The Path to DIAGNOSTIC Enlightenment

By Jorge Menchu

If you don't know where you're going, any road will take you there. When it comes to automotive troubleshooting, the right road is the shortest path to a successful diagnosis.

Every time you successfully repair a vehicle, the outcome was determined by how well you followed a path. For everyday tasks, the path is already very familiar and you may not even give it a second thought. You know how to get from point A to point B without the need for a map or other outside assistance. But what do you do when you're confronted with an unfamiliar vehicle that has a totally new set of problems? How do you increase the chances that you'll reach your destination—a successful diagnosis—in the shortest amount of time and with the smallest amount of aggravation along the way?

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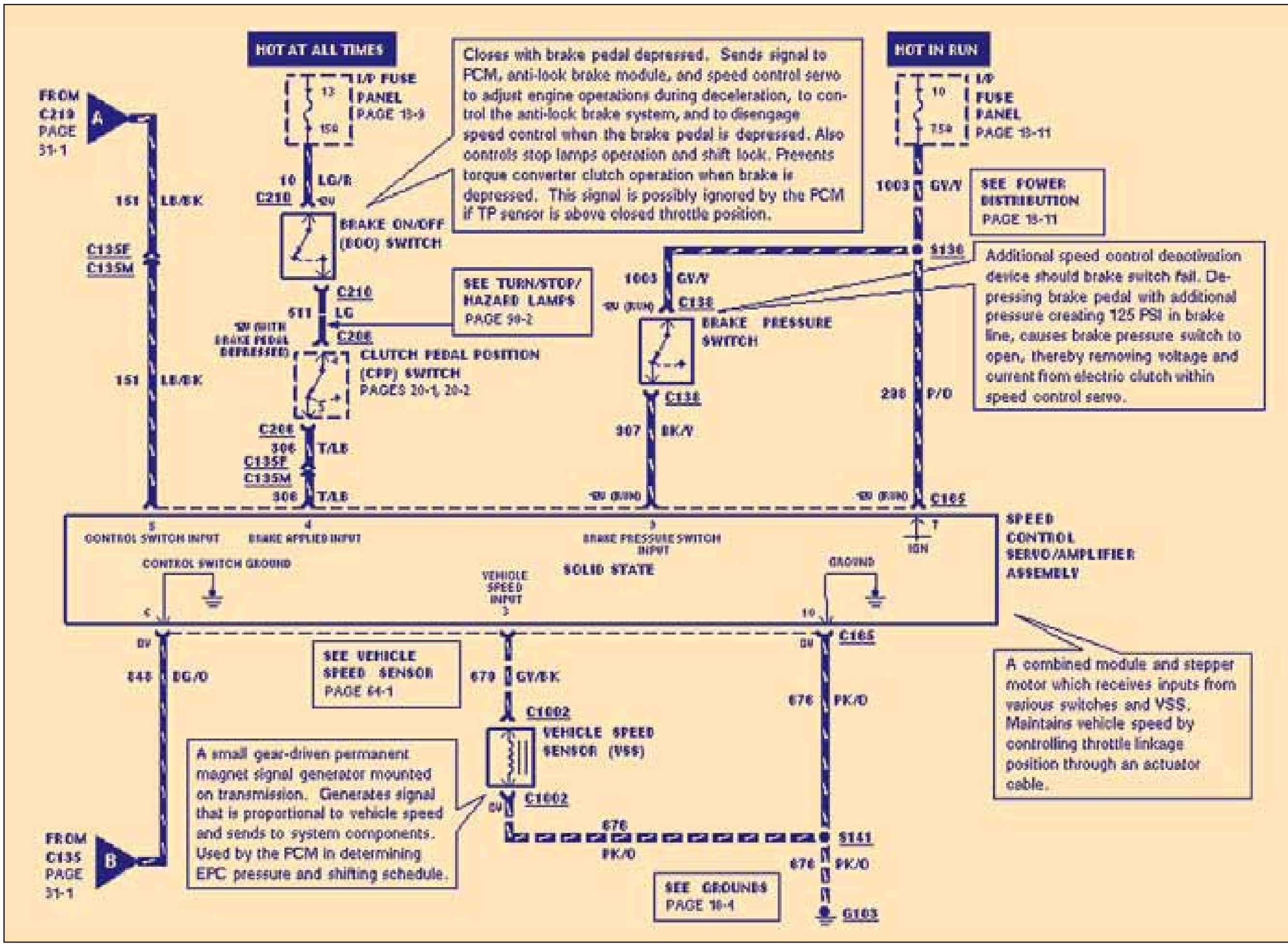

Fig. 1

If it's an electrical or an electronic problem, the journey often begins by consulting the wiring diagram for the affected circuit or circuits. Occasionally you may find that the circuit as presented in the diagram does not correspond with your expectations of the system's operation. In other words, the diagram is either incomplete or incorrect. If we can't rely solely on the diagram, we must determine where it's lacking to develop an understanding (in an engineering sense) of system operation. This process is often referred to as reverse engineering.

When we reverse-engineer a system, we follow the same pattern that was used to design it, in reverse. To truly understand the system, we must first know its desired functions. Fortunately, the desired functions of many systems are fairly obvious or at least easily deduced. Next, we must determine the requirements that must be met, the variables involved, the conditions that can affect system operation and the components needed to make it happen. This is accomplished by referencing wiring diagrams as well as other diagnostic and training information. Combine all of this with an understanding of electronics and there's a very good chance that you'll be able to diagnose and repair the problem.

The Problem

The vehicle we'll use to demonstrate a successful diagnostic approach is a 1996 Ford Ranger equipped with a manual transmission. The customer complains that the cruise control does not work. Our primary information sources are the vehicle wiring diagrams for the cruise control system. We'll use the diagrams to understand how the brake and clutch switches work, as well as their relationship to the speed control unit (SCU). Once we have a clear understanding of how the circuit is supposed to operate, we'll be able to develop a diagnostic path that will help us understand why it's not working properly in this vehicle.

Regardless of whether or not you have previously worked on a cruise control system, anyone who has ever driven a vehicle with cruise control already knows in general how it's expected to work. Depressing the brake

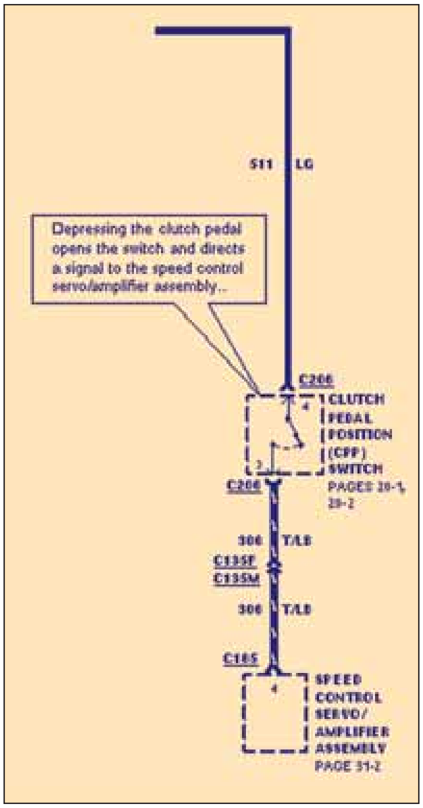

Fig. 2

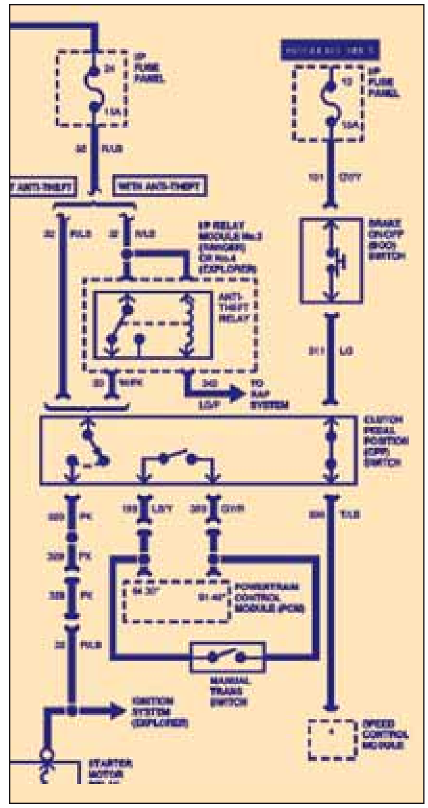

Fig. 3

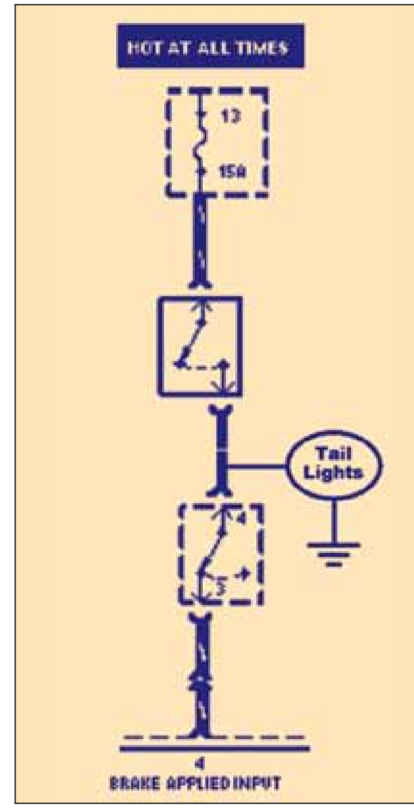

Fig. 4

and/or clutch pedal should disengage the speed control unit. This feature is built into every cruise system for safety. And if the correct signals are not present at the SCU, the speed control will not engage in the first place.

Before you jump to the wiring diagram, remember the golden rule (of thumb) of wiring diagrams: Wiring diagrams are typically drawn to represent the circuit at rest. This means all devices depicted on the diagram should be drawn in a state that represents the vehicle at rest with the ignition off, engine off, engine cold, doors closed and no one in the vehicle.

Now we're ready to examine the wiring diagram (Fig. 1 on page 48). Our initial goal is to become familiar with the diagram. Second, we want to find the pictorial representation of our expectations (how the system operates).

Your examination of the wiring diagram should have revealed what appears to be a contradiction. If we take the diagram literally, it appears that depressing the brake pedal will result in a voltage at pin 4 of the SCU. And, according to the diagram, depressing the clutch removes the same voltage! Our expectation is that the signal would be the same for all conditions that would result in cruise control disengagement. That is, depressing either or both pedals, signifying disengagement, would result in the same signal. From the contradiction, can we conclude that the diagram is either incomplete or simply incorrect?

Taking Inventory

Taking inventory is the next step necessary to increase our understanding of this circuit. In this case, continue to examine the wiring diagram. There's nothing worse than wasting a day, an hour or even 10 minutes because you misunderstood something you read or simply missed. It takes only a few minutes to examine every drop of ink related to the circuit. This includes every symbol, regardless of how trivial it may seem. Read every label, including the wire color and ID. Don't forget the text balloons. As you read, begin to prioritize the information. Many things you'll deem unimportant; others will be directly pertinent to the problem at hand.

At first glance, the overall circuit appears rather simple. It begins with a fuse that's hot at all times, indicating that we should be able to do some testing with the key off. The brake switch is normally open, meaning the SCU should disengage when the switch closes. The clutch switch is in series with the brake switch. It's depicted as normally closed, indicating that it will open to disengage the SCU. From there the circuit goes to the SCU pin 4—the brake-applied input.

Next, focus on the surrounding labels to see if they reveal any qualifying information. The label at the top left of the clutch switch reads: 12 volts with the brake pedal depressed. This qualifies the depiction of the brake switch as normally open.

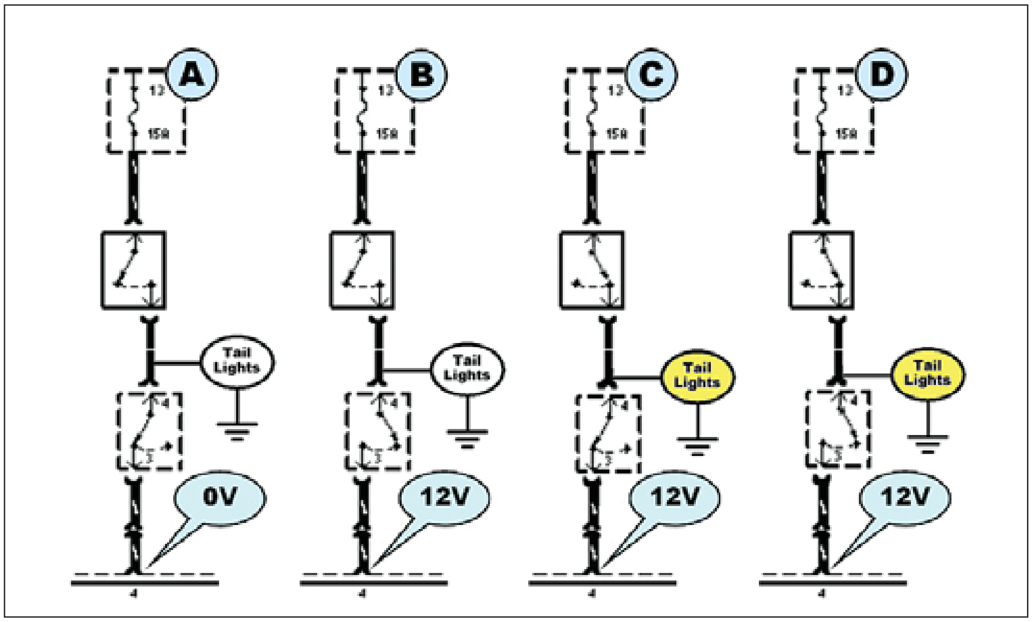

Fig. 5

Switching our focus to the large text balloon, the first sentence also qualifies the brake switch: Closes with brake pedal depressed. Reading on, we find that our initial expectation that the SCU disengages when a voltage signal is present at pin 4 is also backed up: Sends signal to...speed control servo....

Refer to the text box below the text balloon. It indicates that there's a connection to the turn/stop/hazard light circuit, and it's displayed on another page in the manual. This makes sense since we're working with the brake switch. Another item of note is that the clutch switch has more information on pages 20-1 and 20-2.

Where Are We Now?

When you reverse-engineer, it's important to stop and digest new information before you get overwhelmed. At this point, it appears the brake switch operation is clear. The majority of the information we've gathered from the diagram verifies it. We've learned that a voltage at pin 4 should disengage the SCU. It's the operation of the clutch switch that is still unclear. It appears that depressing the clutch will prevent the SCU from disengaging. Our investigation must continue, and the diagram offers two more paths to follow:

- the turn/stop/hazard lights,
- the sections of the manual dedicated to the clutch switch.

Let's continue with the turn/stop/hazard lights diagram. As expected, the brake switch powers many things, including the stoplights. Following through every possible path and connection, there is nothing that explains how the clutch switch works with the brake switch to disengage the SCU.

Another view of the complete brake/clutch/SCU circuit (Fig. 2 on page 50) reveals the clutch switch and its connection to the SCU. Examine this diagram. Do you see anything wrong? This diagram shows the clutch switch open, directly contradicting the original diagram, which shows it normally closed. This definitely raises a red flag regarding the accuracy of both diagrams.

Our next step is to read every label and the text balloon in the diagram. The text balloon offers pertinent information: Depressing the clutch pedal opens the switch and directs a signal to the speed control servo/amplifier assembly. This statement contradicts this diagram's representation of the clutch switch as normally open and helps to qualify our original diagram, which indicates that the switch is normally closed. This diagram was not much help and, in fact, could have made things worse.

The next section of the trail to follow is the clutch switch itself (Fig. 3). I had hoped this might reveal the inner workings of the clutch switch, explaining its operation. After reading every word of the description and the diagnostic instructions, I found no explanation or anything that suggested a new direction to follow. It does show a diagram of the clutch switch connections and internals. But the only thing pertinent is that it also shows the clutch switch as normally closed. Other than that, it's a dead end.

At this point, the wiring diagrams and device descriptions have been exhausted as a source of diagnostic information. The next available source is the diagnostic instructions. Often there are clues to system operation within the system descriptions and diagnostic steps. The challenge is to identify them as such. One way to do this is to ask "Why are they doing this?" for each of the pinpoint tests. And for each of the possible results, ask "Why are they pertinent?"

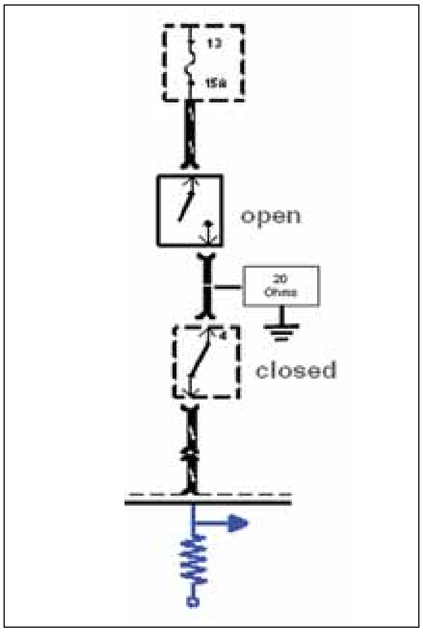

Fig. 6

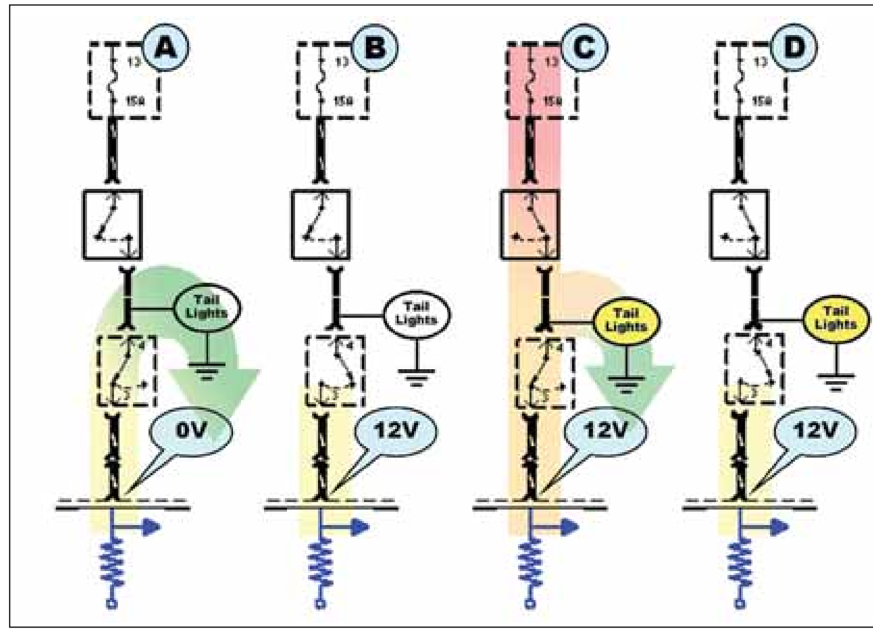

Fig. 7

We're looking for anything related to the brake switch, clutch switch and SCU. Here are a few things I came up with. Do you see anything of value?

Condition	Possible Source	Action
Speed control inoperative	Blown fuse Circuitry Stoplight switch *Burnt stoplight bulb* Speed control actuator switch Vehicle speed sensor Speed control servo	Go to pinpoint test step A1

Test A3: Check Brake/Clutch Circuit

With the ignition switch in the OFF position, measure the resistance between pin 4 (circuit 306) and pin 10 (circuit 676). Is resistance less than 20 ohms?

Yes	No
Brake input circuit OK. Go to A4.	*Brake light bulbs blown* or brake circuit open. Service circuit, including clutch pedal position switch.

The diagnostic information that caught my attention is shown in italics. We now know that the cruise control will not work if there's a burned out stoplight bulb. Test A3 goes further and specifically asks for a measurement of the resistance between the SCU's pin 4 brake-applied input and pin 10 ground. This is the path through the normally closed clutch switch, through the brake lights to ground.

We can conclude that the SCU monitors the condition of the brake light bulbs. But how? In electrical circuits, this is accomplished by monitoring a voltage and/or current level. So, where is the source for this information? It's definitely not through the open brake switch. Now we know for sure what we're looking for.

Before we continue, let's step back and compile all of the known facts to this point. One of the best ways to organize your thoughts is to document them. We'll draw a focused diagram of the brake, clutch and SCU (Fig. 4), while ignoring the brake lights for now. We'll also trim away the other extras from the original diagram.

Next, we'll compile into a logic table everything we know regarding pedal position and corresponding states. A logic table is a simple grid composed of columns and rows. In this case, the first column will list the components and the other columns will list the related conditions. From the diagram we can easily identify the possible relationships and conditions of the brake and clutch switches and stoplights:

	A	B	C	D
Brake Switch	Open	Open	Closed	Closed
Clutch Switch	Closed	Open	Closed	Open
Stoplights	Off	Off	On	On

Next, we can add our expectations of how the SCU will respond to these conditions. Do you remember your initial expectations of this system's operation?

	A	B	C	D
Brake Switch	Open	Open	Closed	Closed
Clutch Switch	Closed	Open	Closed	Open
Stoplights	Off	Off	On	On
SCU	Engage	Disengage	Disengage	Disengage

Now we can add another row of data representing the expected voltage conditions at SCU pin 4 for each of these conditions. The wiring diagram clearly shows that when the brake is applied there should be power to pin 4. The text balloon on our original diagram also confirms this. If we accept this we can conclude that a voltage at pin 4 signals the SCU to disengage and a no-voltage signal allows it to engage.

	A	B	C	D
Brake Switch	Open	Open	Closed	Closed
Clutch Switch	Closed	Open	Closed	Open
Stoplights	Off	Off	On	On
SCU	Engage	Disengage	Disengage	Disengage
Pin 4 Test	No Voltage	Voltage	Voltage	Voltage

Before we continue, it's important to remember what brought us this far. First, we followed a trail of evidence; we didn't guess. Therefore, we can say that all conclusions we've reached so far are based on the evidence. Our conclusions, of course, are the information in the logic table. The system has to meet those expectations if it's going to work.

The logic grid is perfect for mapping out the components, variables, conditions and expected outcomes. However, it falls short when it comes to giving us an understanding of the actual processes the circuit goes through to accomplish its goals.

At this point, there's only one place left to investigate, and that takes us back to the wiring diagram. Wiring diagrams are not as good as the logic grid for mapping out the possibilities, but combining the two helps us understand circuit components and electrical behavior. So for our next step, let's make circuit diagrams to represent each of the conditions in our logic chart. We'll draw the circuit four times (Fig. 5 on page 52), one to represent each of the possible conditions in the logic chart.

Do you see anything unusual in the four diagrams? What about circuits 5B and 5D? We know that under those switch conditions there still has to be voltage at pin 4. So where does it come from? There's only one possibility—the SCU! There must be a voltage source inside the SCU that allows pin 4 to go high when the clutch circuit is open and low when the clutch is not depressed and the switch is closed. Now we know how the SCU monitors the brake lights and why it's important for the brake lights to be in good working order.

Fig. 6 on page 54 is a redrawn circuit with a pull-up resistor inside the SCU. Here's how it works: The voltage source inside the SCU must connect to pin 4 via a high-value resistor, which minimizes the available current that can flow through the clutch switch and to ground through the brake lights. It has to be a high-resistance device or the brake lights would come on.

Now let's make sure we're correct by applying what we've learned to all of our circuit configurations (Fig. 7).

In Fig. 7A, the clutch switch acts as a switch to ground through the stoplights. Since the available current is minimal, the stoplights' low resistance acts as a good path to ground, resulting in a low-voltage signal at pin 4. The stoplights are not on.

In Fig. 7B, the clutch switch is open, which removes the ground path through the stoplights. No ground path results in open-circuit voltage at the test point, signaling the SCU to disengage.

Both switches are closed in Fig. 7C. Current traveling from the fuse and through the brake switch is strong enough to turn on the stoplights and maintain a voltage at pin 4. Since both voltage sources are equal, there is no current feedback into the SCU.

Fig. 7D is the same as Fig. 7B. With the clutch switch open, the brake switch has no effect on SCU pin 4, but the stoplights are on.

End of the Road

A diagnosis can take you through several twists and turns before reaching a successful conclusion. It's important to avoid the dead ends and the need to double back or start over. In this example, we've taken the information provided by the manufacturer and combined it with what we've been able to learn on our own. Logic tables allowed us to compile what we learned, and to make sure our findings made sense when the information was assembled as a whole. By collecting information systematically and documenting everything as you go, you'll always know where you are and, perhaps more importantly, where you're heading.