INTRODUCTION

Welcome to the final e-book in this IEEE-USA series on *Critical Thinking for Engineers—Book 5: On Problem Solving*. In the first e-book, *Critical Thinking for Engineers—Book 1: Analytical Skills*, we explored the ability to examine something carefully, whether it is a problem, a set of data, or even text. In the second e-book, *Critical Thinking for Engineers—Communication Skills*, we extended critical thinking from that of an individual to that of a group—where both oral and written communications are essential to effectiveness in achieving a team's goals. The third e-book, *Critical Thinking for Engineers—Book 3: On Creativity*, explored fun and useful approaches to creativity—for both individuals and groups. In the fourth one, *Critical Thinking for Engineers—Book 4: On Open-Mindedness*, we see the advantages of setting aside pre-conceived notions, assumptions, or judgments—and simply analyzing the information at hand. In this series capstone e-book, *Critical Thinking for Engineers—Book 5: On Problem Solving*, we will dive into methods of tackling engineering challenges. Dinesh Paliwal, CEO of Harman International, an audio and infotainment systems company, said it best: "Problem-solving is essential to engineering. Engineers are constantly on the lookout for a better way to do things."[1] In this e-book, we engage with ten key approaches to problem solving:

- The problem statement
- Root cause analysis
- Abstraction
- Analogy
- Brainstorming
- Trial-and-Error
- Hypothesis testing
- Divide and conquer
- Lateral thinking
- Reduction

1 https://www.brainyquote.com/quotes/dinesh_paliwal_908690?src=t_problem-solving

Let's begin with the most important step of all in problem solving: framing the problem, also known as crafting the problem statement. Charles Kettering, an American inventor, engineer, and head of research at General Motors from 1920 to 1947, famously said: "*A problem well stated is a problem half solved.*"[2]

2 https://www.brainyquote.com/quotes/charles_kettering_181210

THE PROBLEM STATEMENT

Albert Einstein, a contemporary of Charles Kettering, noted on the importance of problem statements: "*If I had an hour to solve a problem, I'd spend 55 minutes thinking about the problem, and five minutes thinking about solutions.*"[3]

Let's go over the key steps in formulating a powerful and highly effective problem statement. After the steps, I'll share three examples of well-done problem statements, so you can model yours after the examples.

Step 1: Provide Context

Before you jump in to coming up with potential solutions to an engineering problem, start with understanding the full context in which you are devising solutions. Literary devices describe context as: "*the background, environment, setting, framework, or surroundings of events or occurrences.*"[4] Simply put, context provides the important backdrop necessary to frame your problem statement.

Step 2: Describe the Current Situation

What is the current reality for the organization facing this particular engineering problem? Identify who the problem is impacting. Describe why this problem is worth addressing. When and where is the problem occurring? Why must the problem be solved now versus later?

Step 3: Clarify the Impact

What is the impact of this problem? What specific metrics quantify the impact of this problem? How acute or severe is this impact? For example, is this problem a mild irritant, a moderate pain, or an intolerable situation that must be addressed? The impact statement will give you an idea of the inertia you may have to overcome, if something must change to address the problem. If the problem isn't severe enough, then the status quo may prevail, until it becomes an unbearable situation.

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3 https://www.goodreads.com/quotes/60780-if-i-had-an-hour-to-solve-a-problem-i-d
4 https://literarydevices.net/context/

Step 4: Describe the Ideal State

Now describe what would it look like if there wasn't a problem at all. For example, what is the ideal environment, once the issue has been resolved, or the problem was entirely eliminated? What would tell you that you've resolved the problem? What are success metrics that clearly and concretely tell you the problem is no longer an issue?

Step 5: Frame Potential Solutions

Provide some general direction or ideas that will guide your engineering team to further research, investigate and solve the problem at hand. You do not need to identify a specific solution, but rather point to areas where a potential solution may lie. Suggest how your engineering team might find solutions to the problem.

Now it's time to look at two examples, where we apply these five steps in crafting concise and actionable problem statements.

Example 1: Converting CO_2 to useful products

One of the biggest engineering challenges of our century is how to deal with the high and rising level of CO_2—thought to contribute directly to climate change. Let's examine one possible solution to addressing climate change: finding ways to convert atmospheric CO_2 into useful products. The XPRIZE foundation has a $20M grand prize for the winner with a breakthrough technology that converts CO_2 emissions into usable products.[5] We might frame the problem statement as:

What technology can convert the most atmospheric CO_2 into the most usable products, with the highest net value?

Let's apply our five-step approach to breakdown this XPRIZE challenge into a more descriptive problem statement—one that moves engineers and entrepreneurs to action.

Context: The level of CO_2 in the atmosphere has been rising for decades—far surpassing historical levels going back more than 800,000 years.[6] Changes in climate are thought to be directly linked to the level of CO_2 in the atmosphere.

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5 https://www.xprize.org/prizes/carbon
6 https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide