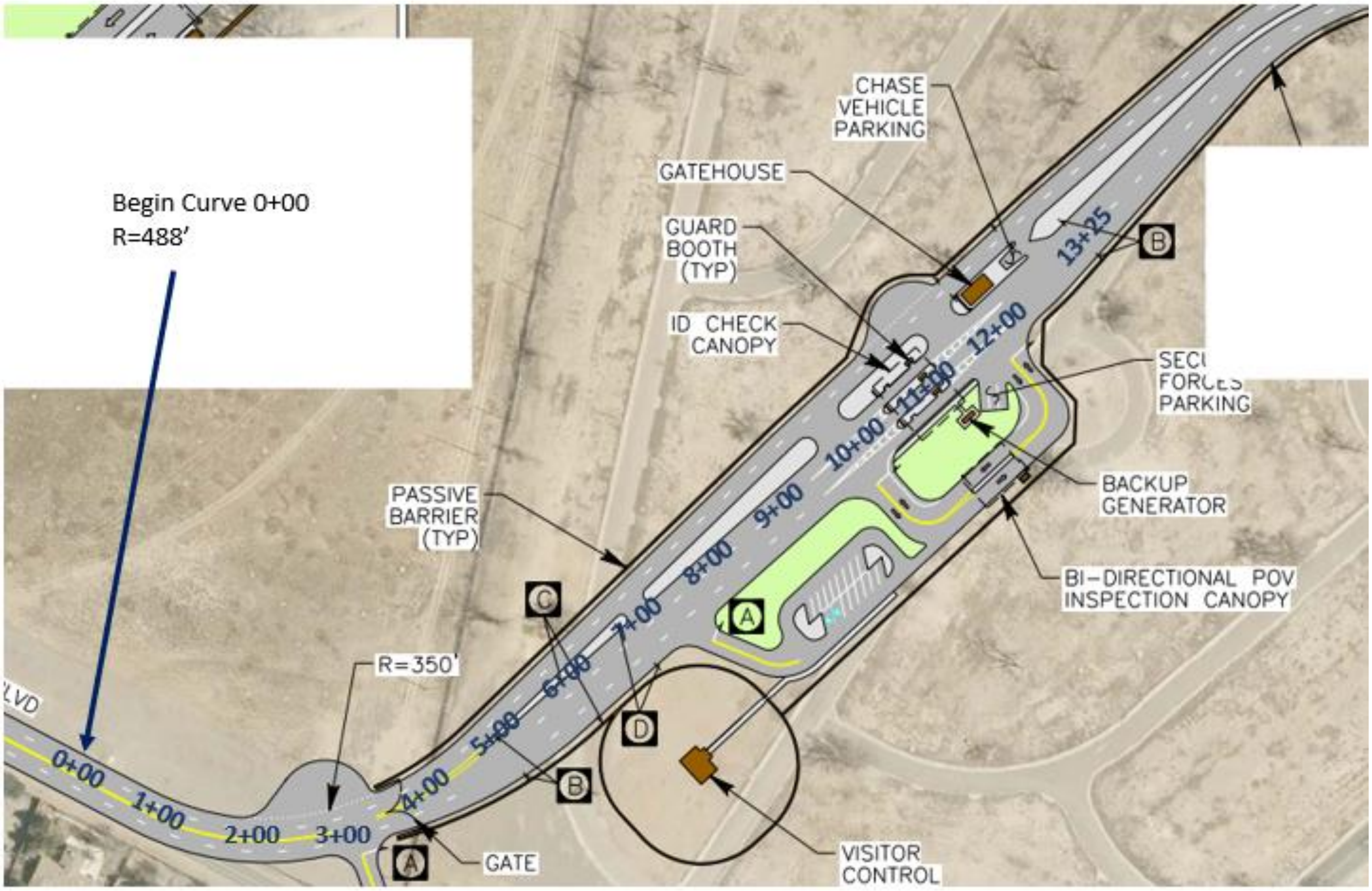
18. Using the same process as before but using row 4 of your Excel document, determine the location of the vehicle in threat 3 after 9 seconds.

19. Mark the location of the vehicle in threat 3 after 9 seconds on the map on the last page of the activity.



Scenario 4: A Threat 1 Example

The vehicle reaches 60 mph at station 0+00 before overspeed detection notifies the guard. Answer the questions below to determine how far the vehicle will make it in 9 seconds. Record the station.



20. What do you notice about the starting station for this threat compared to the other three?

21. How might these differences affect our calculations?

22. What is the initial velocity of the vehicle in this threat (in ft/sec)?

For Questions 23 – 26, perform all calculations in row 5 of your Excel document.

23. The road has a radius of horizontal curvature (R) of 488'. Calculate V_s using Excel.

24. The curved portion of the road extends from station 0+00 to station 5+94. Using this length of the curve, calculate V_f using Excel.

25. These initial calculations in 23 and 24 matter as they inform the process for calculating the time it takes to complete the curve. Use the tangent equation and Goal Seek to determine how far into the curve you can travel before reaching a final velocity equal to the skidding velocity.

26. Use that distance, L, and the tangent equation for time to determine how long it will take you to reach that point of the curve.

27. At this point, the vehicle has not been traveling for 9 seconds yet. Therefore, we need to keep going in our calculations. Since we are still in the curve, use the curve equation for T to determine how long it takes the vehicle to finish the curve. Use row 6 of your Excel file to show work for this question.

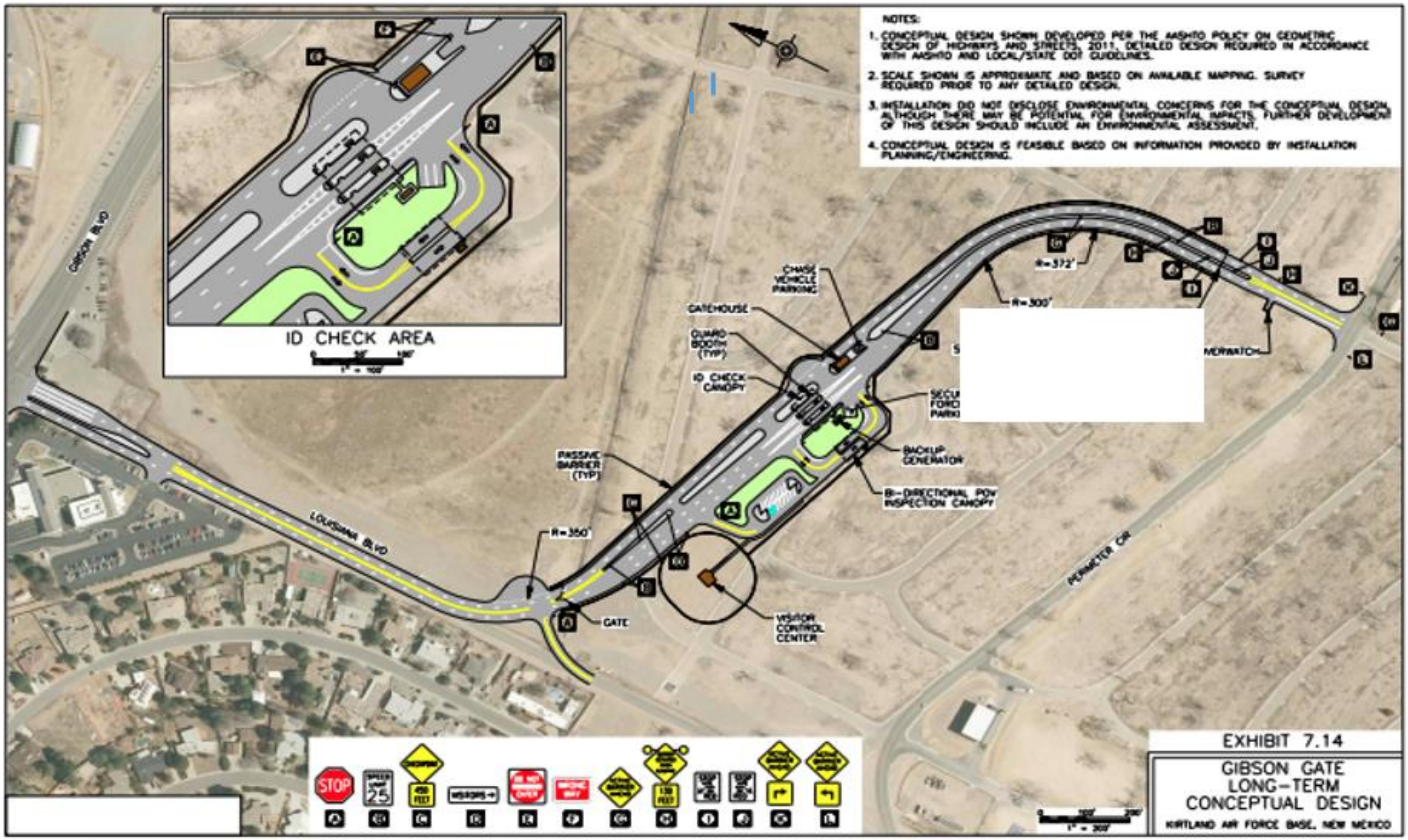
28. How much total time has the vehicle traveled in the curve and how much time remains until they reach 9 seconds?

29. On the straight portion of the roadway, determine how far the vehicle travels in the remaining time.

30. What is the total distance the threat 1 vehicle traveled after 9 seconds?

31. Mark the location of the threat 1 vehicle after 9 seconds on the on the next page.

32. According to the vehicle locations, where should the AVB be located? Justify your answer using complete sentences.



Background Image Source: Google Earth

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