Anticipatory Failure Determination

ITRIZ Applications

Core competency

- Creative Problem Solving
- Vision of future by Evolutionary Patterns

Inventive Problem Solving (IPS)
- How to do something?
- How to improve certain parameters?
- How to eliminate (reduce) a drawback?
- How to reduce cost and improve quality?
- How to solve a non-technical problem**?**

Ideation Failure Analysis (AFD FA)

Ideation Failure Prediction (AFD FP)

Scientific Problem Solving (SPS)

Directed Evolution
- Prediction of useful and harmful events
- Overcoming roadblocks
- Preparing an individual to control his/her destiny

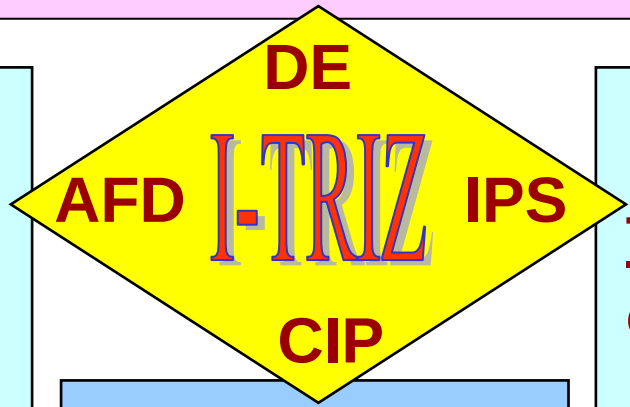
Intellectual Property Validation and Enhancement

I-TRIZ a total system

I-TRIZ APPLICATIONS

Directed Evolution

A systematic procedure for strategically evolving future generations of technological systems



Anticipatory Failure Determination

Failure Analysis

A systematic procedure for identifying the root causes of a failure or other undesired phenomenon in a system, and for making corrections in a timely manner.

Failure Prediction

A systematic procedure for identifying beforehand, and then preventing, all dangerous or harmful events that might be associated with a system.

Control of Intellectual Property

A systematic procedure for increasing IP value and providing protection from infringement and circumvention.

Inventive Problem Solving

A systematic procedure for resolving tough technological problems, enhancing system parameters, improving quality, reducing cost, etc. for current generations of products and technologies.

Anticipatory Failure Determination

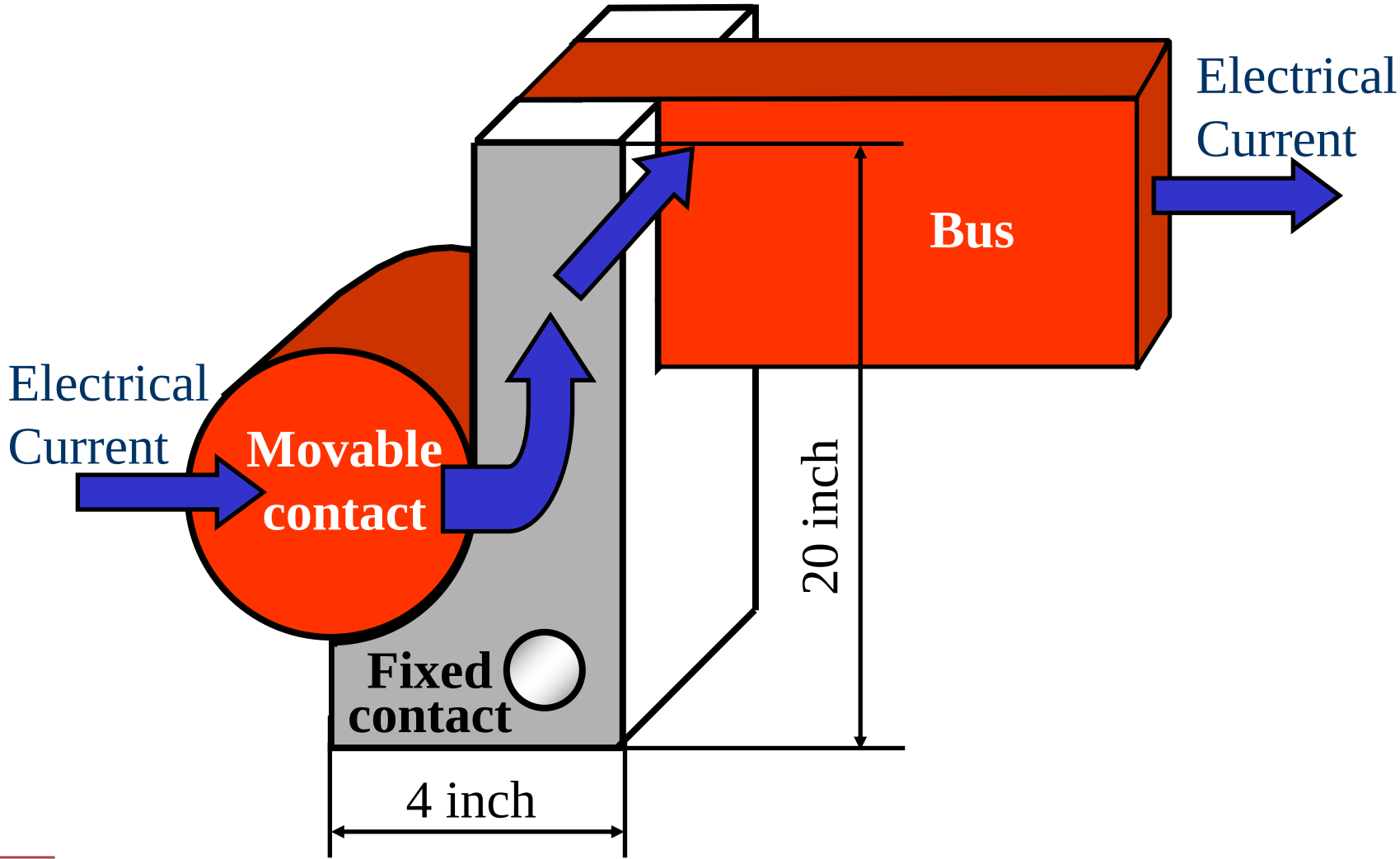
Russian name:
Subversive Analysis

Anticipatory Failure Determination (AFD) – an efficient and effective method for analyzing, predicting and eliminating failures in systems, products, and processes. AFD guides users in documenting the situation, formulating the related problem(s), developing hypotheses, verifying potential failure scenarios, and finding solutions to eliminate the problem(s). It is a unique and powerful approach that favorably impacts costs associated with quality, safety, reliability, recalls, and warranty claims.

Anticipatory Failure Determination

Inception of the Idea

Electrical Contact Cost Reduction Project



Group Reaction

He is too young…

too aggressive…

too insolent …

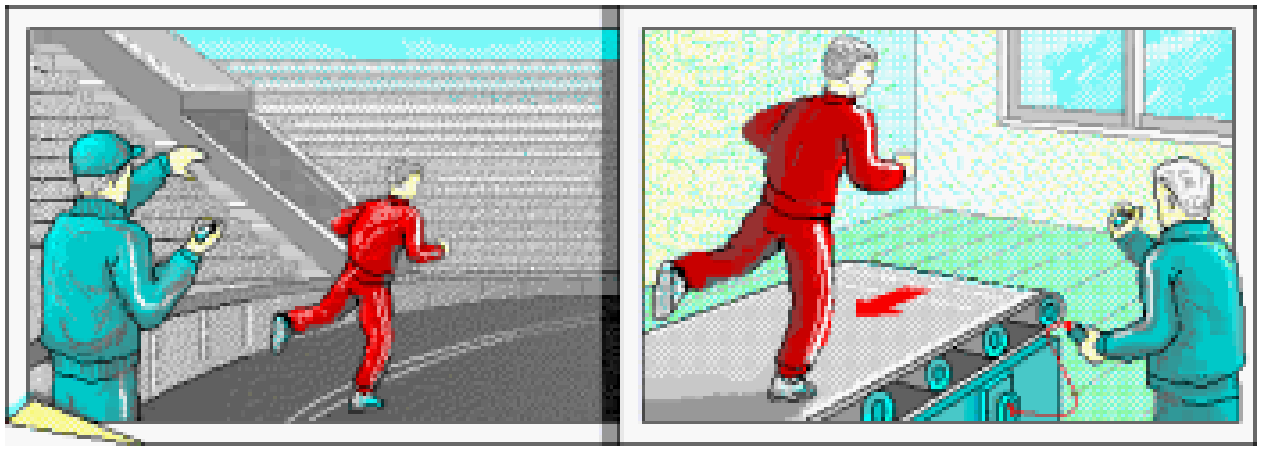
too annoying …

Kill him! Sabotage!

How to inverse the group attitude?

Inversion Operator

a. Instead of an action dictated by the specifications of the problem, implement an opposite action
b. Make a moving part of the object or the outside environment immovable and the non-moving part movable
c. Turn the object upside-down



A correct race chart and an understanding of when to run at a moderate or fast pace are some of the secrets of runners' victories, particularly of medium- and long-distance runners. The race chart is perfected during years of training, during which the coach never ceases clicking his stopwatch.

A more efficient method of training is to have the athlete run on the moving track of a treadmill while the coach varies the track speed, thus controlling the pace of the athlete.

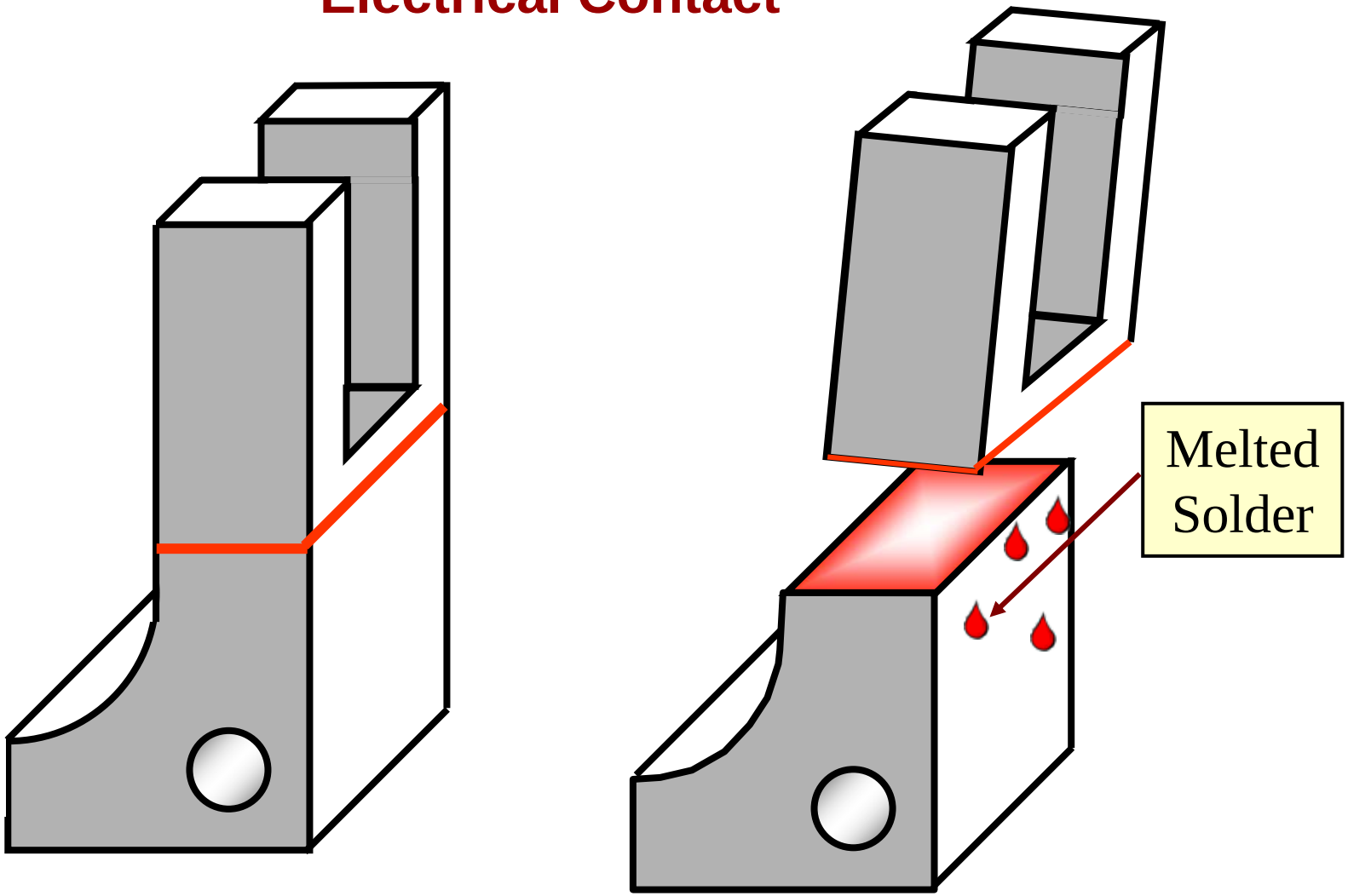
Inversion Operator

a. Instead of an action dictated by the specifications of the problem, implement an opposite action
b. Make a moving part of the object or the outside environment immovable and the non-moving part movable
c. Turn the object upside-down

You do not like to improve the system?
Good!
Try to make it even worse! But you don't want to be blamed for it…

Do you want us to invent a subversion????

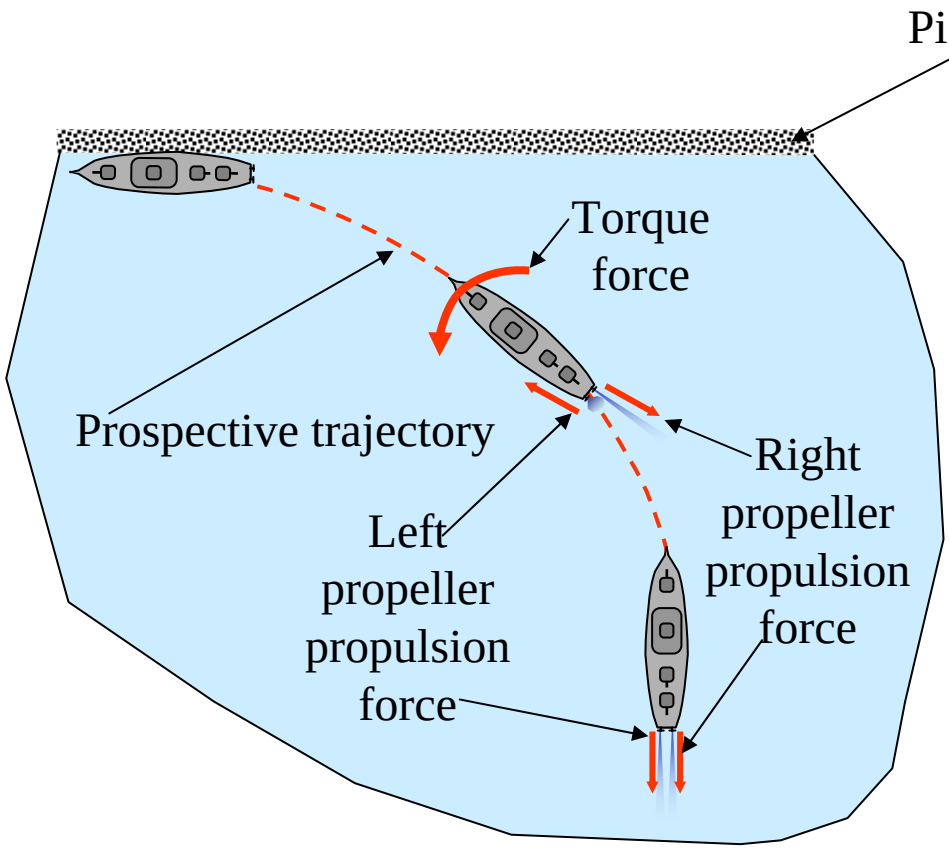
Electrical Contact



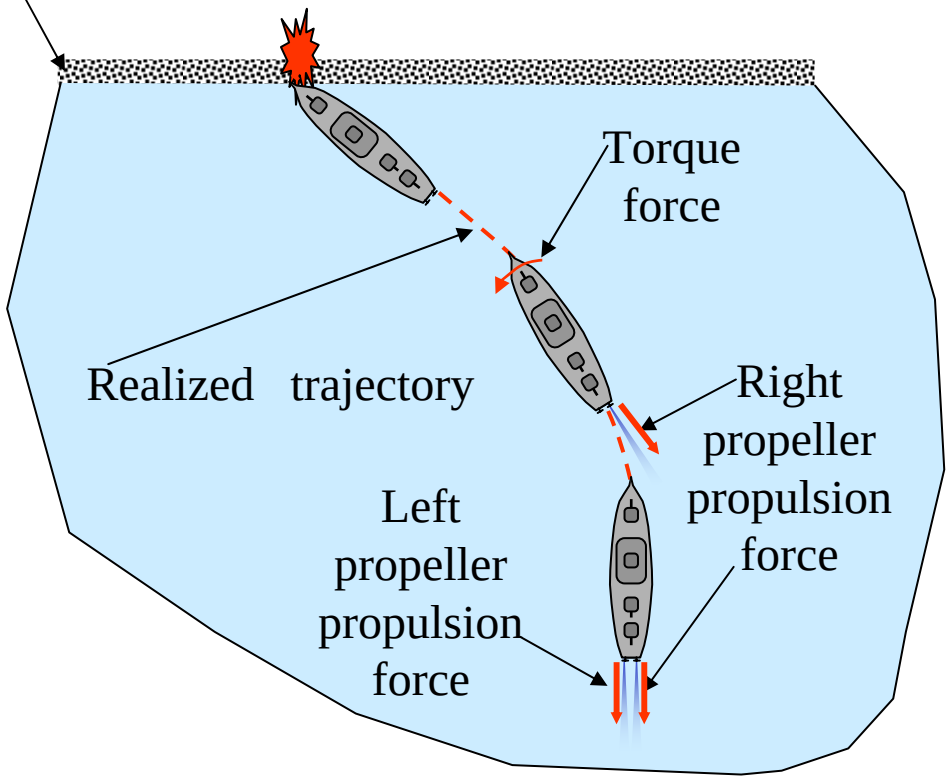
Small and normal current

Enormous current

Ship Accident

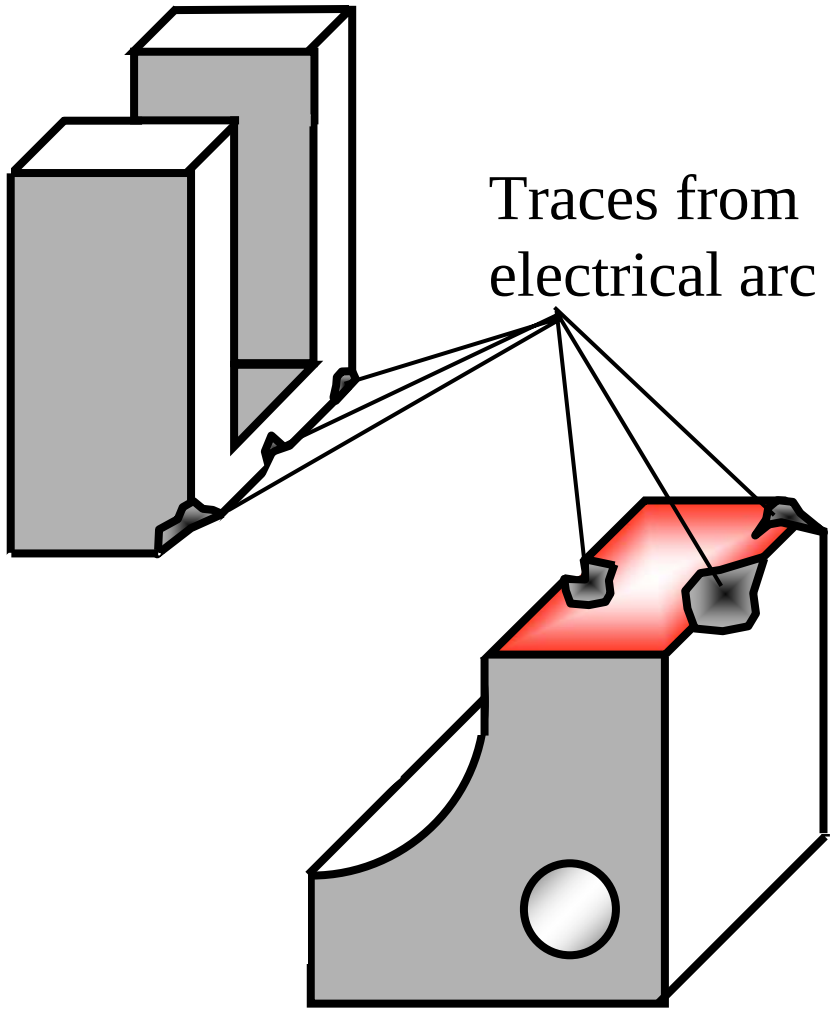


Successful Scenario for the ship mooring



Accident happened during the ship mooring

Parts of Electrical Contact after Accident



Main Idea of Ideation Failure Prediction: Problem Inversion

- ***Move from asking:***
  - "what happened to cause the failure" or;
  - "why did the failure occur"

To...

How can we create or invent the failure?

- ***Use TRIZ tools for solving Inverted Problem***

Problems and Disasters from

A "FFI ISSTT" Full of Harmful Resources

Functional
Field (energy)
Information
Ideas
Substance
Space
Time
Trends

Readily Available
- Visible
- Hidden

Mistakes, sabotage etc.

Useful to harm
- Useful Energy
- Useful Objects
- Space Resources of Useful Functions
- Informational Resources of Useful Functions
- Time Resources of Useful Functions
- Resources of Useful Functions

Accumulation

Concentration

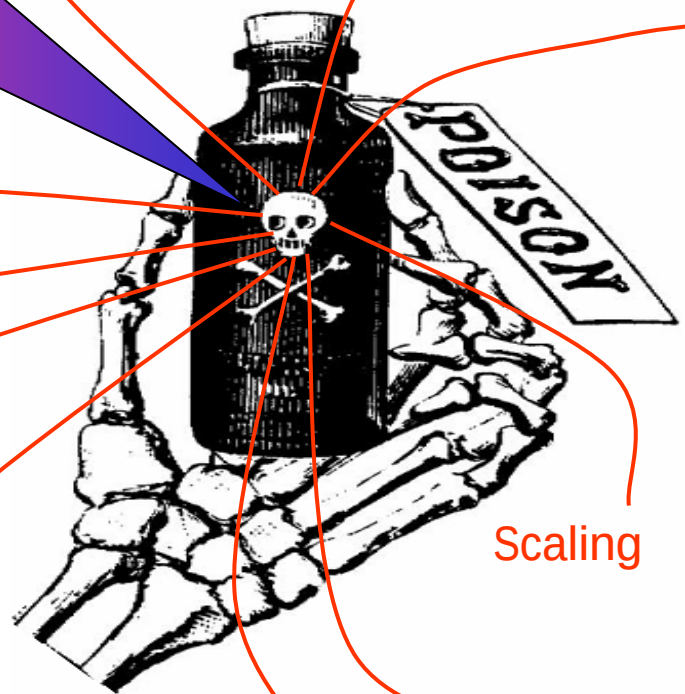
Harmful combination of Ideas, Concepts, Systems

Physical, Chemical and Geometric Effects

Combination of resources

Scaling

Resources of Change

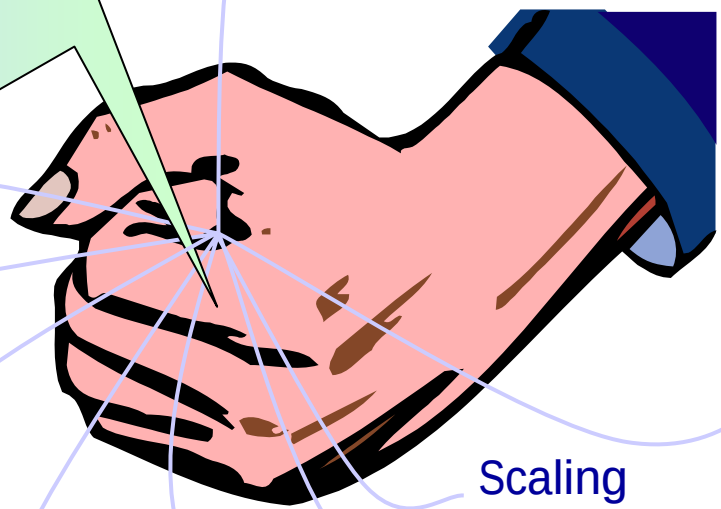


Problems Prevention and/or Elimination
A "FFI ISSTT" Full of Useful Resources

Functional
Field (energy)
Information
Ideas
Substance
Space
Time
Trends

Readily Available
- Visible
- Hidden

Harmful to use
- **Harmful Energy**
- **Harmful Objects**
- **Space Resources of Harmful Functions**
- **Informational Resources of Harmful Functions**
- **Time Resources of Harmful Functions**
- **Resources of Harmful Functions**



Accumulation

Concentration

Leveraging the Combination of Ideas, Concepts, Systems

Natural Use via Physical, Chemical and Geometric Effects

Combination of resources

Scaling

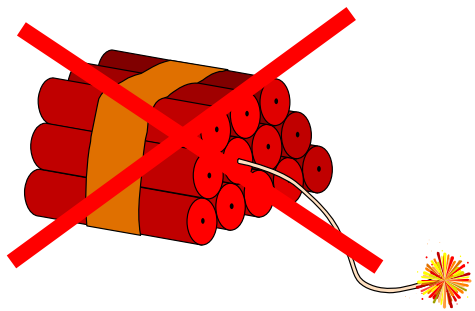
Resources of Change

Anticipatory Failure Determination can help you:

- ***REVEAL***
  the root causes of a failure or drawback

- ***PREDICT***
  all dangerous or harmful events that might be associated with your system, and

- ***PREVENT***
  harm in a timely manner



AFD Applications

AFD - Failure Prediction

Ideation Process for Failure Prediction is a systematic procedure for identifying beforehand – and then preventing – all dangerous or harmful events that might possibly be associated with the system.

AFD -- Failure Analysis

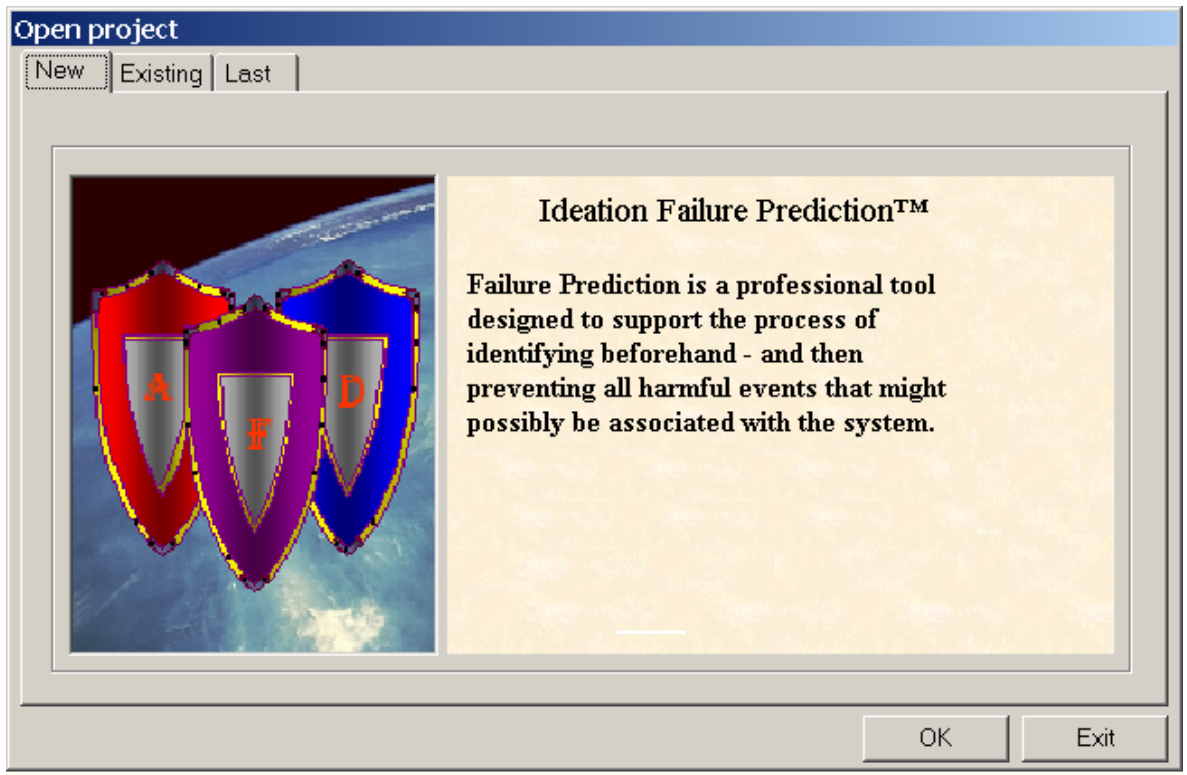
Failure Analysis is a systematic procedure for identifying the root causes of a failure or other undesired phenomenon occurring in a system, and for correcting it in a timely manner.

AFD – Scientific Application

AFD Scientific Application is a systematic procedure for identifying the mechanisms of a phenomenon and discovery of new facts and effects.

ITRIZ Applications

Ideation Failure Prediction



Basic Principles of Murphy's Law:

1. **Mother nature is a bitch**
2. **Anything that can go wrong will go wrong.**
3. **If there is a possibility of several things going wrong, the one that will cause the most damage will be the one to go wrong.**
   Corollary: If there is a worse time for something to go wrong, it will happen then.
4. **If anything simply cannot go wrong, it will anyway.**
5. **If you perceive that there are four possible ways in which a procedure can go wrong, and circumvent these, then a fifth way, unprepared for, will promptly develop.**
6. **Left to themselves, things tend to go from bad to worse.**
7. **If everything seems to be going well, you have obviously overlooked something.**
8. **Nature always sides with the hidden flaw.**
9. **It is impossible to make anything foolproof because fools are so ingenious.**
10. **Every solution breeds new problems.**

Main Idea of Failure Prediction

- ***Instead of asking:***

  "What failures may occur?"

Ask...

How can we *create* or *invent* all possible failures?

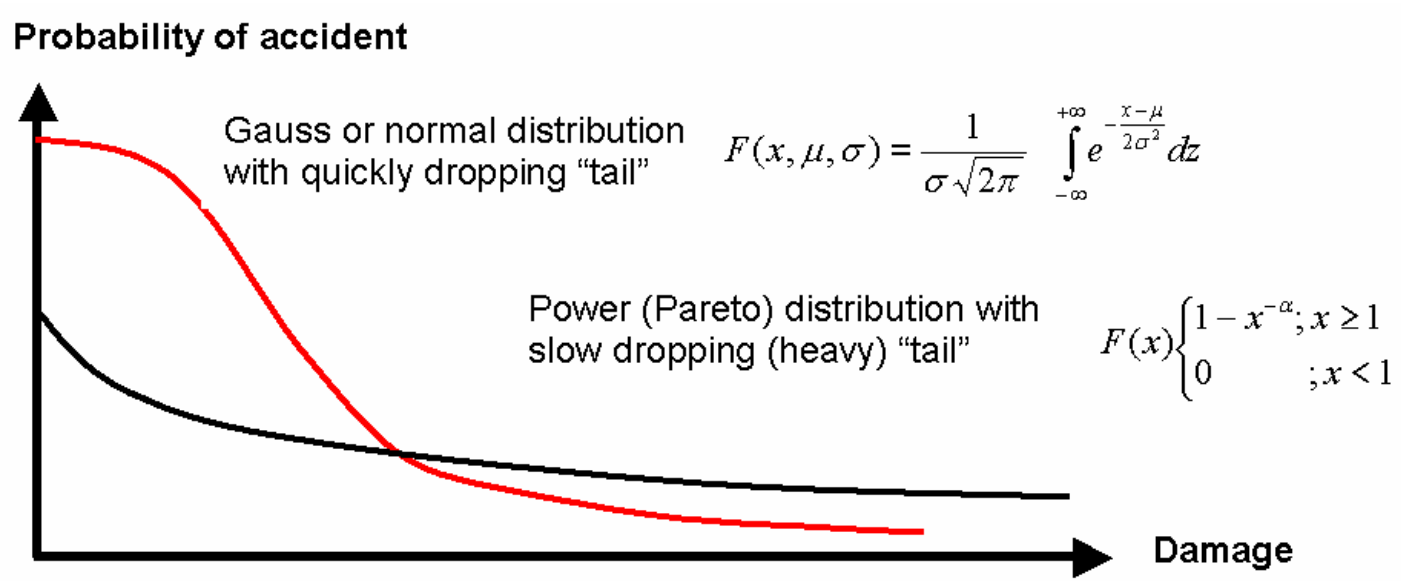
KEY:
Think like
a saboteur!

- ***Use TRIZ tools to solve the Inverted Problems***
- ***Use TRIZ tools to prevent, reduce or eliminate effect of predicted Problems***

Power Function Growth of Damage from Accidents and Catastrophes

It has been recently proven that big accidents and catastrophes associated with substantial damage and number of victims do not comply with usual patterns of normal (Gauss) distribution of probabilities. The real statistics for these types of catastrophes is described by the power (or Pareto) function. These functions have "heavy tail distribution"

Embrechts P., Kluperberg C., Mikosch T., Modeling extremal events for insurance and finance. Springer, Berlin, 1997, 645 p.).

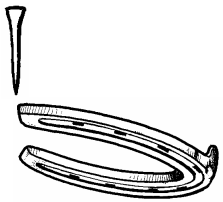


Mechanism of the Power Function Growth

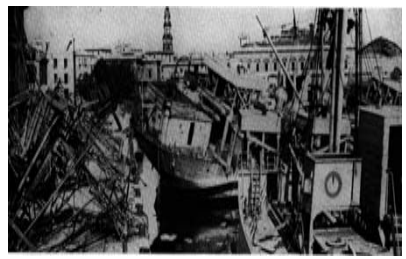
The possible explanation to the power function growth could be that contemporary extreme super powerful catastrophes often represent an expansion of more or less usual accidents that typically should not result in extreme damages, however, they trigger the reinforcing loop resulting in snowball of damages. The reason behind this mechanism could be growing systems' complexity, saturation with feedback links (reinforcing loops) and accumulation of dangerous resources. The size of catastrophic damages ("heavy tail") will grow with increasing complexity of the society.

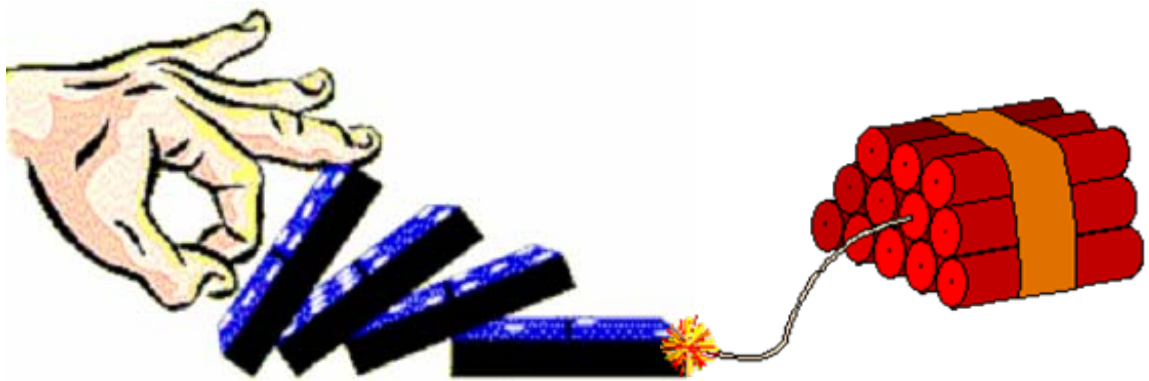
Chain Reactions = Avalanche Action

For want of a nail,
the shoe was lost:
For want of the shoe,
the horse was lost;
For want of the horse,
the rider was lost;
For want of the rider,
the battle was lost;
For want of the battle,
the kingdom was lost,
And all for the want of a nail.



Development of accidents as an avalanche- like release of resources





Failure Prediction Case Studies

What Can Go Wrong with the Marker?

Inversion:

How to Convert Marker in Source of Danger?

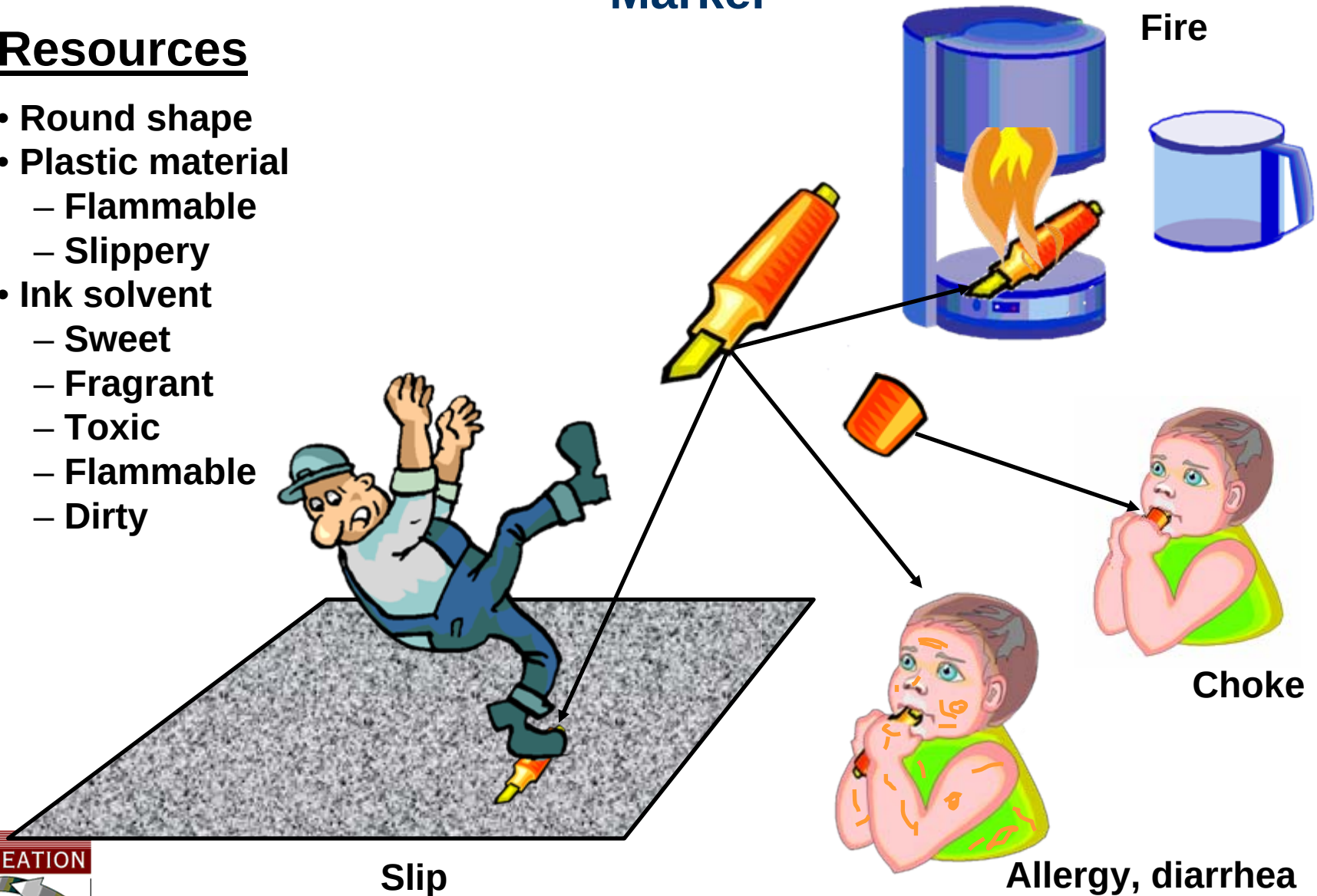
Resources for Harmful Effects

- Round shape
- Plastic material
  - Flammable
  - Slippery
- Ink solvent
  - Sweet
  - Fragrant
  - Toxic
  - Flammable
  - Dirty

Failure Prediction
Marker

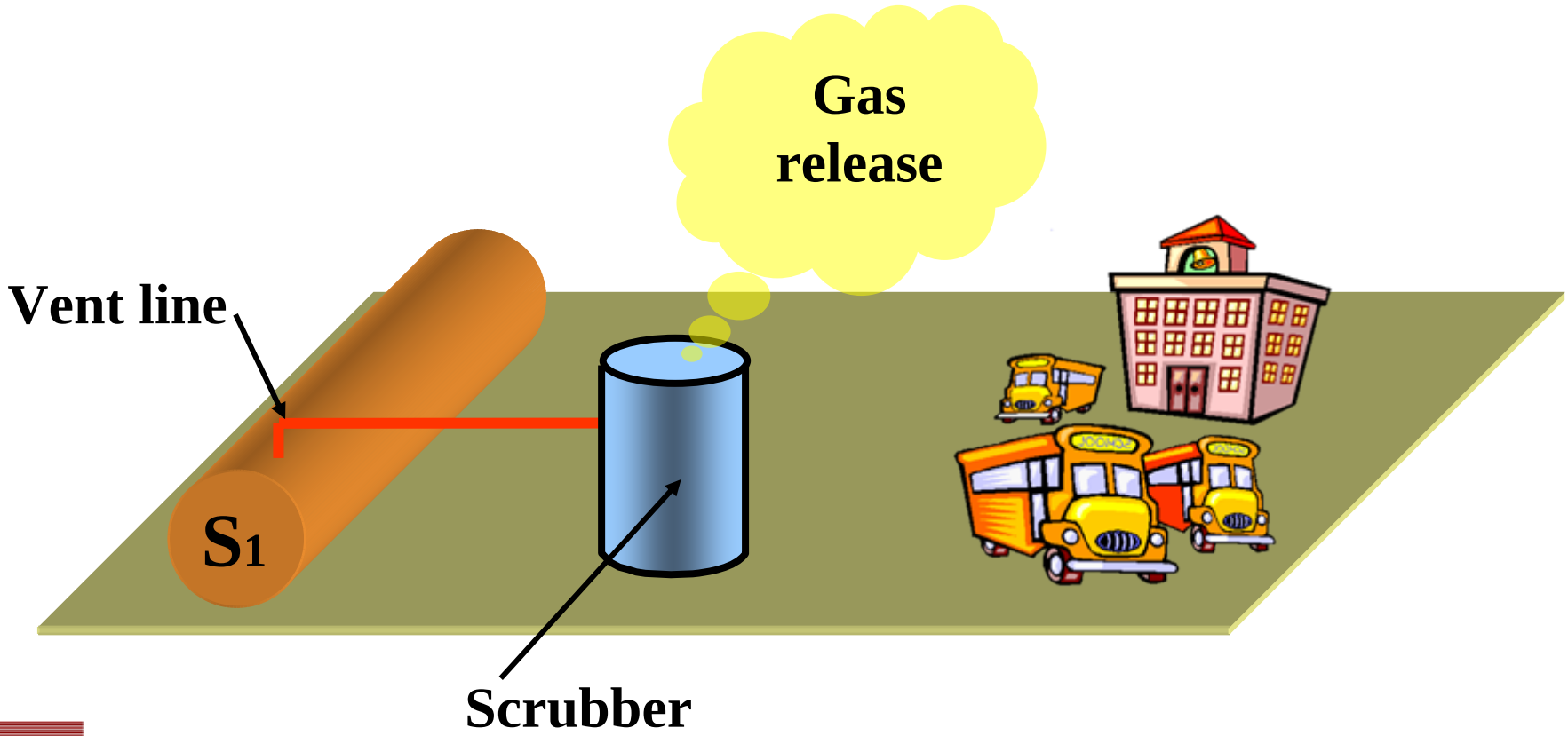
Resources

- Round shape
- Plastic material
  - Flammable
  - Slippery
- Ink solvent
  - Sweet
  - Fragrant
  - Toxic
  - Flammable
  - Dirty



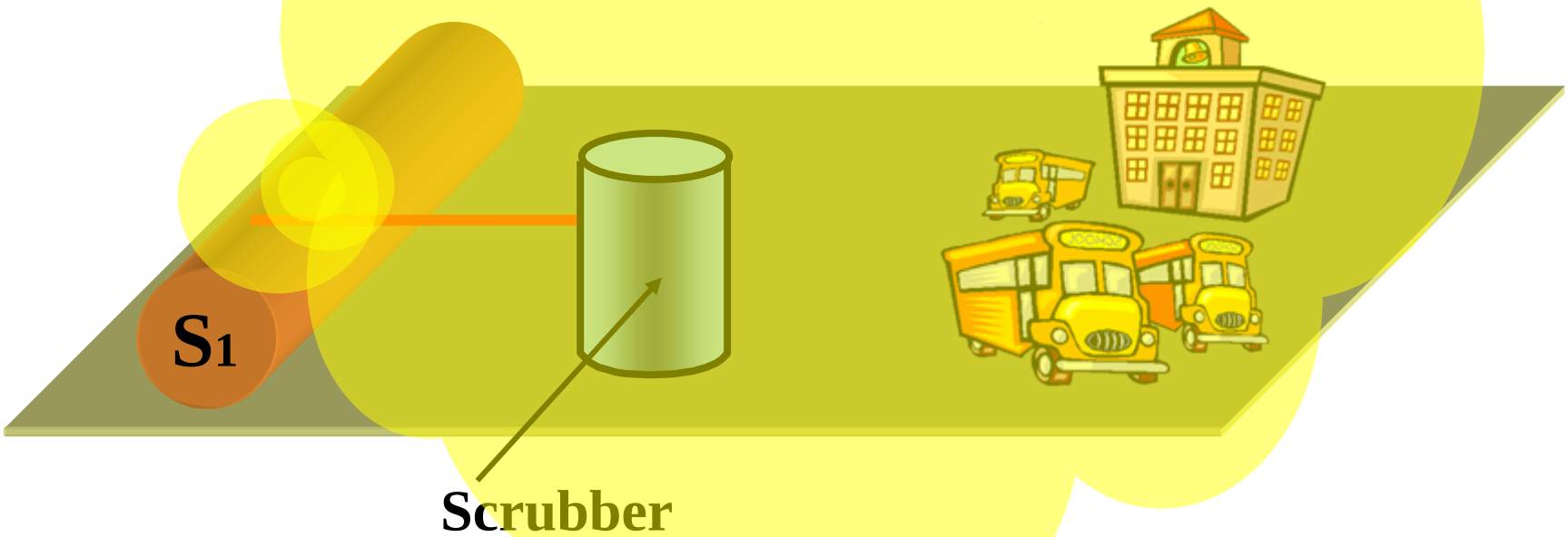
Small Gas Release

Problem/system as stated by customer



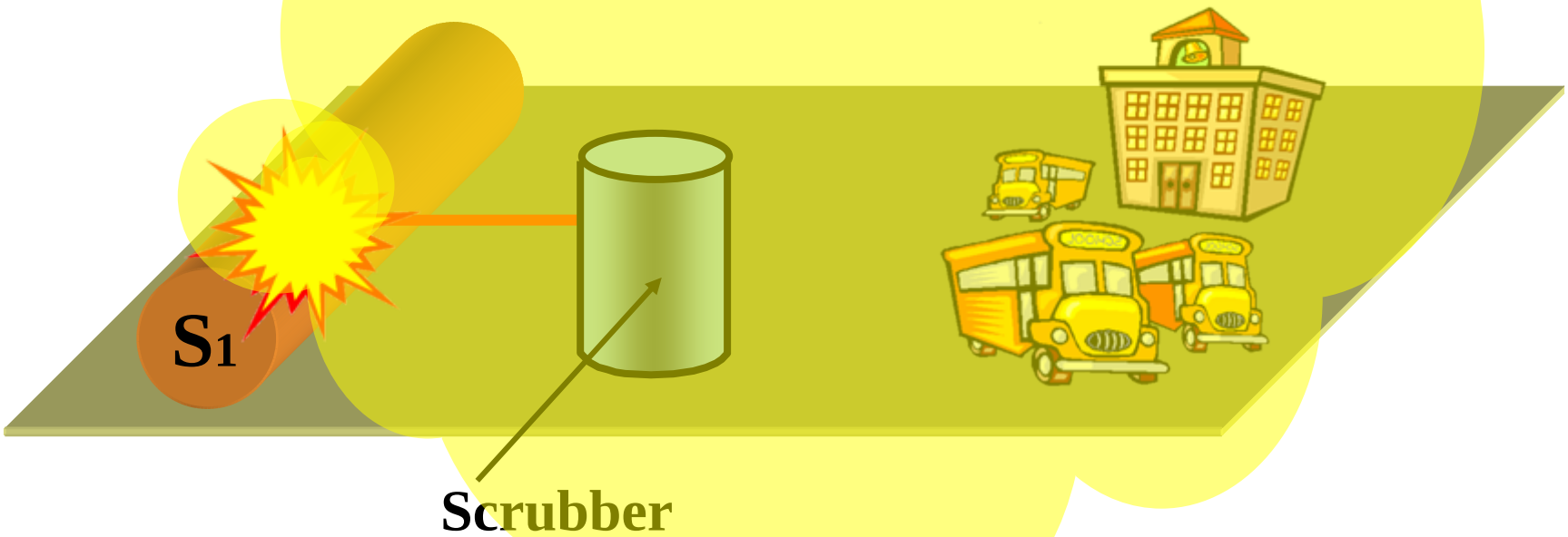
Problem Inversion

Problem as reformulated by AFD specialist



Problem Amplification

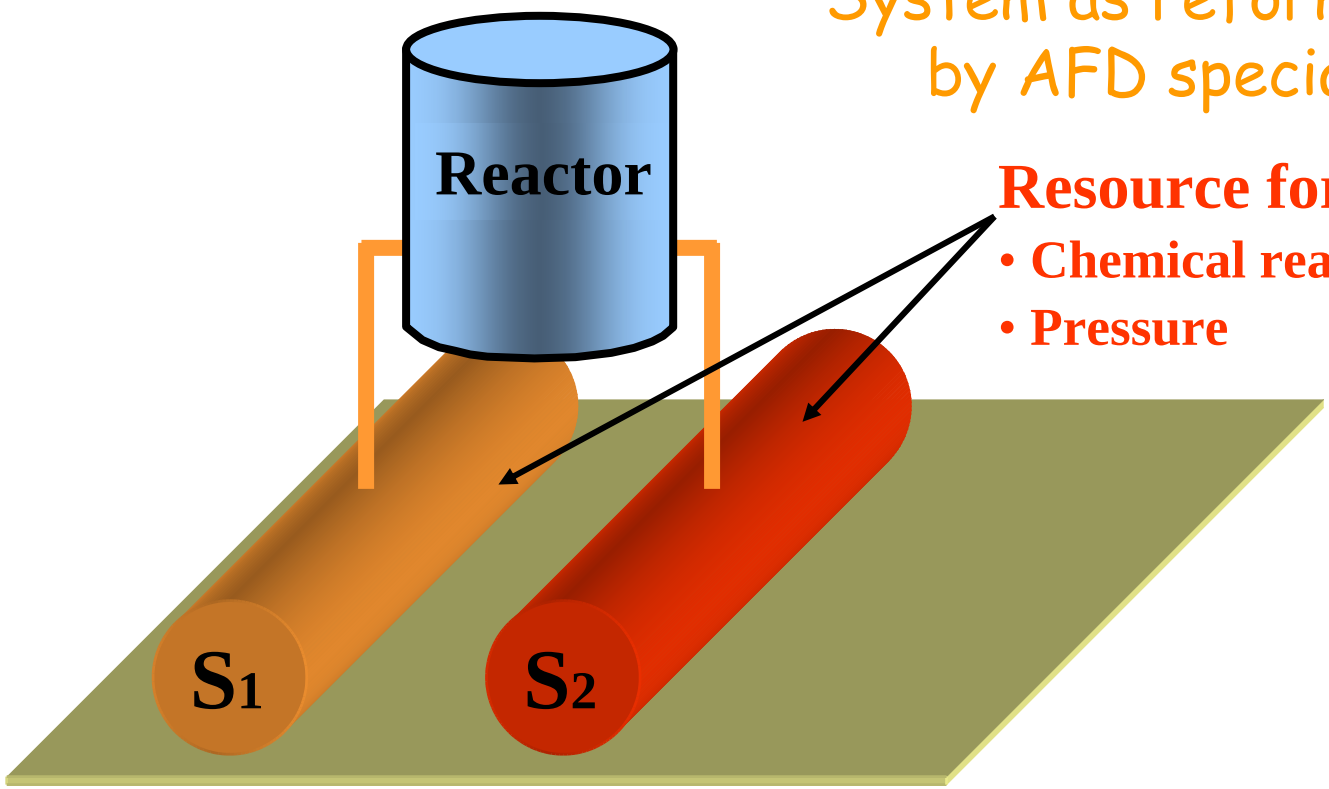
Problem as reformulated by AFD specialist



Resources Revealing

$S_1 + S_2 =$ 

System as reformulated by AFD specialist



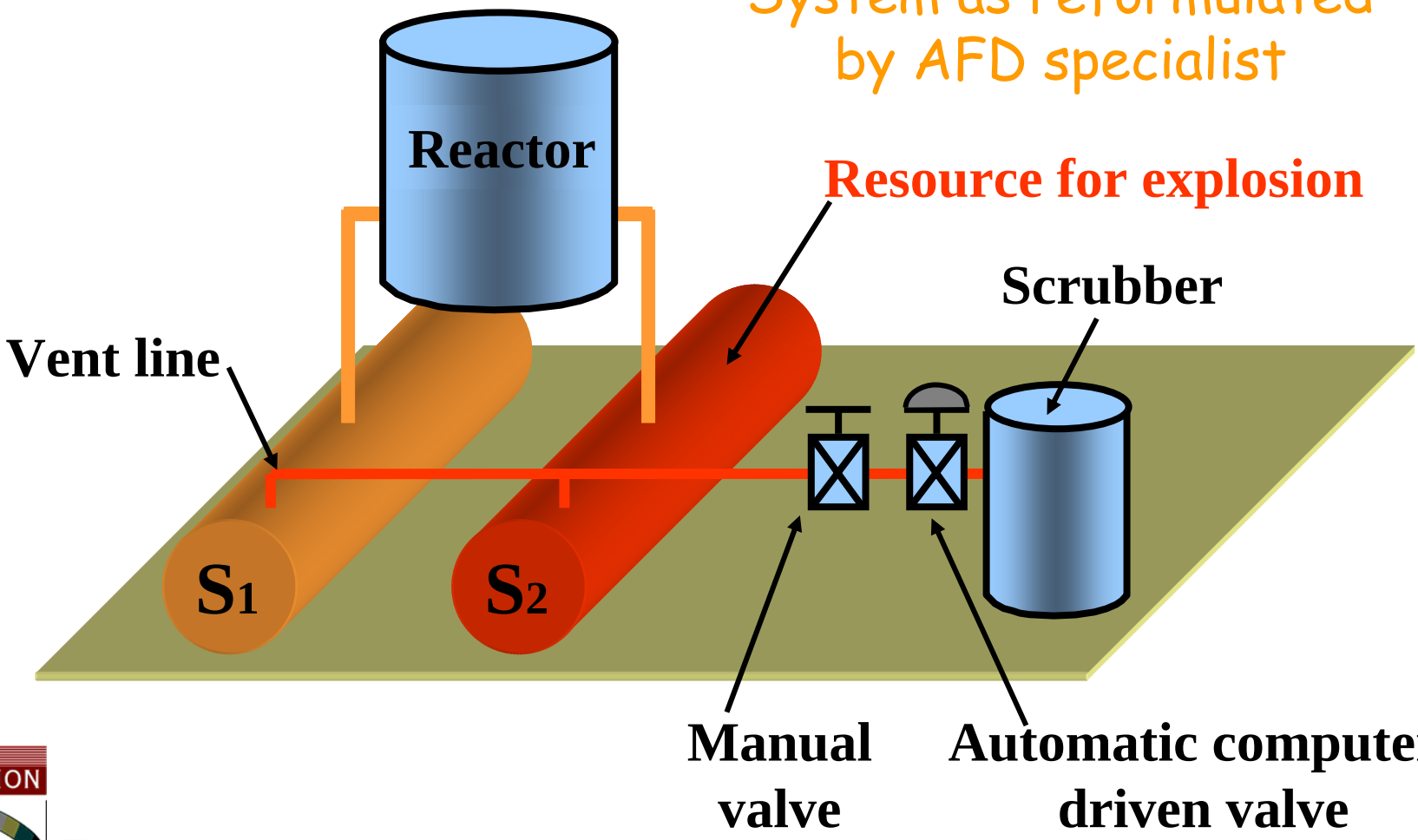
Resource for explosion:

- **Chemical reaction**
- **Pressure**

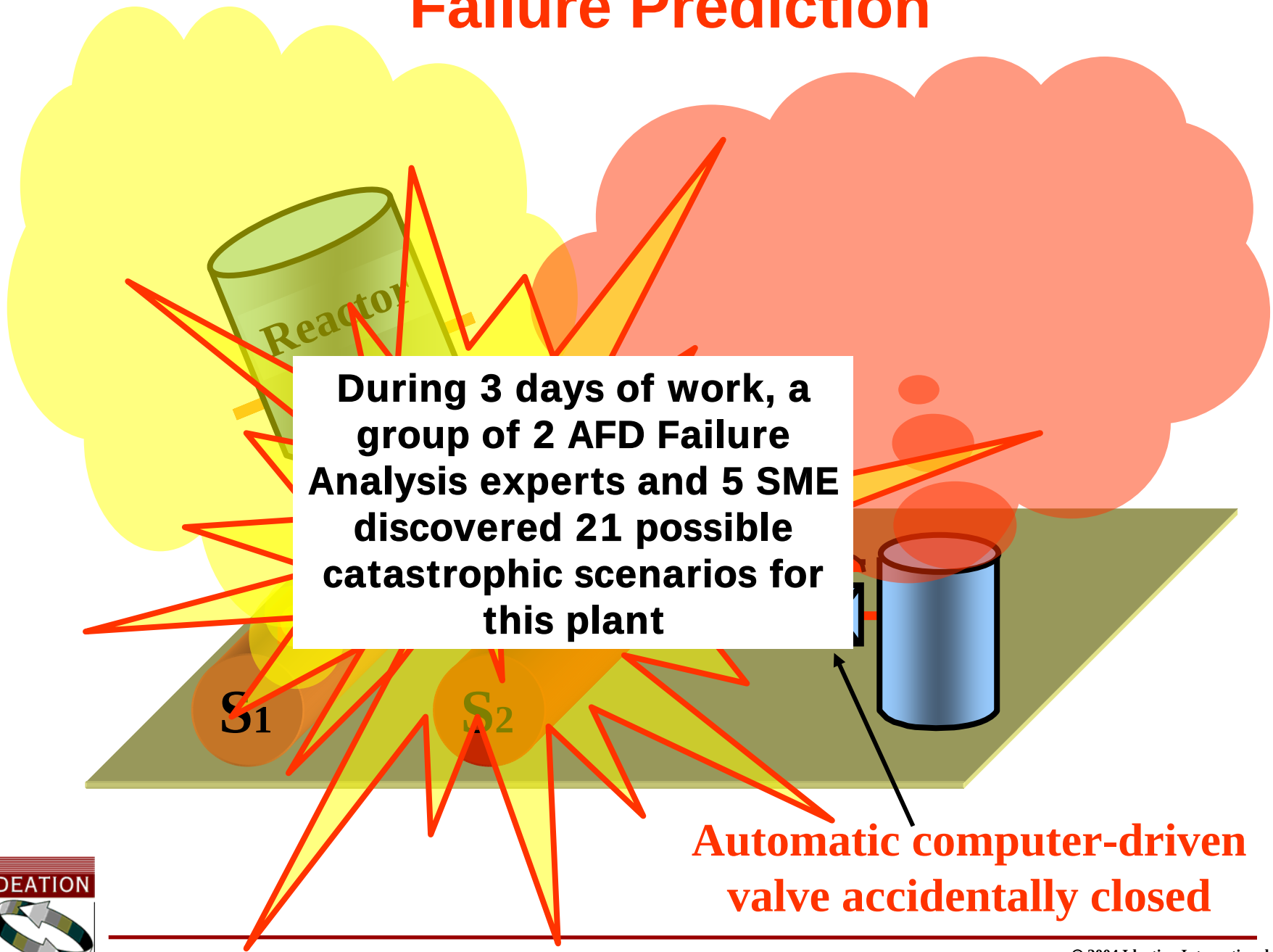
Additional Resources Revealing

$S_1 + S_2 =$

System as reformulated by AFD specialist

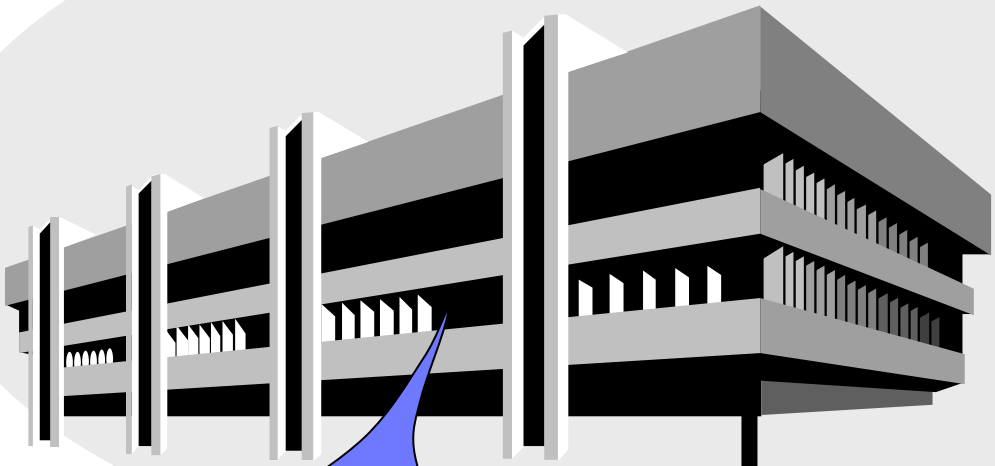


Failure Prediction



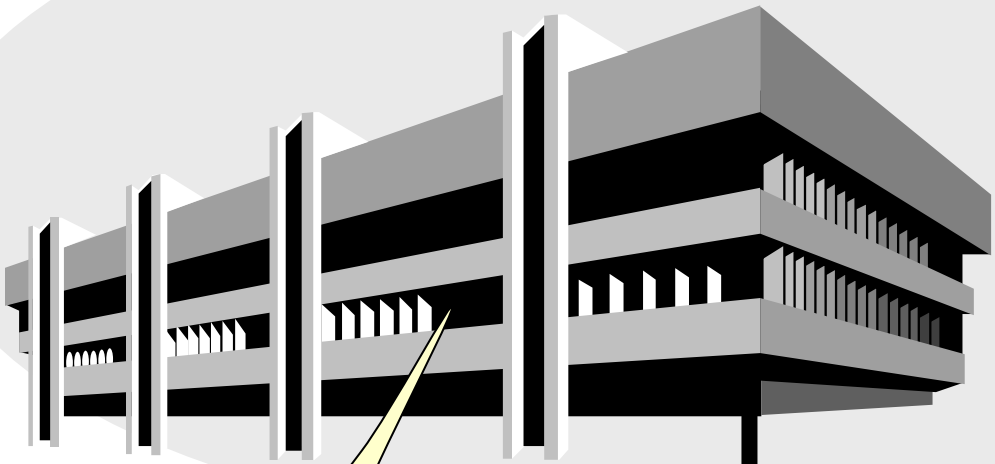
Failure Prediction

Moscow Stock and Commodity Exchange



Failure Prediction

Moscow Stock and Commodity Exchange



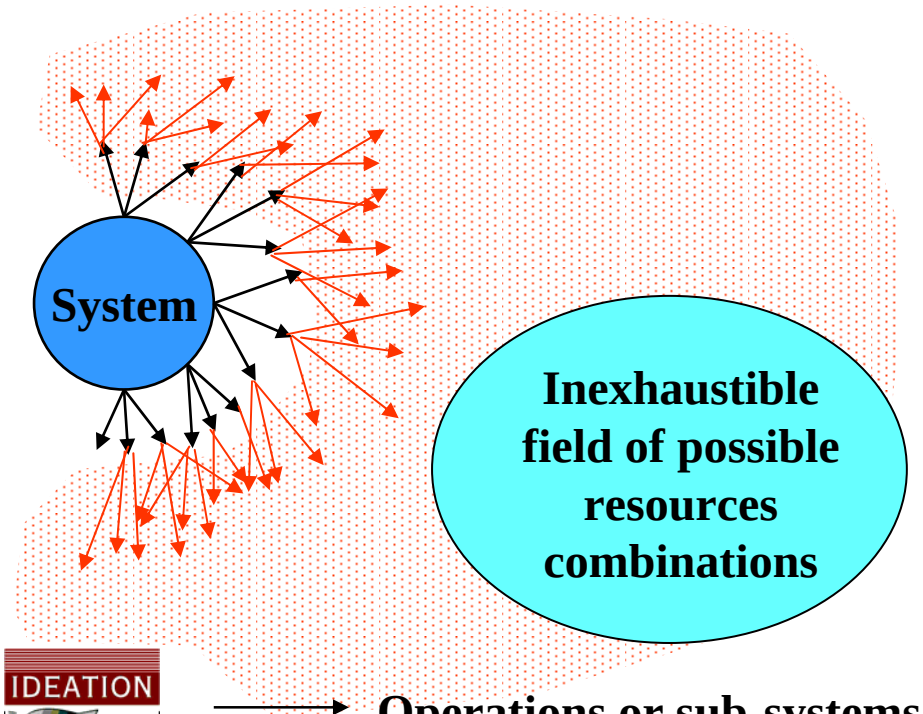
Ventilation

Comparison of Different Methods for Failure Prediction

Direct approach (FMEA, HAZOP. etc.)

What harm can happen?

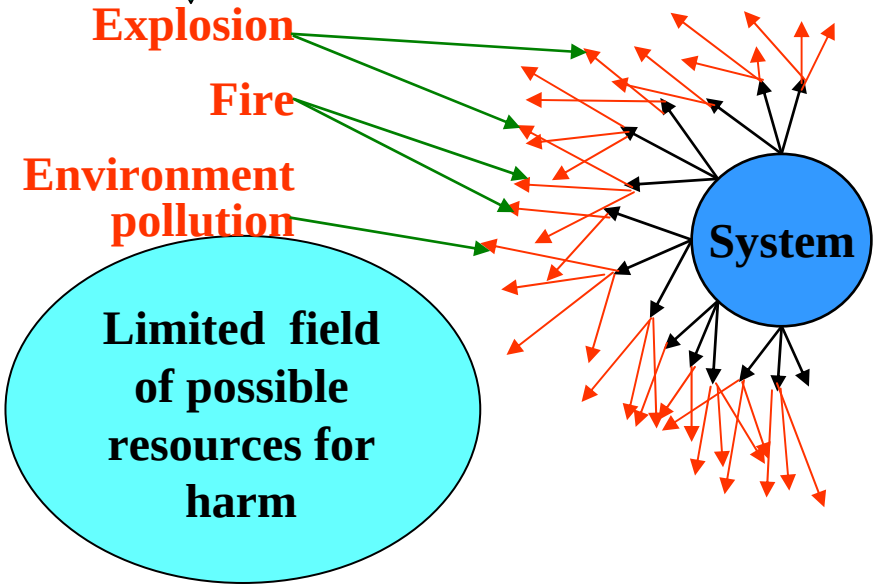
Variants browsing, looking for possible harm



Inverted approach (Ideation Failure Prediction)

What harm can we do?

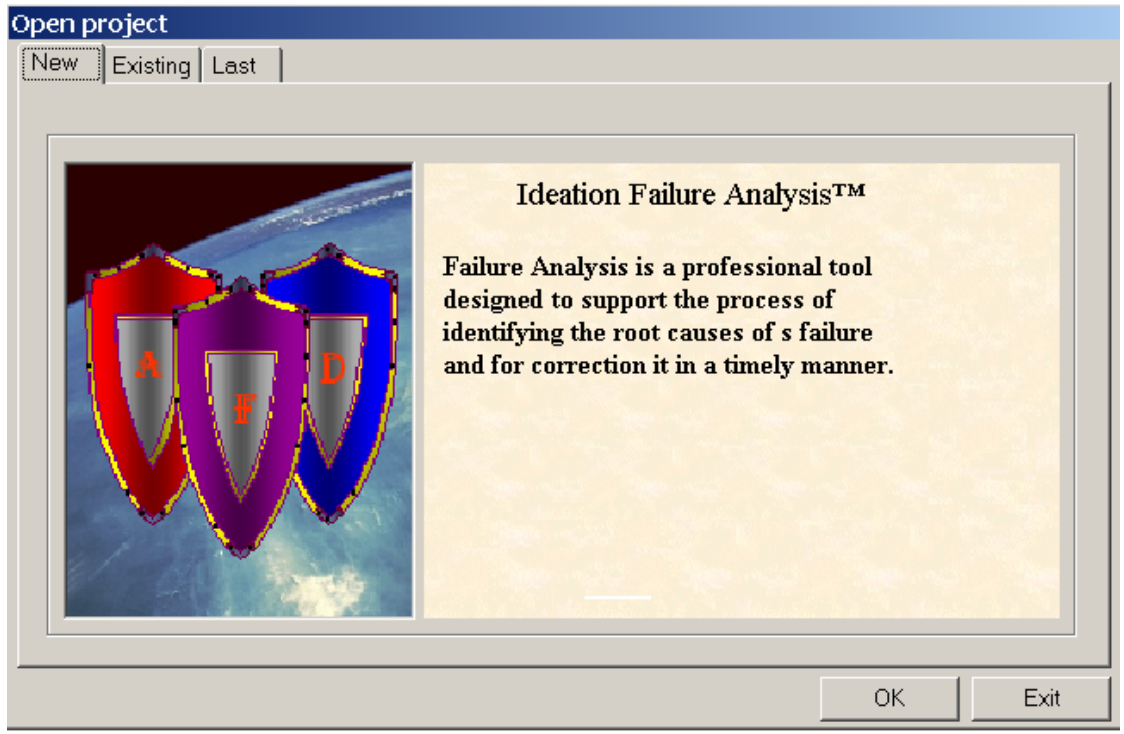
Harm which we should realized → Method of harm realization based on available resources



→ Operations or sub-systems

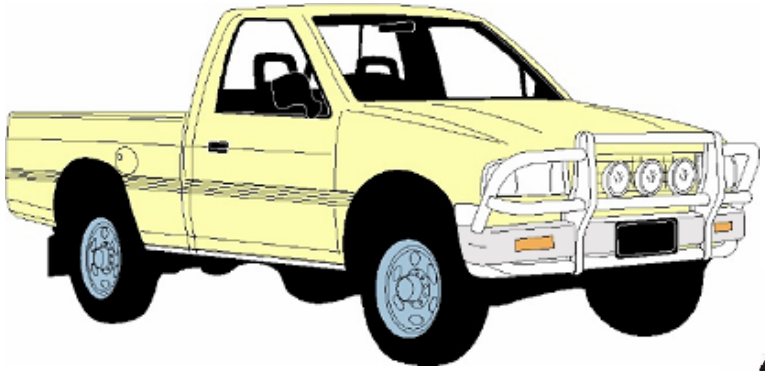
→ Parameters (as a resources)

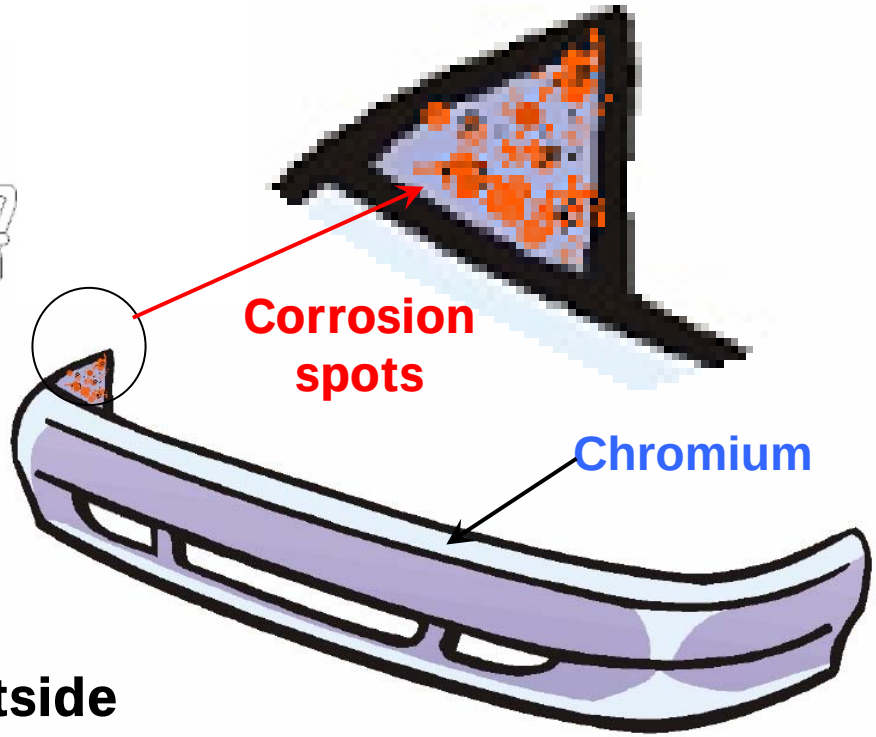
Ideation Failure Analysis



Car Pull Left

Failure Analysis
Bumper Back Side Corrosion Problem





History of one truck

- **Produced – summer 1994**
- **5 weeks on dealership, outside**
- **Dry summer, only one strong rain**
- **Returned to producer with strong corrosion on its back side bumper**

Why corrosion so quick and so strong?

Failure Analysis
Bumper Back Side Corrosion Problem

How to create the strongest corrosion?

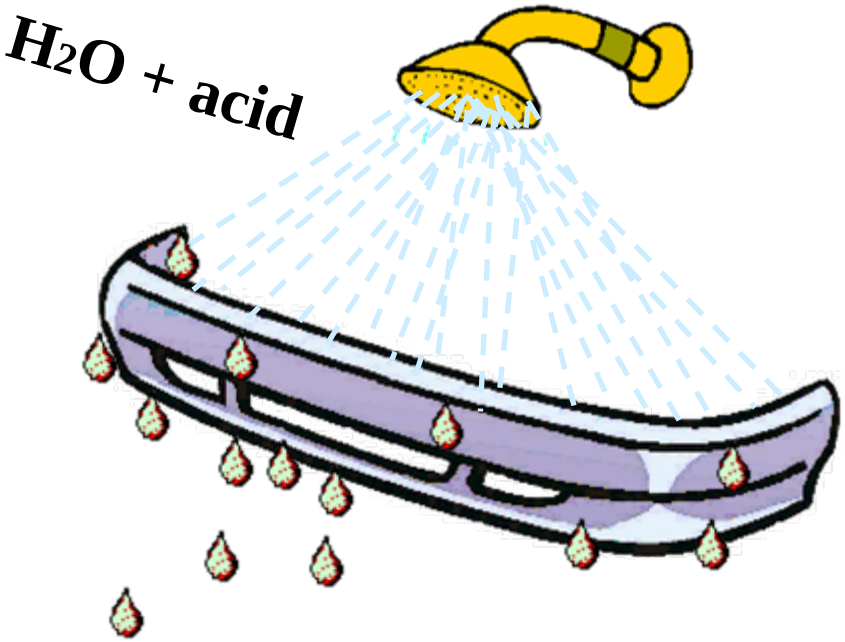
- High humidity in the environment
- Increased oxygen content
- Presence of oxidizing elements – salts, acids, organic waste, etc.
- Electrochemical processes originated by:
  - Passing electrical current
  - Contact of metals with high difference in electrochemical potential.

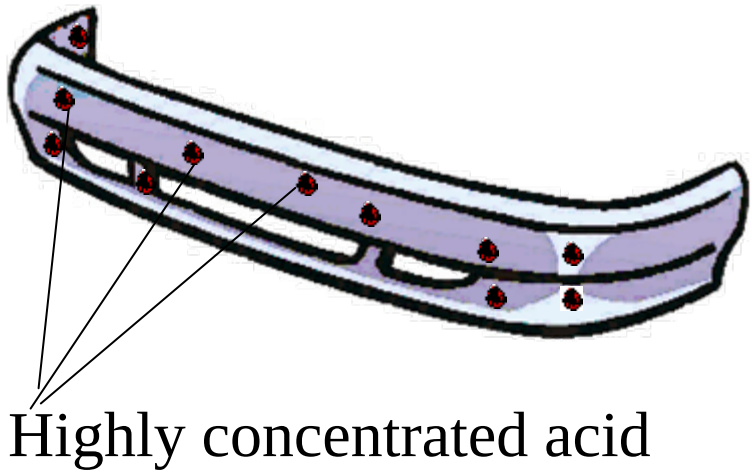
The process' resources include nickel deposited on the surface of the steel bumper as the first layer; chromium layer is deposited on the top of it. Nickel is capable to oxidize iron in the presence of electrolyte.

Bumper Washing and Drying

Washing after
Chromium-Plating

Air Drying
after washing

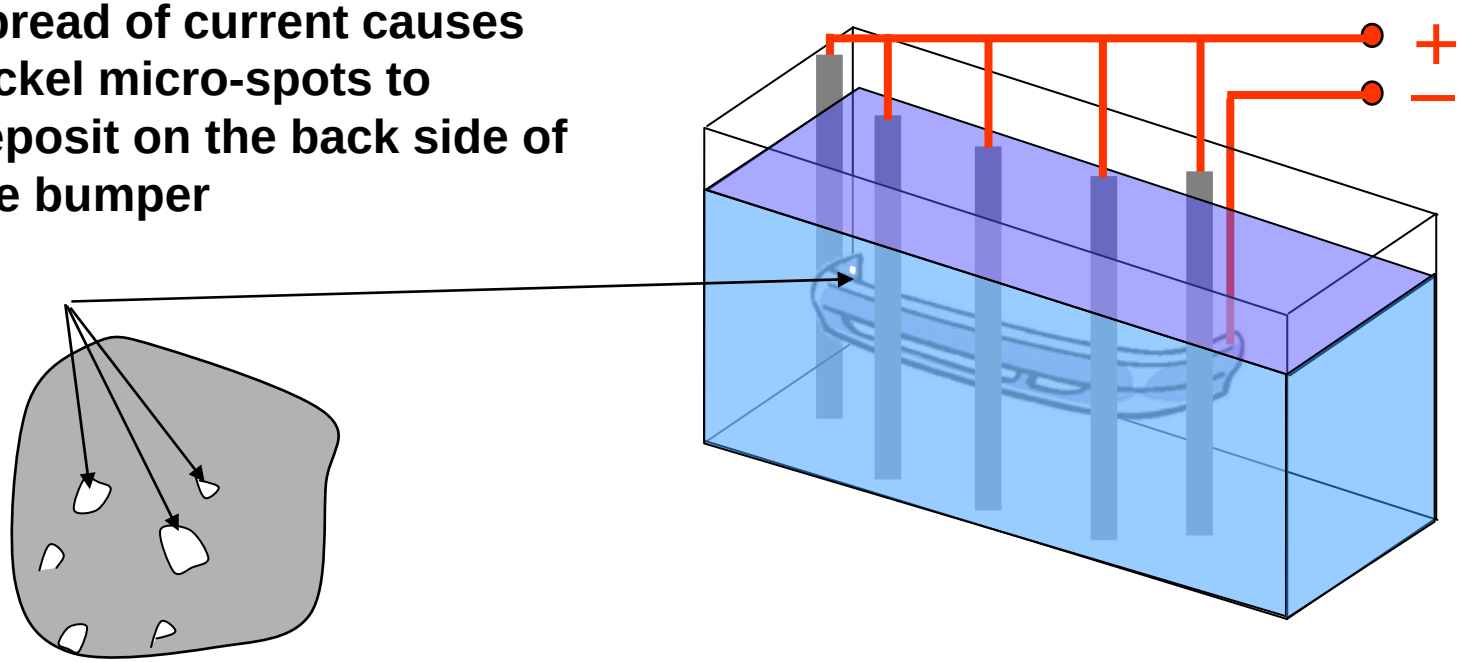




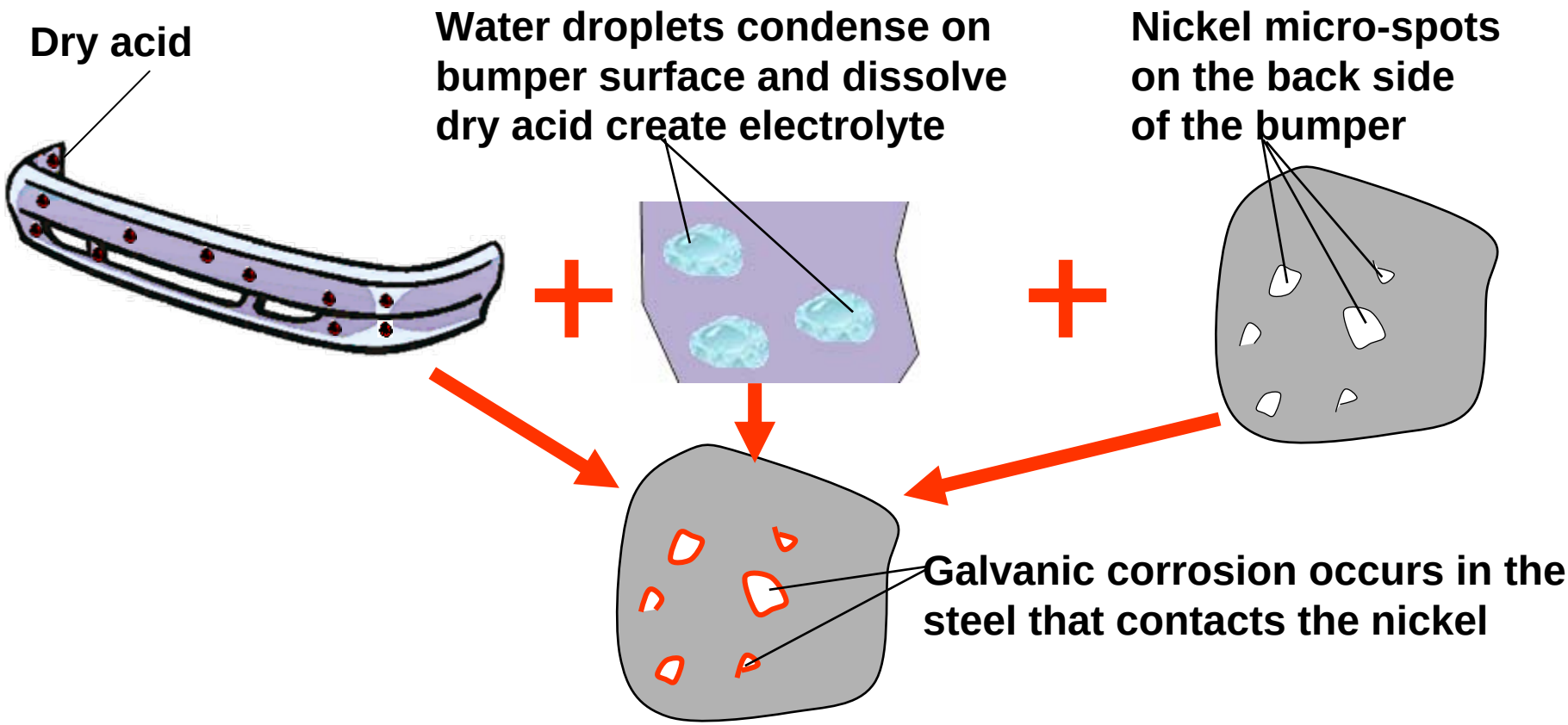
Highly concentrated acid

Bumper Nickel- and Chromium-Plating

Spread of current causes nickel micro-spots to deposit on the back side of the bumper



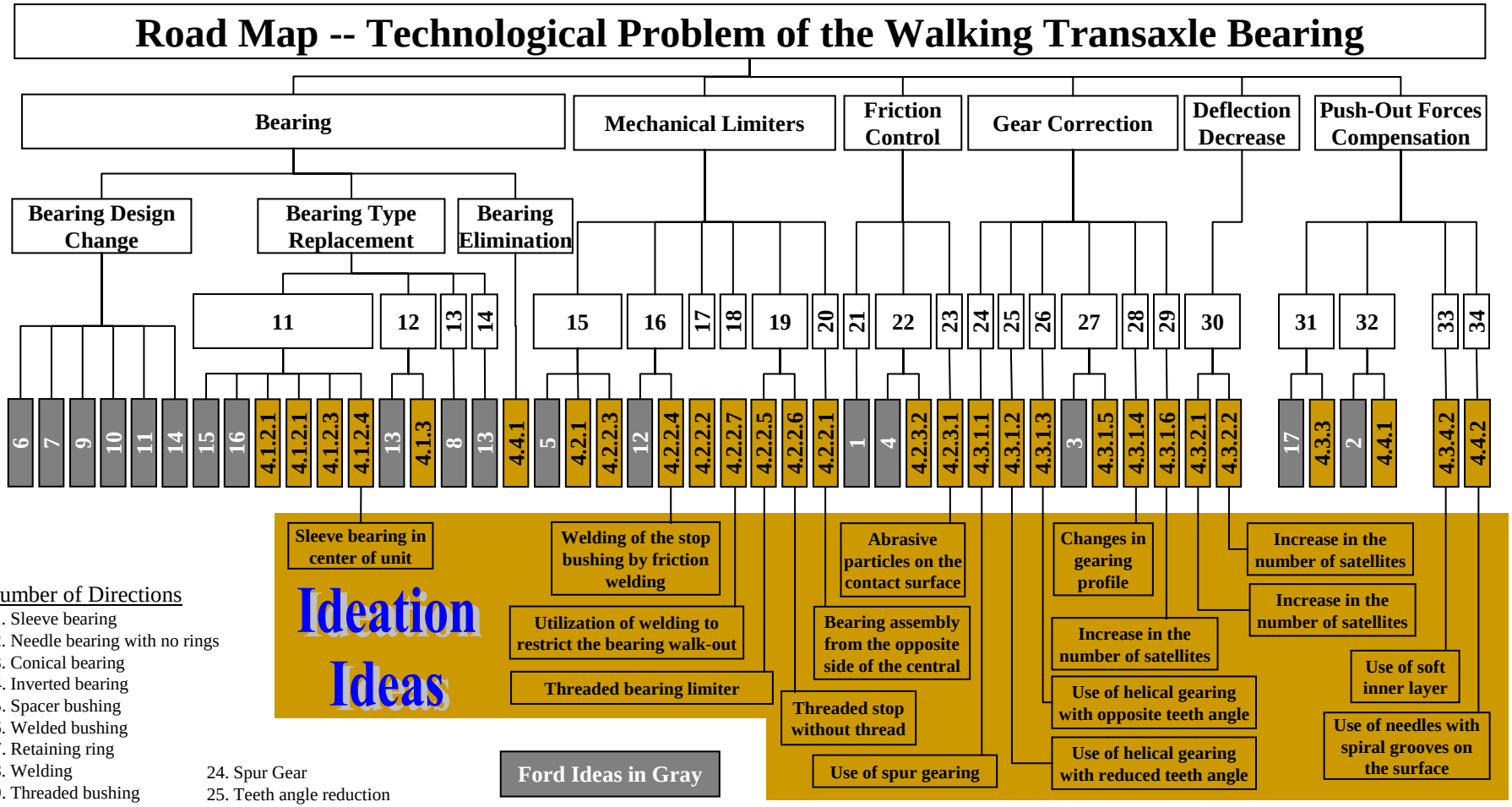
Combination Mechanism of Corrosion



Elimination of the Problem

- Last 30 second of washing without acid
- Protect the back side of the bumper
- Place additional electrodes near the back side; switch the current in the opposite direction for the last 30 sec. of the nickel-plating process to remove the deposition

Ford Motor Company



Number of Directions

11. Sleeve bearing
12. Needle bearing with no rings
13. Conical bearing
14. Inverted bearing
15. Spacer bushing
16. Welded bushing
17. Retaining ring
18. Welding
19. Threaded bushing
20. Step on the bore surface
21. Press fit
22. Loctite
23. Abrasive Particles
24. Spur Gear
25. Teeth angle reduction
26. Gearing angle change
27. Modulus change
28. Satellites Qty change
29. Opposite teeth angle
30. Pre-stress
31. Spline fit change
32. Spiral marks
33. Soft coating of the bearing ring
34. Needles with spiral groove

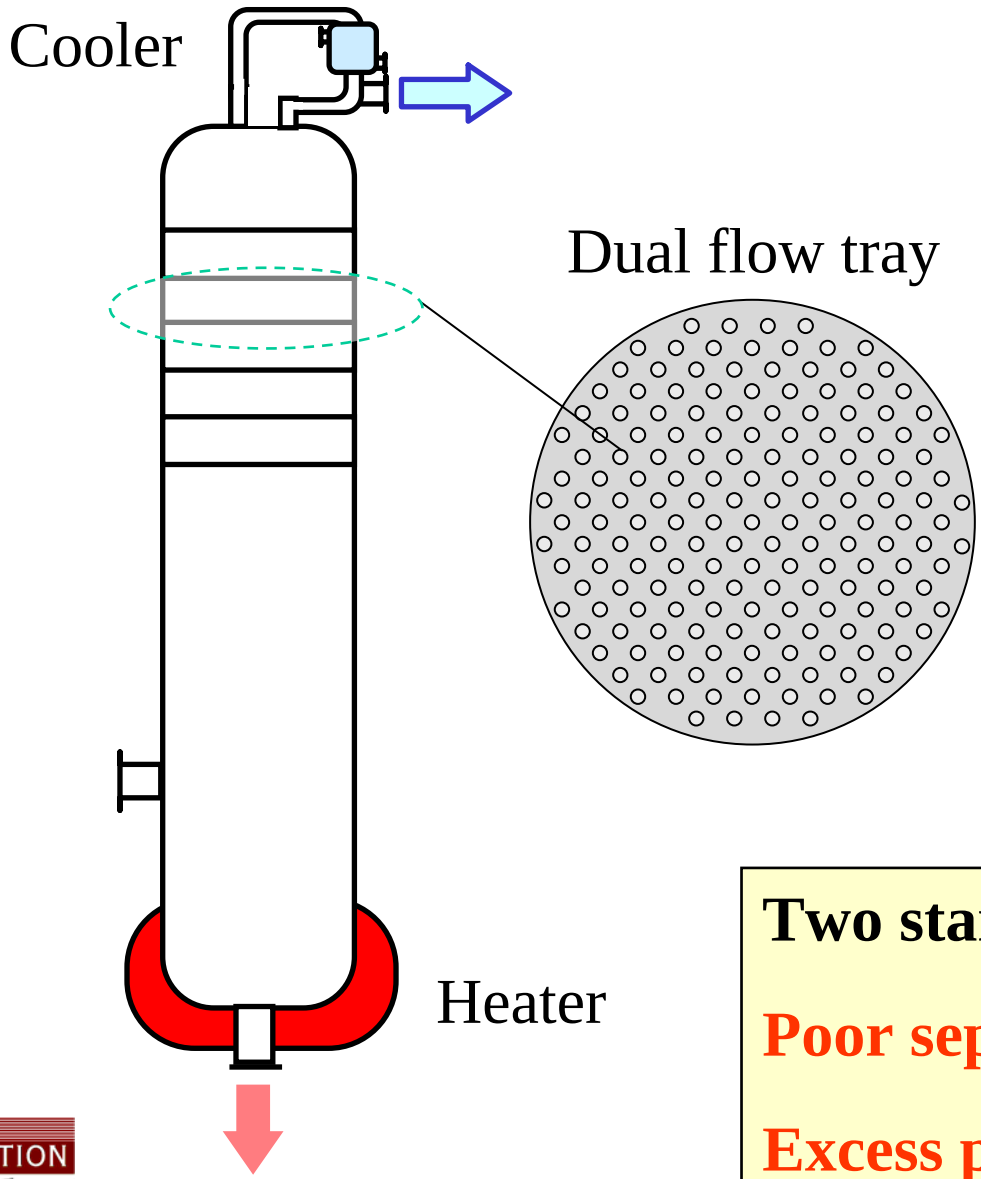
Ford Ideas in Gray

1. Increase of the compression on the contact surface
2. Spiral marks on the central bore surface
3. Sun gear wall thickness increase (gear correction)
4. Using adhesives (Loctite)
5. Mechanical stop (bushing)
6. Make needle bearing longer
7. Combination of thrust and radial bearing
8. Conical roller bearing
9. Needles profile change (crowned)
10. Bearing ring hardness reduction
11. Bearing ring thickness increase
12. Mechanical stop (welded bushing, small step on the bore surface)
13. Inverted needle bearing (no outer ring)
14. Needles profile change (convex)
15. Sleeve bearing
16. One long bushing per unit
17. Change of the fit of the rear carrier to final drive sun gear spline

Problem of the Large Separation Column

(Scale Problem)

Separation Column



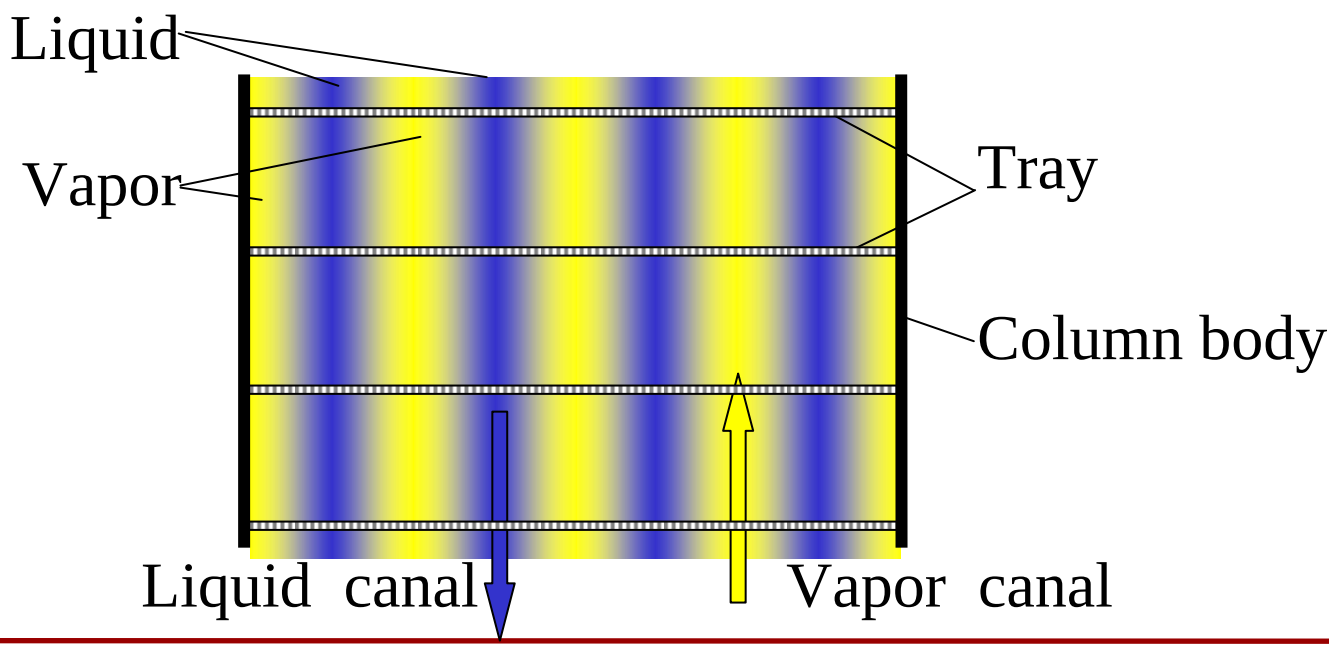
Two start-up problems:

Poor separation in column

Excess polymerization into column

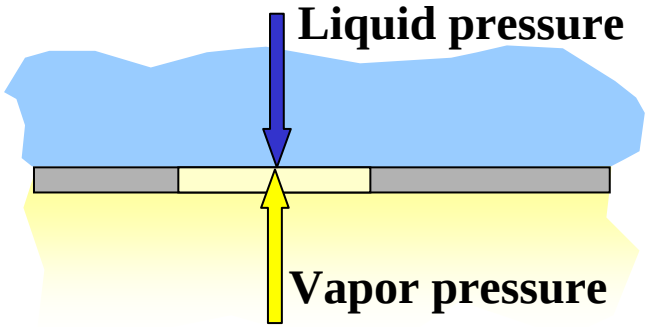
Problem Statement and Inversion

Original problem	Poor separation in column
Inverted problem	How to prevent separation in column
Possible solution for inverted problem	Prevent liquid/vapor contact
Existing analogy	**Channeling**



Liquid / Gas Pulsation in One Opening

1



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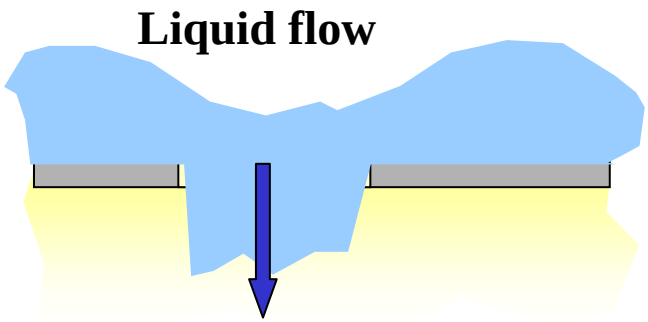

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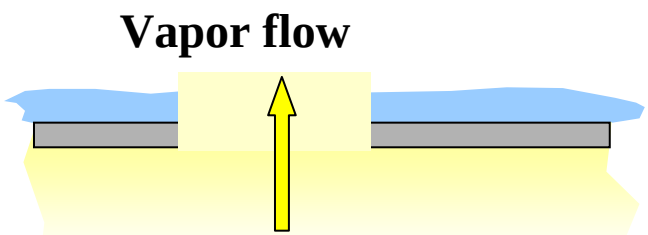
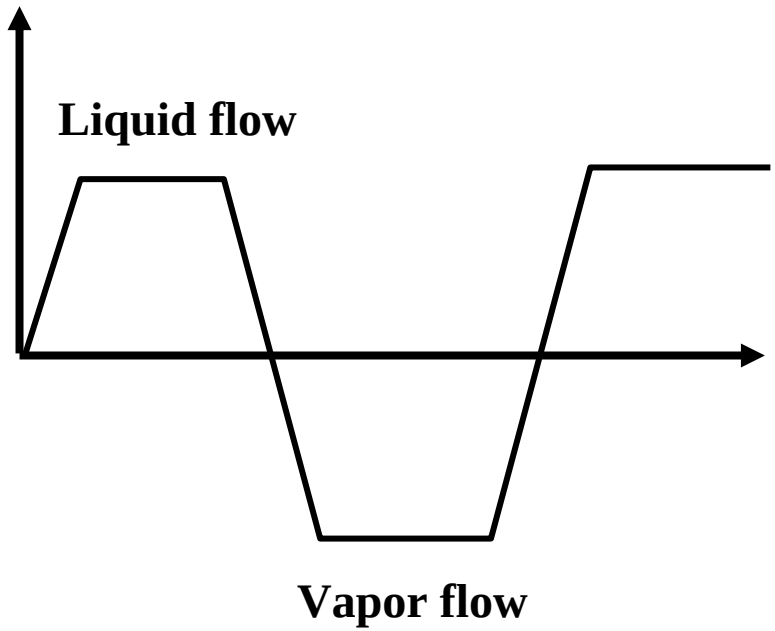
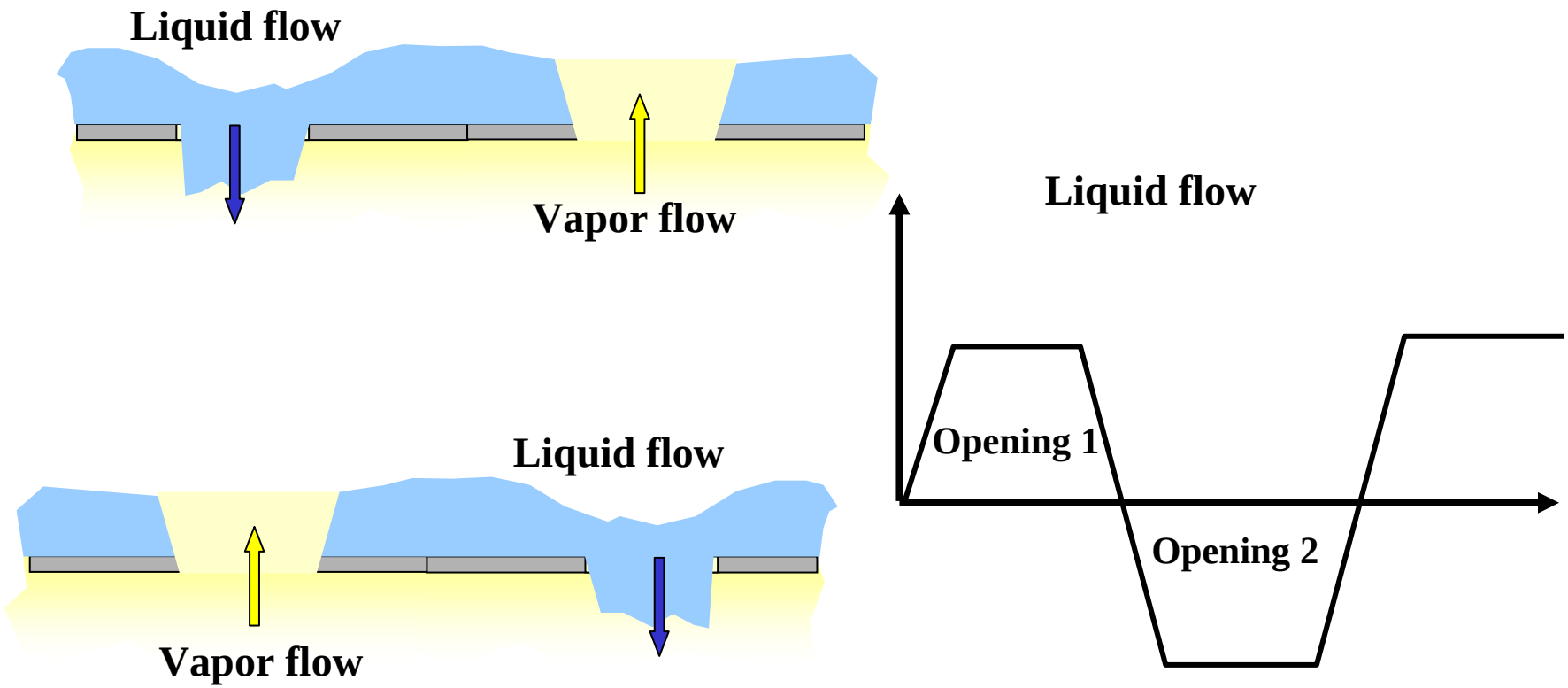




Liquid / Gas Pulsation in Two Openings

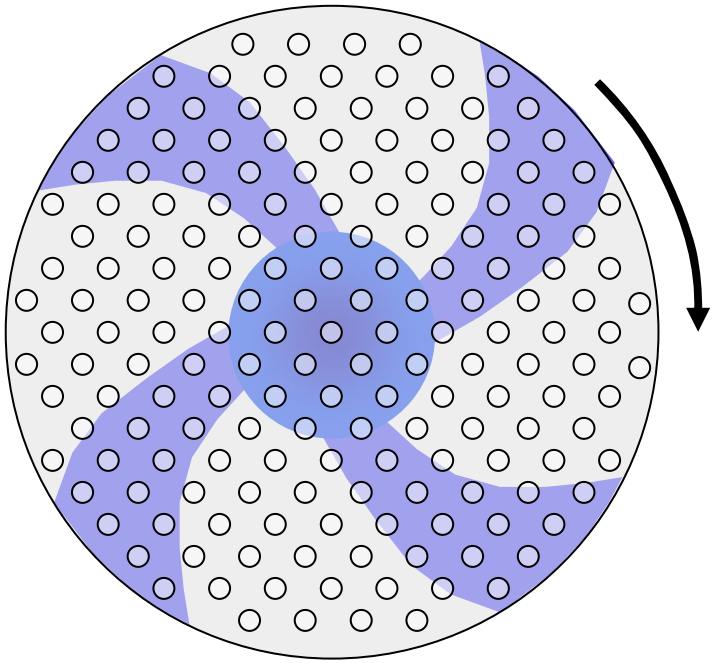


Phenomenon of Auto-synchronization (AS)

AS phenomenon happens when several practically independent objects normally oscillating at different frequencies begin to oscillate with the identical, divisible or commensurable frequencies. The phenomenon is caused by slight interaction between objects.

- **Mid 17th century. The phenomenon was observed by C. Huygens (AS of weight-driven pendulum clocks).**
- **End of 19th century. John Rayleigh described AS in acoustic systems.**
- **Beginning of 20th century. AS in electrical and electromechanical circuits.**
- **First decade of 20th century. Theory of AS developed as a part of Theory of Nonlinear Wave Oscillations.**
- **1940s - The phenomenon of AS discovered for mechanical vibro-exciters, installed on the same foundation.**
- **1946 - First patents for application of AS process filed in Germany, Sweden, USA.**
- **1970s - AS theory applied to celestial bodies (planets, stars, etc. including earth satellites as well).**
- **1980s – AS theory began to be applied to chemical processes and biological systems (organs, organisms, populations, etc.)**

Waves on Tray Surface



Wave rotation

Spiral wave

Typical picture of spiral waves

From the book G. Nicolis and
I. Prigogine, “Exploring complexity”

Waves Synchronization on Different Trays and Dynamic Channeling