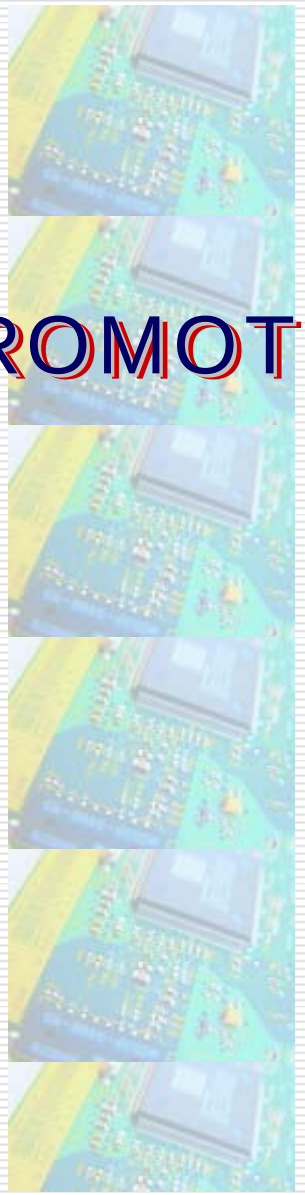


# PROMOTION AND APPLICATION OF TRIZ IN HIGH-TECH COMPANIES

## Part 2. How We Can Apply TRIZ Effectively.

## For Engineers

Valery Krasnoslobodtsev
*e-mail:* kraev@triz.org

Technical Innovation Center, Inc.
100 Barber Avenue, Worcester, MA, USA, 01606
Webpage: www.triz.org

# Structure of Presentation

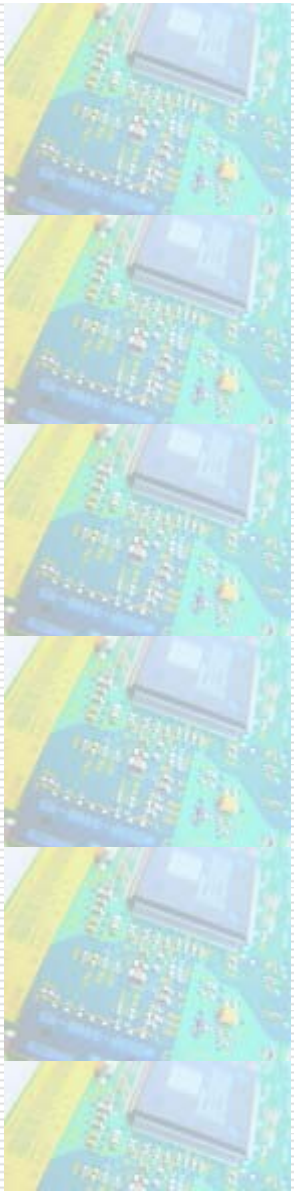
1. Introduction
2. TRIZ Tools And Road Map For Their Application
3. Structure Of Consolidated Algorithm ARIZ And Its Practical Features
4. Best Practice: Exploring the TRIZ Industrial Projects:
   - Developing The Robotic Vacuum Cleaning
   - Developing The Non-Contact Printing
   - Developing The LCD With Wider Viewing Angle

*Questions And Discussion*

# 1. INTRODUCTION

# The Main Goals Of Presentation

- To analyze the features of TRIZ tools application with their utilization in the conditions of real industry
- To introduce a problem solving road map with different types of TRIZ tools
- To become familiar with the consolidated logical algorithm of problem solving
- To present applications of road map and the consolidated logical algorithm for improvement of brand-new technologies with industrial cases studies



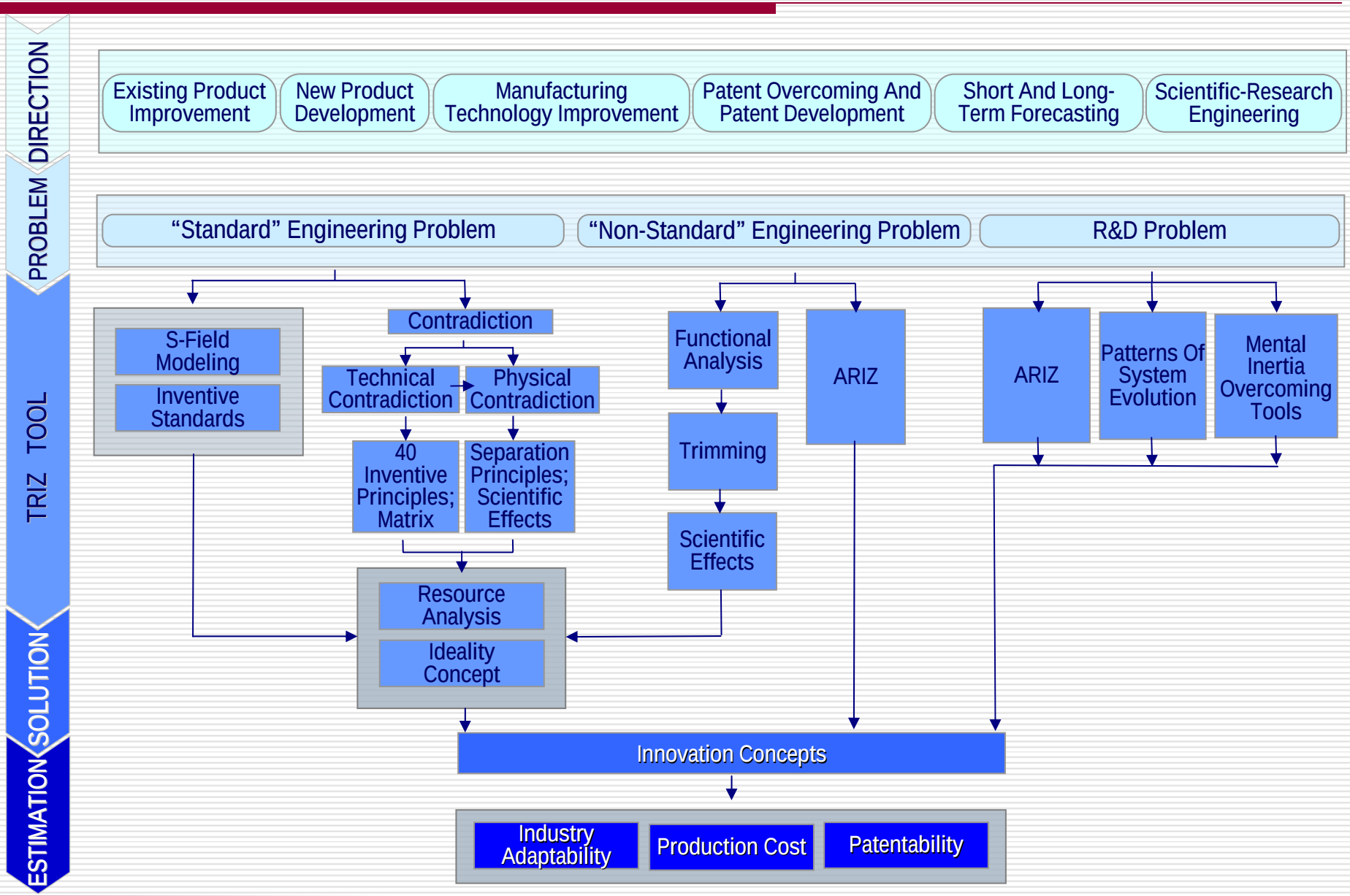
# 2. TRIZ TOOLS AND ROAD MAP

# TRIZ Tools

**There are 15 TRIZ tools that can be used independently or in combinations during problem solving:**

- Algorithm of Invention Problem Solving - ARIZ
- Technical Contradiction
- Physical Contradiction with Separation Principles
- 40 Inventive Principles with Matrix
- S-Field Modeling
- Inventive Standards
- Scientific Effects
- Patterns Of System Evolution
- Ideality Concept, separately
- Resource Analysis
- Functional Analysis
- Trimming
- Multiscreen Thinking
- Dimensions-Time-Cost Method
- Modeling with Smart Small People

# Road Map Of Problem Solving Process

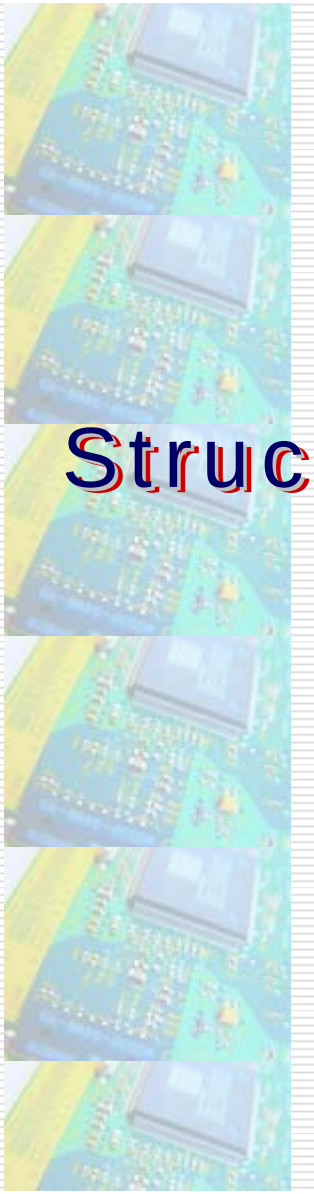


# Types Of Problems

- **The “standard” engineering problems**
  contain obvious technical contradiction that can be expressed by the expert. These contradictions are solved with application of Inventive Principles or Standard Solutions and S-Field Modeling

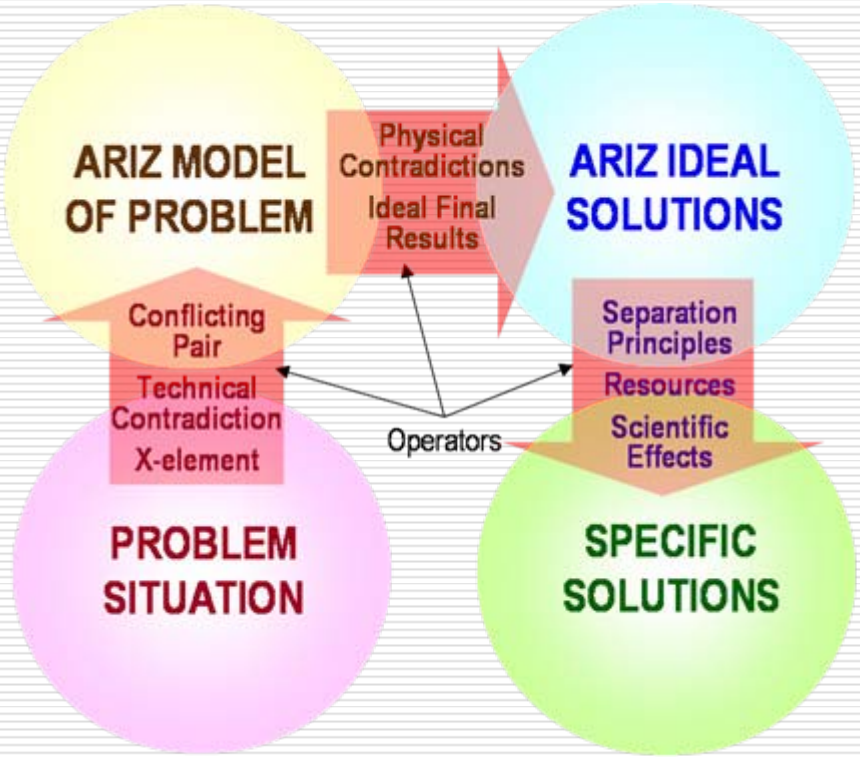
- **The “non-standard” engineering problems**
  contain implicit contradictions and these problems cannot be solved with application of Principles or Standards alone. Their solution needs application of ARIZ or functional analysis of interactions such as "«subject-action-object" with further application of trimming and database of scientific effects

- **The research and development problems**
  related to prediction and application of modern scientific and technical effects do not usually contain an opened contradiction. These problems are solved by application of ARIZ, patterns of system evolution and some methods for overcoming of mental inertia, for instance the 9-screen diagram



# 3. Structure Of Consolidated Algorithm And Its Practical Features

# Consolidated Algorithm




## Exploring problem situation

The process starts from the interview with the customer and description of a problem statement. Typically, the situation that is described by the customer during the first interview has more than one problem. The problem questionnaire provides valuable information which includes a detailed description of the problem situation, the problem development background, previous attempts for solving this problem by customer with a definition of the interactions, and links between the technological operations or components of the system

## Formulating ARIZ model of a problem

The model consists of just two conflicting elements of the system: product and tool, technical contradiction between them and function that should be provided by an x-element for solving problem.

## Developing ARIZ ideal solutions

During this stage, the technical contradiction should be replaced with a physical contradiction. The step of formulating an ideal final result (IFR) helps to decide how to increase the beneficial factors and eliminate the harmful factors. The ideal solution serves as an abstract model and a goal for future specific solutions.

## Generating the specific solutions

During this stage, the abstract model of an ideal solution should be transformed into specific solutions. Creation of the solution concepts is implemented by applying listed resources, scientific phenomena and separation principles for resolving the physical contradiction.

# 4.
# The Best Practice:
# Exploring The TRIZ Industrial Projects

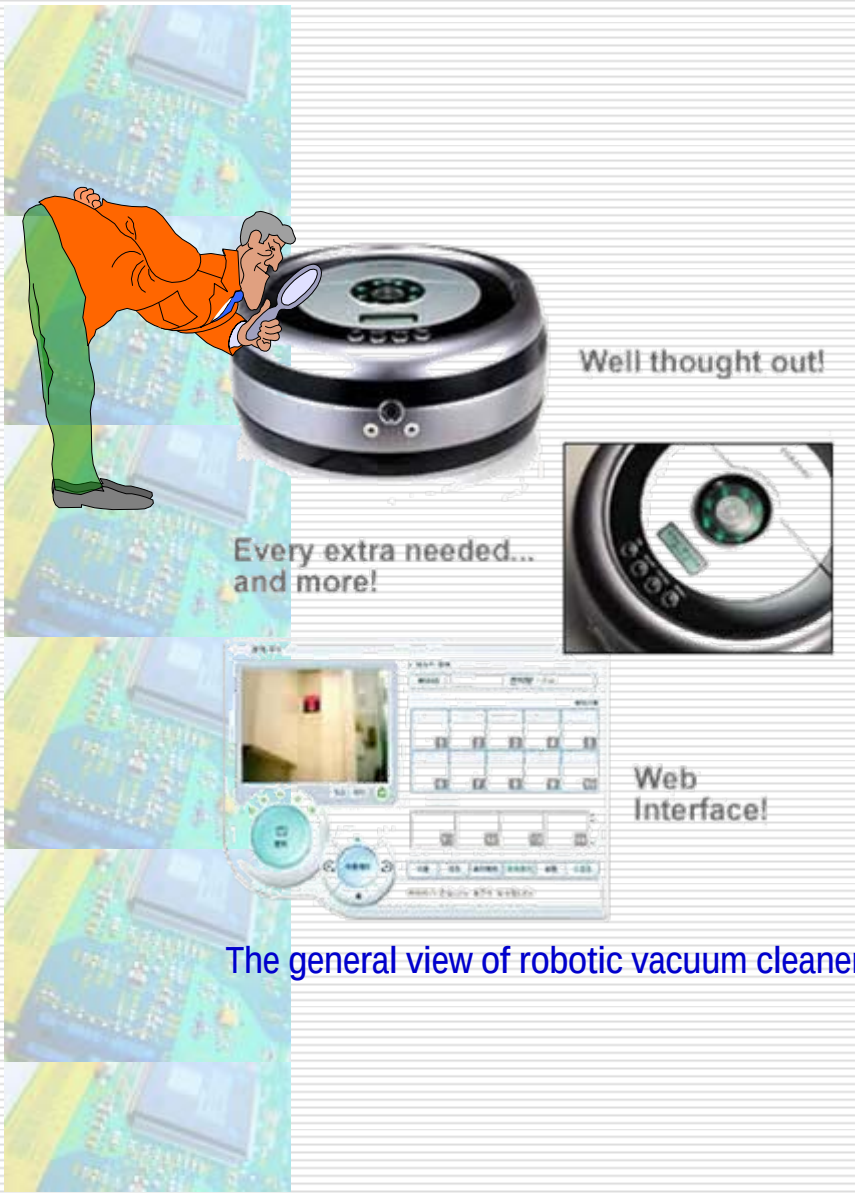
# Best Practice

We will explore in detail some specific industrial projects from different areas with TRIZ application:

- Developing Robotic Vacuum Cleaning
- Developing Non-Contact Printing
- Developing The LCD With Wider Angle Of View

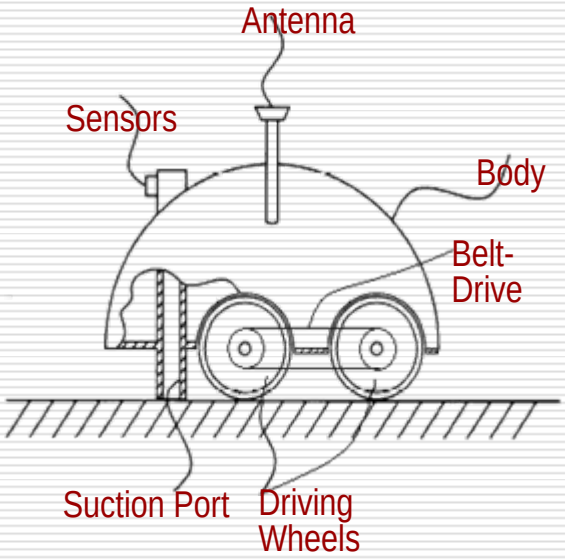
These projects demonstrate how TRIZ tools can be used for solving real technological problems.

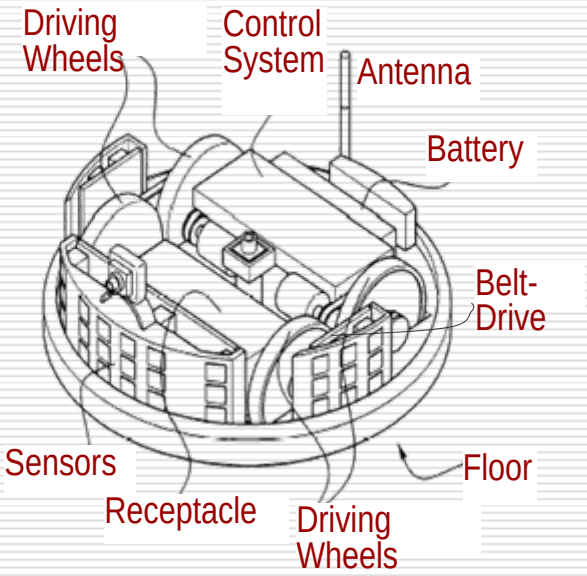
# 4.1. Developing Robotic Vacuum Cleaning




The general view of robotic vacuum cleaner

# Exploring Problem Situation



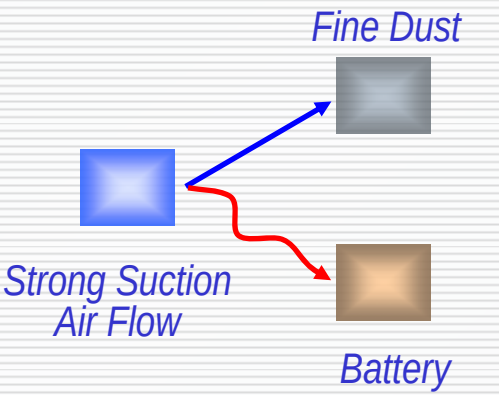

This problem was related to development of a **brand-new robotic vacuum cleaning machine.** The robot serves as an autonomous vacuum cleaner for cleaning different floor surfaces in the room without human participation.
The battery lasts about 50-60 minutes before needing to be recharged. If the battery gets low during operation, the robot vacuum automatically shuts down, returns to its charging base and recharges itself. Then, when it is fully charged, it resumes vacuuming where it left off.

**The main problem:** In order to improve cleaning ability of the robot, customer has tried to increase the suction force by using more a powerful motor but this reduced the time of cleaning and required more frequent battery recharging.

Thus, the **managerial statement** of this project was: "It is necessary with minimum modifications to the existing vacuum cleaner to provide improved vacuum cleaning without increasing the battery capacity and power of suction motor."

# Formulating The Problem Model

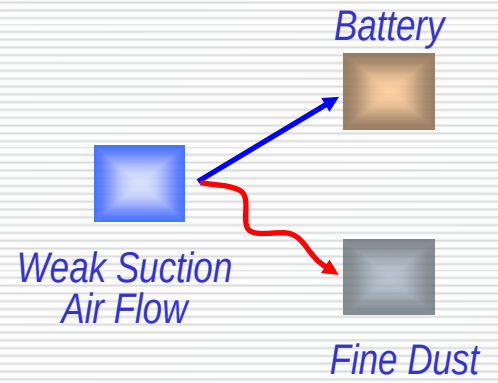
*Technical Contradiction 1*




**The Technical Contradiction 1:** "If the suction power of the robotic vacuum cleaner is a strong one, then fine contaminants are removed from cleaning surface very well but the battery will run down quickly due to increased electricity consumption and vacuum working time is decreased"

**The Technical Contradiction 2:** "If the suction power of the robotic vacuum cleaner is a weak one, then the battery works for a long time but the fine contaminants are not removed from the cleaning surface"

*Technical Contradiction 2*



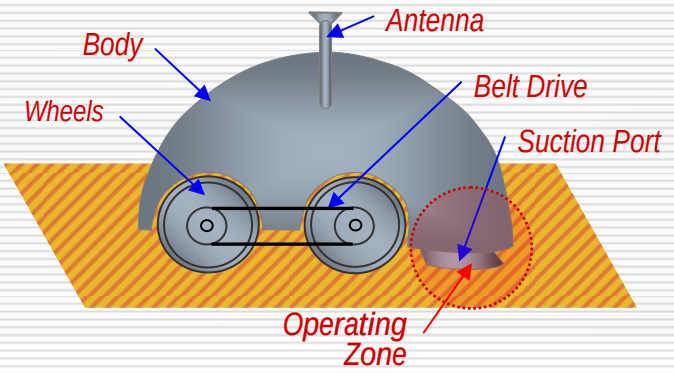

**Main Function** is providing the better vacuum cleaning (i.e. the 1st scheme)

**Product:** Fine Dust and Contaminants

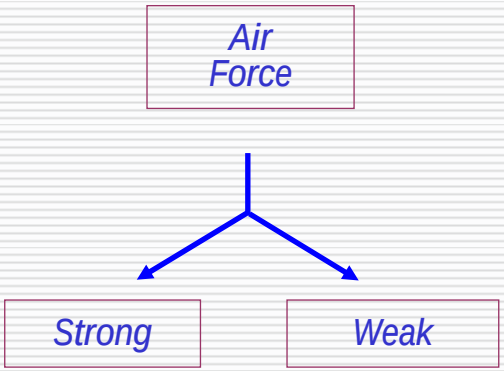
**Tool:** Airflow in Suction Port

In order to solve this problem we should find some **X-element** (changes to the system) that provides strong air flow at the suction port without increasing electricity consumption and therefore without increasing battery and motor capacity.

# Developing An Ideal Solution




*Physical Contradiction*




**The Physical Contradiction:** "The air force at the suction port should be strong for removing the fine contaminants and should be weak for decreasing the electrical power consumption".

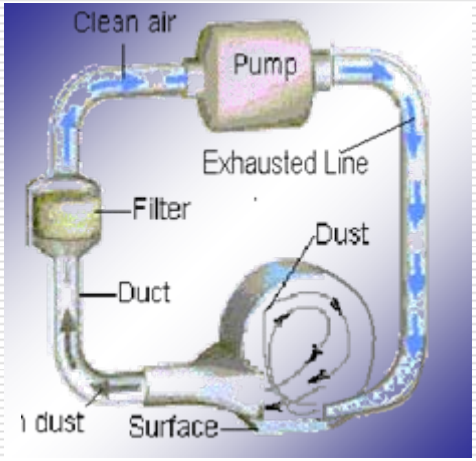
**Technical Ideal Final Result:** "The robotic vacuum cleaner itself provides the big air force acting on the fine contaminants at the suction port and preserves long working time of the battery between recharges with minimal modification of the cleaner"

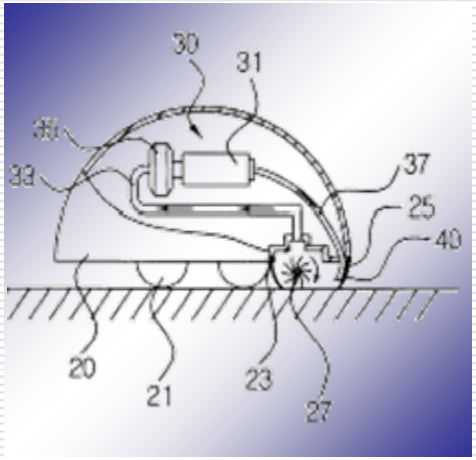
**Physical Ideal Final Result:** "An air flow at the *operating zone* of interaction of the suction port with the cleaning surface itself provides a big force acting on the fine contaminants at the suction port and preserves long working time of battery between recharges with minimal modification of the suction port"

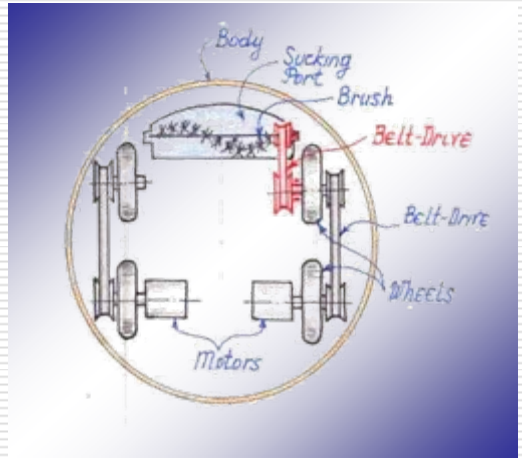
# Resource Analysis

| Table of S-Field Resources | | Substances | Fields |
|---|---|---|---|
| **Internal System** | Product | Contaminant | Gravity Force, Mechanical Adherence, Electrostatic Adhesion |
| | Tool | Air Flow | Negative Static Pressure, Dynamic Pressure, Viscosity, Friction Force |
| **External System** | Super-System | Suction Air and Port, Exhausted Air and Port, Battery, Motor, Wheels, Sensors, Control System, Antenna, Other Robot's Components | Electricity, Magnetic Field, Rolling Friction, Sliding Friction, Inertial Force |
| | Environment | Ambient Air, Floor, Carpet, Furniture, Wall, Obstacles | Atmospheric Pressure, Gravity Force, Geomagnetic Field |
| | By-Product | Exhausted Air | Static and Dynamic Positive Pressure |

# Developing Specific Solution:
## Robotic Cleaning With Air Agitation



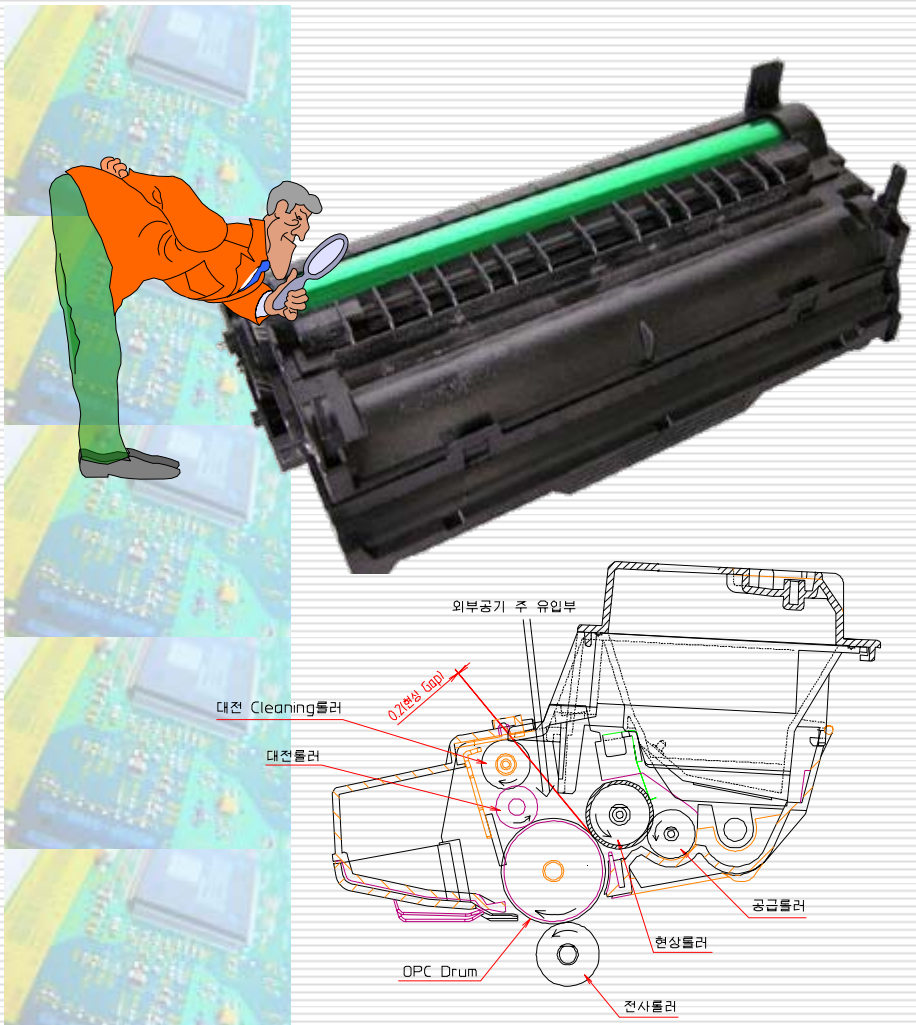




The robotic vacuum cleaner with air agitation

*Left picture is a scheme of vacuum cleaning; middle picture is a schematic side section view; right picture is a bottom view*

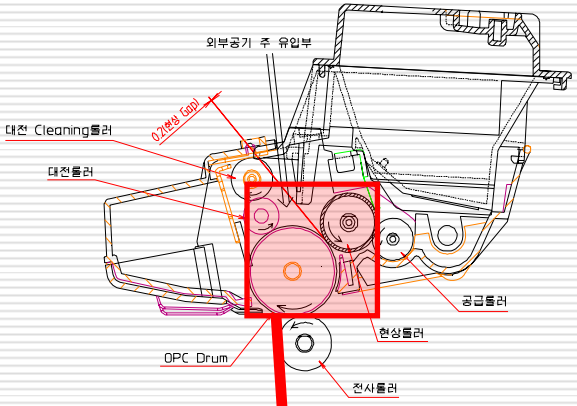
**Example of Specific Solution:** How to approach the ***ideal final result*** while using the substance-field resources of the whole vacuum cleaner? It was proposed to use the filtered exhausted airflow of vacuum into the operating zone while using the technical scheme as shown in left picture*.
The scheme has a suction port through which contaminants are drawn in from a cleaning surface and at least one means of agitation including an air circulating mechanism for filtering out contaminants from the air. This dirty air is drawn in through the suction port and filtered. The filtered air is recirculated into the exhaust line with an air jet opening to help dislodge contaminants from the cleaning surface. The air jet opening is near to the suction port and is surrounded by a sealing member. By sealing off a portion of the cleaning surface near the cleaner body, we prevent the contaminants that are scattered by the air jet from being dispersed outwardly.

* ***Robot Vacuum Cleaner with Air Agitation.*** U.S. Patent No.US7059012B2 (U.S.Patent Application No. US2003/0192144A1, Priority Date 16Apr 2002), Inventors: Jeong-Gon Song, Jang-Young Ko, Hwa-Gyu Song, Dong-Lyoul Shin, Valery Krasnoslobodtsev. Applicant: Samsung Electronics Co Ltd
http://v3.espacenet.com/origdoc?DB=EPODOC&IDX=US7059012&F

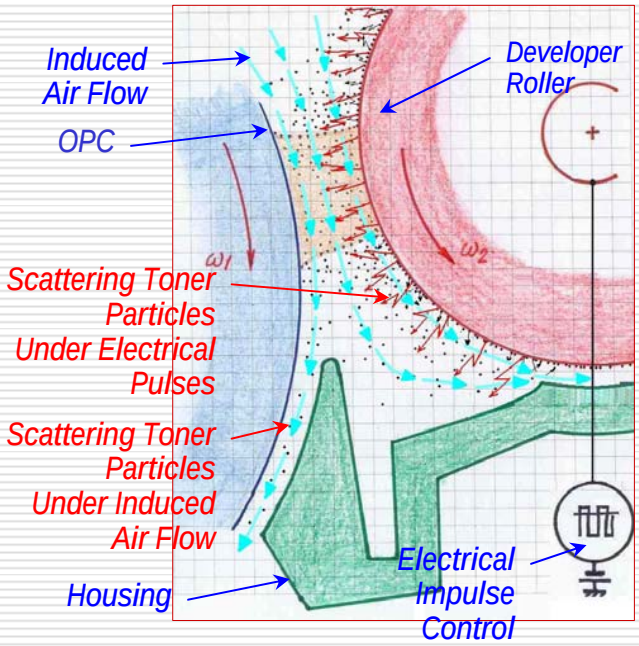



# 4.2. Developing Non-Contact Printing

# Exploring Problem Situation




## Initial Design




**Brand-new printing process by non-contact method** is implemented with using high voltage impulses with plus and minus potential. These impulses move negatively charge toner particles from Development Roller (DR) to Organic Photo Conductor (OPC) Drum and then part of particles return back. Some of the particles (small %) get incorrect positive charge. These particles are called Wrong Signed Toner (WST).

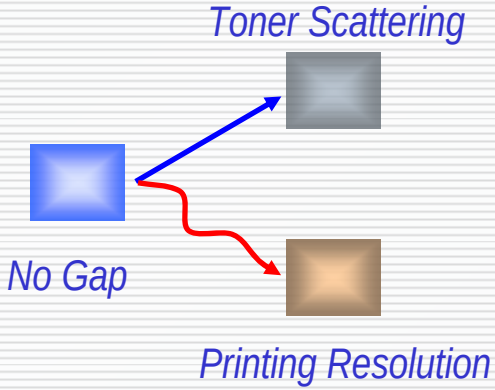
During printing process in the close space between OPC, DR, and housing, the ***toner is scattered***. Due to this phenomenon, toner particles are carried out through gap between OPC and housing and fall on the paper sheet. Therefore, the general quality of printing process is getting worse.

**The main problem is:** "How to eliminate rejection of toner particles outside the housing on the paper sheets and thus to increase the quality of the printing process?"

Thus, the **managerial statement** of this project was: "It is necessary with minimum modifications to the printer cartridge to eliminate particle rejection and to preserve initial design and operating principle of the cartridge."

# Formulating The Problem Model

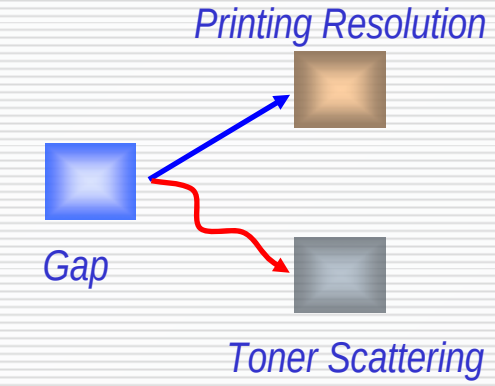
*Technical Contradiction 1*




**Technical Contradiction 1:** If there is no gap between OPC Drum and Developer Roller/Housing (they are located with contact) then toner scattering is absent, but printing resolution and image quality are getting worse.

**Technical Contradiction 2:** If there is gap between OPC Drum and Developer Roller/Housing (they are located without contact) the printing resolution and image quality is improved, but toner particles are scattered outside between OPC and housing on the paper.

*Technical Contradiction 2*



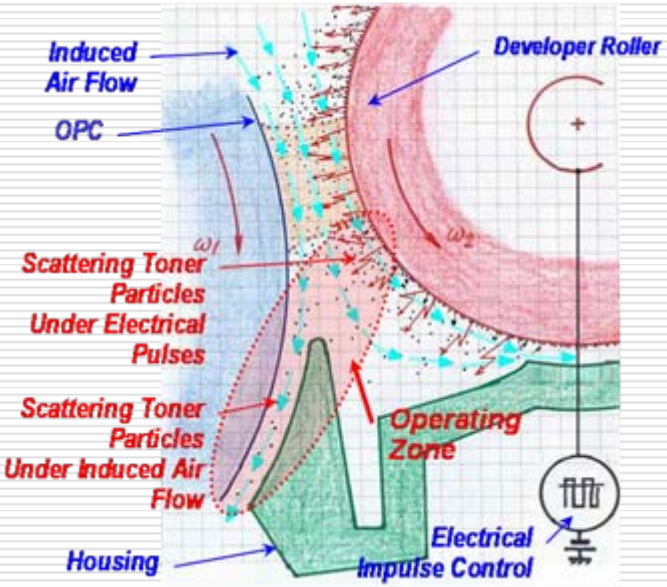

**Main Function** is providing the better printing resolution (i.e. the 2d scheme)

**Product:** Toner Particles

**Tool:** Gap between OPC Drum and Developer Roller/Housing

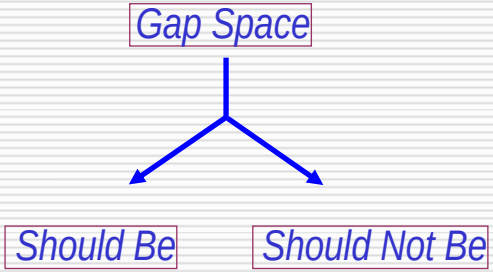
In order to solve this problem, we should find some **X-element** (changes to the system) that keeps gap between OPC and Developer/Housing and eliminates scattering of the toner particles outside housing.

# Developing An Ideal Solution



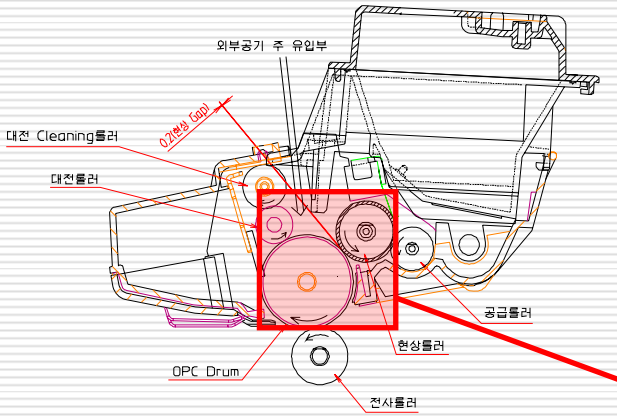

**Physical Contradiction:**
In the ***operating zone,*** the gap between OPC, developer and housing, there should be an air flow force because this flow is induced by rotating OPC and DR, and there should not be an air flow force for eliminating particles rejection outside housing

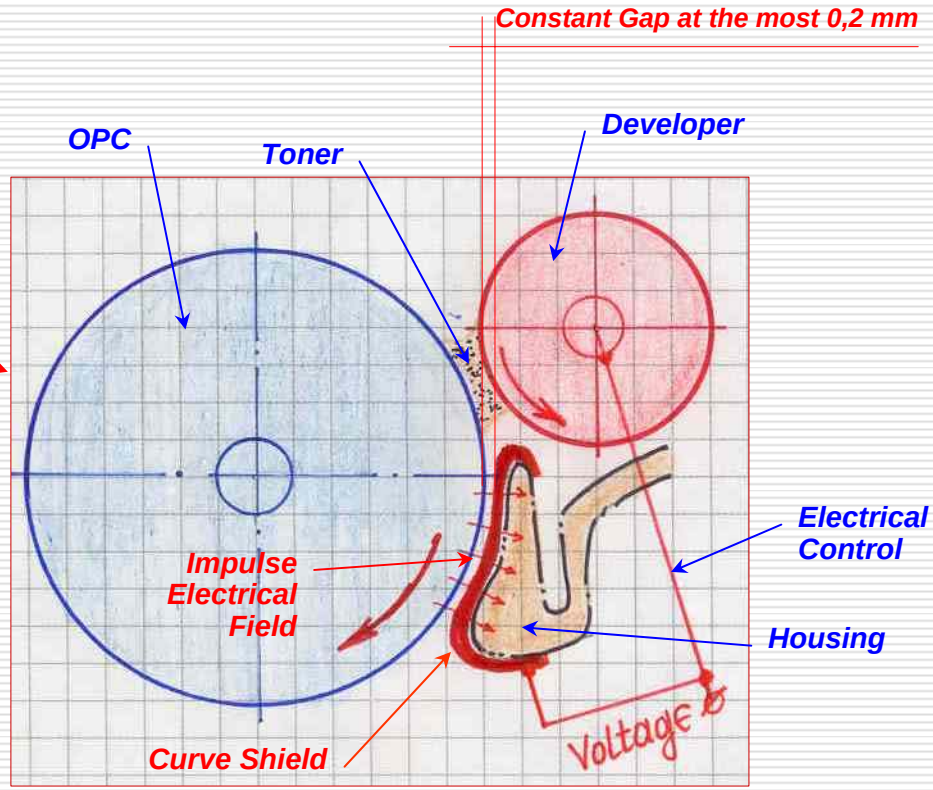
*Physical Contradiction*




**Ideal Solution:**
The space in the gap between OPC and housing *(operating zone)* itself eliminates scattering of toner particles by induced air flow force during printing process and save induced air flow for performing desired function

# Developing Specific Solution:
## Cartridge With Curve Electrical Shield

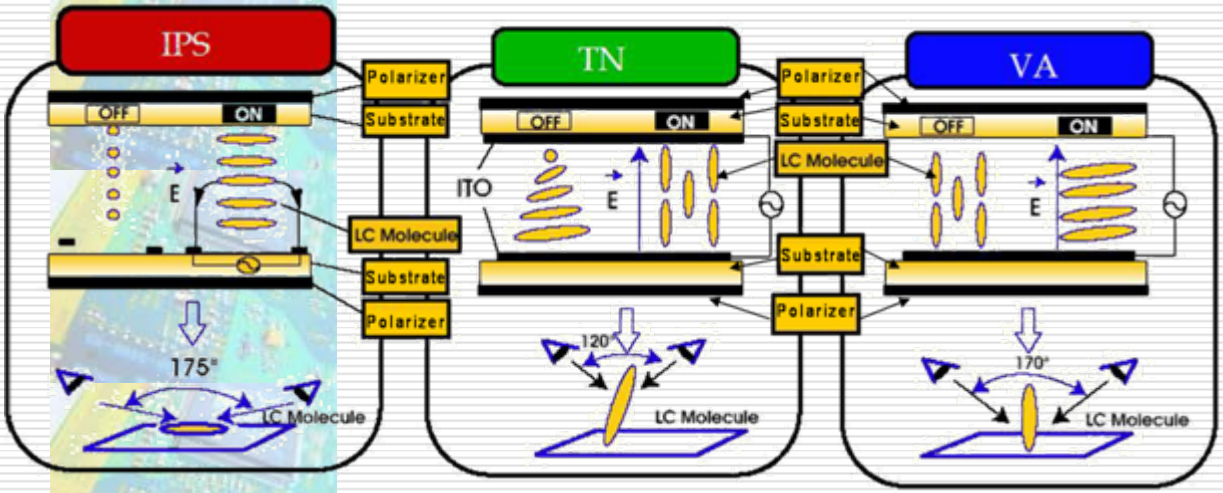


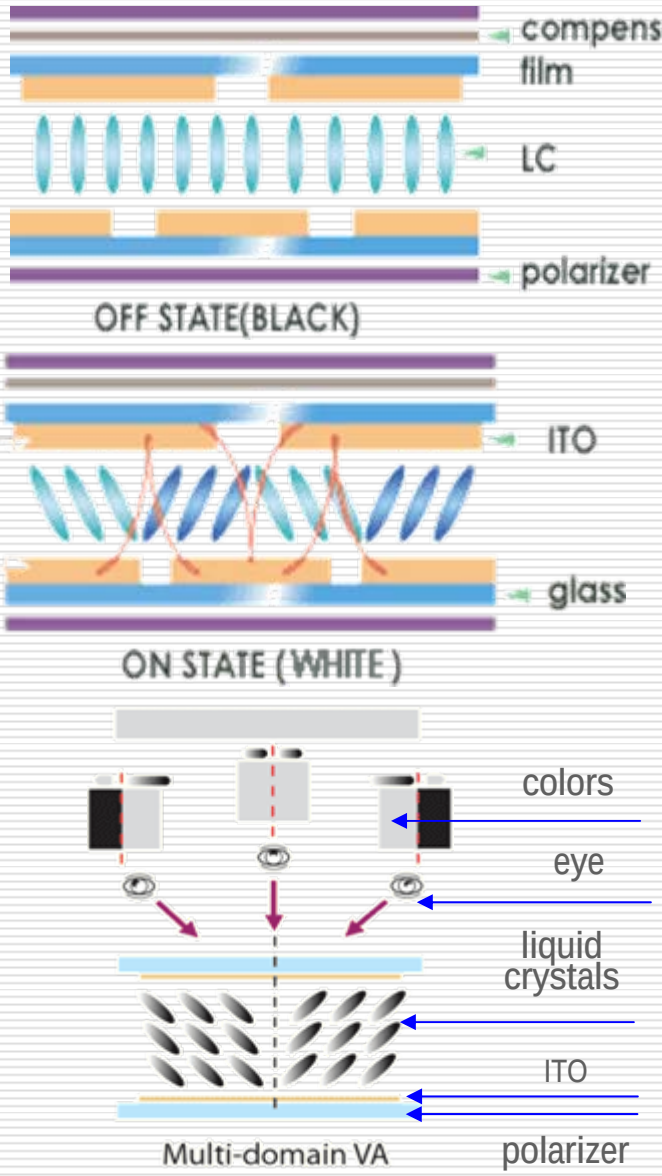

**Example of Specific Solution:** **For resolving indicated physical contradiction, it was proposed to install a curved shield on the housing surface*. This shield will act as a scattering preventive member and is located downstream of the developing roller at a predetermined distance from the photosensitive medium on the OPC. A controller is regulating the voltage that is applied to the scattering preventive member to return the toner back to the photosensitive medium. According to Coulomb's Law, the electrical field will push off charged toner particles with like charges to OPC and does not allow them go out of the cartridge.**

* ***Electro-Photographic Image Forming Apparatus Having A Function For Preventing Toner For Scattering And Control Method For The Same.*** US Patent Application No.US2005/0053392A1; Pub.Date Mar.10.2005; Inventors: Ki-jae Do, Jeong-seon Kim, In-cheol Jeon, Valery Krasnoslobodtsev. Applicant: Samsung Electronics Co Ltd
http://v3.espacenet.com/origdoc?DB=EPODOC&IDX=US2005053392&F

# 4.3. Developing LCD With Wider Viewing Angle



# Exploring Problem Situation

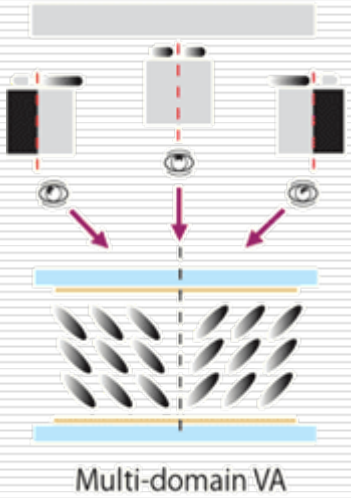


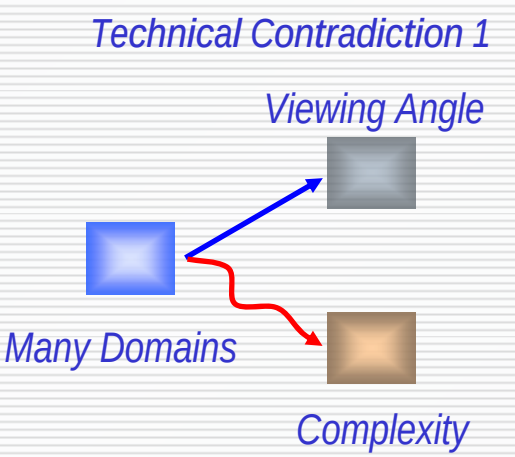

**LCD PVA is the Brand Liquid Crystal Display with Patterned Vertical Alignment.** In the absence of an electric field, a liquid crystal material which has a negative dielectric anisotropy is homeotropically aligned, so that completely black state can be achieved under the cross-polarizers. When an electric field is applied, the fringe field is generated between the two patterned ITO electrodes. As a result, we can get wide viewing angle characteristics due to the spontaneously formed multi-domain structure with the compensation film. Nevertheless PVA method has viewing angle less then In-Plane-Switching (IPS) method (compare 170 and 175 degree). Therefore, the general quality of display picture is getting worse.

**The main problem**: "How to increase the viewing angle of display with patterned vertical alignment and thus to increase the quality of the display picture?" For receiving this result a domain (pixel) should be divided at least into two sub-domains (sub-pixels) for improving the lateral visibility, and sub-domains should have different voltages. However, such a division seriously increases complexity of the LCD structure.

**The managerial statement** of this project was: "It is necessary with minimum modifications of the display to increase the viewing angle and to preserve initial design and operating PVA principle of the LCD."

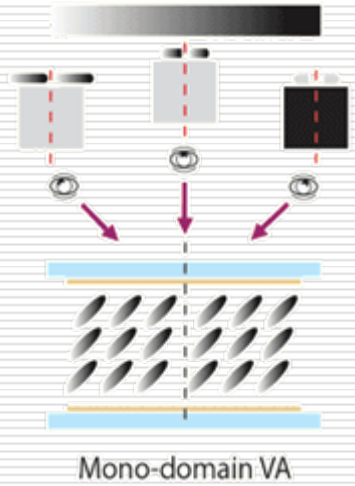
# Formulating The Problem Model

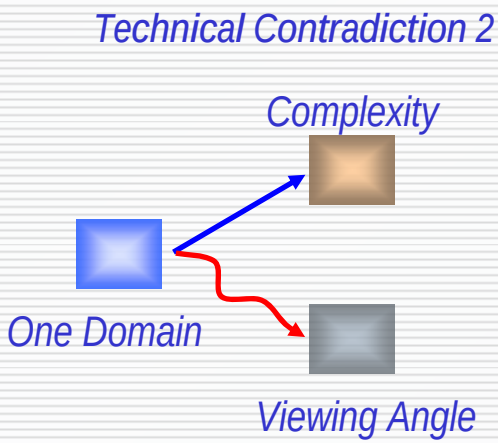



**Technical Contradiction 1:** If there are many domains then the viewing angle is improved but the complexity of the LCD structure is increased and it's design is getting worse

**Technical Contradiction 2:** If there is one domain then complexity of LCD structure is decrease (and design is improved), but the viewing angle is getting worse.



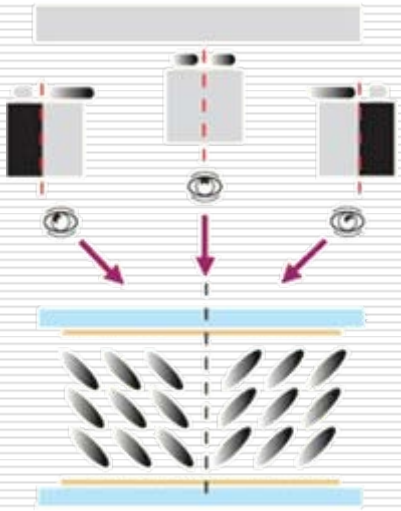

**Main Function** is providing an enlarged viewing angle (i.e. the 1st scheme)

**Product:** luminous flux through domain

**Tool:** Domain

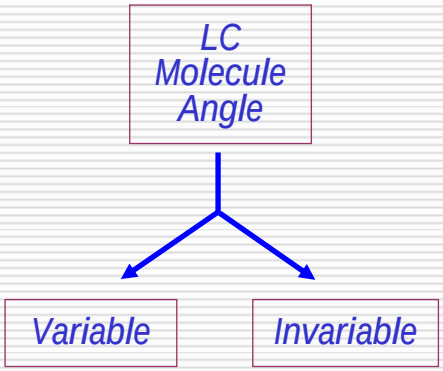
In order to solve this problem we should find some **X-element** (changes to the system) that provides multi-domain structure with enlarged viewing angle and eliminates complexity of the LCD structure

# Developing An Ideal Solution



Multi-domain VA

*Physical Contradiction*



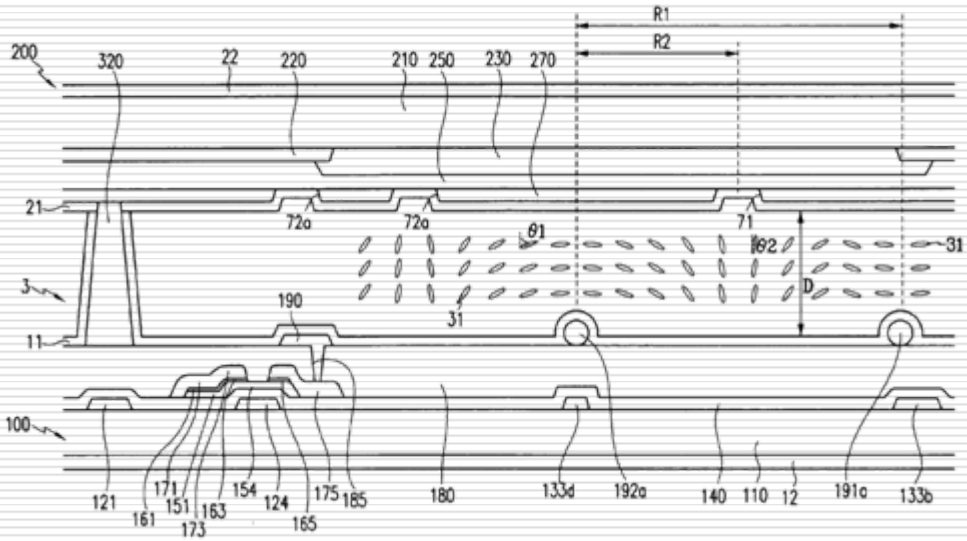

**Physical Contradiction:**

In the ***operating zone*** of the domain between two polarizers the oblong molecules of liquid crystals should be located with variable tilt angle relatively domain's axis for providing enlarged viewing angle, and should be located with invariable angle in order to use just the same voltage and provide simple LCD structure

**Ideal Solution:**

The space into the domain between polarizers *(operating zone)* itself arranges molecules of liquid crystals with variable tilt angle during light-transformation process *(operating time)* and apply just the same voltage for providing simple LCD structure

# Developing Specific Solution:
## Pixel With Nonhomogeneous Electric Field




**Example of Specific Solution:** For resolving indicated physical contradiction, the pixel's structure of the liquid crystal display* with nonhomogeneous electric field and application of just the same voltage has been proposed.
The strength of the electric field in the LC layer 3 continuously decreases farther from the branch electrodes 191a-192a. Since the tilt angle of the LC molecules 31 depends on the strength of the electric field, the LC molecules 31 near the branch electrodes 191a-192a have a large tilt angle θ1 relative to those far from the branch electrodes 191a-192a that have a small tilt angle θ2. The LC molecules 31 that are disposed equidistant from adjacent branch electrodes 191a-192a, i.e., those on a vertical plane passing through the cutouts 71-72 have the largest tilt angle.
Accordingly, the tilt angle of the LC molecules 31 on each sub-area continuously varies such that a region (referred to as a domain) of the LC layer 3 disposed on each sub-area has an infinite number of sub-domains having different tilt angles. The optical properties of the sub-domains compensate for each other to improve the lateral visibility.

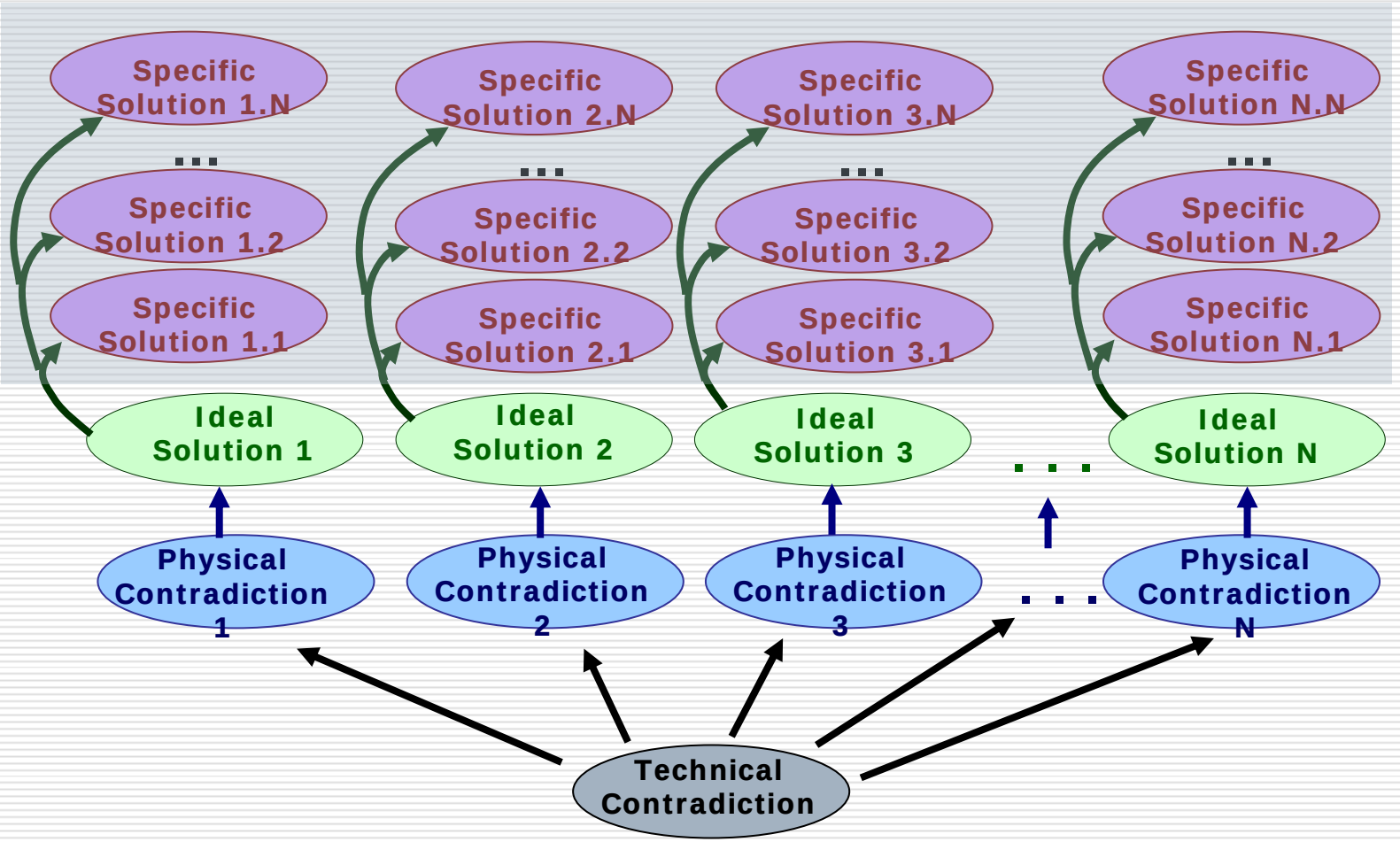
So, the physical contradiction has been resolved by separation in space and inside each domain tilt angle is the same but in different domains tilt angles are different one at the same voltage. The shapes and the arrangements of the branch electrodes 191a-192a and the cutouts 71-72 may be modified.

- ***Liquid Crystal Display.*** U.S. Patent Application No. US2006092116; Pub.Date 2006-05-04; Inventors: Um Y.-S., Lyu J.J., Lee W.-S., Jang T.-S., Kim J.-S., Krasnoslobodtsev V. Applicant: Samsung Electronics Co Ltd
  http://v3.espacenet.com/textdoc?DB=EPODOC&IDX=US2006092116&F=0

# Projects' Results

| | Robotic Vacuum Cleaning | Non-Contact Printing | LCD View Angle Improving |
|---|---|---|---|
| **Project Period** | **5** months | **3** months | **3** months |
| **Developed TRIZ Solutions** | 30 | 25 | 18 |
| **Consolidated Patent Applications** | 14 | 5 | 6 |
| **Industrial Applications** | 3 | 3 | 3 |

# Solution Area




The cases studies show that one technical contradiction can be transformed to several different physical contradictions. Then, each physical contradiction can be solved by using several physical phenomena with development of different designs for the device. So, we developed new proposals from different solution space. This situation is preferable for both inventor and customer because they have several alternative choices for future manufacturing with less cost and improved performance of the product. Also, this multiversion designing provides an effective implementation program for patenting policy for the customer.

# Conclusion

- The structure of the solving process and further application of different TRIZ tools depend on the complexity of the engineering problem. Using TRIZ terminology, the three basic groups of problems which were proposed include: “standard”, “non-standard”, and “research-and-development”.
- The place of each TRIZ tool in the road map of the problem solving process is exhibited. All these tools (totally 15) and their application in problem solving process were presented.
- Utilization of offered road map and consolidated algorithm of problem solving give knowledge for developing solutions for the initial problem. The case studies display significance of this multiversion designing with development of the several solution concepts for providing alternative choices for manufacturing and strong patenting policy

# Questions And Answers