Assessing Innovation and Invention Knowledge and Skills

ITEA Annual Conference

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Cal Halliburton

My Mission

- Introduce you to a new technology for design.
- Suggest methods for assessing knowledge of the new technology for design.
- This technology will...
  - Increase student knowledge
  - Increase student skills and abilities
  - Increase the likelihood that your students will be knowledgeable and able to invent.

What do our design briefs look like?

- Build the tallest free standing tower using one 8 ½ x 11 sheet of paper and 4 inches of clear tape.
- Score—25 points possible
  - Tallest—30 points
  - 90%--25 points
  - 80%--20 points, etc.

What do our design briefs look like?

- Design and build a CO_2 race car.
- Design and build a trebuchet
- Design and craft a paper airplane
- Design and build a stick bridge that supports 30 kg
- Design and build a foundation, etc.

All are fun activities and stimulate interest

Design Briefs

- What do we assess?
- How?
- What does the student take from the activity?
- Can our students use their experience with our design briefs to improve their ability to invent?

Pre-Test—1

Design Trade-offs

- What is a design trade-off?
- What methods do we use and teach our students about dealing with Trade-Offs?

Pre-Test—2

- Conflicting design requirements
- What are they?
- What methods do we use/teach our students to enable them to deal with design requirement conflicts?

Design Continuum

- Routine problem solving at one end
- Inventive problem solving at the other end
- What’s the difference? They’re both problem solving.

Routine Problem Solving

Characteristics:

- brief searches for similar problems (problem definition)
- brief searches for a “known” solution that might fit the problem
- a small number of trials, and
- knowledge within the individual, company or classroom

Inventive Problem Solving

Characteristics:

- The unknown (in the problem situation)
- Lengthy searches for the problem (problem definition)
- Lengthy searches for known solutions, and
- Many trials...

Inventive Problem Solving

- knowledge that often resides outside the individual, company, industry, classroom or even the field of study
- presence of contradictory or conflicting design requirements

- Since the Inventive end is much more difficult and time consuming,
- What can we do differently?
- What should we do differently?

- What do we do at the routine end that works well?
- We use a system!
- That’s what technologists do.
- We design systems, processes, procedures, to get things done.

What do we need?

A System that provides:

- Knowledge of the unknown (in the problem situation)
- A rapid and systematic search for the problem (problem definition)
- A rapid and systematic search for solution ideas
- A quickly accessible knowledge base
- Methods for overcoming contradictions
- Reduced number of trials
- Reliability, and a Process

That can be learned and practiced by everyone.

Is there a System for Invention?

Or is systematic invention an oxymoron?

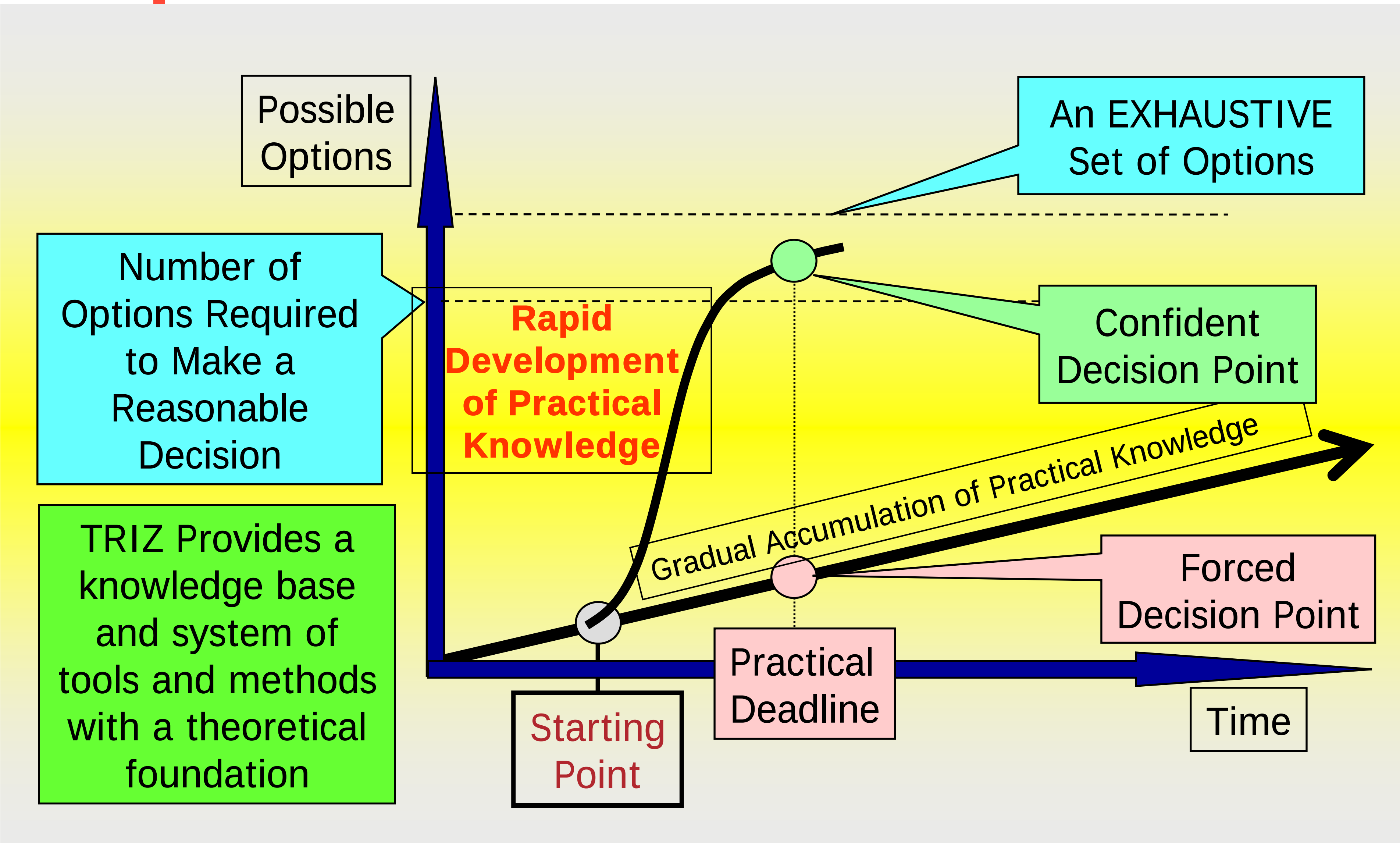
A system for Invention

The Theory of Inventive Problem Solving—TRIZ

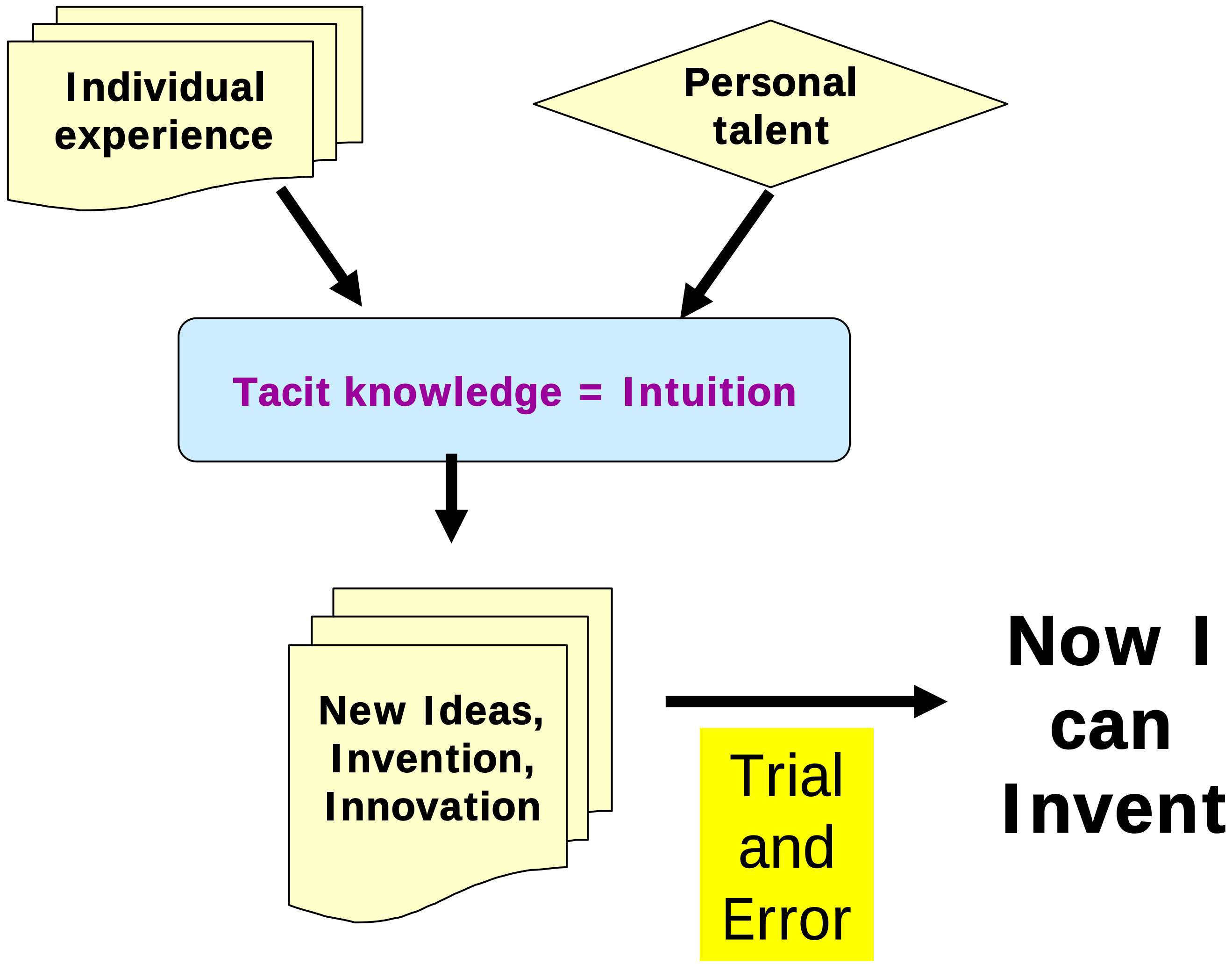
TRIZ, the Theory of Inventive Problem Solving

- Russian acronym for the Theory of Inventive Problem Solving originated in 1946 by Genrich Altshuller
- Systematic, structured way of thinking
- Science of technological evolution
- Results of analysis of over 3 million worldwide patents within all engineering disciplines

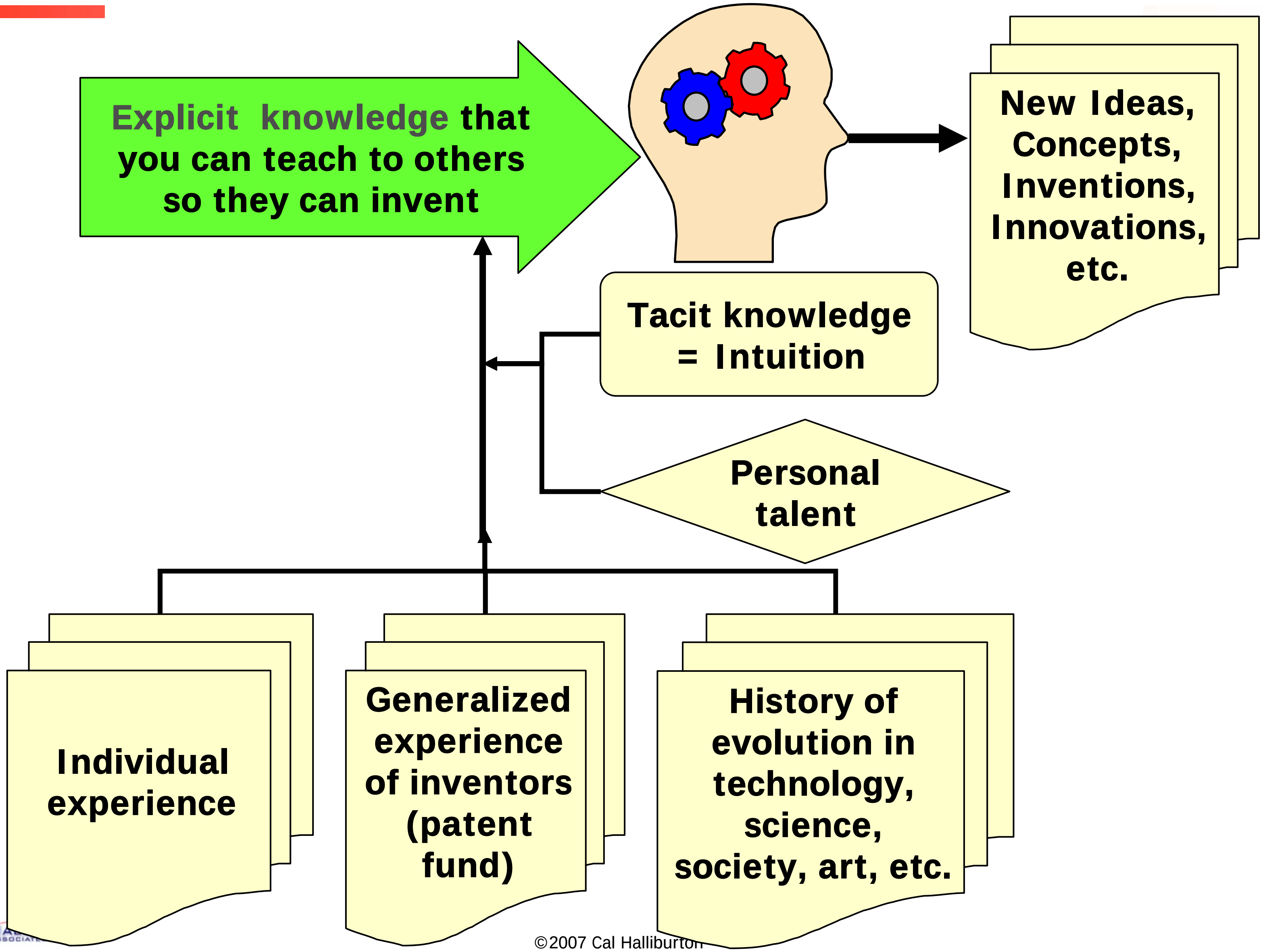
What Does TRIZ Do?



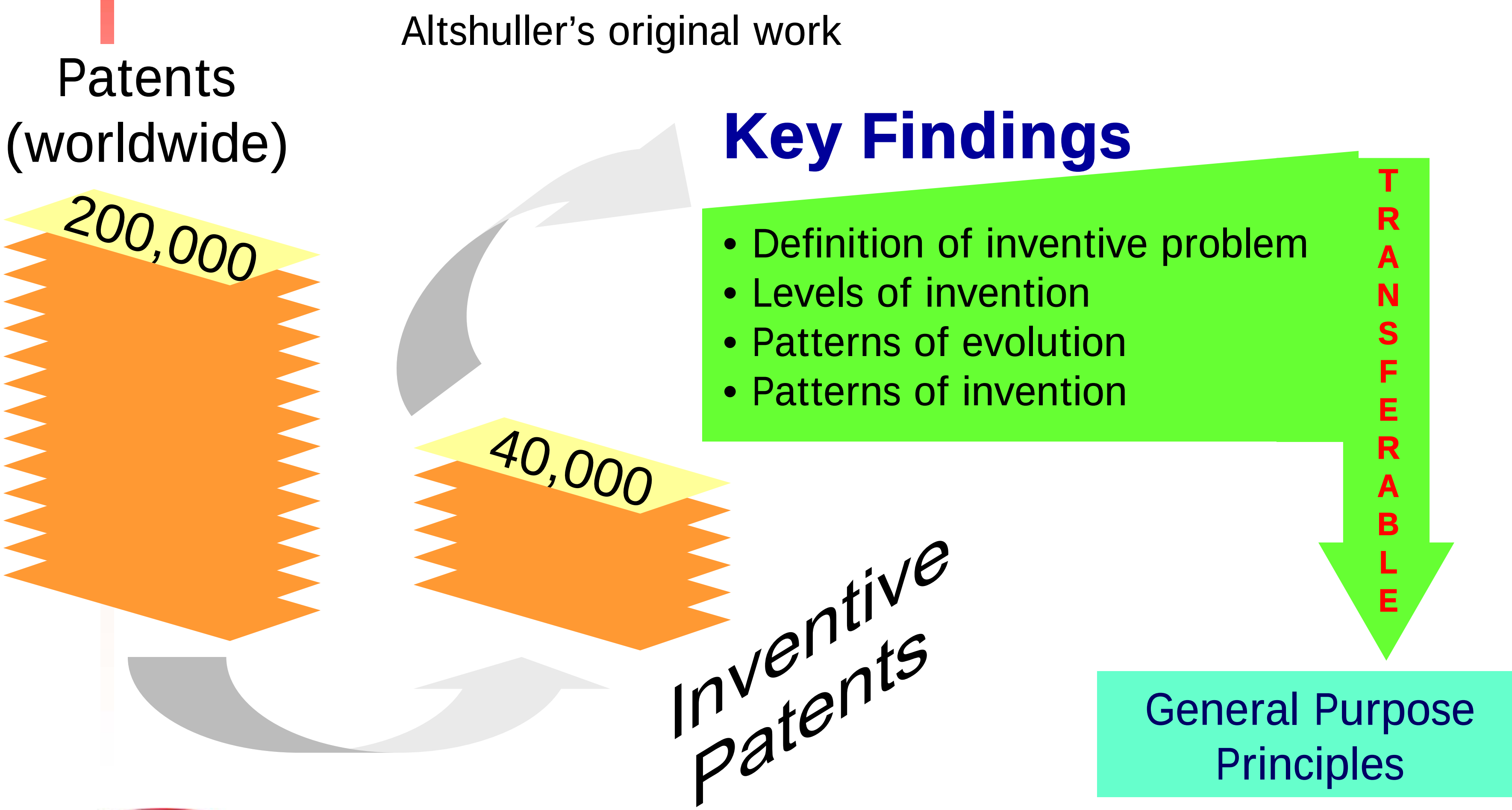
Classical Idea Generation



TRIZ-based Idea Generation



TRIZ is Based on the Abstraction of Knowledge Rather than Guesswork



What is an Inventive Problem?

- Suggests no known ways or means of solution

- Involves one or more <u>contradictions</u>

Assessment—Definition

- Define an Inventive Problem
- Describe a problem that requires a true invention

Classification of Solutions: We need to raise innovation skills via methods and tools.

Levels of Invention (Solution)

Moving to higher levels of innovation

Level 5: Discovery

Level 4: Invention outside the paradigm

Level 3: Invention inside the paradigm

Level 2: Improvement

Level 1: Apparent solution (no innovation)

Levels of Problems (Invention)

- **Level 1**-Small changes of an existing system, usually well-known in other areas of technology, like using an adjustable pedal, well-known in aviation, in a car
- **Level 2**-Improvements of an existing system, usually with some compromise, like bifocal glasses, telephone with internet connection
- **Level 3**-Invention inside the paradigm, **e**ssential improvement of an existing system like coffee-machine, car automatic transmission, radio telephone
- **Level 4**-Invention outside the paradigm, system, based on the new principle of performing the primary function, like jet aircraft, integrated circuit
- **Level 5**-Pioneering of an essentially new system based on a discovery, like a laser, radio, or airplane

Assessment—Levels

- List and describe the five levels of Invention
- Classify these 5 inventions by level
- Justify your selections
- How did each invention change the previous system?

Patterns of Evolution: The Primary TRIZ Postulate

- Systems evolve not randomly, but according to objective patterns
- These patterns have been abstracted from research of the history of technology, markets and society
- They have been purposefully used for systems development without numerous blind trials

Patterns of Evolution: Common threads between evolving systems.

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Main Patterns of Evolution

1. Increasing system Ideality
    1. Evolution of useful functions
    2. Elimination of harmful functions
    3. Evolution of applications
2. Integration/ structuring
3. Increasing of dynamism and controllability
4. Evolution with matching/mismatching
5. Evolution of resources application
6. Evolution of contradictions
7. Increasing complexity followed by simplification
8. Evolution of fields
9. Evolution towards multi-levels
10. Changes in human involvement
11. Evolution along the S-Curve of life

Assessment—Evolution

- Explain two of the patterns of evolution
- Provide an example of a product that has...
  - evolved toward greater control
  - evolved toward less human involvement
  - increased dynamism
- Analyze the position on the S-curve of...
- Evaluate the likelihood of the next step(s) of evolution of...

Patterns of Invention

Discovery: There is repetition in the way people solve creative problems.

- Altshuller recognized that the same fundamental problem (contradiction) had been addressed by a number of inventions in different areas of technology.
- He also observed that the same fundamental solutions were used over and over again, separated by many years and in different technologies.
- He reasoned that if inventors had knowledge of earlier solutions, their task would be straightforward.
- He sought to extract, compile, and organize such information.

Contradiction

- Conflict
- Challenge
- Paradox
- Dilemma

Types of Contradictions, 1

- Direct Physical Contradiction
  - When something has conflicting physical requirements that must be satisfied in the system. Something must be:
    - Both large and small
    - Both open and closed
    - Both heavy and light
    - Both flexible and rigid
    - Both present and not present
  - Opposites of characteristics must exist in the same system

Types of Contradictions, 2

- Simple (Technical) Contradiction or different required characteristics that conflict
  - When a system has requirements such as:
    - Strong and light weight
    - Complex and easy to repair
    - Accuracy and speed
    - Reliable and complex
    - Productive and low energy use
  - When one characteristic improves the other characteristic degrades
  - Commonly called **trade-offs**

Physical Contradictions

- A characteristic must exist in **two opposite states**
  - An airplane wing must have a large area for easy takeoff, and a small area for higher speed
  - A pen tip must be sharp to draw fine lines, and blunt to avoid tearing the paper
- A characteristic must be both **present *and* absent**
  - Aircraft landing gear should be present for landing and absent during flight
  - Sandblasting abrasive must be present to abrade, and absent from the product

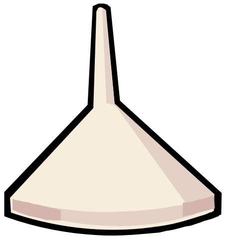
Separation Principles

To eliminate physical contradictions, the two contradictory requirements are separated . . .

- in space
- in time
- between the parts and the whole
- based on different conditions

Separation in Space

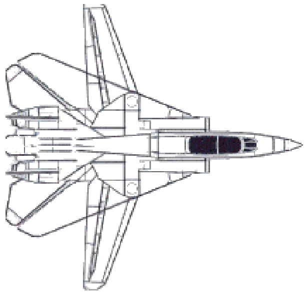
- A characteristic is made **larger** in one place and **smaller** in another
  - One end of a funnel is wide so that material can be easily poured into it; the other end is narrow so that it can fit inside a small opening.



- A characteristic is **present** in one place and **absent** in another
  - The lower part of bifocal glasses serve as reading glasses; the upper part provides correction for long-distance vision.

Separation in Time

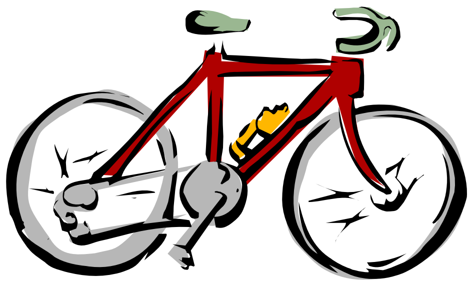
- A characteristic is made **larger** during one time and **smaller** during another
  - The airplane wings of some military aircraft can extend to provide large area for takeoff and landing, and retract for high-speed flight.



- A characteristic is **present** during one time and **absent** during another
  - A staple is pointed as it pierces through paper, and flat when holding papers together.

Separation within Structure

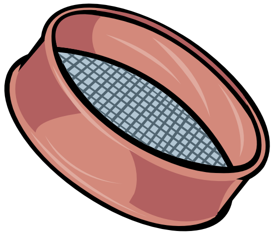
- A characteristic has **one value** at the system level and the **opposite value** at the component level
  - A bicycle chain is made up of multiple rigid components, yet is flexible overall.



- A characteristic **exists** at the system level and **does not exist** at the component level (or vice versa)
  - Epoxy resin and epoxy hardener are liquids, yet become solid when mixed.

Separation Based on Condition

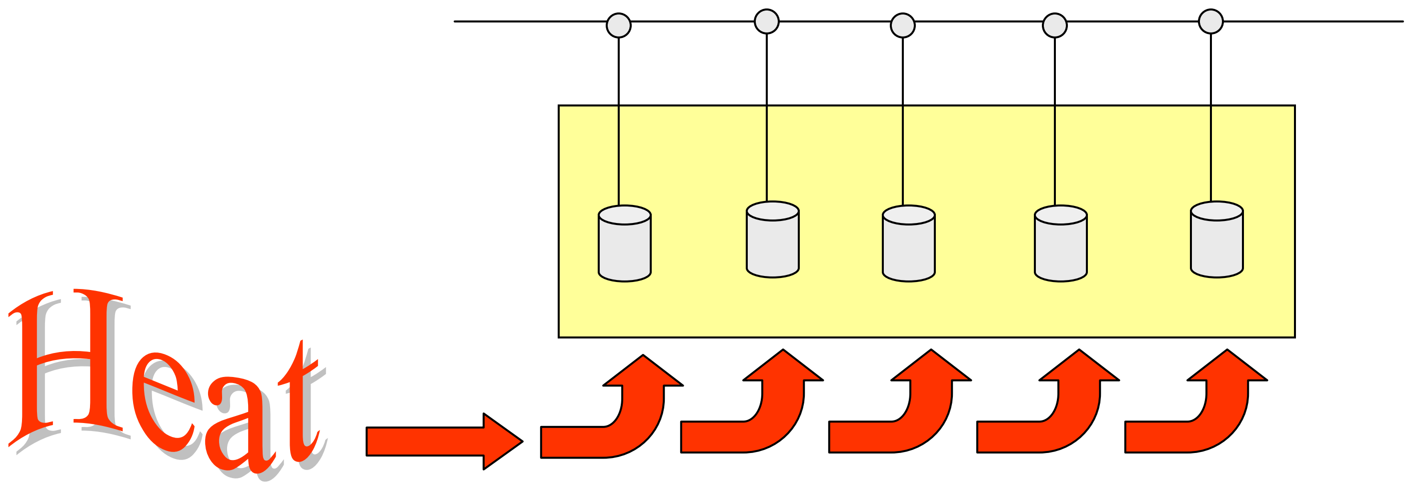
- A characteristic is **high** under one condition and **low** under another
  - A sieve is porous for liquids but solid for sand or other solid material.



- A characteristic is **present** under one condition and **absent** under another
  - A light-sensitive circuit is open in the presence of light and closed in the dark.

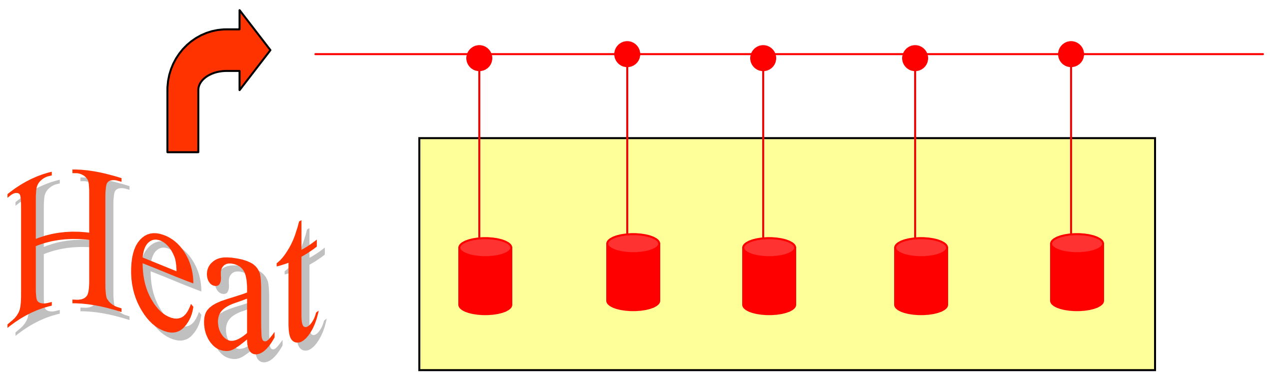
Plating Metal Parts Problem

- To plate metal parts with nickel they were placed in a bath of nickel salt. The bath was heated to increase the productivity of the process. However, heating reduced the stability of the salt solution and it started to decompose.



Separation in Space

- In the nickel plating of parts, increased temperature is necessary only in proximity to the parts. To accomplish this, the parts themselves may be heated, rather than the solution.



Assessment--Contradictions

- Identify and provide examples for 5 contradictions
- Classify the contradictions
- Justify your choices and classifications

Patterns of Invention:
Processing Sweet Peppers

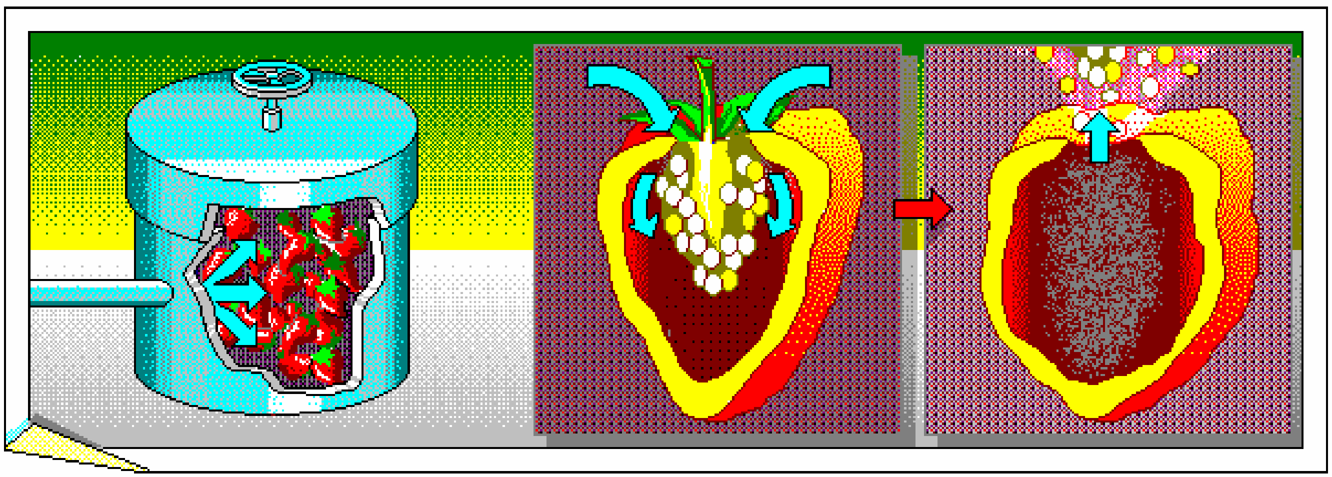
We must create an automated method for removing the stem and the seeds from sweet peppers.

Think of some possible methods.
What are some known methods for accomplishing this repetitive task in large volume?
Keep in mind that the peppers are food and must be Handled with care.

Patterns of Invention:

Processing Sweet Peppers

We must create an automated method for removing the stem and the seeds from sweet peppers.



A Pattern of Invention

A Pattern of Invention to use over and over again to solve similar problems in other domains of invention.

If it is necessary to destroy or split a product which has open cavities, pores or cracks, consider the possibility of placing the product in a hermetic chamber. Slowly increase the pressure inside the chamber and then cause an abrupt drop in pressure.

Patterns of Invention

- 40 Principles of classical TRIZ
- 4 Separation principles—higher level
- Many additional principles have been identified

Assessment—Principles

Assess the patterns or Principles of invention by...

- Asking students to find where a principle has been applied in products in their environment.

Problem Identification

- Identify the right problem or you may end up solving the wrong one.

"It's not what you don't know that will hurt you, it's what you know that ain't so"

—Will Rogers

System Approach

Nine Windows on the Problem

	Sub-system	System	Super System
Past	Previous Sub-system	Previous System	Previous Super System
Present	Current Sub-system	Current System	Current Super System
Future	Future Sub-system	Future System	Future Super System

Assessment—System Approach

- Fill the nine windows for a cup, pencil, light bulb or some other product or system that is familiar to your students

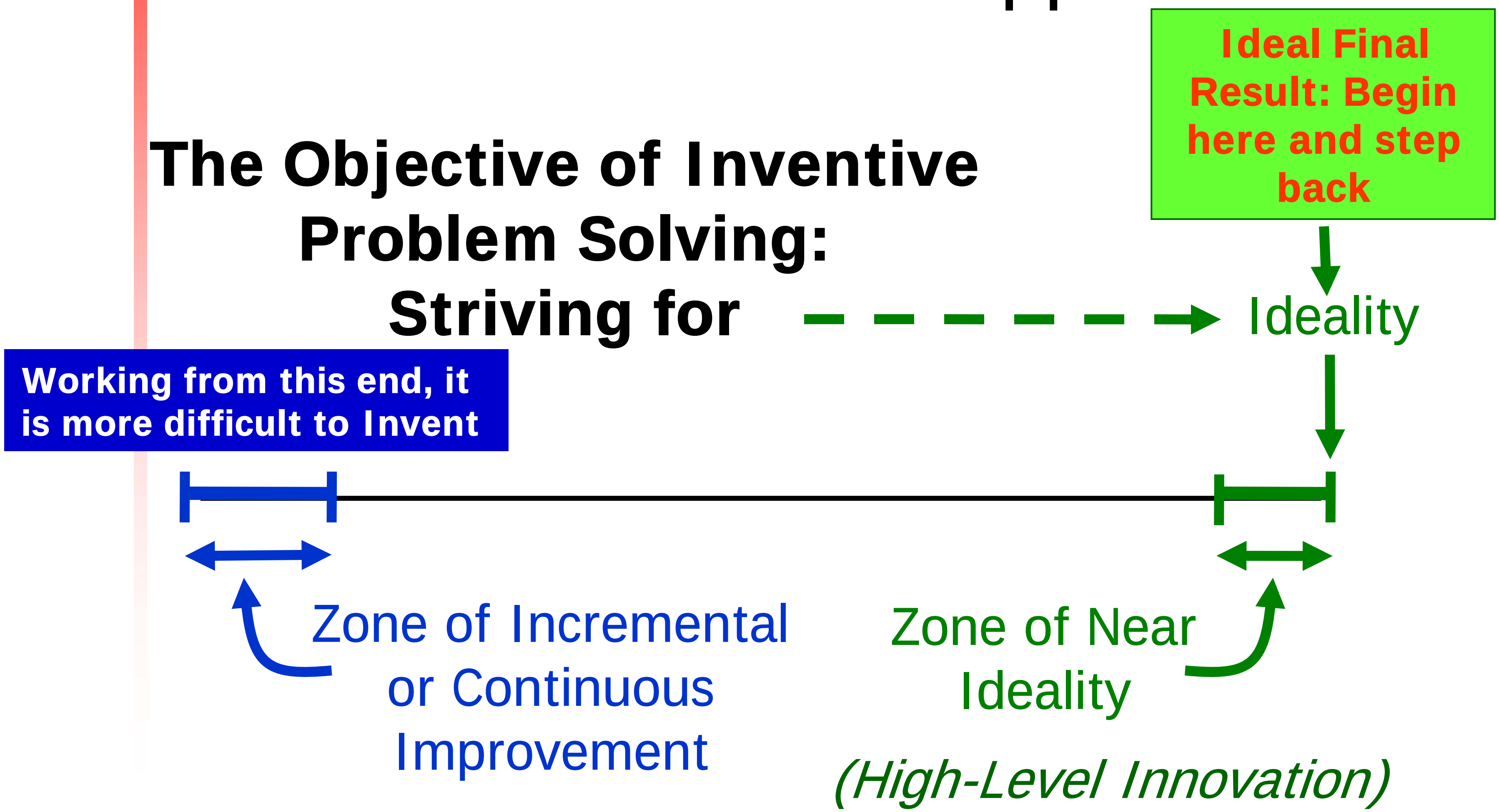
Ideality Approach

$$\textbf{Ideality} = \frac{\text{All } \textit{Useful} \text{ Functions}}{\text{All } \textit{Harmful} \text{ Functions}}$$

- The ideal system performs a required function without actually existing. The function is often performed using existing resources.
- Nothing changes; everything remains the same and the problem is resolved.

Ideality Approach:

A Different Set of Opportunities



Assessment--Ideality

- State an Ideal Final Result for an improvement in a system
- State an Ideal Final Result for replacing a system
- Describe the Ideality concept and apply it to a product or situation

Assessment--Ideality

- Describe the Ideal Final Result for a product or situation from several points of view.

Ideality Approach

TRIZ provides two general approaches for achieving close-to-ideal solutions (solutions that do not increase system complexity):

- Use of **resources**
- Use of physical, chemical, geometrical and other **effects**

Using Effects to Increase Ideality

- Often a complex system can be replaced with a simple one if an appropriate physical, chemical or other effect is used.

  Example: In the manufacturing of pre-stressed concrete slabs, reinforcing rods must be stretched. Instead of using a complex hydraulic device, the rods are heated and expand by themselves.

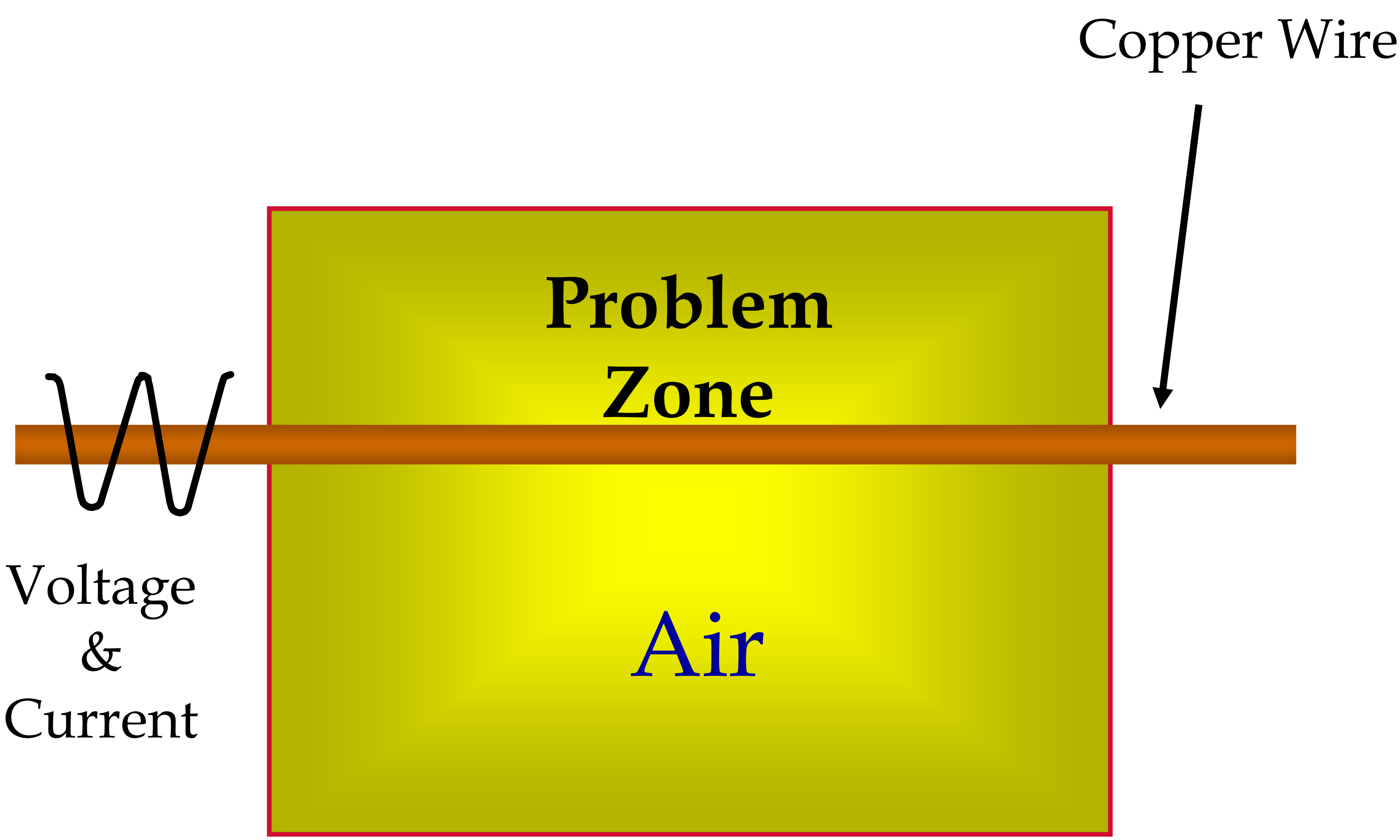
Use Resources to Increase Ideality

- A resource:
  - is any substance or anything of substance (including waste) available in the system or its environment
  - has the functional and technological ability to jointly perform additional functions
  - is an energy reserve, free time, unoccupied space, information, form, etc.

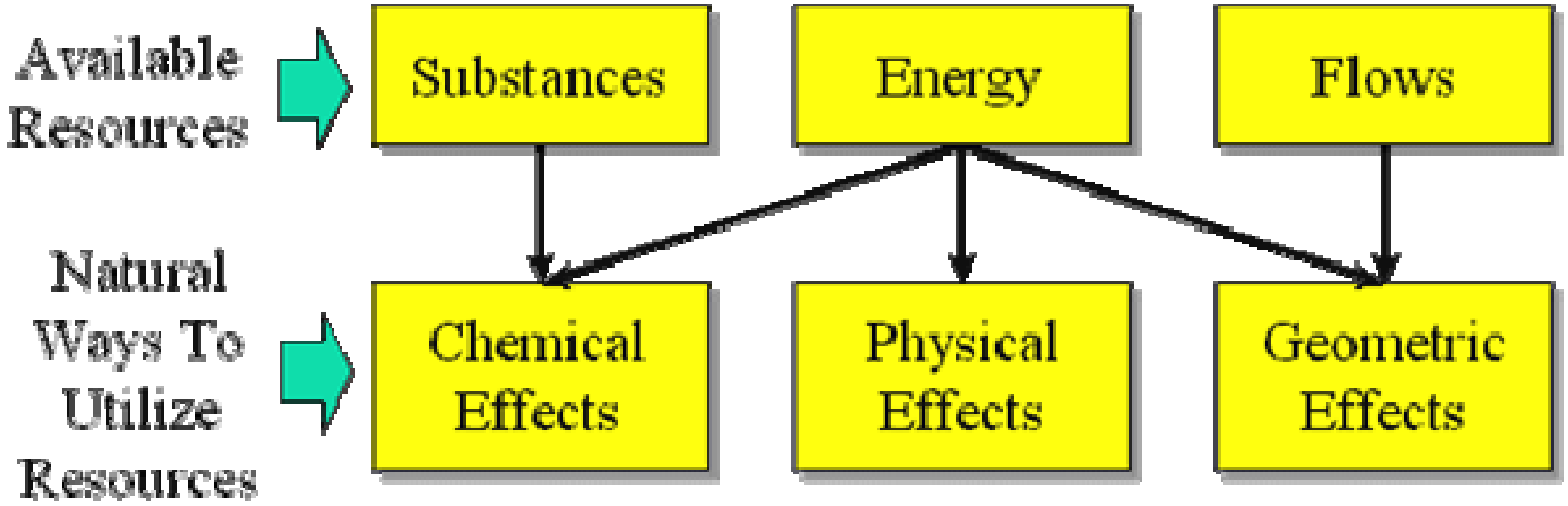
Find Resources You Didn't Know You Had

What resources do you need?

Resources -- Wire Example



Resources



Available Resources
Natural Ways To Utilize Resources
Substances
Energy
Flows
Chemical Effects
Physical Effects
Geometric Effects

Assessment—Resources

- Find x number of resources in a product or situation
- Suggest resources that can be concentrated
- Suggest resources that can be derived from ready resources in a system.

Content for Teaching Invention

TRIZ provides the technology teacher and curriculum developer with content knowledge, principles, skills, tools, and methods for students to tackle the inventive end of the design continuum and become ***inventive*** problem solvers.

Knowledge, Tools, and Methods

Students can learn:

- How to recognize an inventive problem
- How to classify different levels of invention
- To recognize contradictions and work with them without compromising
- To distinguish between technical (trade-off) and physical (conflict) contradictions
- To use the patterns of technological evolution
- How a system might evolve in the future, and
- How to locate and use unused resources in the system.

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Content for Teaching Invention

- Students learning TRIZ will improve their skills and creativity when working with inventive problems and will improve their problem-solving skills at all positions of the design continuum.
- Students learning TRIZ will also begin to see that the principles can be applied to their everyday lives to solve problems outside the realm of technology. They will become better problem solvers in life.