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Mark Sampson, UGS

- Generating design alternatives
- Origins and advantages of TRIZ
- The TRIZ Tool to generate solutions to Technical Contradictions

Generating Design Alternatives - an Introduction to Methods for Innovation

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Innovation & Conflicting Requirements

- QFD translates the voice of the customer into engineering requirements.
- Engineering requirements are often conflicting.
  - Example: The product gets stronger, but the weight increases.
- Generating solutions that satisfy conflicting requirements is usually performed using various methods such as:
  - Free association brainstorming
  - Cross fertilization (drawing analogies from other disciplines)
  - Futuring (thinking to the future when these constraints may no longer exist)
- The above methods *occasionally* generate a solution to conflicting requirements, but is there a reliable method for generating solutions? **YES**
- **TRIZ** is a method for generating Inventive Solutions to conflicting engineering requirements that is based on patterns of innovation identified in patents.

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TRIZ: A Brief History

- **TRIZ** is the Russian acronym for the Theory of Inventive Problem Solving.

Теория Решения Изобретательских Задач

- Pronounced *treez*
- Created by Genric Altshuller (1926-1998)
  - 1926: Born in Soviet Union
  - 1940: First invention at age 14
  - 1942: First author's certificate (Soviet Patent)
  - 1945: Joined Navy as inspector of inventing
  - 1946: Decided to create new science for theory of innovation
  - 1948: Established foundation for TRIZ by studying over 200,000 patents and identifying levels of innovation
  - 1948: Imprisoned in Siberia by Stalin for criticizing existing Soviet inventive process
  - 1953: Released from prison (Stalin dies)
  - 1956 to 1985: Continues TRIZ development and publishes 14 books
  - 1985 to 1998: Failing health reduces output, but disciples continue work in Russia
  - 1998: Dies, leaving his work to the public domain

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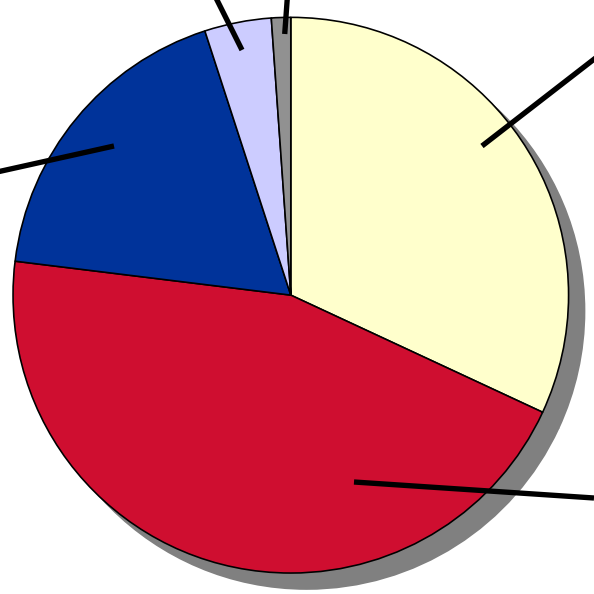
Patent Analyses

- Altshuller selected 40,000 of the most innovative patents and sorted them into 5 Levels of Innovation based on the degree on inventiveness in the solution and not the problem itself:



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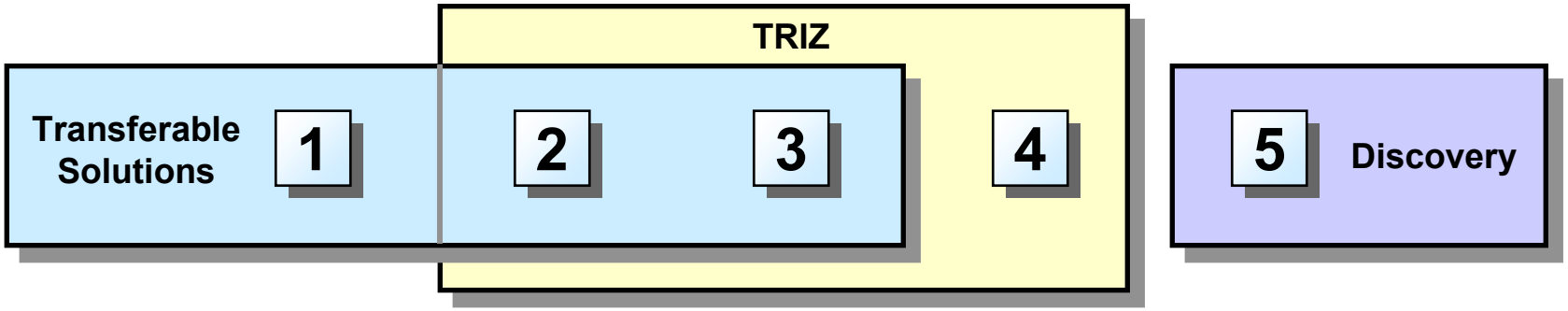
Levels of Innovative Solutions

- Altshuller made the following observations:
  - Levels 1, 2, and 3 (95% of innovative solutions) are transferable from one field to another
  - Level 1 solutions are not innovative (most solutions are obvious)
  - Level 5 solutions are based on new discoveries and have little in common
- He realized that he could help anyone develop Level 2, 3, or 4 solutions (67% of innovative solutions).

Levels of Innovative Solutions



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Patent Analyses: Problems and Solutions

- Detailed analyses of the 40,000 patents revealed that:
  - The most difficult problems in engineering involved **Technical Contradictions**.
  - The same contradictions (inventive problems) were addressed over and over again in different fields and technologies
  - The same inventive solutions were applied over and over again in different fields and technologies
- Identification of these patterns of innovation was the breakthrough that Altshuller was looking for.

- **Inventive Problem:** a problem containing at least one technical contradiction.
- **Inventive Solution:** a solution that improves a single part or characteristic of the system without impairing other parts or characteristics of the system or adjacent systems.

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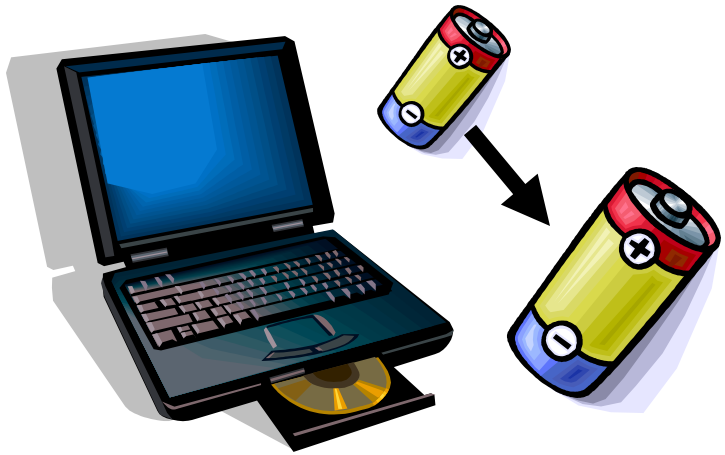
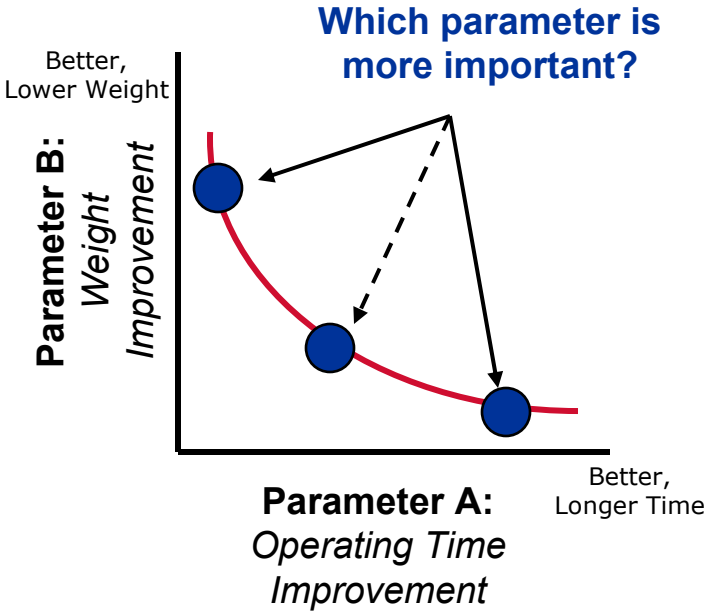
Technical Contradictions

- **Technical Contradiction:** Changing one part or function of a system has a negative impact on the system's other parts or functions.
- **Technical Systems** consist of interrelated parts.
- Most engineering "trade-offs" involve technical contradictions.
- Example:



Increasing the laptop operating time requires a larger battery, which increases the overall weight.



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Design Parameters

- Altshuller identified 39 common Design Parameters found in inventive problems:

1-Weight of moving object
2-Weight of stationary object
3-Length of moving object
4-Length of stationary object
5-Area of moving object
6-Area of stationary object
7-Volume of moving object
8-Volume of stationary object
9-Speed
10-Force (Intensity)
11-Stress or pressure
12-Shape
13-Stability of the object's composition
14-Strength
15-Duration of action of moving object
16-Duration of action by stationary object
17-Temperature
18-Illumination intensity
19-Use of energy by moving object
20-Use of energy by stationary object
21-Power
22-Loss of Energy
23-Loss of substance
24-Loss of Information
25-Loss of Time
26-Quantity of substance/the matter
27-Reliability
28-Measurement accuracy
29-Manufacturing precision
30-Object-affected harmful factors
31-Object-generated harmful factors
32-Ease of manufacture
33-Ease of operation
34-Ease of repair
35-Adaptability or versatility
36-Device complexity
37-Difficulty of detecting and measuring
38-Extent of automation
39-Productivity

- A technical contradiction can be formed by any two design parameters.

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Inventive Principles

- Altshuller identified 40 common Inventive Principles used in inventive solutions:

1-Segmentation
2-Take out
3-Local Quality
4-Asymmetry
5-Merging
6-Universality
7-Nested Doll
8-Anti-weight
9-Preliminary anti-action
10-Preliminary action
11-Cushion in advance
12-Equipotentiality
13-Other way around
14-Spheroidality or use of curves
15-Dynamism
16-Partial/excessive action
17-Another dimension
18-Mechanical Vibration
19-Periodic action
20-Continuity of action
21-Skipping (do fast)
22-Blessing in disguise
23-Feedback
24-Intermediary
25-Self-service
26-Copying
27-Cheap short life
28-Replace mechanical system with fields
29-Pneumatic/hydraulic
30-Flexible shell, films
31-Porous materials
32-Change color
33-Homogeneity
34-Discard/recover
35-Change parameters
36-Use phase transition
37-Use thermal expansion
38-Strong Oxidants
39-Inert Atmosphere
40-Composite materials

- The 40 Inventive Principles are used to resolve technical contradictions among pairs of the 39 Design Parameters.

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Contradiction Matrix

- Altshuller created a 39 x 39 matrix where the 39 design parameters were listed vertically as Improving Features and repeated horizontally as Degraded Features.
- The matrix contains the top four Inventive Principles that Altshuller found were used to resolve technical contradictions between pairs of Design Parameters.

Select Improving Design Parameter

[1] *Weight of a Moving Object*

Select Degraded Design Parameter

[9] *Speed*

Choose Best Inventive Principle

[2] *Take Out*
[8] *Anti-Weight*
[15] *Dynamism*
[38] *Strong Oxidants*

Improving Feature	Degraded Feature	1-Weight of moving object	2-Weight of stationary object	3-Length of moving object	4-Length of stationary object	5-Area of moving object	6-Area of stationary object	7-Volume of moving object	8-Volume of stationary object	9-Speed
		1	2	3	4	5	6	7	8	9
1	Weight of moving object		-	15, 8, 29, 34	-	29, 17, 38, 34	-	29, 2, 40, 28	-	2, 8, 15, 38
2	Weight of stationary object	-		-	10, 1, 29, 35	-	35, 30, 13, 2	-	5, 35, 14, 2	-
3	Length of moving object	8, 15, 29, 34	-		-	15, 17, 4	-	7, 17, 4, 35	-	13, 4, 8
4	Length of stationary object	-	35, 28, 40, 29	-		-	17, 7, 10, 40	-	35, 8, 2,14	-
5	Area of moving object	2, 17, 29, 4	-	14, 15, 18, 4	-		-	7, 14, 17, 4	-	29, 30, 4, 34
6	Area of stationary object	-	30, 2, 14, 18	-	26, 7, 9, 39	-		-	-	-
7	Volume of moving object	2, 26, 29, 40	-	1, 7, 4, 35	-	1, 7, 4, 17	-		-	29, 4, 38, 34

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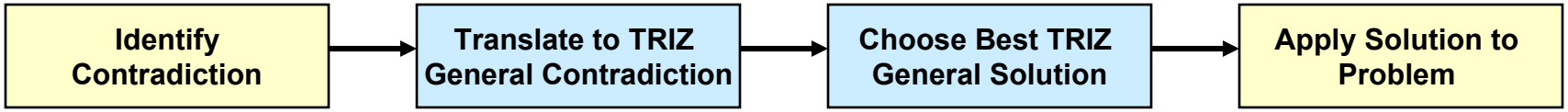
Method for Solving Technical Contradictions

- Methodology for resolving Technical Contradictions:
  1. Identify the Technical Contradiction.
  2. Determine which Feature in the contradiction is to be Improved and which one is Degraded (or worsened).
  3. Choose the Design Parameters that most closely match the Improving Feature and Degraded Feature in the contradiction.
  4. Examine the proposed Inventive Principles.
  5. Select the best Inventive Principle.
  6. Apply the Inventive Principle to the Technical Contradiction.



- SDI's TRIZ tool (part of the Triptych tool suite) performs Steps 3 and 4 by providing a simple interface to Altshuller's Contradictions matrix with 130 definitions and 167 examples.

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TRIZ Method Example

- **Engineering Requirement:** Customers are asking for a lighter laptop with longer operating time.
- **Technical Contradiction:** Increasing the laptop operating time typically requires a larger battery, which increases the overall laptop weight.
  - **Improving Feature:** Laptop operating time.
  - **Degraded Feature:** Laptop weight.
- Several Design Parameters are a close match to the Improving Feature, but for this example use #15:
  - 15-Duration of action of moving object
  - 21-Power
  - 22-Loss of Energy
  - 24-Loss of Information
  - 25-Loss of Time
- Degraded Feature, use:
  - 1-Weight of moving object

If there are several design parameters that are a close match, explore them all.

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SDI's TRIZ tool (TRIPTYCH) included in UGS' TcSE DFSS Template

"Live" Requirements Spreadsheet…

Microsoft Excel - 1145375486683.mhtml [Read-Only]

	Home	Name			Number	ROIN	Create User	Subtype	Text
2		Weight Constraints	0	1	13	74	nadimetla	Requirement	To achieve portability, weight shall not exceed .75 lbs.
3		Goal profile or scenario: How the system accomplish its goal objective	0	1	14	12	msampson	Requirement	Fast transfer rate and high capacity portable media.
4		Utilization environments: How the various system components to be used	0	2	15	14	msampson	Requirement	Removal media to store maximum of 1 Terabye of data. Use a computer system to access and store data on removal media. Zip drive type device read and wr to removal media.
5		Environment: the environments where the system be expected to operate (in an effective manner)	0	4	16	17	msampson	Requirement	
		Power Performance	1	1	17	67	msampson	Requirement	Customer states that they need a portab zip drive: Inputs: I need to use my zip drive on a 4 hour plane flight. Zip driv uses power at the following rates: Seek Write Standby Spin up Sp

TcR-1180.0.1130649564426

Triptych v3.0

TRIZ

1 Project Contradiction:

It is desired to achieve a shorter cooking time without the added size, cost, and energy consumption of a high

2 TRIZ Generic Contradiction:

	Category	Design Parameter
Feature to Improve:	(all)	1-Weight of moving object
Degraded Feature:	(all)	3-Length of moving object

3 TRIZ Generic Solution:

ID	Inventive Principles	Rank
8	Anti-weight	32
15	Dynamism	6
29	Pneumatic/hydraulic	14
34	Discard/recover	15

Definition(s) 1 2: To compensate for the weight of an object, merge it with other objects that provide lift.

Example(s) 1 2: Inject foaming agent into a bundle of logs, to make it float better.

TRIZ Process: Identify Contradiction in Project → Translate to TRIZ Generic Contradiction → Choose best TRIZ Generic Solution → Generate ideas using TRIZ Generic Solution

4 Project Idea:

Save Close

TRIZ Contradiction		TRIZ Generic Solution			Project Ideas
Improving Feature	Degraded Feature	TRIZ Principle	Explanation	Example	
25-Loss of Time	21-Power	Preliminary action	Pre-arrange objects such that they can come into action from the most convenient place and without losing time for their delivery.	Kanban arrangements in a Just-In-Time factory.	Arrange food objects correctly in th
	20-Use of energy by stationary object	Segmentation	Increase the degree of fragmentation or segmentation.	Replace solid shades with Venetian blinds.	Separate large food objects into sm
9-Speed	22-Loss of Energy	Periodic action	Instead of continuous action, use periodic or pulsating actions.	Hitting something repeatedly with a hammer.	Use high-power MW pulse energy continuous

TRIZ tool guides the user through the TRIZ process

All information created and maintained in editable Excel spreadsheets that can be stored with requirements

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Overview of TRIZ Tool

1. Enter the **Project Contradiction** or a description of the problem to be solved

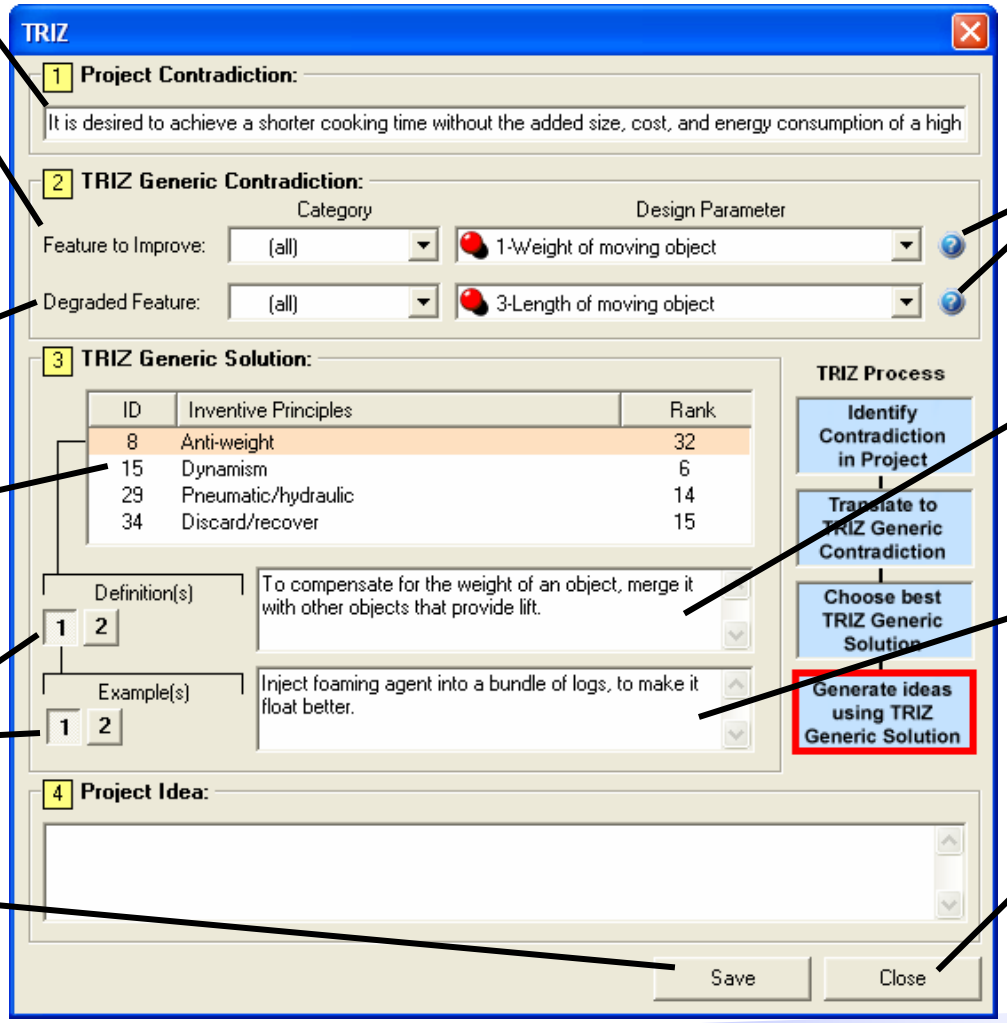
2a. Select the **Feature to Improve** from the list of 39 Design Parameters. The Category selection filters the list to assist in the selection.

2b. Select the **Degraded Feature** from the list of 39 Design Parameters

3. Up to four **Inventive Principles** are listed here, along with their rank (in terms of frequency of use)

Number Buttons cycle through definitions and examples

Save Button † is used to store selected information on a TRIZ worksheet



? Button provides definitions for selected Design Parameters

One or more **Definitions** for the selected **Inventive Principle** are shown

One or more **Examples** for the selected **Inventive Principle Definition** are shown

Close Button closes TRIZ Tool

† Buttons are disabled if the active worksheet is not a TRIZ worksheet

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Example: Examine a Variety of Inventive Principles

- **Use the TRIZ tool to generate solutions for the *Laptop Operating Time vs. Weight* problem**
  - **Engineering Requirement:** Customers are asking for a lighter laptop with longer operating time.
  - **Technical Contradiction:** Increasing the laptop operating time typically requires a larger battery, which increases the overall laptop weight.
  - **Improving Feature:** Laptop operating time.
  - **Degraded Feature:** Laptop weight.

- Select several Design Parameter Improving – Degraded Feature pairs and see what ideas develop
  - Do different Design Parameters lead to different potential solutions?
  - Do different Definitions and Examples stimulate different ideas?
  - Are you able to create solutions that address different aspects of the product, such as: power savings, weight reduction, power generation, etc.

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Apply Inventive Principles to Specific Problem

- The TRIZ Tool has provided several Inventive Principles that have been used to solving similar technical contradictions.
- The next step is to apply Inventive Principles and Ideas to the specific laptop technical contradiction.
- Potential solutions:
  - **Periodic Action** → Reduce CPU speed to conserve battery life
  - **Discard/Recover** → Create a a laptop with an internal microturbine that runs on small disposable propane cylinders
  - **Porous Materials** → Remove material from laptop housing to offset weight increase due to a larger battery
  - **Anti-Weight** → Fill cavities with lighter-than-air gases to provide lift

Improving Feature	Degraded Feature	TRIZ Principal	Explanation	Example	Idea
15-Duration of action of moving object	1-Weight of moving object	19-Periodic action	Instead of continuous action, use periodic or pulsating actions.	Replace a continuous siren with a pulsed sound.	Reduce CPU speed when operating on a battery. This will extend the operating time.
		34-Discard/recover	Make portions of an object that have fulfilled their functions go away (discard by dissolving, evaporating, etc.) or modify these directly during operation.	Use a dissolving capsule for medicine.	Propane powered laptop using microturbines for power. Disposable or rechargeable propane tanks. Less weight than a battery?
		31-Porous materials	Make an object porous or add porous elements (inserts, coatings, etc.).	Drill holes in a structure to reduce the weight.	

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Key Results & Capabilities

- TRIZ is not limited to solving technical contradictions -- the results have been applied to:
  - business processes
  - software development
  - process improvement
- The key concept behind TRIZ is that there is a 95% probability that someone else, in some other industry has solved the same fundamental technical contradiction.

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Guidelines for using TRIZ in Product Development

- Use TRIZ
  - (or other appropriate methods) to deal with the real product issues and what is needed to truly delight the customer.
  - to probe potential solutions to customer needs that appear to be *impossible* to achieve.
  - as a way to kick-off or facilitate brainstorming sessions.
  - as a method for finding alternatives to viable, but prohibitive solutions.
  - as a method for investigating requirements that appear to contradict each other.

- After your Experience, Brainstorming, or TRIZ has provided various alternatives for satisfying the requirements … use trade study and selection methods to identify the *BEST* approach.

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