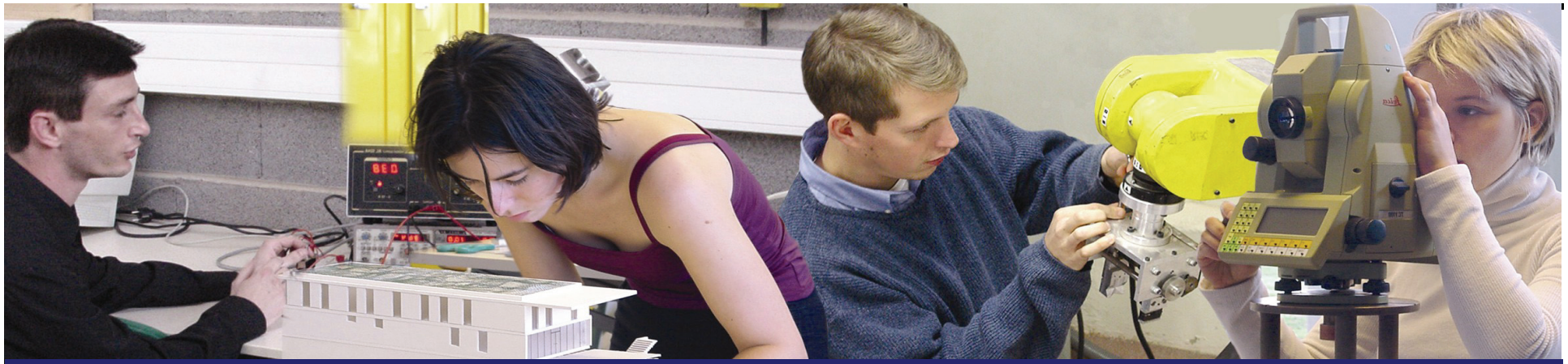

INSA STRASBOURG GRADUATE SCHOOL OF SCIENCE AND TECHNOLOGY

ARCHITECTS + ENGINEERS

TRIZ INSTRUMENTS FOR FORECASTING: PAST, PRESENT AND FUTURE

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CONTENTS

"If one does not know to which port one is sailing, no wind is favourable." Lucius Annaeus Seneca (c. 4 BC–AD 65)

- Is TRIZ a method?
- What is difference between prediction and forecast?
- Why do we need to forecast?

1. INTRODUCTION

Is TRIZ a method?

[introduction: approach, techniques, method, theory]

Blind commitment to a theory is not an intellectual virtue: it is an intellectual crime. Imre Lakatos, 1973

TRIZ specialists

it is a theory, science, philosophy...

Consultants

it is a method, toolbox…

Scientists

it is applied science … it is not a science at all…

Engineers

it is a method and technique…

Inventors

"I don't use it. I just formulate some contradictions towards IFR and when physical contradiction is clear, I have got a solution…"

where is classical TRIZ coming from?

I stage:

From unsystematic and non-system approaches to “scientific approach to creating inventions”.

- First version of method (program): “Scheme of creative process” (prototype of future ARIZ).
- Altshuller, G.S. and R.V. Shapiro, ABOUT A TECHNOLOGY OF CREATIVITY. Questions of Psychology, 1956(6): p. 37-49.

II stage:

From approaches to a method: ”..it is necessary to build a *program that performs step by step systematic analysis of the problem*, disclose, study and overcome technical contradiction.”

- Six consecutive versions of **the method for inventive problems** solving. 1965: method was named *Algorithm of Inventive Problem Solving* (ARIZ).
- Books: Altshuller, G.S., HOW TO LEARN TO INVENT. 1961, p.128; Altshuller, G.S., THE FOUNDATION OF INVENTION. 1964. p.240; Altshuller, G.S., THE INNOVATION ALGORITHM. 1st ed. 1969; 2nd ed. 1973. p. 296

where is classical TRIZ coming from?

III stage:

From the efficient method to a Theory: "..it is necessary to get a Theory of inventive problem solving. The theory has to be based on the knowledge of objective Laws of Technical Systems Evolution."

- Four new versions of ARIZ. Several versions of System of Inventive Standards. New versions of Pointer of scientific effects.
- First regular Public University of TRIZ – Baku, 1971. Regular training courses in various cities in the USSR.
- Books: Altshuller, G.S., THE INNOVATION ALGORITHM. 2nd ed. 1973. Altshuller, G.S., CREATIVITY AS AN EXACT SCIENCE. 1979.

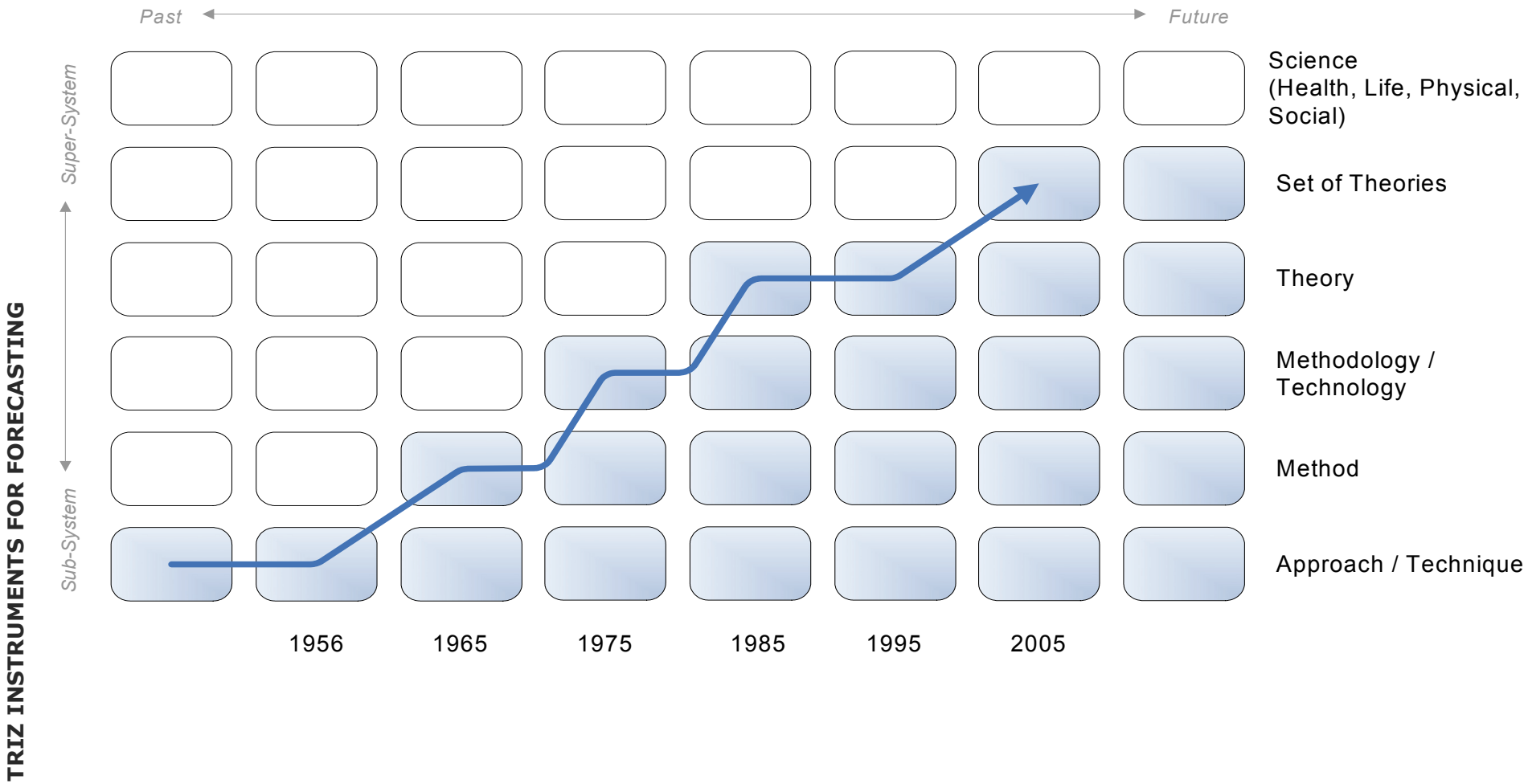
IV stage:

Research target formulated "from TRIZ to the *Theory of Technical Systems Evolution*". TRIZ methods and techniques start to be applied for non-technical systems improvements.

- Three new versions of ARIZ. Several updates of System of Inventive Standards. Considerable updates of Pointer of scientific effects. Advanced Functional analysis + TRIZ methods.
- Books: Altshuller, G.S. and A.B. Selutskii, WINGS FOR ICARUS. 1980 Altshuller, G.S., CREATIVITY AS AN EXACT SCIENCE. 1984 in English Altshuller, G.S. et al., PROFESSION: TO SEARCH FOR NEW. 1985, Altov, G., AND SUDDENLY THE INVENTOR APPEARED. 1984. several books of other authors

Is TRIZ a method?

[introduction: approach, techniques, method, theory]



where is classical TRIZ coming from?

"…Behind the specific theories of evolution, it will be revealed clearly step by step the general theory, which we temporary named the General Theory of Advanced Thinking…"
[G.Altshuller, G.Filkovsky. Actual state of TRIZ. Baku, 1976]

V stage:

Research target formulated towards Theory of Systems Evolution. First publications about Theory of Creative Personality Evolution (TRTL). Worldwide spread of TRIZ (mostly as some techniques out of TRIZ).

- A lot of published books:
  - More than dozen books about engineering TRIZ,
  - two books about teaching elements of TRIZ-thinking to children,
  - two books about creative problem solving in advertisement,
  - a book about creative personality evolution:
    Altshuller, G.S. and I.M. Vertkin, How to Become a Genius. 1994.
- 1989 – International TRIZ Association is created in former Soviet Union.
- 1990 – first issue of Journal TRIZ in Russian.
  1990-1994 – 7 issues were published.
- 1989 – first TRIZ-software was commercialized.

Is TRIZ a method?

[introduction: approach, techniques, method, theory]

Actual stage:

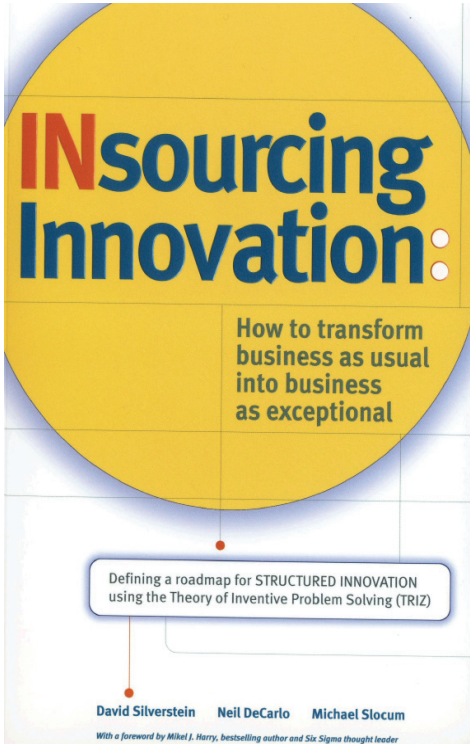
Massive application of TRIZ methods and techniques for engineering system development worldwide. Growing application of TRIZ concepts and paradigms for improvements of non-engineering systems.

- Books about TRIZ were translated, written, and published in English (>35), in German (>23), in Polish (4), in French (3), in Spanish (3), in Italian , in Japanese (5), in Korean (>5), in Chinese (5), in Portuguese, in Vietnamese and other languages…
- Nov. 1996 –The TRIZ Journal (in English) in Internet: monthly issues.
- 1998 – Altshuller Institute for TRIZ Studies (USA): annual conferences; eight proceedings - about 260 articles.
- 2001 – European TRIZ Association: annual conferences; six proceedings - about 270 articles.
- Many national TRIZ associations and conferences were organized worldwide…

Is TRIZ a method?

APPLICATION OF TRIZ

- International Space Station
- Self-heating container
- Trident missile
- SeaWolf submarine
- Cassini satellite
- Prius hybrid car
- Heat dissipation of Intel chips
- Intel board assemblies
- Lockheed Launch Vehicle
- Pluto Fast Flyby
- Delta Launch Vehicl
- Fuel Cell
- Large LCD and PDP displays
- E Ink and OLED displays …



TRIZ INSTRUMENTS FOR FORECASTING

Source: Silverstein, D., N. DeCarlo, and M. Slocum, Insourcing Innovation: How to Transform Business as Usual into Business as Exceptional. 2005: Breakthrough Performance Press. 175.

APPLICATION OF TRIZ (continuation)

…WOIS - Contradiction Oriented Innovation Strategy (The School of Mechanical Engineering of the University of Applied Sciences in Coburg: H.J. Linde)

ASIT - Advanced Systematic Inventive Thinking (Roni Horowitz)

I-TRIZ problem-solving methodologies (Ideation International Inc.):

USIT - Unified Structured Inventive Thinking: problem-solving methodology (Ford Motor Company Research Laboratory: Ed. Sickafus)

xTRIZ - eXtended TRIZ (V.Suchkov)

Simplified TRIZ (K.Rantanen, E.Domb)

OTSM-TRIZ - General Theory of Powerful Thinking (G.Altshuller, N.Khomenko)

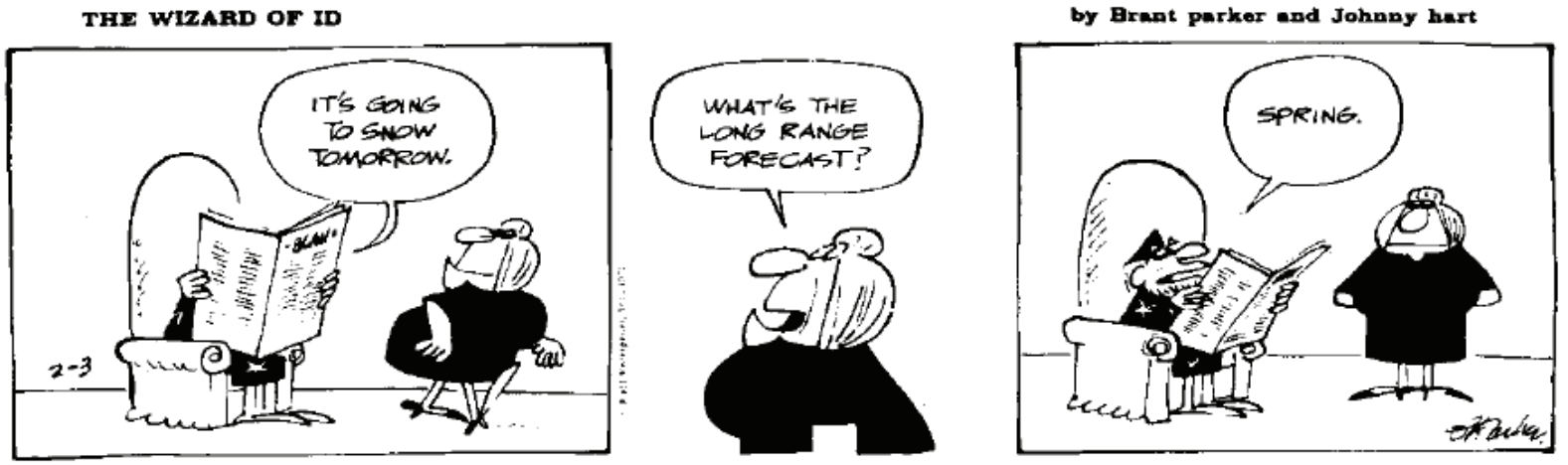
GTI - General Theory of Innovation (G.Yezersky) …

- Is TRIZ a method?
- **What is different between prediction and forecast?**
- Why do we need to forecast?

1. INTRODUCTION

Prediction and forecast…

[…foresight, provision, prophecy, foretelling, prognosis, anticipation…]



* Source: Armstrong, J.S. Long Range Forecasting. From Crystal Ball to Computer. (John Wiley & Sons, Inc., 1985), 689. ISBN 0-471-82360-0.

Prediction or forecast…

[…foresight, provision, prophecy, foretelling, prognosis, anticipation…]

What do we foresee with Technological Forecast?

	Weather forecast	Technological Forecast
What?	Cloud / Precipitation / Sunshine; Temperature (max/min) (°C); Air pressure (mm); Humidity (%); Wind / Storm (m/s); Duration of Sunshine (h); Geomagnetic Activity / Magnetic Storms; Air quality ???	
Where?	Latitude | Longitude Krutenau / Strasbourg / France / Europe	
When? (resolution)	by the hour / (am / pm / overnight) / Tomorrow / 4 days / 10 days /	
Update Frequency	by the hour / 4 times a day / daily	
Why?		
Probability		

Qualitative and Quantitative tendencies

[qualitative tendencies]

Prediction with help of lines-patterns-trends in TRIZ.

Table 1: Wound Healing Trends Compared to Similar Trends

Trend	Wound Healing	Similar Trend
Solid	Banana or other leaf/thin potato layer	Soap
Granules/powder/paste	Turmeric/turmeric paste/lint/animal grease/honey	Granules
Liquid	Alcohol (in Arabic medicine beginning 10th century)/boiling water (during 15th century)/chemicals (recent)	Liquid soap
Aerosol/spray	Disinfectant spray (open wound healing), analgesic spray (closed wound healing)	Cleaning sprays
Fields	Electrical stimulation/electromagnetic field (e.g., short wave diathermy (closed wound healing)/electric field stimulating catalysts	Ultrasound or ionization

Figure 2: Trends of Evolution

Source: Creax Inc.

Source: KRD Pravin, Shweta Phadke and Amita Vijay Rumde. 2007. Using Trends of Evolution to Direct Wound Treatments. http://www.triz-journal.com/archives/2007/10/03/

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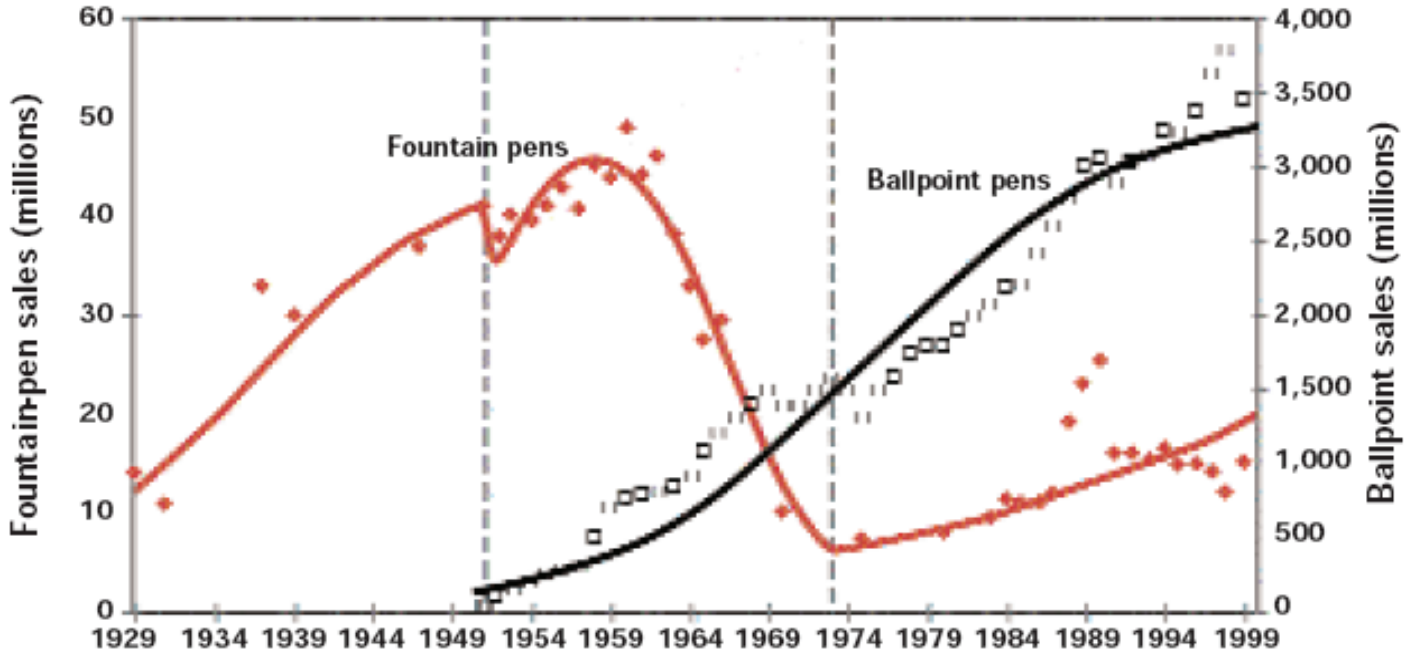
Qualitative and Quantitative tendencies

[quantitative analysis of tendencies]



The struggle between ballpoint and fountain pens.

Sales (millions of units) of pens in US.

Source: Modis, T. A Scientific Approach to Managing Competition. The Industrial Physicist, 2003, 9(1), 24-27.

Technological forecast and prediction

[working definitions]

- **Technological forecast** is a comprehensible description of emergence, performance, features, and impacts of a technology in a particular place of a particular point of time in the future. (What? When? Where? Why?)
- **Technological forecasting** (main function): <to develop> <the explicit models> in order to describe the future state of technology and its environment (super-systems) for target time-series at particular place.
- **Prediction** is a statement made about the future, anticipatory vision or perception. This statement is mostly qualitative (What? Why?).

Prediction with TRIZ techniques

[Case Study: Yarn Spinning Technology]

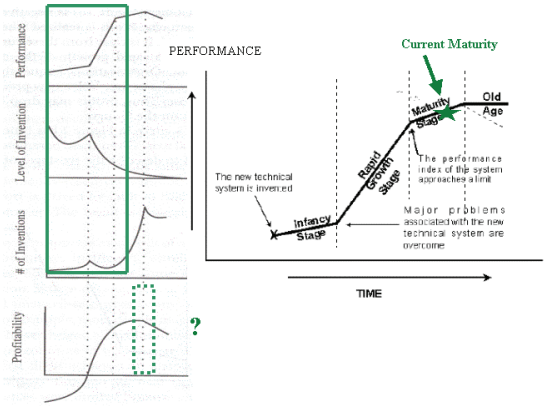


Figure shows that rotor spinning technology is in the mature stage. …The system has reached a threshold and recommendations are to *use the patterns of evolution* with a focus on a change of the core technology. …Actions should be taken now to insure a profitable future. Yarn rotor spinning has reached a maturity. A dramatic change (to the core itself) is strongly recommended.

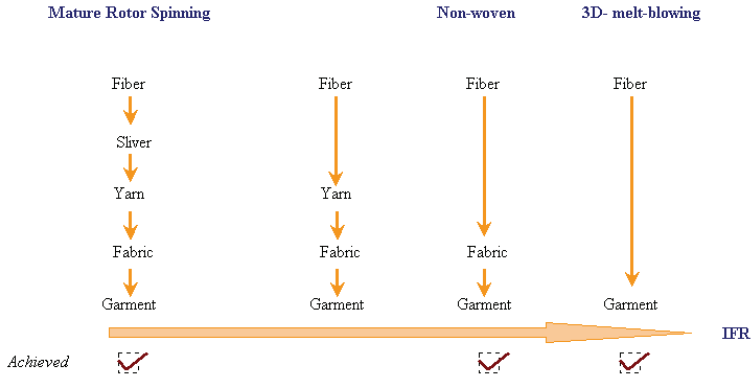


Figure represents the trend of ideality for Rotor spinning.

Summary: Since 1) rotor spinning is mature, 2) the trend of dynamization recommends the use of field as the ultimate devolvement and 3) early vortex machines were not successful when the new vortex machines are, it is relevant to analyze the maturity of fasciated yarns to forecast innovation in spinning…

The other patterns of evolution can be applied to generate additional solution directions to provide a complete picture of possible technological developments in yarn formation.

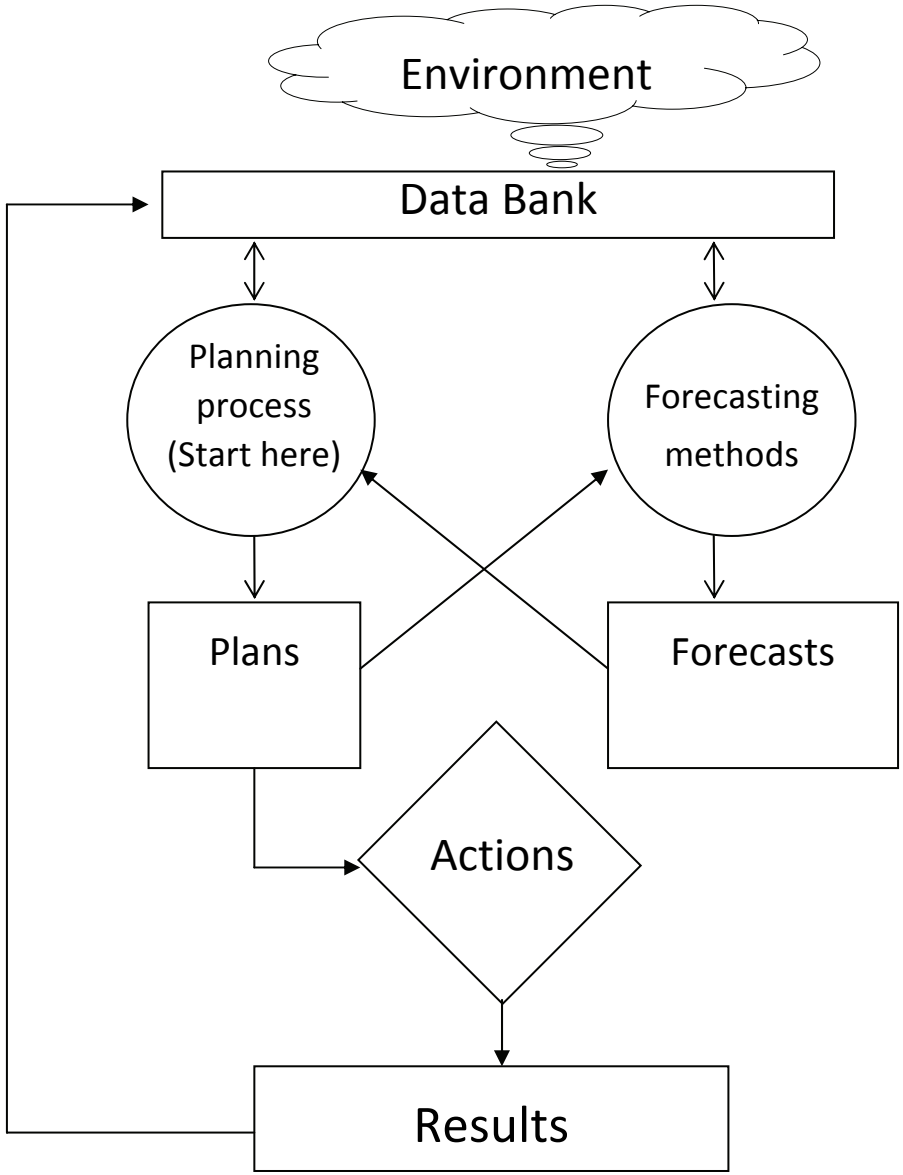
… even though the focus was on rotor spinning, the patterns clearly showed new core technologies, such as nonwovens and fasciated assembly technologies to replace the existing core technology.

* Source: Severine Gahide, . (2000) Application of TRIZ to Technology Forecasting. Case Study: Yarn Spinning Technology. www.triz-journal.com

- Is TRIZ a method?
- What is different between prediction and forecast?
- **Why do we need to forecast?**

1. INTRODUCTION

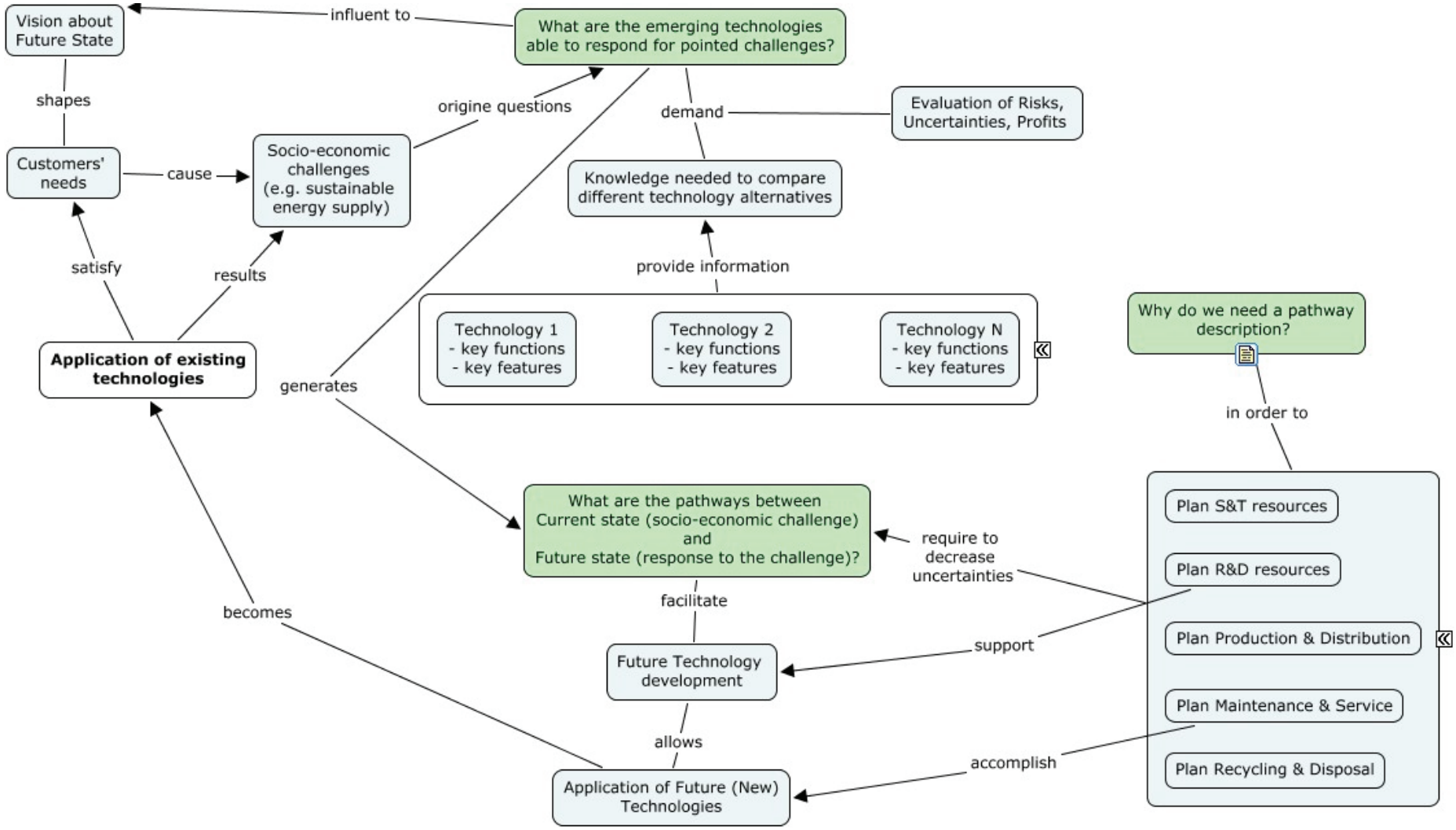
Why do we need to forecast?



* Source: Armstrong, J.S. Strategic Planning And Forecasting Fundamentals. 1983

Why do we need to forecast?

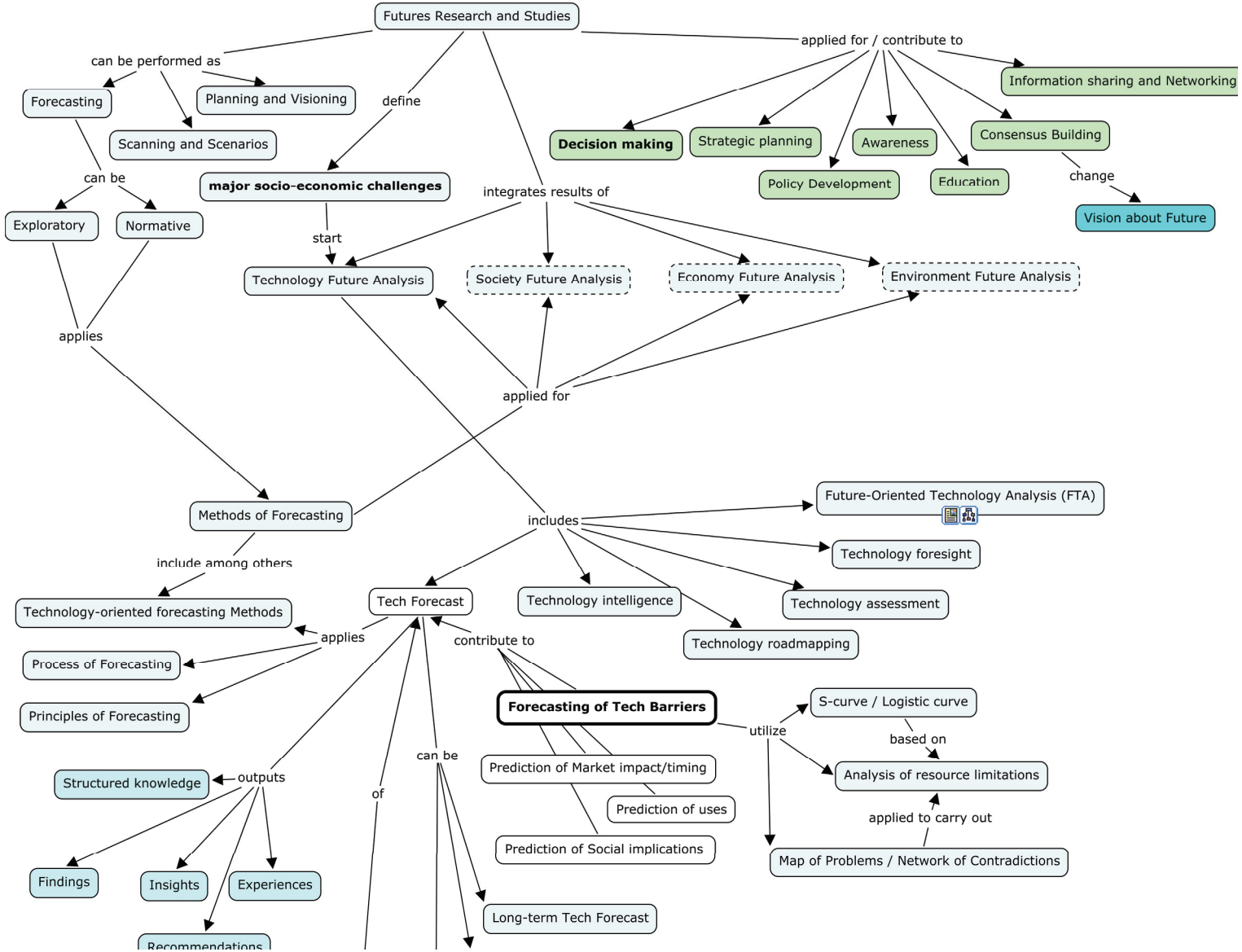
[What are the pathways between Present and Future?]



TRIZ INSTRUMENTS FOR FORECASTING

Why do we need to forecast?

[introduction: scope of technological forecast]



TRIZ INSTRUMENTS FOR FORECASTING

Why science and technological forecast?

[What are the pathways from Present to Future?]

Main function of technological forecasting:

to provide a consensual vision of the future science and technology landscape to decision makers.

High quality technological forecast:

- accurate, credible and visionary;
- to portray the evolving relationships with adequate breadth and depth;
- to provide a comprehensive description of the evolution and relationship of most critical sciences and technologies in the past, present and future;
- to provide a high degree of certainty, reliability and objectivity (bias-free).

Alternatives to forecast

[introduction: scope of technological forecast]

- No forecast;
- Anything can happen;
  - There is no attempts to anticipate future
  - There are attempts to build as multiple scenarios
- Seduced by success (ignore the future);
- Future will be like the past (higher, faster, and father);
- Emergency service (waiting until the problem has arrived).

Why do we need forecast?

[just prediction is not enough today]

- We delay to recognize and to be agree about problem.
- We delay to solve problem and to be agree about solution.
- We delay to implement a potential solution and recognize its limitations.

Forecast supposes to cover these delays for securing potentially threats:

- Consumption exponential growth;
- Waste exponential growth;
- Pollution exponential growth;
- Environmental destruction exponential growth.

Introduction - summary

- **Is TRIZ a method?**
- **What is difference between prediction and forecast?**
- **Why do we need to forecast?**

2. HISTORY OF FORECASTING IN SCOPE OF TRIZ

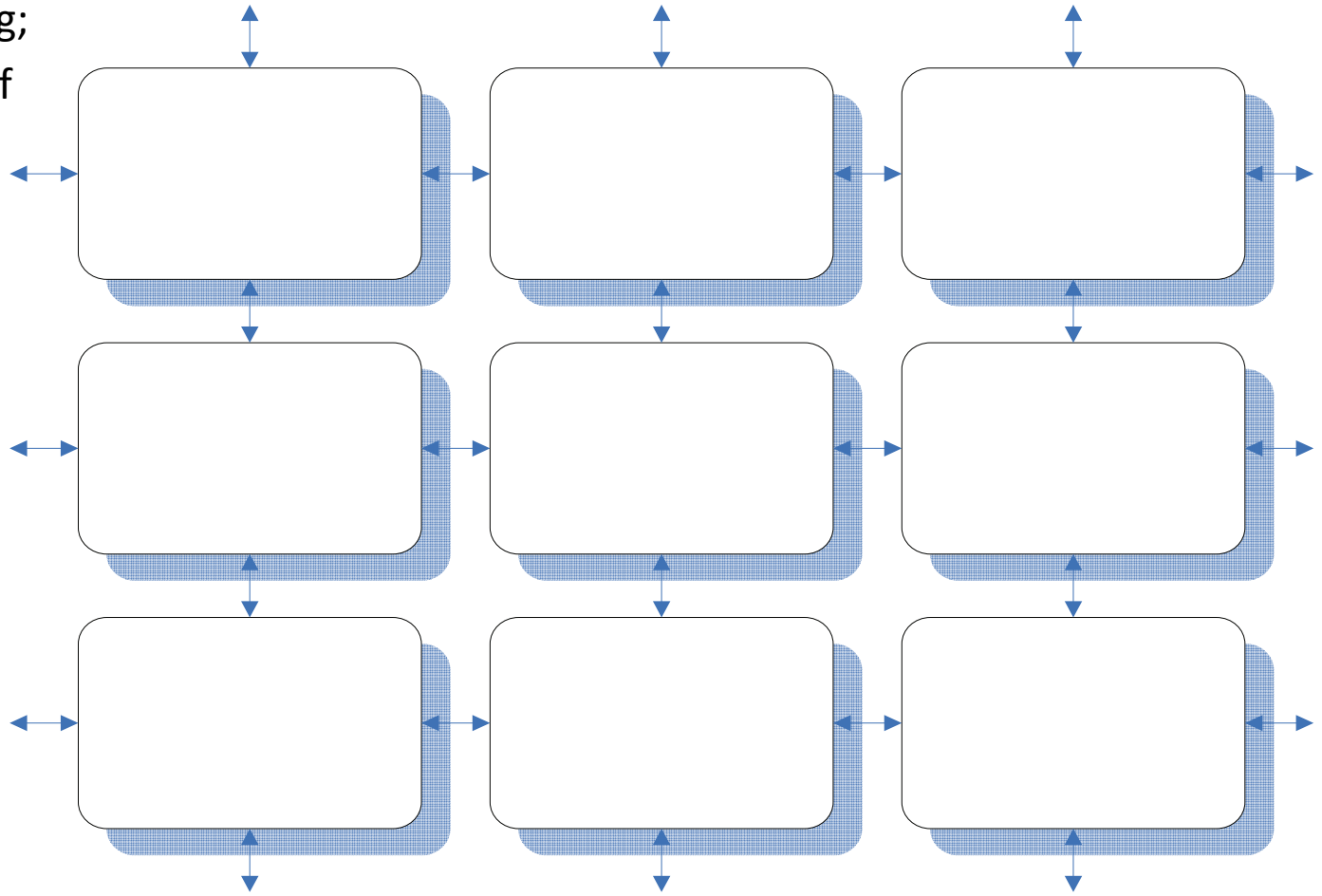
Inventive problem solving and prevision

[multi-screen view, system operator]

- Decision making;
- Management of technologies;
- Inventions;
- Diffusion of Innovations

Practice of Technological Forecasting

Methods, Techniques, Instruments…

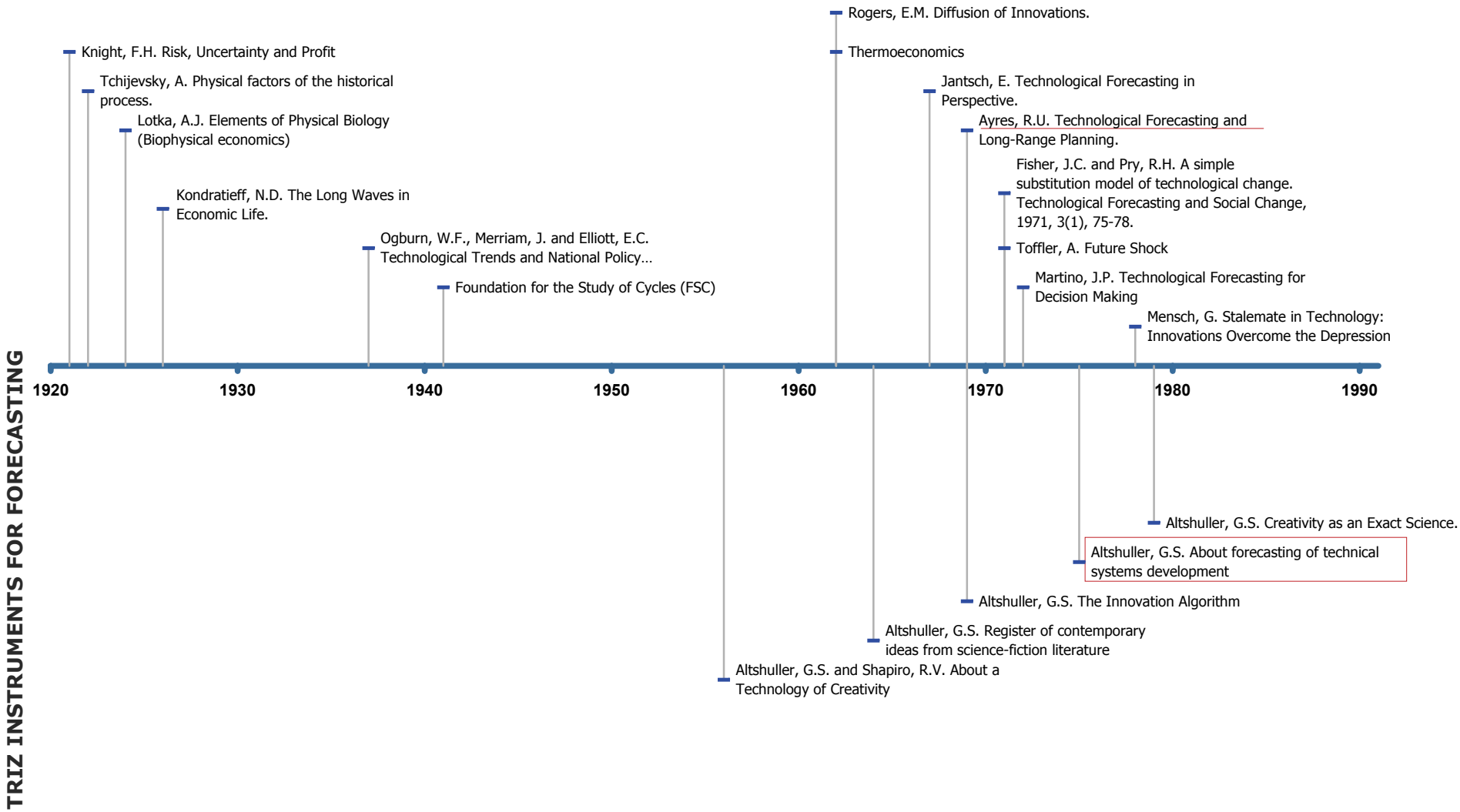


… 1975… 1991… 2007…

TRIZ INSTRUMENTS FOR FORECASTING

Forecasting and TRIZ (past)

[timeline fragment #1]



Inventive problem solving and prevision

[when a method for inventive problems became mature]

G. Altshuller's problem statement (April 18, 1975)*:

- There are more than 100 methods of forecasting: scientific-and-technological, economic, and social. Four books was proposed as references.
- "Inventor is looking answers for **qualitative** questions*:
  - What is growth potential of given engineering system?
  - What is system that substitute the existing one in future?
  - What are the fundamental and principal problems should be solved in future?"
- Starting assumption: inherent drawback for most of the known forecasting methods: they are essentially subjective (full of biases).

* Source: Altshuller, G.S. *About forecasting of technical systems development*. Seminars materials p. 8 (Baku, 1975). Manuscript in Russian

Inventive problem solving and prediction

[how to foresee technological future]

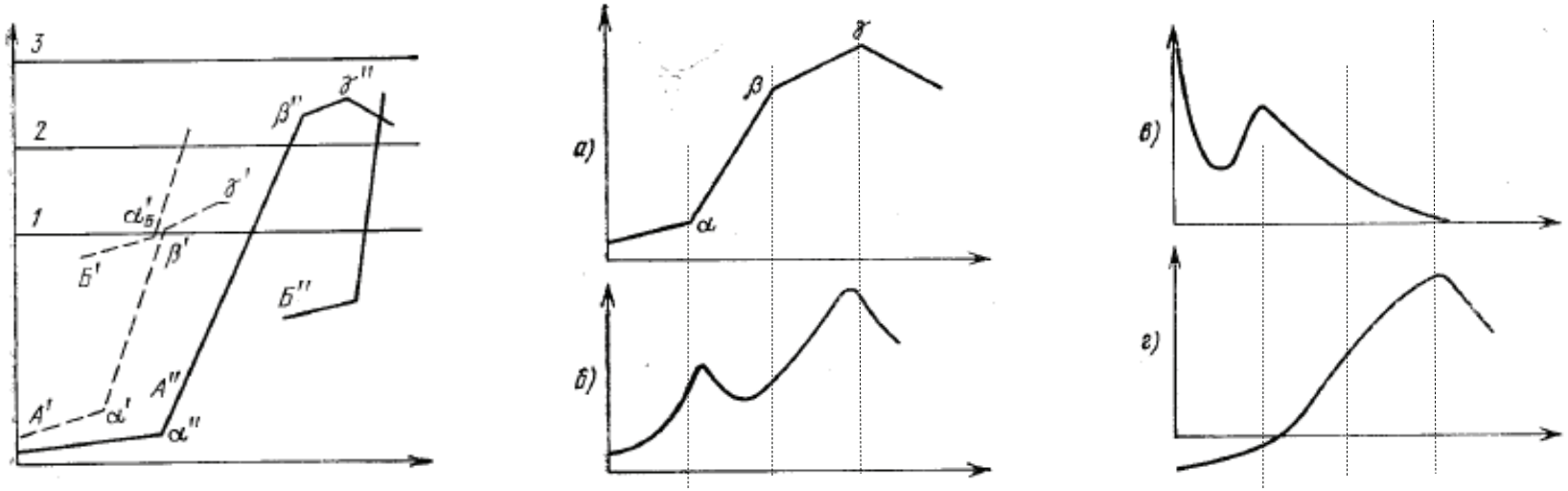
What was proposed by G. Altshuller (April 18, 1975)*:

- To apply existing 'Extrapolation of trends and curve fitting' methods. As a main reference was proposed: Ayres, R.U. *Extrapolation of Trends.* in Technological Forecasting and Long-range Planning. (McGraw-Hill book Company, 1969), 237. ISBN 0070026637.
- "…Curve fitting… gives opportunity to recognize *unbiased regularities of engineering systems evolution*…"
- Further application of curve fitting method for Theory of Inventive Problem Solving (TRIZ) was proposed:
  - Four sections on the evolution curve;
  - Peculiarities of theoretical and some real curves of substitutions;
  - Natural reasons of ceiling for curves;
  - Three cases of data analysis for curves;

* Source: Altshuller, G.S. *About forecasting of technical systems development*. Seminars materials p. 8 (Baku, 1975). Manuscript in Russian
Altshuller, G.S. *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems*. (Gordon and Breach Science Publishers, 1984), 320. (in Russian - 1979)

G. Altshuller (April 18, 1975): (continuation)

- Regularity: next generation system includes the foregoing one as subsystem. In other words: “evolution by becoming a subsystem”.
- It was suggested some correlations between engineering system evolution curve and inventive curves (number of inventions, level of inventions, and profitability).



* Source: Altshuller, G.S. *About forecasting of technical systems development*. Seminars materials p. 8 (Baku, 1975). Manuscript in Russian
Altshuller, G.S. *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems*. (Gordon and Breach Science Publishers, 1984), 320. (in Russian - 1979)

[how to foresee the future]

G. Altshuller (1976):

- Altshuller, G.S. and Filkovsky, G. *Current State of Theory of Inventive Problem Solving*. Seminar materials. (Baku, 1976).
  There is no even a paragraph about forecasting and prediction techniques.

G. Altshuller (1988):

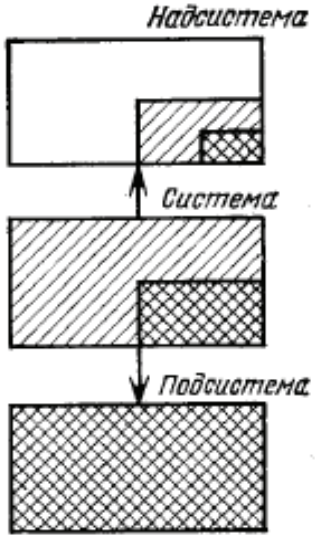
- Altshuller, G.S. *Information about TRIZ-88*. Seminar materials. (Baku, 1988).
  There is nothing about forecasting and prediction techniques in body of TRIZ.

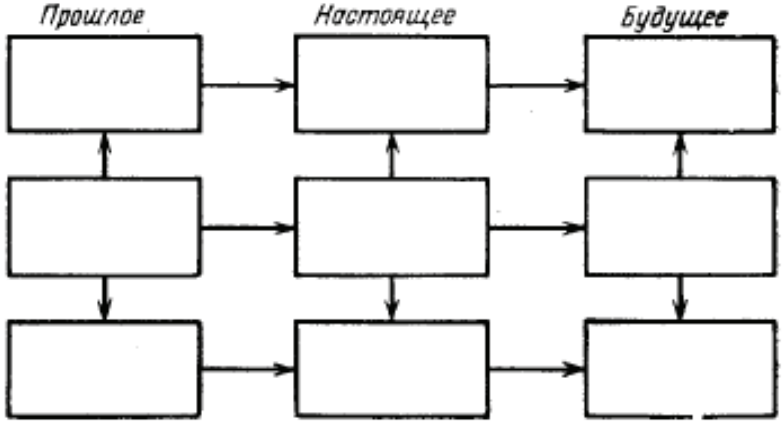
Inventive problem solving and prediction

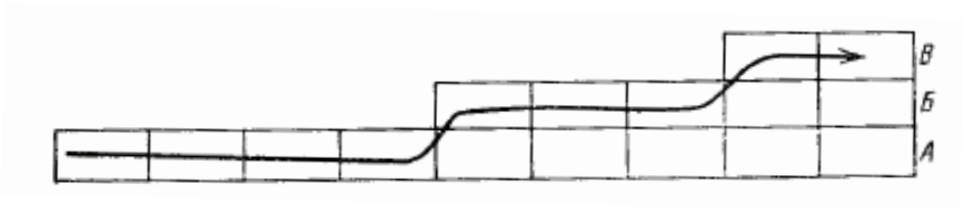
[how to foresee the future]

G. Altshuller (1979):

System operator or Multi-screen scheme of advanced thinking.







TRIZ INSTRUMENTS FOR FORECASTING

* Source: Altshuller, G.S. *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems*. (Gordon and Breach Science Publishers, 1984), 320. (in Russian - 1979)

Inventive problem solving and prediction

[how to foresee the future]

G. Altshuller (1977-1979)*:

System of laws of technical systems evolution.

- law of System Completeness
- law of Energy Conductivity in systems
- law of Harmonization

- Law of Increasing Ideality
- law of Irregularity of the Evolution of a System's Parts
- law of Transition to the Super-system

- law of Transition from Macro- to Micro-level
- law of Increasing Substance-Field Interactions
- law of Dynamics Growth (added in 1985)

* Source: Altshuller, G.S. *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems*. (Gordon and Breach Science Publishers, 1984), 320. (in Russian - 1979) Altshuller, G.S. *About Laws of technical systems evolution*. Manuscript (20.01.1977).

Engineering systems evolution

[how to foresee the future in scope of problem solving?]

Altshuller G.S., Zlotin B.L., and Philatov V.I. (1985)*:

Principal ways for increasing rate of Ideality.

1. Towards differentiation: special-purpose engineering systems with better efficiency for particular purpose (customization).
2. Towards versatility: many-purpose system perform many functions.
3. New deployment of existing properties and parts of system.
4. Transition to self-adjusting systems: many-purpose specially adjusted system. Towards adaptability for effective operation.
5. Towards increasing harmonization of system and external changes without changing working principle.
6. Transition to super-system when no other ways.
7. Transition from macro- to micro-level when no other ways.
8. Increasing system completeness towards pushing out human as a part of system.

* Source: Altshuller, G.S., Zlotin, B.L. and Philatov, V.I. *PROFESSION: TO SEARCH FOR NEW*. (Kartya Moldovenyaske Publishing House, Kishinev, 1985), 196. in Russian

TRIZ forecast

[example]

G. Altshuller, M. Rubin (1987):

What Will Happen After the Final Victory. Eight thoughts about Nature and Technology. (English condensed version: Izobretenia, 1999, 1, pp. 4-9)

- Several impressive and uncommon (at those time) trends are disclosed. Concept of Natureless technological world (NTW) is proposed and developed.
- Method of forecasting is not described. Data sources are not presented. Basic assumptions and hypothesis presented inexplicit way.
- Social impact and proposals about strategy are discussed.
- Twenty years later, a lot of described aspects can be recognized in reality.
- It is impossible to judge about accuracy of this forecast, due to its qualitative nature and fuzziness of “Where” and “When” estimates.

[how to foresee the future: bypassing biases]

G. Altshuller as Science Fiction writer:

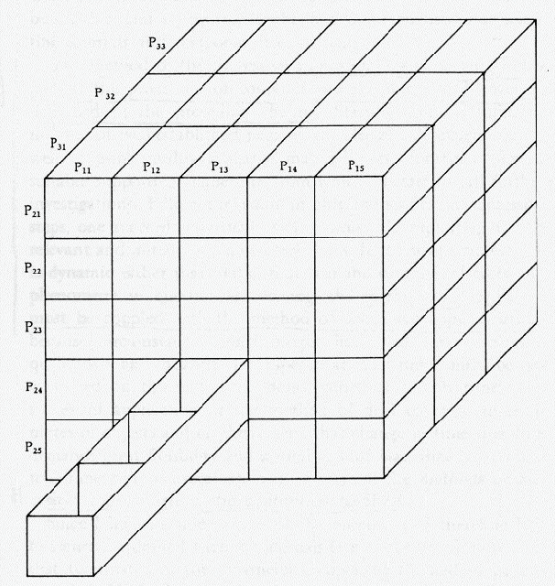
- "Register of contemporary ideas from science-fiction literature*" (1964-1997): 11 classes, more than 1000 typescript pages.
  - Methods and techniques to design and develop science-fiction ideas (e.g. 'Four levels' scheme, 'Fantogramma' - 1971);
  - "Scale Fantasy-2" scale (mid of 80's) is a technique to measure science-fiction ideas (metrics).
- Analysis of science-fiction ideas from literature as support for long-term technological forecasting.
  - More than 85% of ideas from Jules Verne science-fiction novels today are real engineering systems (e.g. submarine, aviation, helicopter...)
  - Stanisław Lem - Summa Technologiae ("Sum of Technologies" in English) 1964…

* Source: http://www.altshuller.ru/rtv/sf-register.asp in Russian

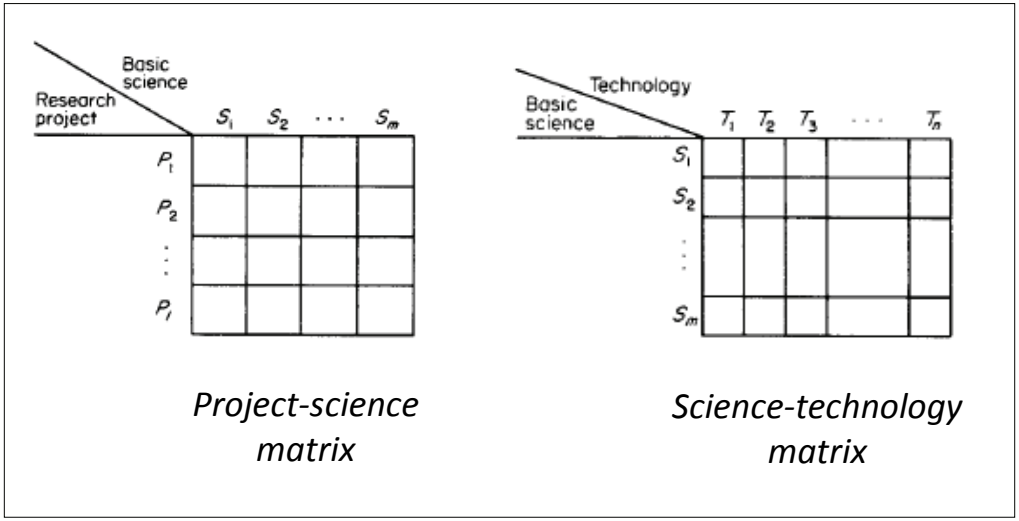
[how to foresee the future: how to see non-obvious?]

Morphological analysis

- Zwicky F. *Discovery, Invention, Research through the Morphological Approach.* (1966)
- Ayres, R.U. *Technological Forecasting and Long-range Planning*. (McGraw-Hill book Company, 1969), 237.



A 3-parameter Zwicky box containing 75 cells or "configurations" (Zwicky, 1969, p. 118.)



Project-science matrix

Science-technology matrix

TRIZ INSTRUMENTS FOR FORECASTING

Engineering systems evolution

[how to foresee the future in scope of problem solving?]

Altshuller G.S., Zlotin, B.L., Zusman, A.V. and Philatov, V.I. (1989)*:

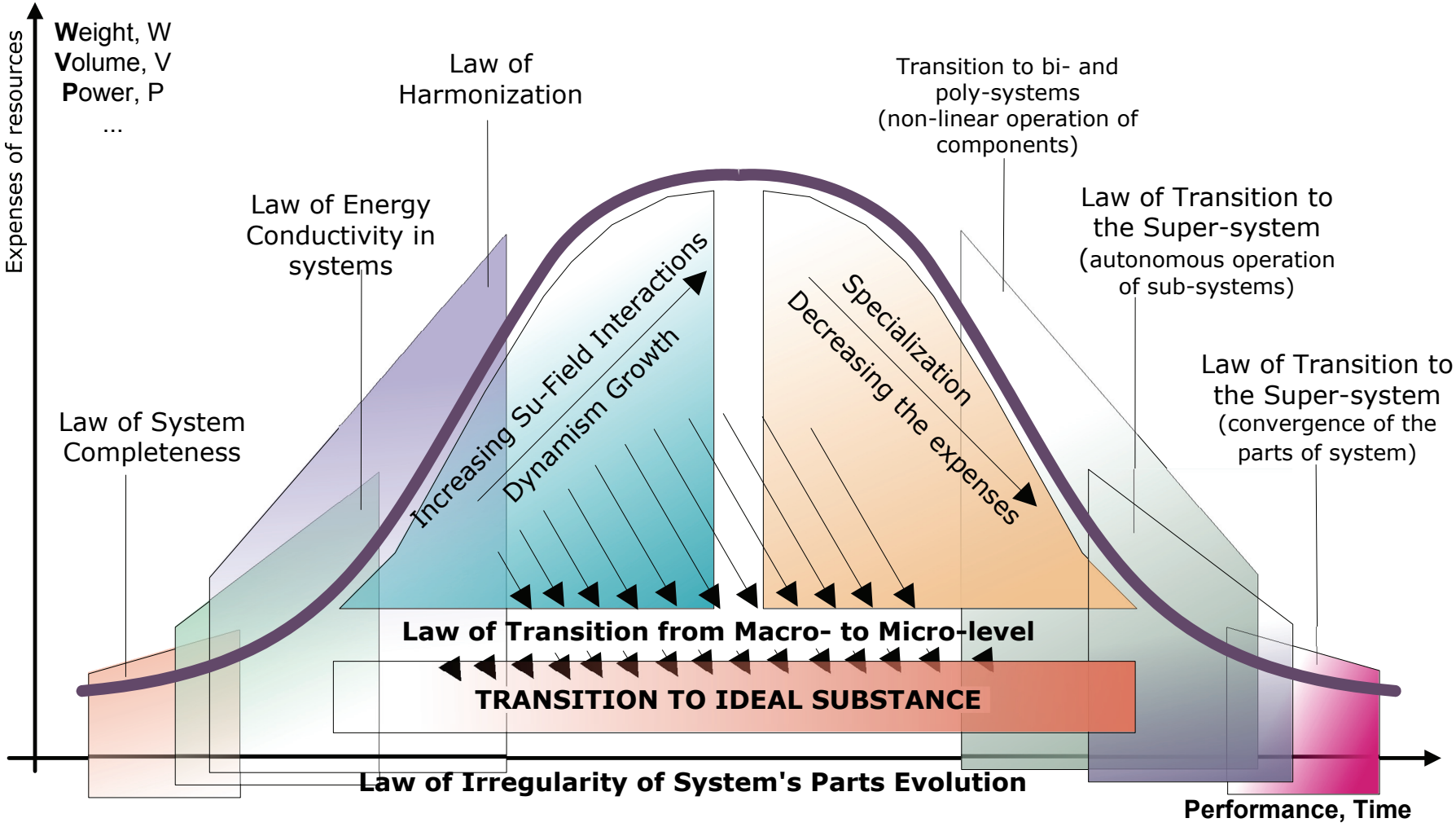
- Basic principles of technological forecasting based on TRIZ.
- Forecasting procedure was proposed
  (4 stages; 26 steps; recommendations):
  1) express forecast;
  2) preparation to forecast;
  3) forecasting using laws of technical systems evolution;
  4) aggregate forecast.
- 22 lines of engineering systems evolutions were presented.
- Some peculiarities of practical forecasting were discussed.
- Example of interim results of TRIZ forecast were described.

* Source: Altshuller, G.S., Zlotin, B.L., Zusman, A.V. and Philatov, V.I. Search for New Ideas: From Insight to Technology. (Kartya Moldovenyaske Publishing House, Kishinev, 1989), 381. ISBN 5-362-00147-7. in Russian

Engineering systems evolution

[how do systems evolve in long-run?]

Salamatov Y.P (1984-1991)*: wave model (bell-shaped running curve)



TRIZ INSTRUMENTS FOR FORECASTING

* Source: Salamatov, Y.P. *System of The Laws of Technical Systems Evolution*. CHANCE TO ADVENTURE, pp. 7-174 (Karelia Publishing House, Petrozavodsk, 1991). in Russian

Engineering systems evolution

[how do systems evolve in long-run?]

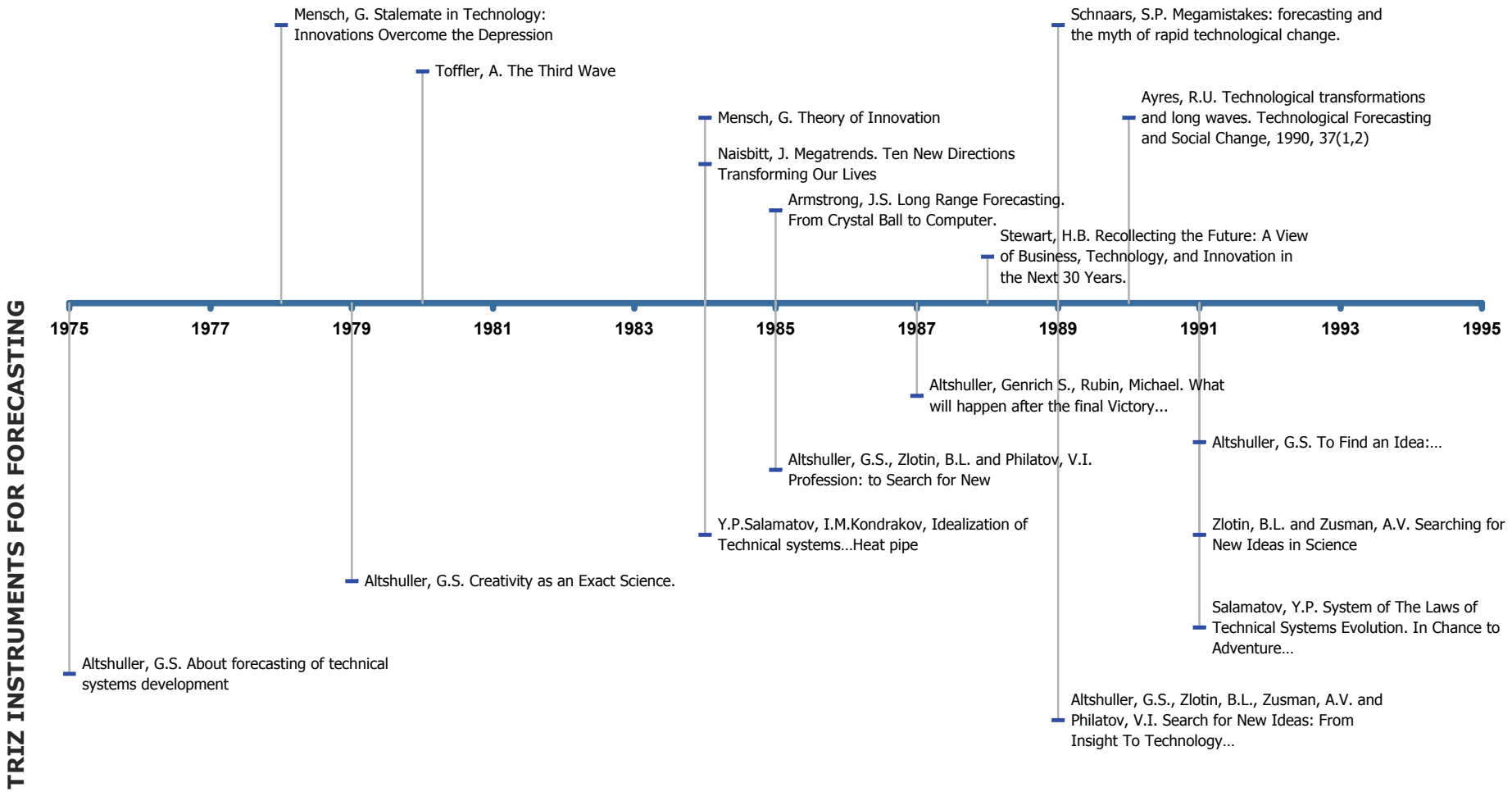
Salamatov Y.P (1991)*:

- Detail summary description for laws of technical systems evolution, proposed by Altshuller G.S. with examples.
- Analysis of technical system's origin and evolution.
  Line of evolution for instruments of production.
- Definition of technical system and its properties.
  Graphical language to describe structure of systems was proposed.
- Laws of technical system evolution with examples and lines (patterns) of evolution.
- Generic scheme of technical systems evolution: bell-shaped curve (running curve).
- Brief information about Long wave cycles of Kondratieff N.D.

* Source: Salamatov, Y.P. *System of The Laws of Technical Systems Evolution*. CHANCE TO ADVENTURE, pp. 7-174 (Karelia Publishing House, Petrozavodsk, 1991). in Russian

Technological forecasting & TRIZ (past)

[timeline fragment #2]



Past of forecasting and TRIZ - summary

[interim conclusions]

- **TRIZ instruments** for prediction: S-curve, system operator, laws of technical systems evolution, lines of evolution (trends) towards Ideality increase, morphological analysis, wave model of systems evolution, ARIZ.
- Prediction instruments produce **essentially qualitative** outcome.
- No two research teams, working independently, will ever get the same prediction. **Reproducibility** and biases free issue.
- TRIZ instruments for prediction support problem oriented, visionary and farseeing **engineering outcome**.

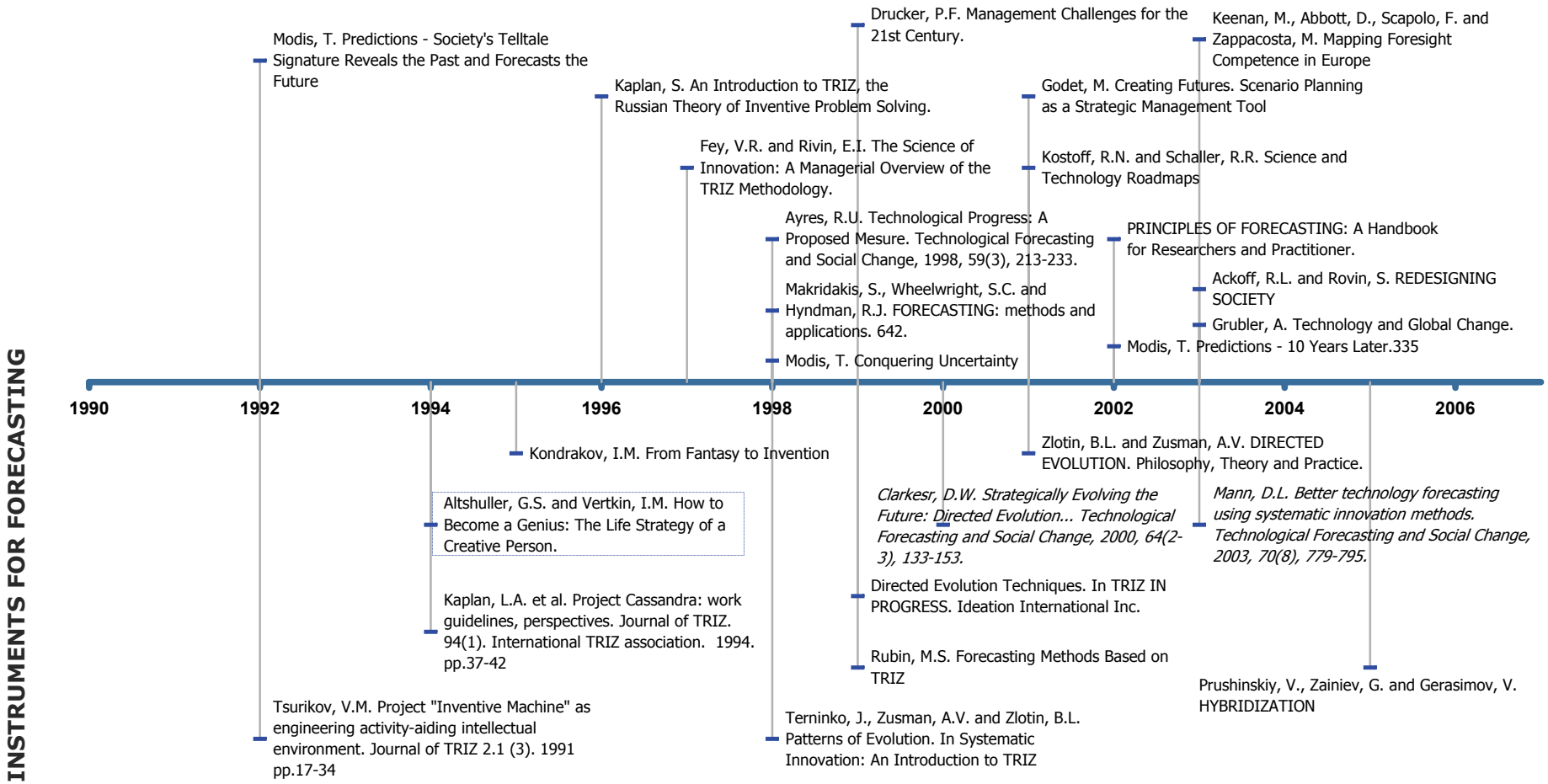
Science is nothing but perception.

Plato

3. TRIZ forecasting (present)

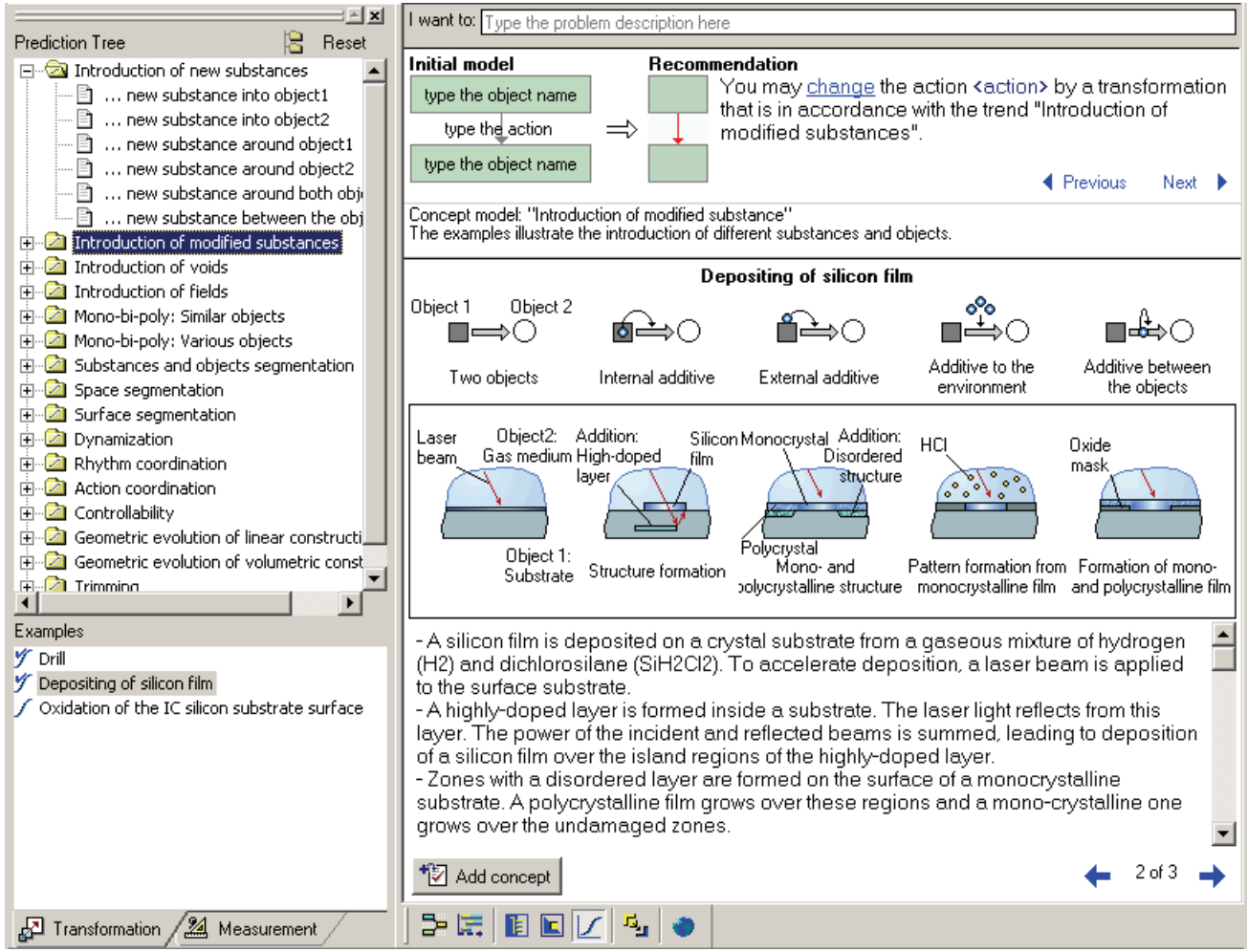
Technological forecasting & TRIZ

[timeline fragment #3]



TRIZ software for prediction

[IM-prediction 1991-1999]



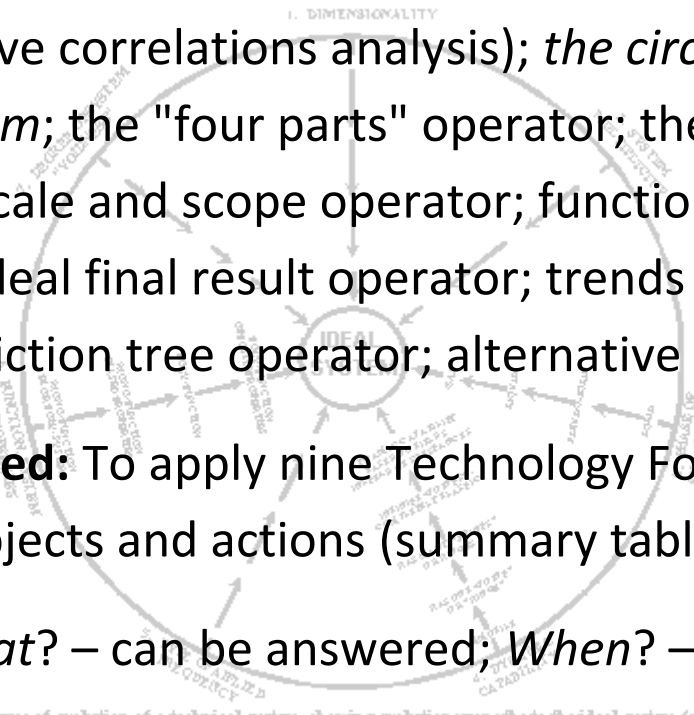
…predict the next phases in the evolution…

* Source: TechOptimizer 3.01 (Invention Machine Corp. 1995-1999)

AFTER-96 (1997)

[Algorithm for Forecasting Technology-Evolution Roadmaps]

- **What is applied as instruments:** the four relationship curves operator (S-curve correlations analysis); *the circular evolutionary-patterns diagram*; the "four parts" operator; the "four stages" operator; the scale and scope operator; function, phenomena, form operator; the ideal final result operator; trends of evolution/prediction tree operator; alternative systems operator.
- **What is proposed:** To apply nine Technology Forecasting Operators (TFO) on the objects and actions (summary table is suggested).
- **Questions**: *What*? – can be answered; *When*? – n/a; *Where*? – n/a;
- **Repeatability**: n/a. **Qualitative forecast** – Yes. **Quantitative** – n/a.
- **Adaptability**: n/a.



Seven measures of evolution of a technical system, showing evolutionary paths to the ideal system (or ideal function, or ideal interaction). The outer circle represents a basic, workable system. The inner circle

* Source: *TECHNOLOGY FORECASTING WITH TRIZ - Predicting Next-Generation Products & Processes Using AFTER - 96* (Algorithm for Forecasting Technology-Evolution Roadmaps) - By: James F. Kowalick, PhD, PE. January 1997 www.triz-journal.com

Directed Evolution (1999)

[questions to be answered]

Traditional technological forecast

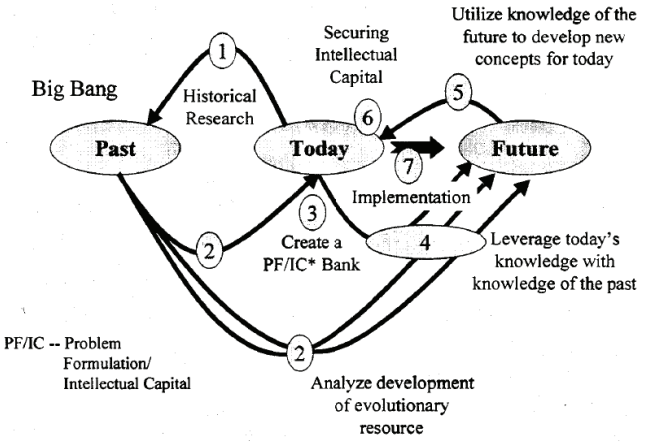
What is going to happened with my product of process parameters?

TRIZ (Technological) forecasting

What change(s) should be made to move my product or process to the next position on a specific pre-determinded Line of Evolution?

Directed Evolution

Which evolutionary scenario should be selected from an identified comprehensive set of scenarios to mak it a winner?



* Source: *TRIZ IN PROGRESS*. (Ideation International Inc., 1999). ISBN 1928747043.

Directed Evolution (1999)

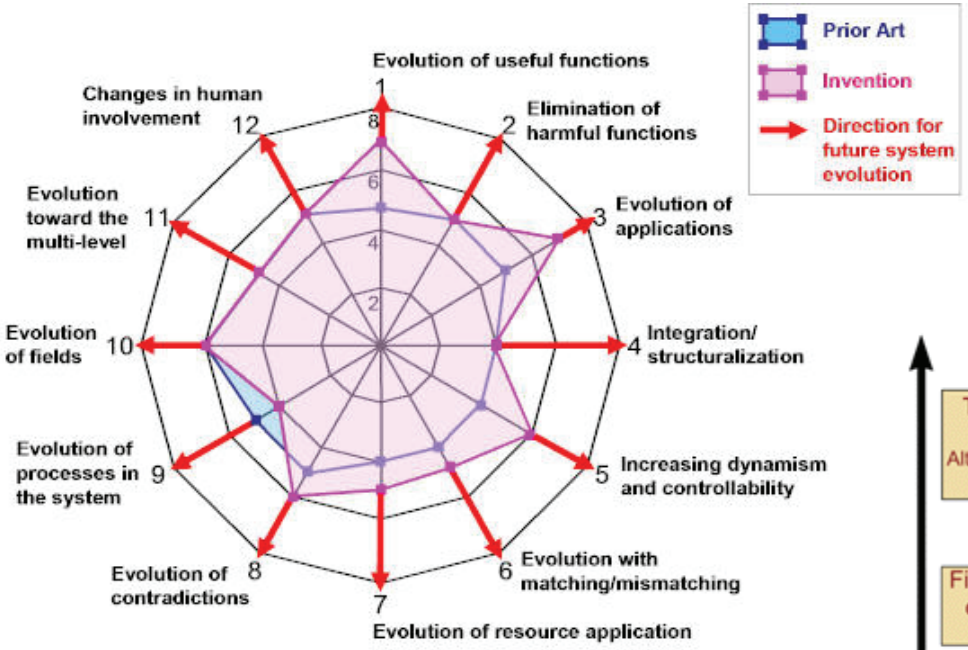
[continuation]

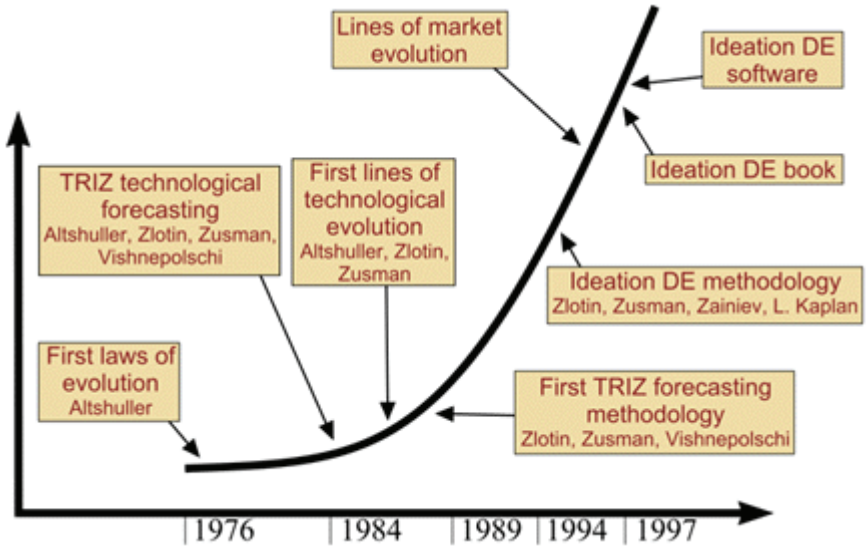
- **What is applied as instruments:** specific information search; S-curve analysis; developing general scenarios of evolution; new system synthesis technique; hybridization technique; integration technique; utilization of pseudo-primary function; Anticipatory Failure Determination (AFD) technique.
- **What is proposed:** Directed evolution process; set of techniques; updated trends, patterns and lines of evolution.
- **Questions**: *What*? – answered; *When*? – n/a; *Where*? – n/a;
- **Repeatability**: n/a. **Qualitative forecast** – Yes. **Quantitative** – n/a.
- **Adaptability**: postulated for product/service; technology; company/organization; industry; market; society.

* Source: *TRIZ IN PROGRESS*. (Ideation International Inc., 1999). ISBN 1928747043.

Directed Evolution (2007)

[directed evolution and the patterns of evolution]





- Directed Evolution™ is based on the 12 Patterns together with over 400 Lines of Evolution.
- The DE process has been applied not only to products but to markets, industries, organizations, technologies, processes, and services.

* Source: http://www.ideationtriz.com/DE.asp#STAGE_5

Guided technology Evolution (1999)

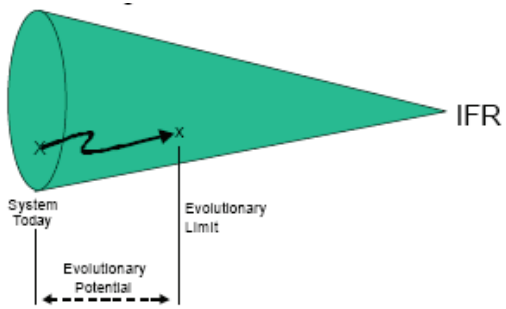
[Victor R. Fey, Eugene I. Rivin]

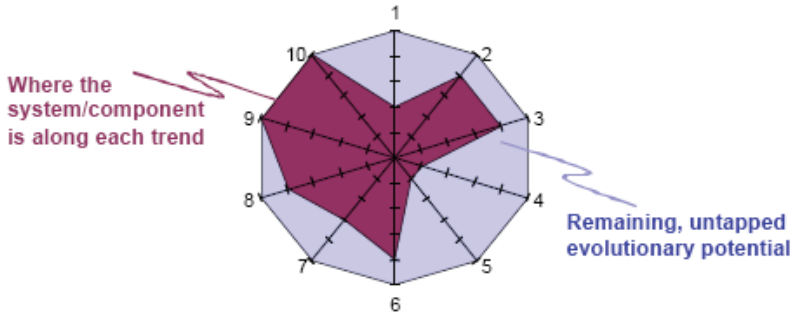
- **What is applied as instruments:** Laws and Lines of Technological Systems Evolution.
- **What is proposed:** Steps of the TRIZ technology forecasting; case examples; comparison between traditional and TRIZ technology forecasts; analysis of the system's evolution by an S-curve.
- **Questions:** *What*? – answered; *When*? – n/a; *Where*? – n/a;
- **Repeatability:** n/a. **Qualitative forecast** – Yes. **Quantitative** – n/a.
- **Adaptability**: limited by scope of laws of technical systems evolution.

* Source: Victor R. Fey, Eugene I. Rivin, *Guided Technology Evolution(TRIZ Technology Forecasting*). January 1999. www.triz-journal.com

Evolutionary potential (2002)

[D.L. Mann]



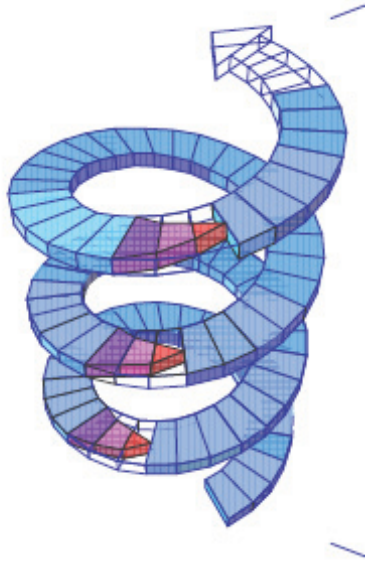


- **What is applied as instruments:** model of Ideal Final Result; patterns of technical systems evolution; technology evolution trends.
- **What is proposed:** updated version of technology evolution trends; procedure to "measure" evolutionary potential of system; business equivalent trends; example for hypothetical organization.
- **Questions:** *What*? – answered; *When*? – n/a; *Where*? – n/a;
- **Repeatability:** n/a. **Qualitative forecast** – Yes. **Quantitative** – quasi(?).
- **Adaptability**: to engineering systems, to business systems.

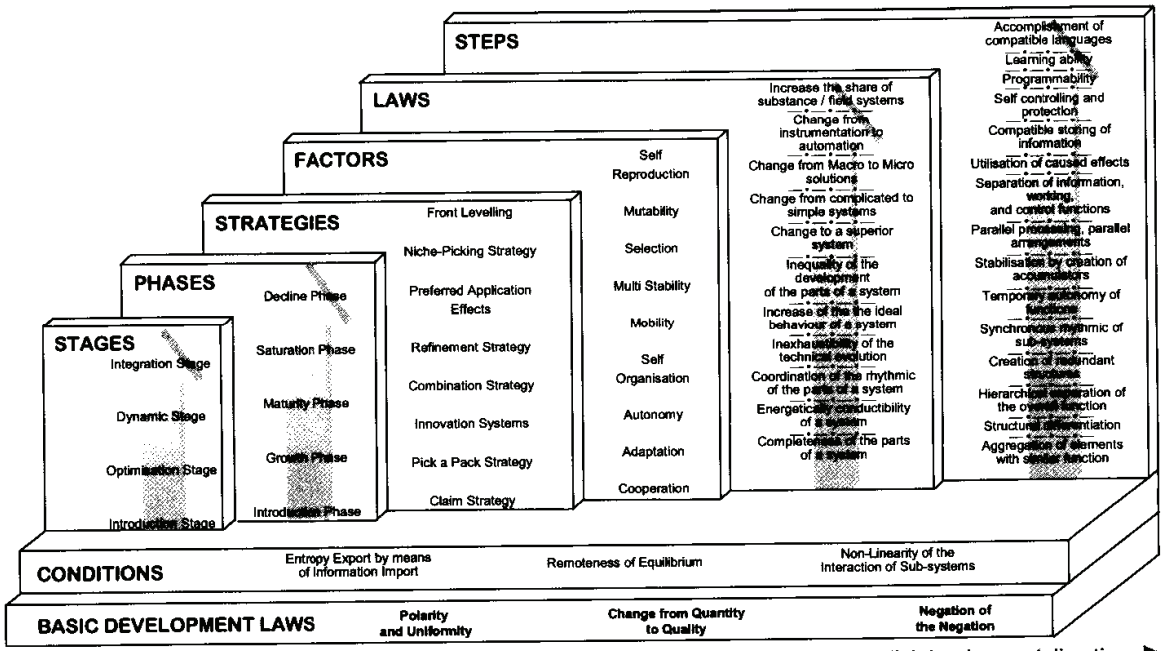
* Source: Mann, D.L. *Better technology forecasting using systematic innovation methods*. Technological Forecasting and Social Change, 2003, 70(8), 779-795.

Model of Evolution with Contradictions (2002)

[Hansjürgen Linde]



WOIS-Spiral as a model of evolution with contradictions

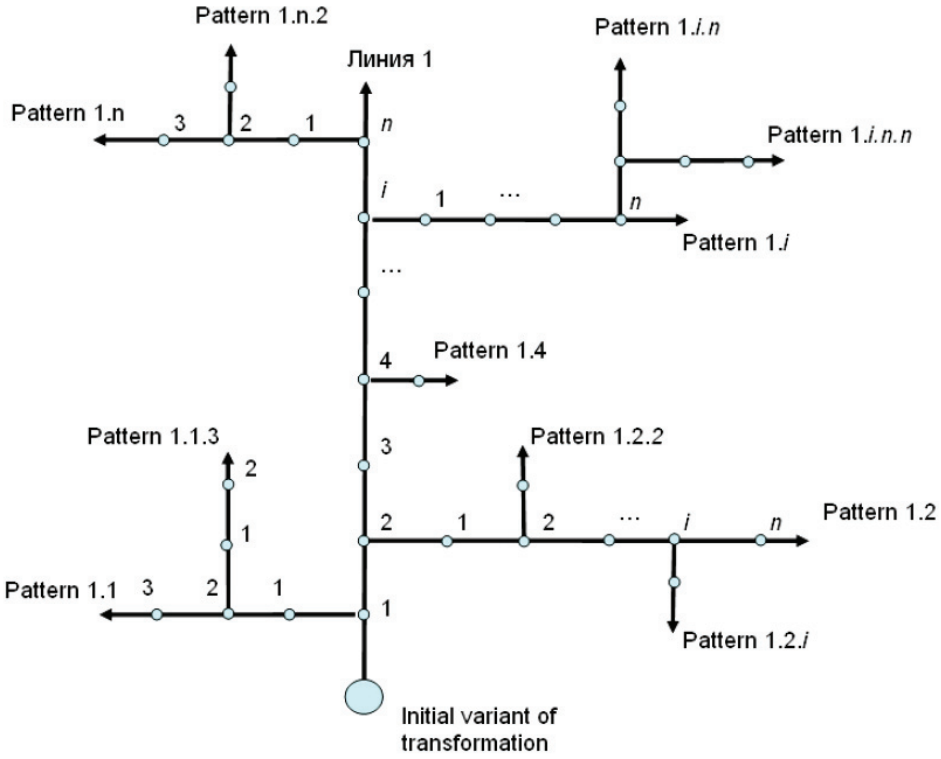


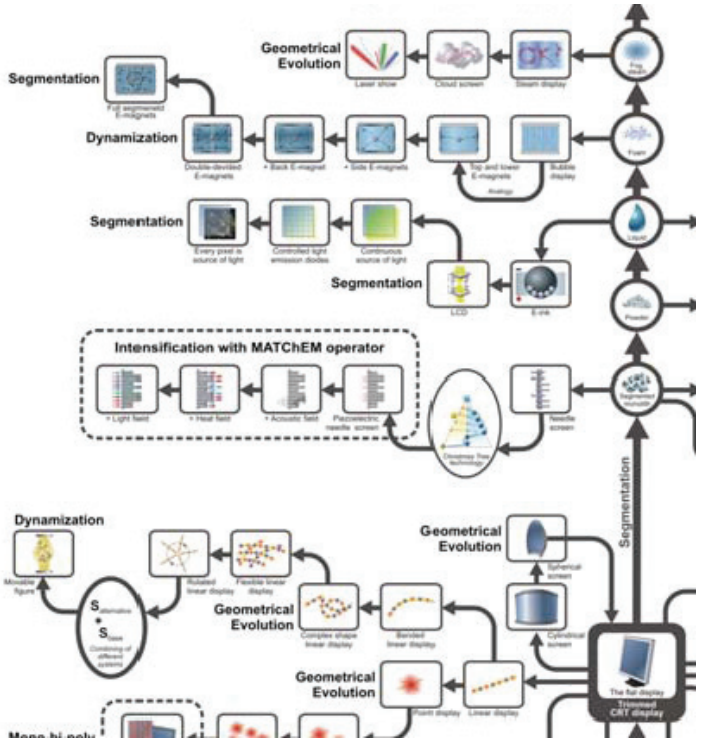
TRIZ INSTRUMENTS FOR FORECASTING

* Source: Hansjürgen Linde, Gunther H. Herr. Professional Strategic Innovation by Intrating TRIZ and WOIS. In TRIZ Future Conference 2004. In ETRIA World conference. Cascini, G., ed. p. 530, (Firenze: Firenze University press, Florence, Italy, 2004).

Evolution trees (2003)

[N. Shpakovsky]





TRIZ INSTRUMENTS FOR FORECASTING

* Sources: 1. *Tool for generating and selecting concepts on the basis of trends of engineering systems evolution*. In World Conference TRIZ Future 2002. In TRIZ Future 2002. p. 402, (ETRIA, European TRIZ Association, Strasbourg, France, 2002).
2. http://www.gnrtr.com/tools/en/a03.html
3. *Analysis and Representation of Information In Forecasting*. In TRIZ Future Conference 2005. In ETRIA World conference. Jantschgi, J., ed. (Leykam Buchverlag, Graz, Austria, 2005).

Evolution trees (2003)

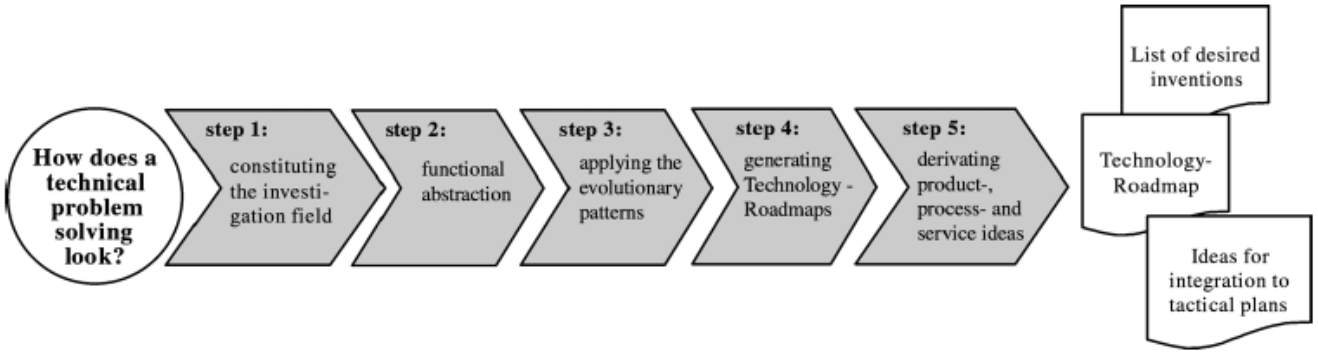
[N. Shpakovsky]

- **What is applied as instruments:** trends, evolution patterns and laws of technological systems evolution; rules to apply evolution patterns.
- **What is proposed:** procedure for constructing an evolution trees; procedure for information classification; the evolution tree structure; procedure for analysis of structured information.
- **Questions:** *What*? – answered exhaustively; *When*? – n/a; *Where*? – n/a;
- **Repeatability:** n/a. **Qualitative forecast** – Yes. **Quantitative** – n/a.
- **Adaptability**: n/a.

* Sources: 1. *Tool for generating and selecting concepts on the basis of trends of engineering systems evolution*. In World Conference TRIZ Future 2002. In TRIZ Future 2002. p. 402, (ETRIA, European TRIZ Association, Strasbourg, France, 2002).
2. http://www.gnrtr.com/tools/en/a03.html
3. *Analysis and Representation of Information In Forecasting*. In TRIZ Future Conference 2005. In ETRIA World conference. Jantschgi, J., ed. (Leykam Buchverlag, Graz, Austria, 2005).

TRIZ-based technology-roadmapping (2004)

[Martin G. Moehrle]

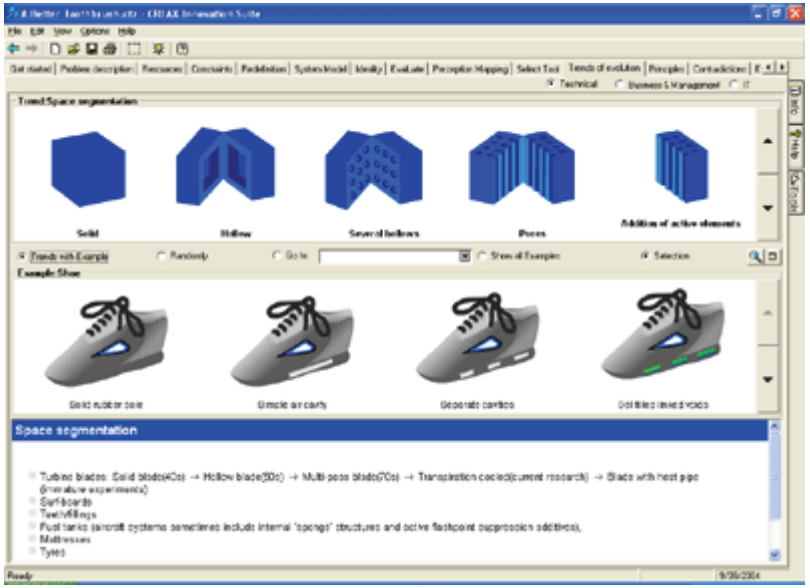


- **What is applied as instruments:** laws of technological systems evolution; invention principles; evolutionary patterns of technical systems.
- **What is proposed:** procedure for technological roadmapping using some of TRIZ techniques.
- **Questions:** *What*? – answered; *When*? – n/a; *Where*? – n/a;
- **Repeatability:** n/a. **Qualitative forecast** – Yes. **Quantitative** – n/a.
- **Adaptability**: to engineering systems with various complexity.

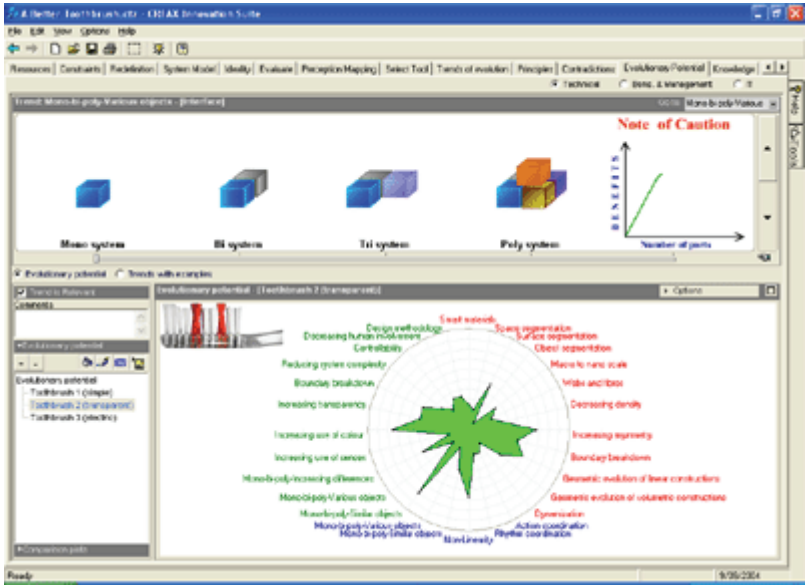
* Source: Moehrle, M.G. *TRIZ-based technology-roadmapping*. Int. J. Technology Intelligence and Planning, 2004, 1(1), 87-99.

Creax innovation suite 3.1

[trends of evolution & evolutionary potential]



Trends of Evolution will show you how products or processes evolve over time.



Evolutionary Potential can visualize where your product, process or service is in its innovation process.

* Source: http://www.creaxinnovationsuite.com/

TRIZ INSTRUMENTS FOR FORECASTING

TRIZ forecasting - summary

[interim results of observation]

- **TRIZ instruments** for prediction: updated, adopted and enhanced patterns and lines of evolution; new ways to apply knowledge about laws of technical systems evolution; problem solving techniques applied for predictions.
- Prediction instruments produce **qualitative** outcome with some quasi quantitative results.
- **Reproducibility** of TRIZ forecasting is questionable.
- TRIZ instruments for prediction become more **customized** and can be applied for non-engineering domains.

…TRIZ is definitely a valuable tool for innovation in engineering. There is a continuing need for advances in many engineering tasks and they merit a major share of attention in technological forecasting…

Harold A. Linstone (May 2000)
Editor-in-Chief of International Journal Technological Forecasting and Social Change

1. Linstone, H.A. Victor R. Fey and Eugene I. Rivin -- The Science of Innovation: A Managerial Overview of the TRIZ Methodology: Southfield, MI, The TRIZ Group, 1997, 82 pages. ISBN 0-9658359-0-1. Technological Forecasting and Social Change, 2000, 64(1), 115-117.
2. Clarke Sr., D.W. Strategically Evolving the Future: Directed Evolution and Technological Systems Development. Technological Forecasting and Social Change, 2000, 64(2-3), 133-153.
3. Mann, D.L. Better technology forecasting using systematic innovation methods. Technological Forecasting and Social Change, 2003, 70(8), 779-795.

SUMMARY

[trends in methods and practice of TRIZ technological forecasting]

- Customization: special techniques to predict technological future, company or organization evolution, market future, and social changes.
- Increasing number of applied lines and patterns (increasing complexity).
- Integration with methods and techniques outside TRIZ (towards super-system) and including some techniques as part of complex problems analysis (towards additional sub-system).
- Attempts to enrich qualitative predictions by quantitative analysis.
- Attempts to develop methods and techniques that will facilitate reproducible results development.

Prediction is very difficult, especially if it's about the future.

Nils Bohr, Nobel laureate in Physics

4. FUTURE OF TECHNOLOGICAL FORECASTING AND TRIZ

Problems of technological forecasting

We fail more often because we solve the wrong problem than because we get the wrong solution to the right problem. Russell Ackoff

Gather information & knowledge:
How to select information and knowledge from myriad inputs?
Noise and Signal Problem.

Identify Key Applications & Key Technologies:
How to detect future application and non-existent needs?
Social, Economic, and Environmental contexts foresee.

* Source: Kucharavy, D. and De Guio, R. Problems of Forecast. ETRIA TRIZ Future 2005Graz, Austria, 2005).

Problems of technological forecasting

[Statement of the problems]

Determine drivers & technical barriers:

How to assess pros and cons of emerging technologies before experience them?

Preconceived limitations, biases, and personal and organizational agendas of the experts.

Describe results in shape of S&TRM:

How to select the final roadmap elements from a multitude of inputs?

Learning and interpretation capacity limitations of human being.

Example of a contradiction

If a forecasting method applies **qualitative** analysis, then it can be applied for long-term forecast due to compatibility with law (of dialectic) of transformation quantity to quality; however, it is difficult to achieve repeatable results from experts, it costs a lot, it takes a lot of time (low frequency to update results), the results contains a lot of biases.

If forecasting method applies **quantitative** analysis, then the results can be obtained a reproducible way, the process is cost effective, it is possible to update result frequently, the results consist less biases; however, it is not compatible with law of transformation 'quantity to quality', consequently it is mostly applied for short-term forecast.

> The law of transformation of quantity into quality: *"For our purpose, we could express this by saying that in nature, in a manner exactly fixed for each individual case, qualitative changes can only occur by the quantitative addition or subtraction of matter or motion (so-called energy)."*
>
> [Engels' Dialectic of Nature. II. Dialectics. 1883]

Question to be answered

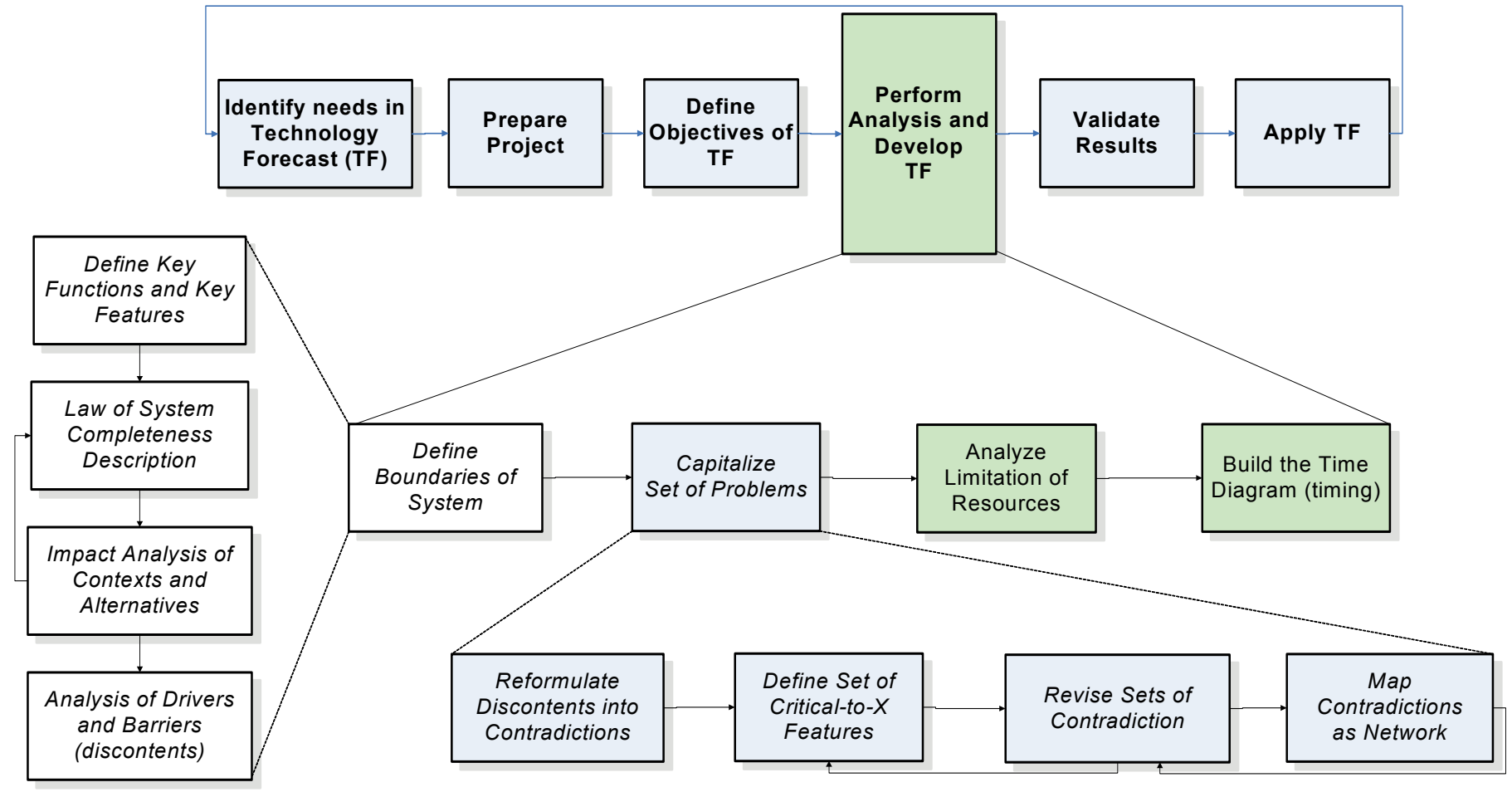
[why is it difficult?]

How to assess the advantages and shortcomings of emerging technologies before having experienced them?

For the problem perception stage:

In order to decrease risks and make a trustworthy assessment, we should have knowledge;
however, we do not have the required knowledge,
because the technology is emerging.

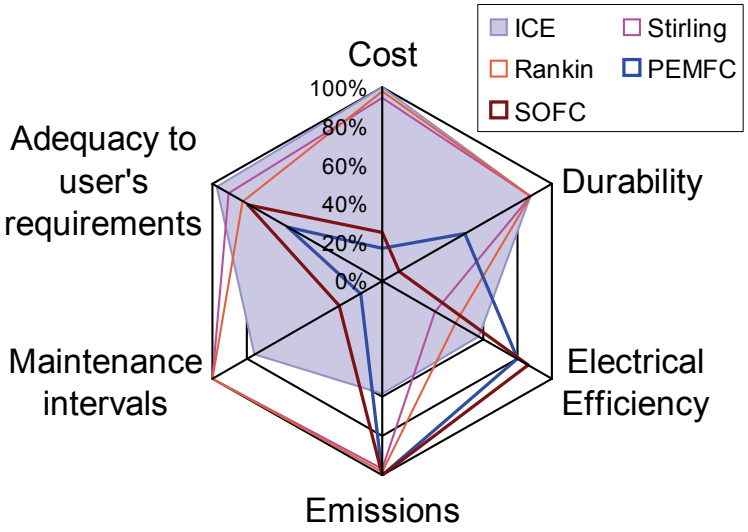
a procedure for technological forecasting



TRIZ INSTRUMENTS FOR FORECASTING

example: critical-to-market features values

[Define set of critical-to-X features (SFC)]



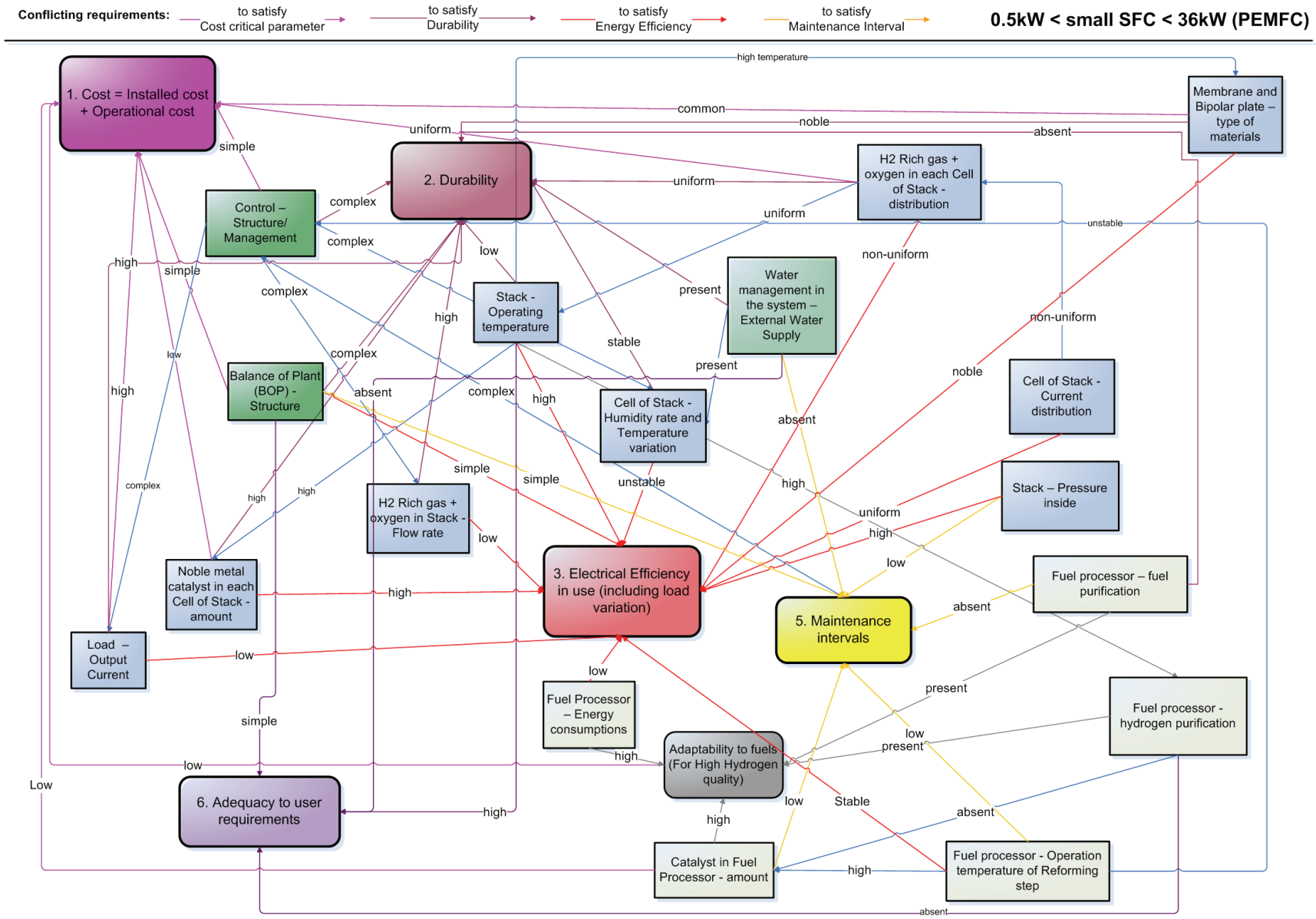
		PEMFC			SOFC		
		actual	*market target*	*performed*	*actual*	*market target*	*performed*
1.	**Cost:**	***17%***	***100%***		***25%***	***100%***	
1.1.	Installed Cost NG, EUR/kW	15000	4000	27%	10000	4000	40%
	Importance: *High*						
1.2	Operational cost, EUR/kWh	0.3	0.02	7%	0.2	0.02	10%
	Importance: High						
2.	**Durability:**	***49%***	***100%***		***10%***	***100%***	
2.1	Durability in operating conditions, years	2	15	13%	2	15	13%
	Importance: *High*						
2.2	Cycling ability, number of stops per year	125	125	100%	10	125	8%
	Importance: *High*						
2.3	Start up time, min	90	15	17%	240	15	6%
	Importance: *Moderat e*						
3.	**Energy Efficiency, %**	***85%***	***100%***		***93%***	***100%***	
3.1	Electrical efficiency, %	28%	35%	80%	30%	35%	86%
3.2	Thermal efficiency, %	59%	65%	91%	55%	50%	100%
3.3	Ratio Electrical power / Thermal Power	0.51	0.04		0.04	0.04	
4.	**Emissions**	***100%***	***100%***		***100%***	***100%***	
	Importance: *High*						
4.1	Substances, ppm	40	CO < 56ppm NOx<34 ppm	***100%***		CO < 56ppm NOx<34 ppm	***100%***
	Importance: High						
4.2	Noise, dB	0		***100%***	0		***100%***
	Importance: High						
5.	**Maintenance interval, h**	1000	8000	***13%***	2000	8000	***25%***
	Importance: *Moderate*						
6.	**Adequacy to user requirements,**	***56%***	***100%***		***79%***	***100%***	
6.1	min. temperature return, °C						
	Importance: *High*	50	60	83%	500	70	100%
6.2	min. flow temperature, °C						
	Importance: *Moderate*	70	80	88%	900	90	100%
6.3	size, m	1.5x0.85x1.7	0.5x0.5x1		0.55 x 0.55 x 1.60	0.5x0.5x1	
	Importance: *Moderate*	2.17	0.25	12%	0.48	0.25	52%
6.4	weight, kg	500	70	14%	170	70	41%
	Importance: *Moderate*						
	Average for technology:	**39%**	**100%**		**40%**	**100%**	

Larger gap between desired value of feature and actual one indicates more problems to be solved on the way to commercialize an emerging technology.

TRIZ INSTRUMENTS FOR FORECASTING

example: network of contradictions for PEMFC

[Map contradictions as network (SFC)]



TRIZ INSTRUMENTS FOR FORECASTING

comments: network of contradictions

[Structure of problem map]

Nodes_1 – Critical-to-X features (Critical-to-Market for SFC)

Nodes_2 – Element + Features "responsible" for problem (contradiction).

Links – Opposite values of Features for Nodes_2; they can be connected to Nodes_1 or to Nodes_2.

assessment of resource limitations

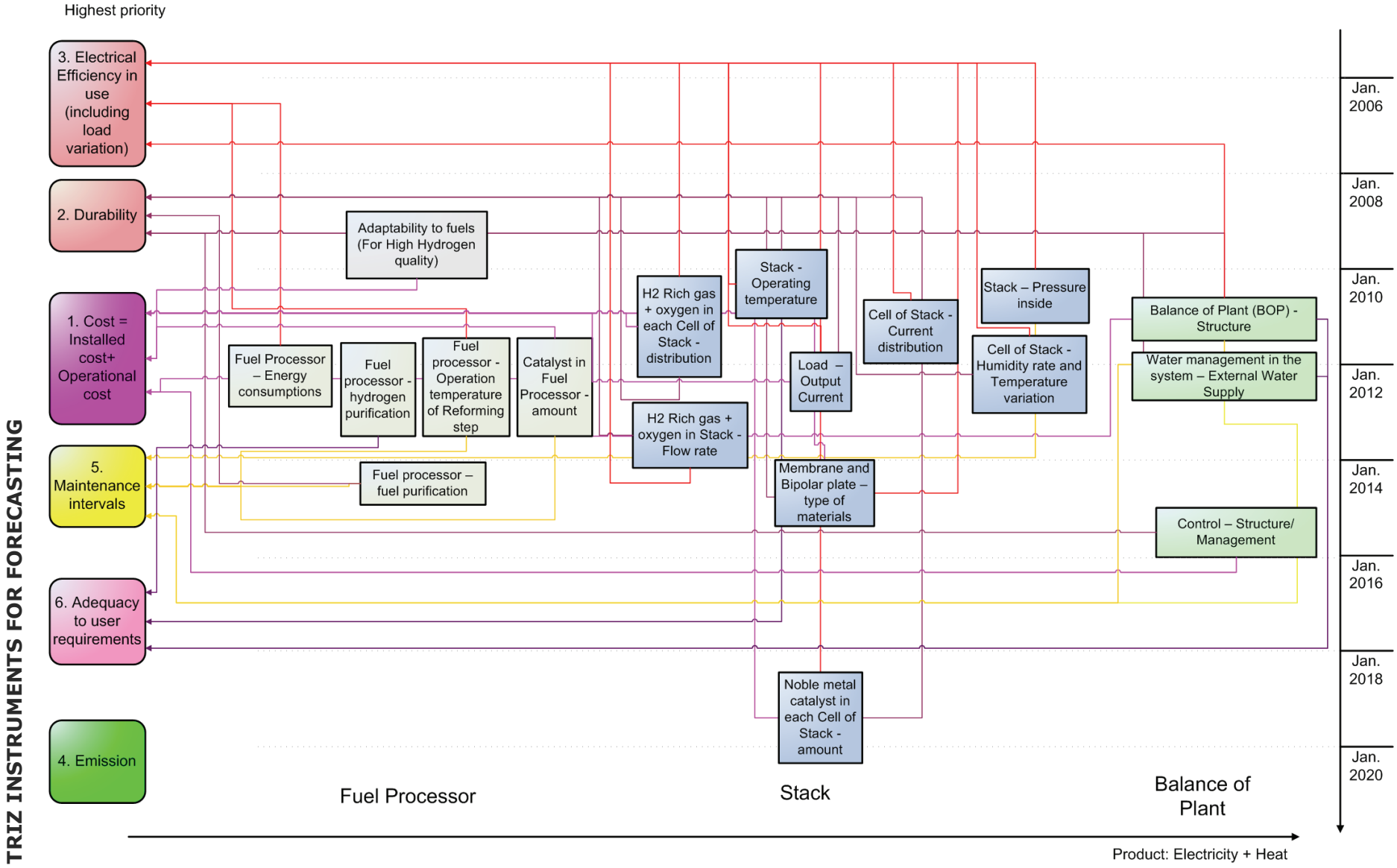
[S&T and R&D activities identification]

Element-Feature	Value 1, V	Value 2 (opposed), Λ	Limiting resources	S&T, R&D activities, Project names	Exploration, years	Experimentation & examination, years
Noble metal catalyst in each Cell of Stack - amount	Low	High	Platinum needed at low temperature (<400°C)	<Project 1 name>	<Project1 duration>	<Time for field tests>
<E2 – F2>	<V>	<Λ>	<Substance, Field, Time, Space etc.>	<Project 2 name>	<Project2 duration>	<Time for field tests>
<E3 – F3>	Present	Absent	<Time, Space etc.>	No specific project	<Project3 duration ??>	<Time for field tests ??>
<…>	<…>	<…>	<…>	<…>	<…>	<…>
<…>	<…>	<…>	<…>	<…>	<…>	<…>
Fuel processor - Quality of outlet gas	Low	High	complex fuel processing technology for NG and biofuels	<Project N name>	<Project N duration>	<Time for field tests>

TRIZ INSTRUMENTS FOR FORECASTING

Map of problems of PEMFC on a time scale

[technological context]



some reasons of difficulties

- ..at different stages of a system's evolution, different resources can be identified as 'scarce resources' - *Dynamic nature of limited resources*;
- ..it is necessary to take into account also economic, social and environmental resources. How to measure and unify all these resource limitations? - *Multiple contexts compatibility*;
- ..appropriate data should be collected - *Noise and Signal*;
- ..for emerging technologies it is necessary to work with experts to overcome knowledge shortages - the problem of *preconceived limitations, and biases of experts*;
- ..to identify a system it is necessary to define its boundaries, and its interaction with the environment in the dynamics – the *Dynamics of necessary and sufficient description*.

So What?

…Everything has been said before, but since nobody listens we have to keep going back and beginning all over again…

a French author (1869-1951) and winner of the Nobel Prize in Literature in 1947

- Systems evolve in accordance with law of nature… in competition with limit of resources…
- These laws can be revealed from accumulated knowledge about systems evolution…
- These laws can be represented computable way… in order to apply them reproducible way…
- The scientific method seeks to explain the events of nature in a reproducible way, and to use these reproductions **to make useful predictions**…

Thank you for your attention :-)

Many thanks:

- for organizers of ETRIA TFC 2007 for opportunity to present our viewpoint in front of so experienced auditorium.
- to the European Institute for Energy Research (EIFER), Karlsruhe for support of the research on Technological forecasting.
- to our colleagues from the LICIA team of LGECO, INSA Strasbourg for their questions, comments, and notes that helped to clarify many presented points.

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