This paper was first published in the proceedings of TRIZCON2005, the meeting of the Altshuller Institute in Brighton, MI USA, April 2005.

The TRIZ Give Way to the Wind, and Give the Wind Away
A Repeatable Process for Improving Sustainable Wind Energy Generation

Authors

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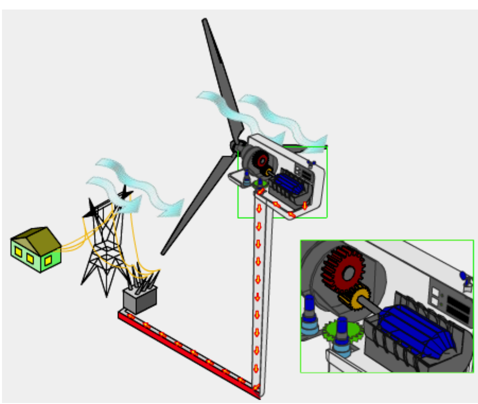
Abstract

Given the fast growing population and the ever increasing consumption of resources it is imperative that breakthrough innovations make alternative energy sources more commercially viable. Wind turbines represent an attractive source of sustainable and environmentally friendly energy. World wind energy capacity has been doubling every three years during the last decade and growth rates in the last two years have been even faster. Yet the technology still needs a higher profile and greater efficiency.

Using the improvement of Wind Turbine Development as a case study, this presentation focuses on a proven and repeatable process that overcomes common TRIZ deployment challenges by showing a workflow and methodology for how to get started working on a problem with TRIZ, how to compliment TRIZ with Value Methodologies for problem identification, and how to leverage internal and external knowledge sources to accelerate concept identification.

Introduction - Wind Turbine Development

The potential for wind energy production is yet to be realized, but holds great promise for as a renewable and environmentally friendly source of energy.

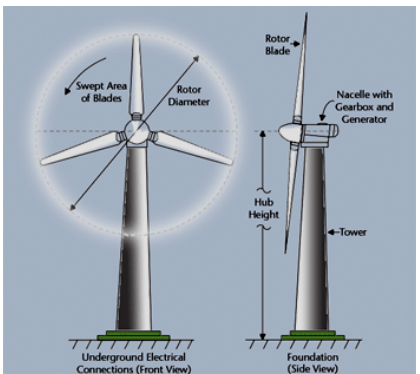


- Wind power is expected to grow at an annual rate of 20 % resulting in a total of about 40 000 MW of installed capacity around the world by 2004.
- According to recent study "Wind Force 10" wind power could generate 10 % of global electricity by 2020, and create 1,7 million jobs at the same time.
- International installation of 1,2 million MW of wind capacity by 2020 would generate more electricity than the entire continent of Europe consumes today.
- Total wind energy potential in the world is 53 trillion kWh, 17 times higher than the Wind Force 10 goal.
- According to the study the cost of generating electricity with wind turbines is expected to drop to 2.5 US cents/kWh by 2020, compared to the current 4.7 US cents/kWh.

- Environmental benefits of the 10 % target would be enormous – savings of 69 million tones of CO_2 in 2005, 267 millions tons in 2010 and 1780 million tones in 2020.

The potential for TRIZ as a high-value problem solving methodology has also yet to be fully realized, especially in combination with Value Engineering and a fund of targeted informational resources. But with an effective roadmap to guide the practitioner, the benefits of combining and deploying these discrete resources and methodologies are readily attainable. This paper describes such a roadmap and thereby provides a repeatable process for improving not only sustainable wind energy generation, but a method for improving virtually any technical system.

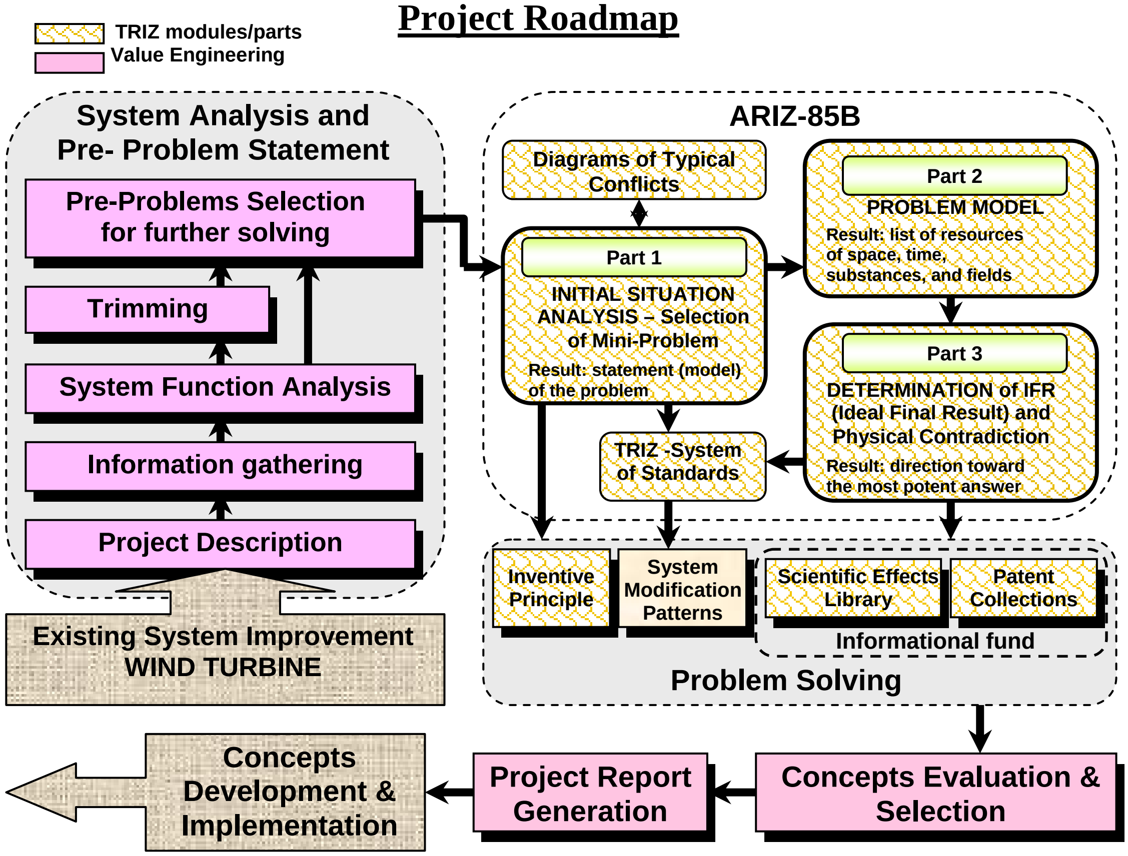
Project Description & Initial Situation



http://www.nrel.gov/wind/animation.html
Drawing of the rotor and blades of a wind turbine, courtesy of ESN

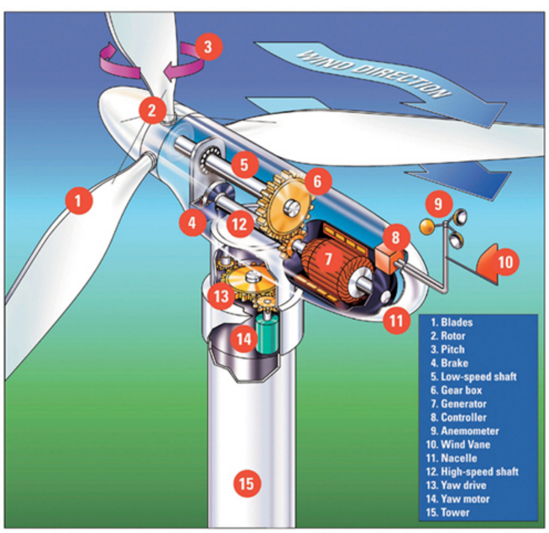
We have selected Three-Blades Turbine as a base Turbine design for our research project. The Three-Blade Turbine is most common, sometimes known as a Danish Concept. These three-bladed wind turbines are operated "upwind," with the blades facing into the wind. Wind turbine works the opposite of a fan. Instead of using electricity to make wind, a turbine uses wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. The electricity is sent through transmission and distribution lines to a substation, then on to homes, business and schools.

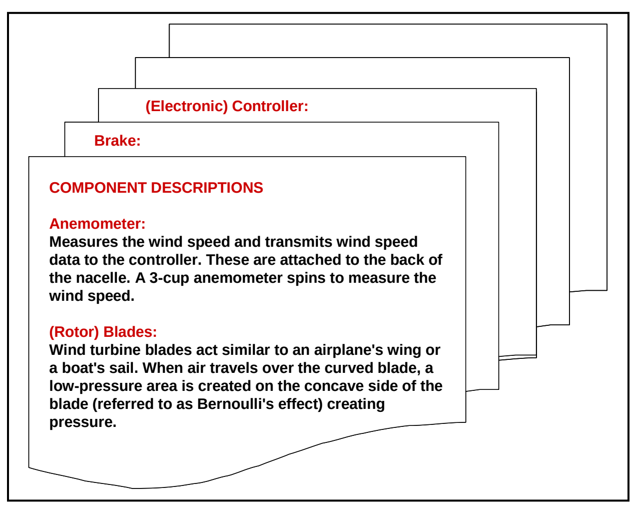
Project Roadmap



Information Gathering

Identify and define the component structure of the wind turbine





(Electronic) Controller:

Brake:

COMPONENT DESCRIPTIONS

Anemometer:
Measures the wind speed and transmits wind speed data to the controller. These are attached to the back of the nacelle. A 3-cup anemometer spins to measure the wind speed.

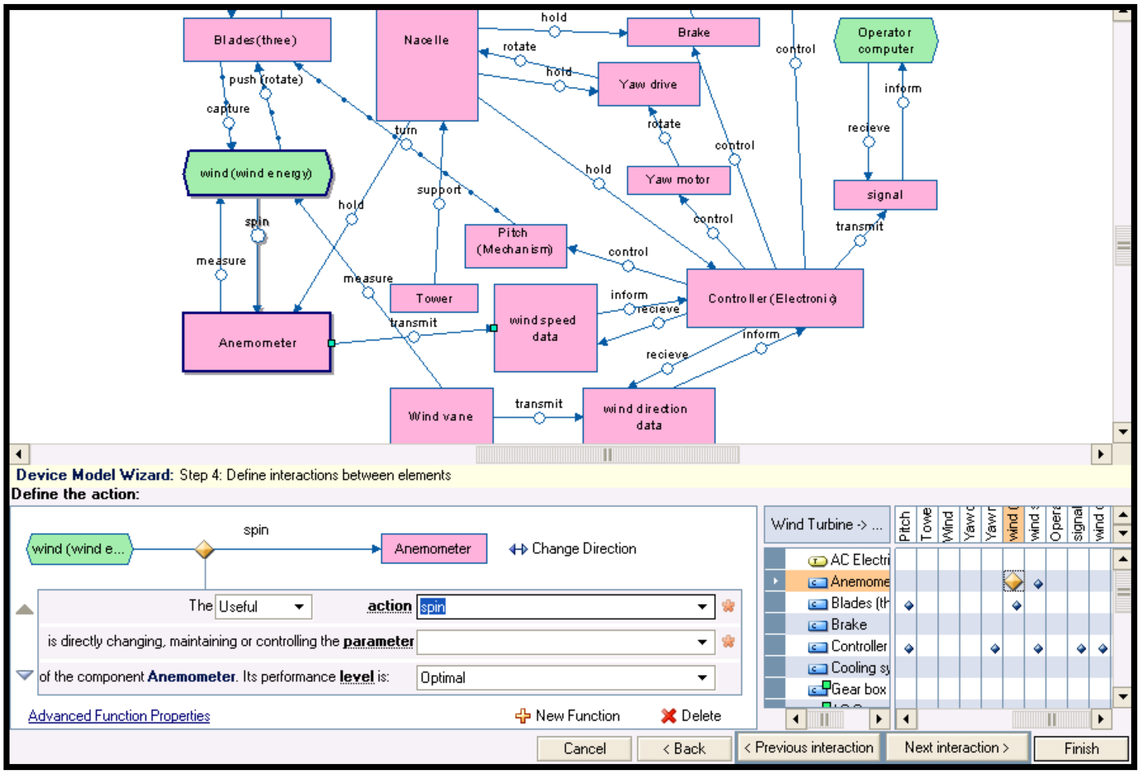
(Rotor) Blades:
Wind turbine blades act similar to an airplane's wing or a boat's sail. When air travels over the curved blade, a low-pressure area is formed on the concave side of the blade (referred to as Bernoulli's effect) creating pressure.

Identify trends of past and present R&D efforts that have contributed to current utility-scale turbine technology

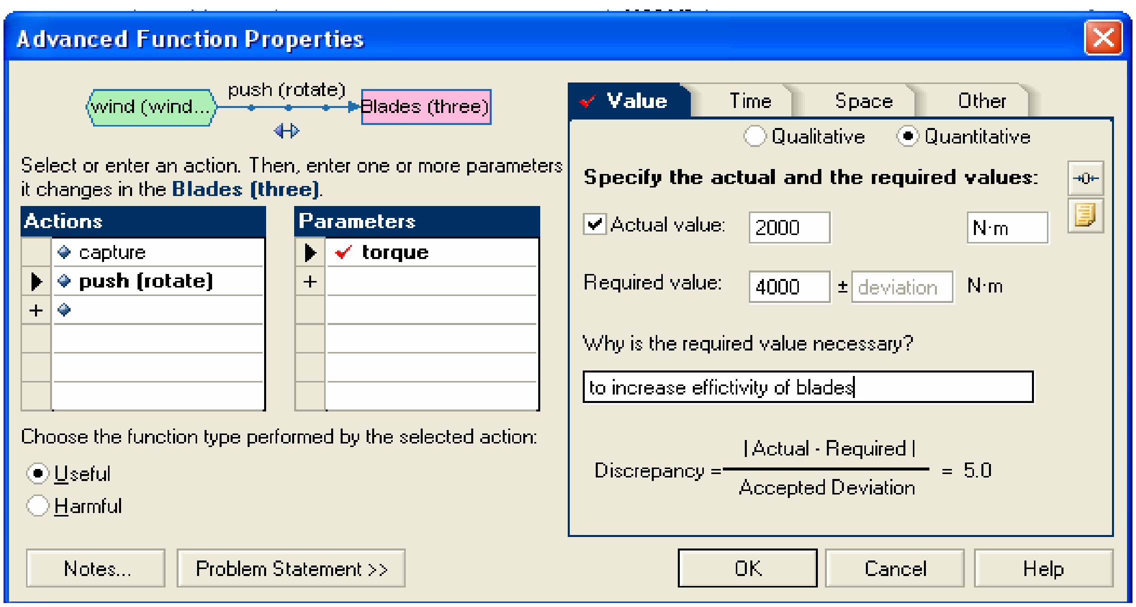
- Improvements in the aerodynamics of wind turbine blades, resulting in higher capacity factors and an increase in the watts per square meter of swept area performance factor.
- Development of variable speed generators to improve conversion of wind power to electricity over a range of wind speeds.
- Development of gearless turbines that reduce the on going operating cost of the turbine.
- The general trend is toward wind turbines with maximum power output of 1 MW or more. European firms -- such as Danish companies Vestas and NEG Micon -- currently have more than 10 turbine designs in the megawatt range with commercial sales.
- Wind turbine manufacturers optimize machines to deliver electricity at the lowest possible cost per kilowatt-hour (kWh) of energy.
- Development of lighter tower structures. A by-product of advances in aerodynamics and in generator design is reduction or better distribution of the stresses and strains in the wind turbine. Lighter tower structures, which are also less expensive because of material cost savings, may be used because of such advances.
- Smart controls and power electronics have enabled remote operation and monitoring of wind turbines. Some systems enable remote corrective action in response to system operational problems. The cost of such components has decreased. Turbine designs where power electronics are needed to maintain power quality also have benefited from a reduction in component costs.

System Functional Analysis

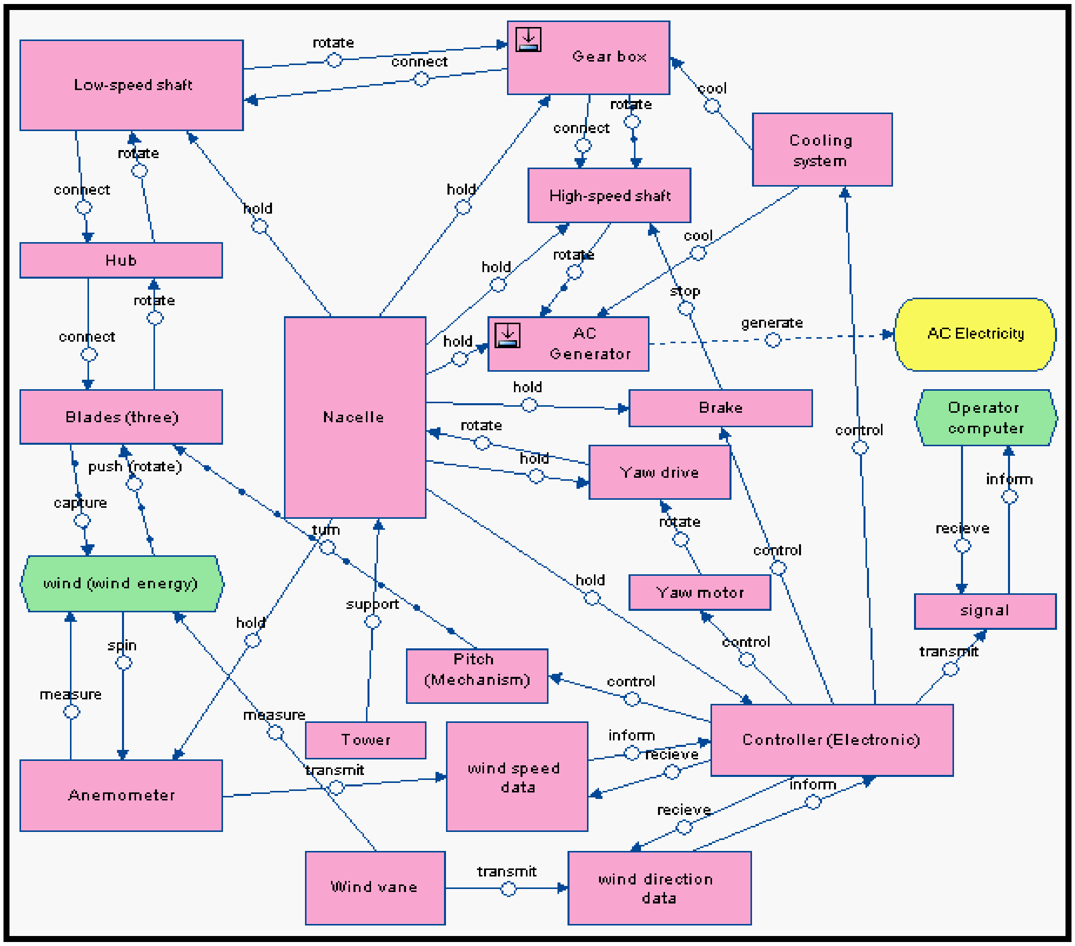
A functional model of the system is nessesary to obtain a proper understanding of system behavior. Each component and function must be defined.



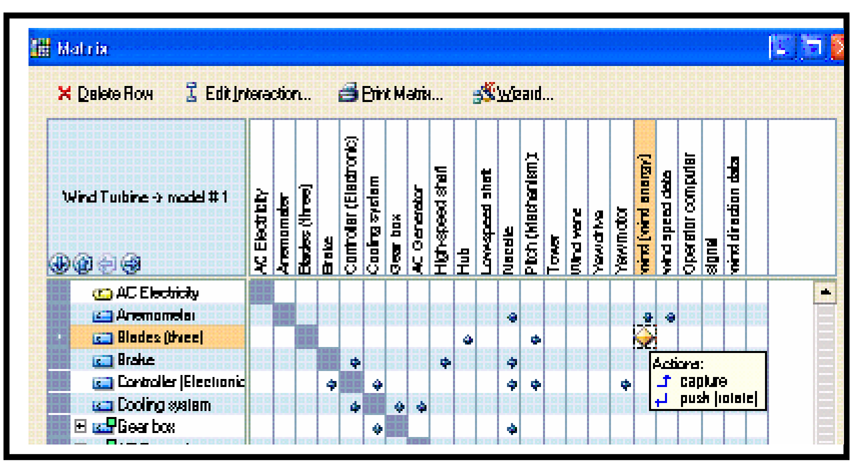
Advanced function analysis allows us to define parameters of functions, their actual and required values, and their dependencies.



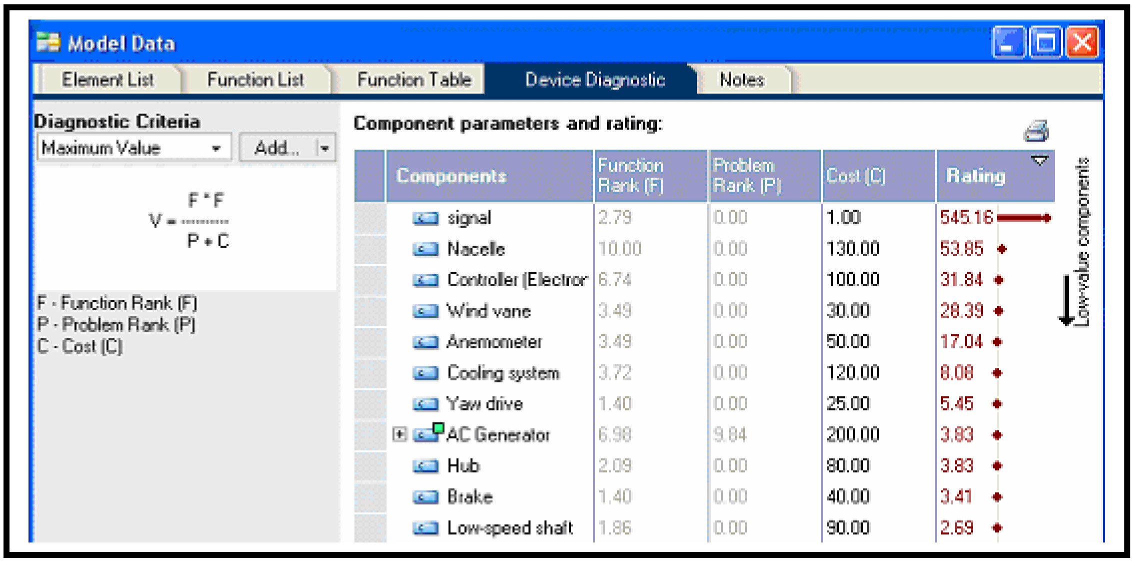
The completed full function model will document the system sufficiently to enable the recognition of problematic areas in the system. Additionally, the documented model permits an in depth automated evaluation from a Value Engineering perspective.



Use a matrix to provide a checkpoint confirmation that all functions are identified.



Model Data Device Diagnostic: Component Parameters and rating help define strategies for subsequent changes or simplifications of the system configuration. A variety of criteria can be evaluated in order to select strategies that best align with the project goals.



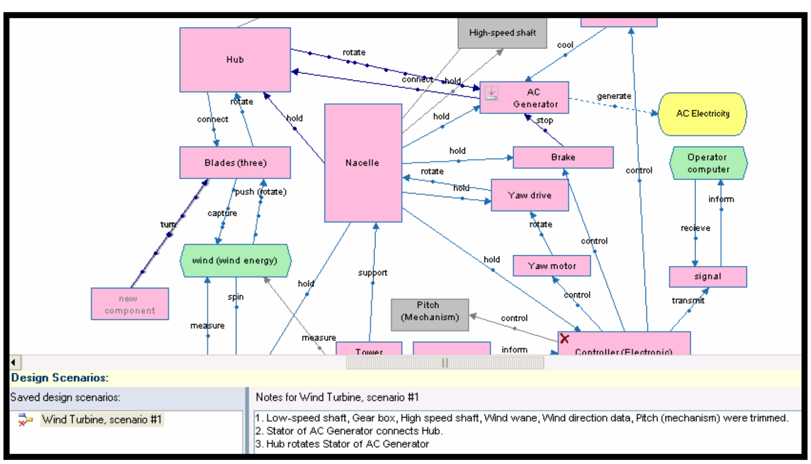
Components	Function Rank (F)	Problem Rank (P)	Cost (C)	Rating
signal	2.79	0.00	1.00	545.16
Nacelle	10.00	0.00	130.00	53.85
Controller (Electror	6.74	0.00	100.00	31.84
Wind vane	3.49	0.00	30.00	28.39
Anemometer	3.49	0.00	50.00	17.04
Cooling system	3.72	0.00	120.00	8.08
Yaw drive	1.40	0.00	25.00	5.45
AC Generator	6.98	9.84	200.00	3.83
Hub	2.09	0.00	80.00	3.83
Brake	1.40	0.00	40.00	3.41
Low-speed shaft	1.86	0.00	90.00	2.69

Design Simplification Strategy - Trimming Method

- Improves product/process by eliminating low value (problematic) components and redistribution their useful functions between other components.
- Simplifies and reduces the cost of user product/process, while preserving the essential functionality.
- The design variants that results from Trimming will generate different problem statements, if solved, can lead to highly innovative solutions.

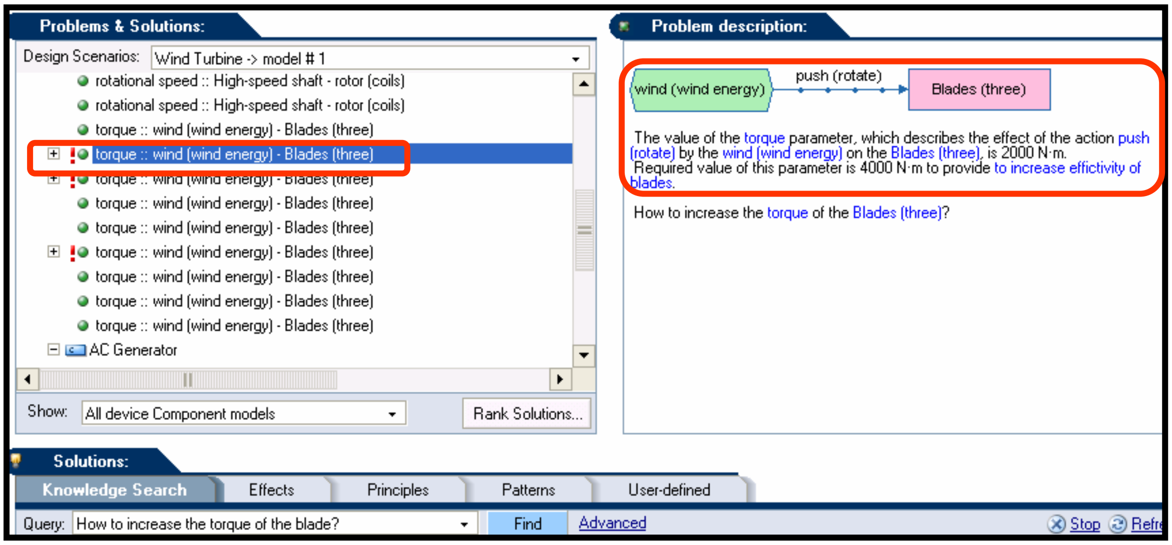
Wind Turbine -> trimming scenario results

1. Low-speed shaft, Gear box, High speed shaft, Wind wane, Wind direction data, Pitch (mechanism) were trimmed.
2. Stator of AC Generator connects Hub.
3. Hub rotates Stator of AC Generator



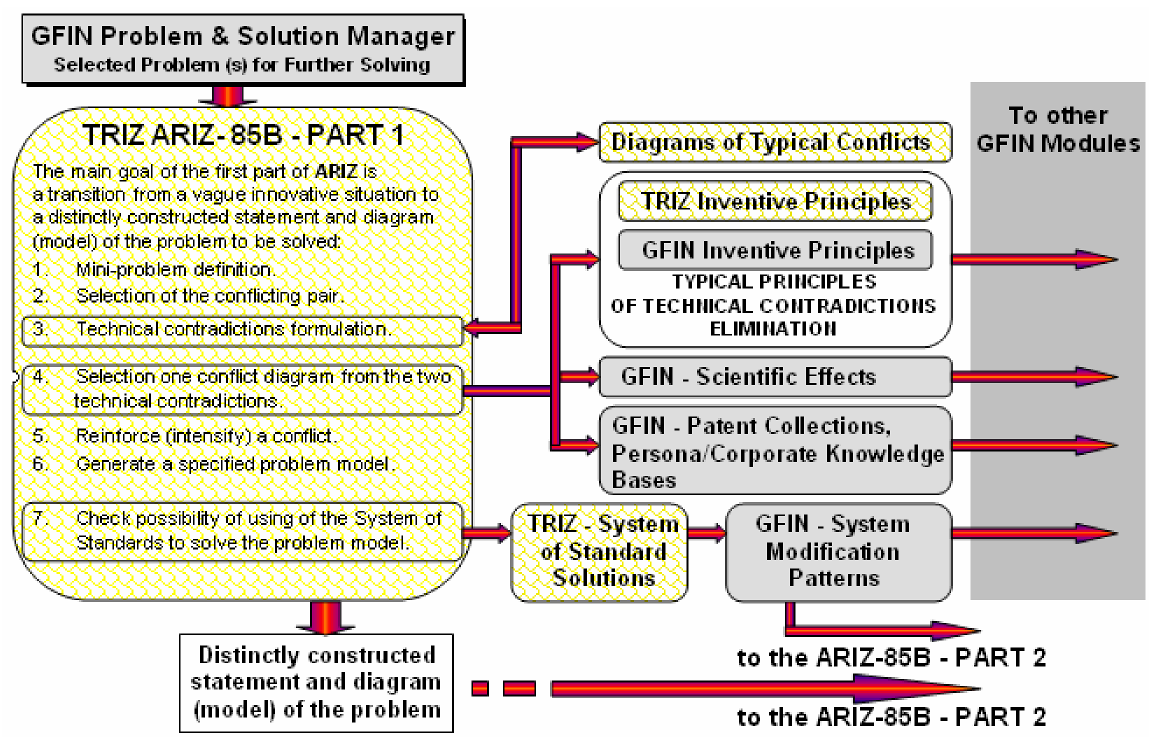
Pre-Problem Selection

We have selected one problem (pre-problem) for the next stage of the project: The value of the torque parameter, which describes the effect of the action push (rotate) by the wind (wind energy) on the Blades (three), is 2000 Nm. The required value of this parameter is 4000 Nm to provide to increase efficiency of blades. The problem is: How to increase the torque of the Blade?



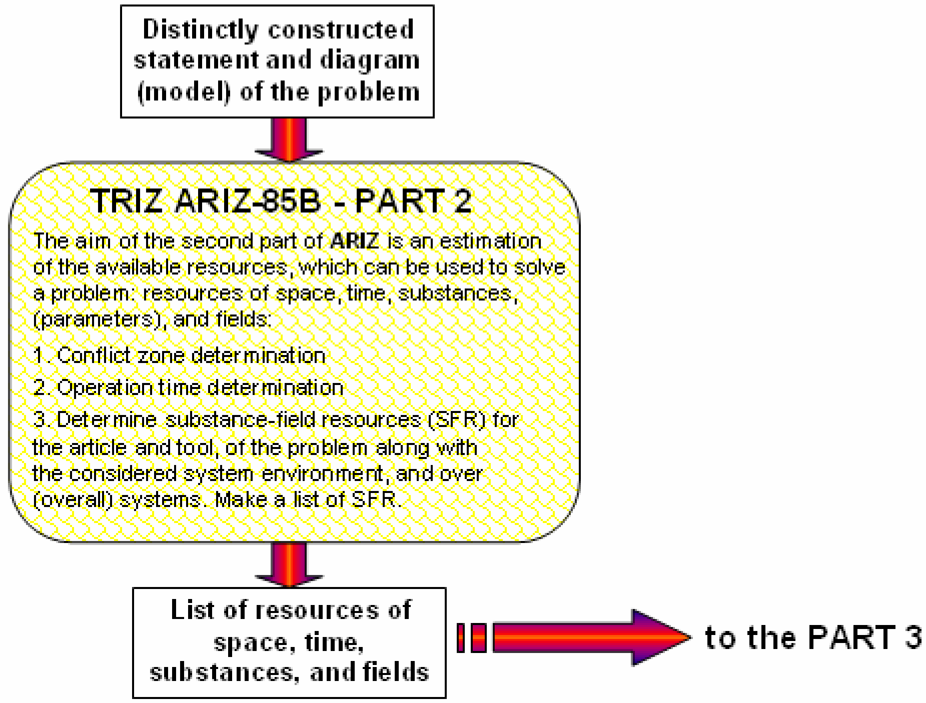
Algorithm for Inventive Problem Solving – Part 1

INITIAL SITUATION ANALYSIS – Selection of Mini-Problem



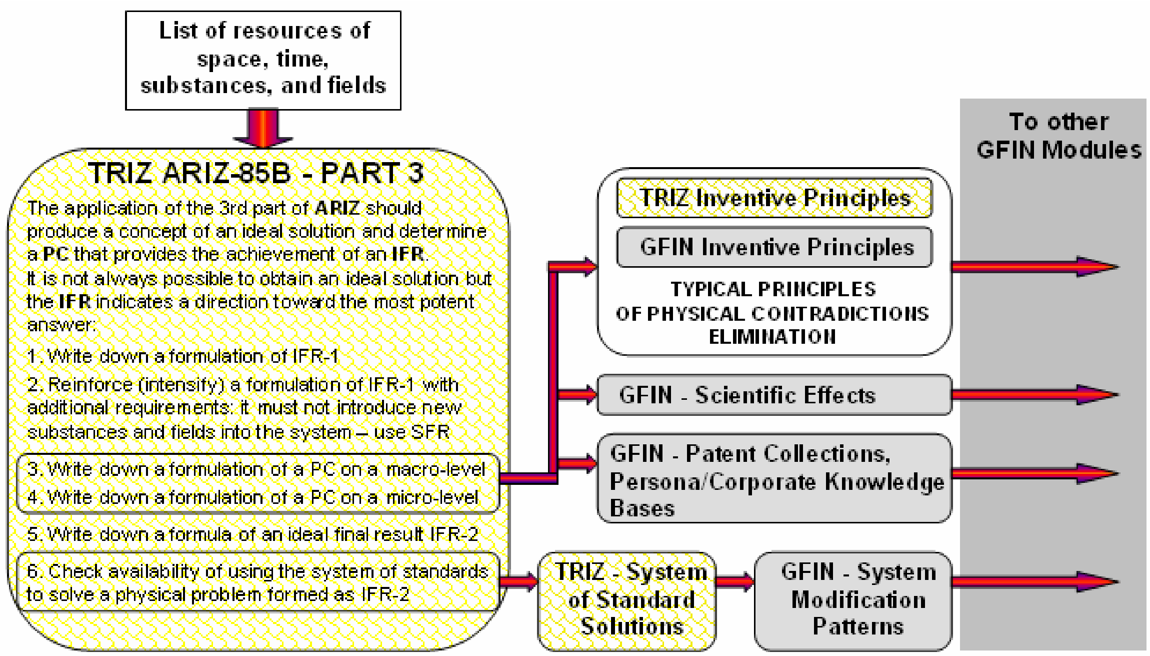
Algorithm for Inventive Problem Solving – Part 2

PROBLEM MODEL ANALYSIS - List of resources of space, time, substances, (parameters), and fields



Algorithm for Inventive Problem Solving – Part 3

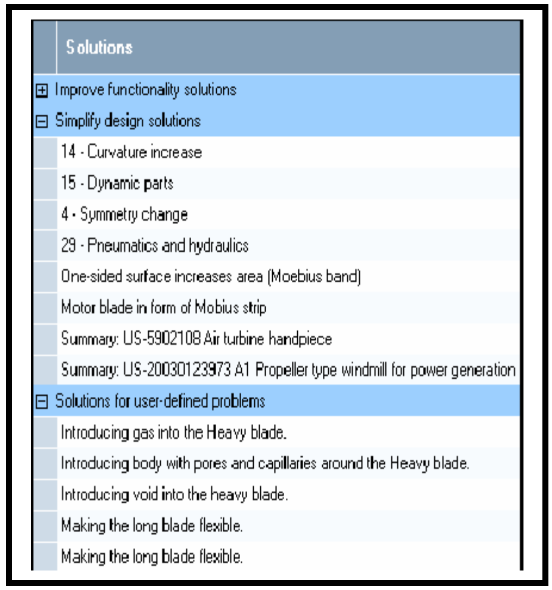
DETERMINATION of IFR (Ideal Final Result) and PC (Physical Contradiction)



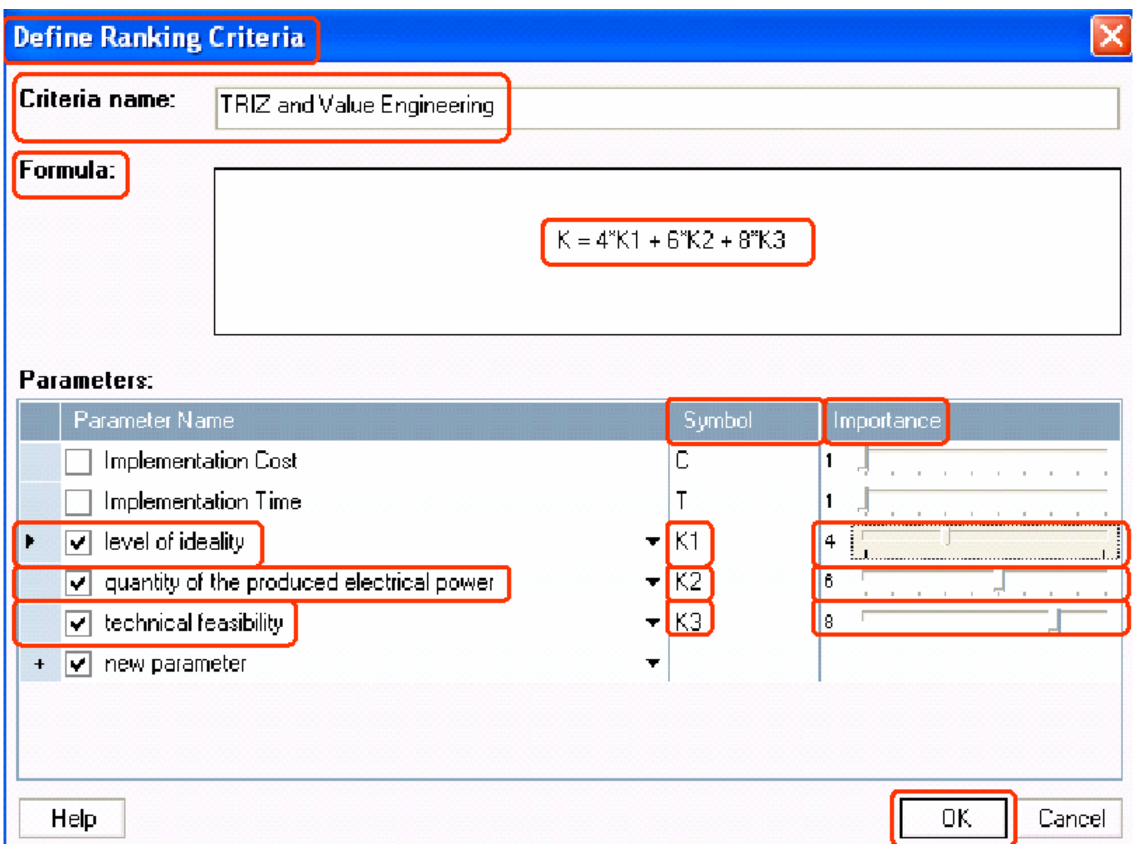
Concepts Evaluation & Selection

We created 32 available solutions for farther development by using TRIZ, Value Engineering, and Informational Fund (Scientific Effects Library, Patent Collections, WEB based information), including:

- 9 - From the Inventive Principles
- 2 - From the Effects Library
- 12 - From the System of Standards
- 9 - From Patent Collections and Web based information



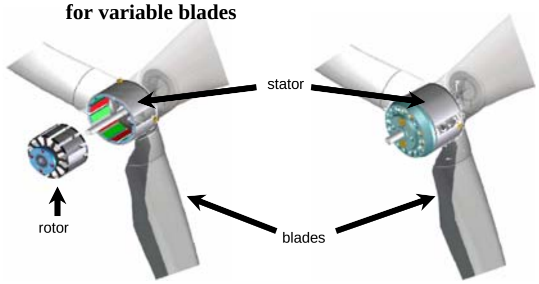
Solutions must be ranked to help decide which ones to research further and implement.



Conclusion - Best Solutions

In total, 6 concepts were ranked as high level available solutions, having the ranking equal or higher than 10, including:

1. Stator of Permanent Magnet Synchronous Generator directly connects Blades.
Blades rotate directly Stator of Permanent Magnet Synchronous Generator.
Permanent Magnet Synchronous Generator works good for variable blades

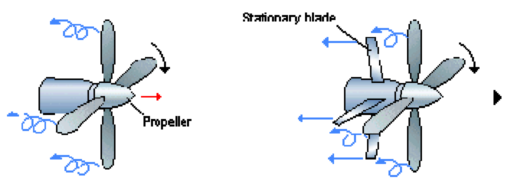


2. Doubled Propeller – Doubled Blades.

The propeller is the contra rotating with a diameter of 4.5 m (14 ft 9 in).
It has blades made of advanced composites and pronounced scimitar-like curvature on the leading-edge. It offers increased efficiency under high-speed cruise, and improved acoustics.

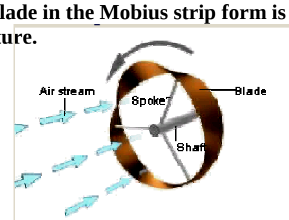
3. Efficient propeller – Efficient blades.

A propeller produces a propulsion that drives an airborne vehicle.
<u>Disadvantage:</u> This causes an air stream to be driven back, causing high turbulence. This decreases the propulsion.



4. Blade in form of Mobius strip.

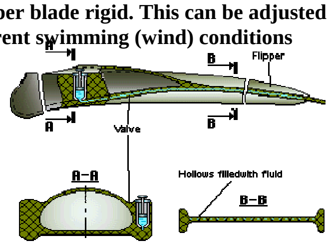
A blade is fixed on a <u>shaft</u> by means of spokes. The blade is made of elastic material and has the <u>Mobius strip</u> form.
<u>Advantages:</u>
1. The propeller blade in the <u>Mobius strip</u> form is simple in design.
2. The blade in the Mobius strip form is easy to manufacture.



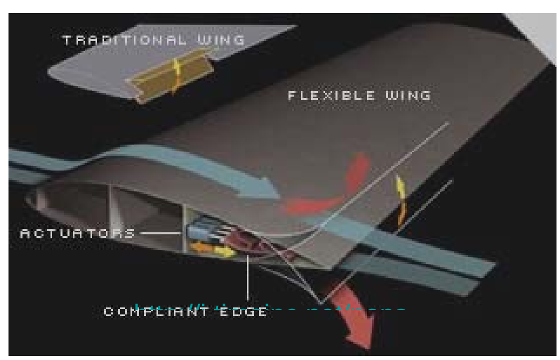
The air stream rotates the blade made in the form of a Mobius strip

5. Variable-rigidity flipper - blade.

Different rigidity is required in swimming flippers under different water conditions (governed by speed and length of stay).
<u>It is proposed:</u>
to use hydraulic constructions and variability (dynamism) to improve the flipper design. One can form an enclosed longitudinal hollow in the elastic flipper material. This is filled with an fluid whose pressure can be adjusted using a piston valve. High pressure makes the flipper blade rigid. This can be adjusted to optimize for current swimming (wind) conditions



6. Flexible wing - blade.



This repeatable process overcomes common TRIZ deployment challenges by showing a workflow and methodology for how to get started working on a problem with TRIZ, how to compliment TRIZ with Value Methodologies for problem identification, and how to leverage internal and external knowledge sources to accelerate concept identification.

About the Authors:

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Isak has spent 7 years at IMC and currently serves as their Chief Methodology Specialist. He is a TRIZ Master, Value Methodology (VM), and 6Sigma certified specialist with more then 20-year practice in the product/process development and manufacturing areas. He guided development of innovation projects for several world leading companies such as Philips, Mattel/Fisher-Price, Microsoft, Shell, Samsung, LG, POSCO, Masco, Medtronic, Xinetics, Henkel, etc.

He also directed a team of more than 100 scientists, experts, developers, and animators that designed and developed about 8000 detailed description and running movies of scientific and engineering effects. He created the unique functional/parametric classification system for the scientific/engineering knowledge database and developed the Control & Connect Modes for new knowledge creation by linking effects.

He has delivered numerous basic and advanced seminars (some together with Genrich Altshuller), and educated and trained more than 600 Managers, Engineers, and Researchers in TRIZ/Value Methodology, and in Product/Process Evolution and Development.

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Stephen Brown, Vice President Strategic Marketing, Invention Machine Corp.,

Steve is responsible for product marketing activities including the positioning and future evolution of the company's market strategy. Prior to Invention Machine, he spent 10 years at Vality Technology, the industry's leading supplier of data quality software for the ERP, CRM, and business intelligence markets where he served as Vice President of Product Strategy until its acquisition by Ascential Software in April 2002. At Ascential, he served as Executive Director, leading Product Management and Marketing functions for Ascential's suite of data-integration products. Previously Steve had served 20 years in technology management and development capacities at Legent Corporation, Cullinet Software and Honeywell. He is a graduate of Harvard University.

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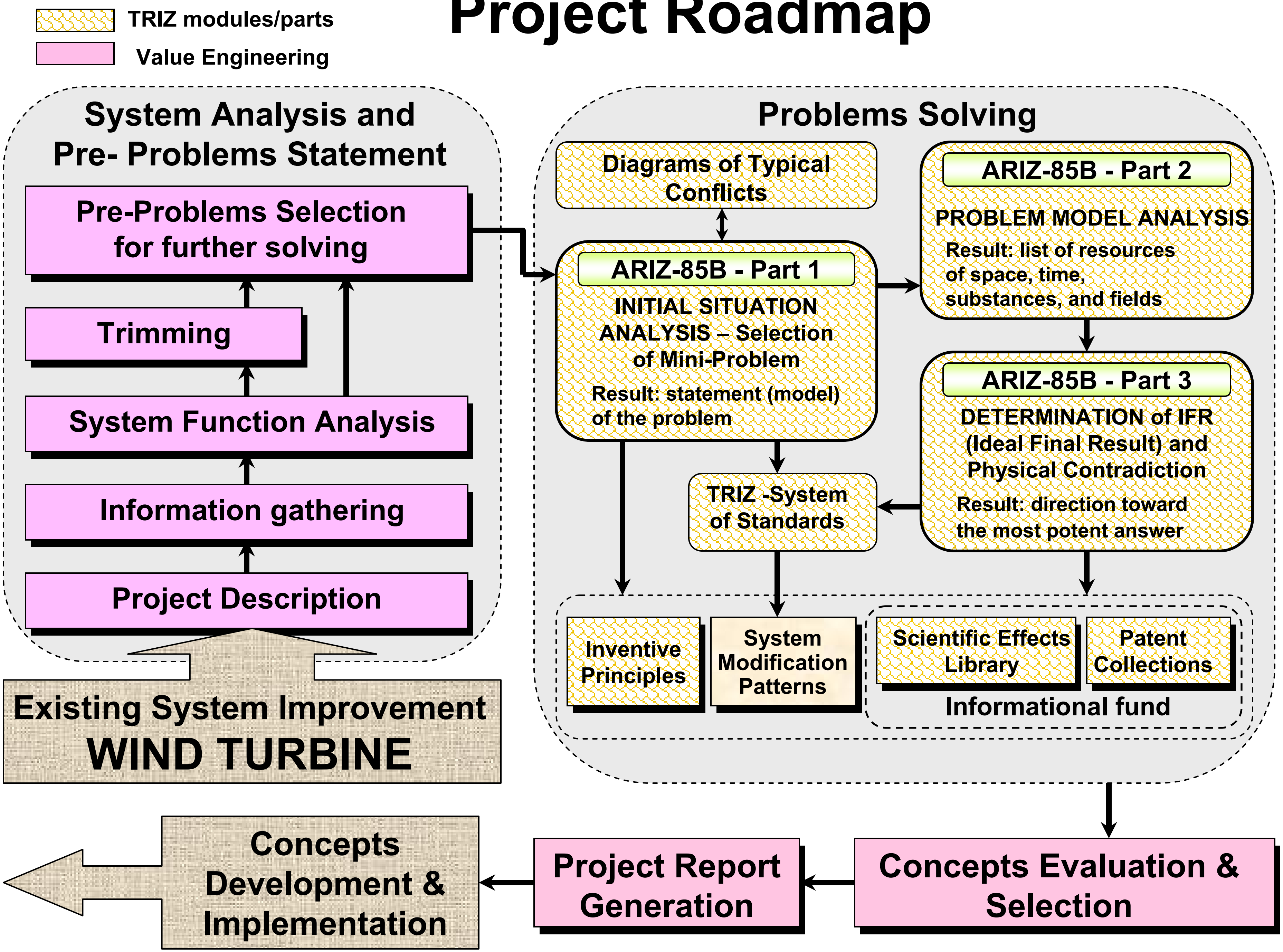
Project Roadmap



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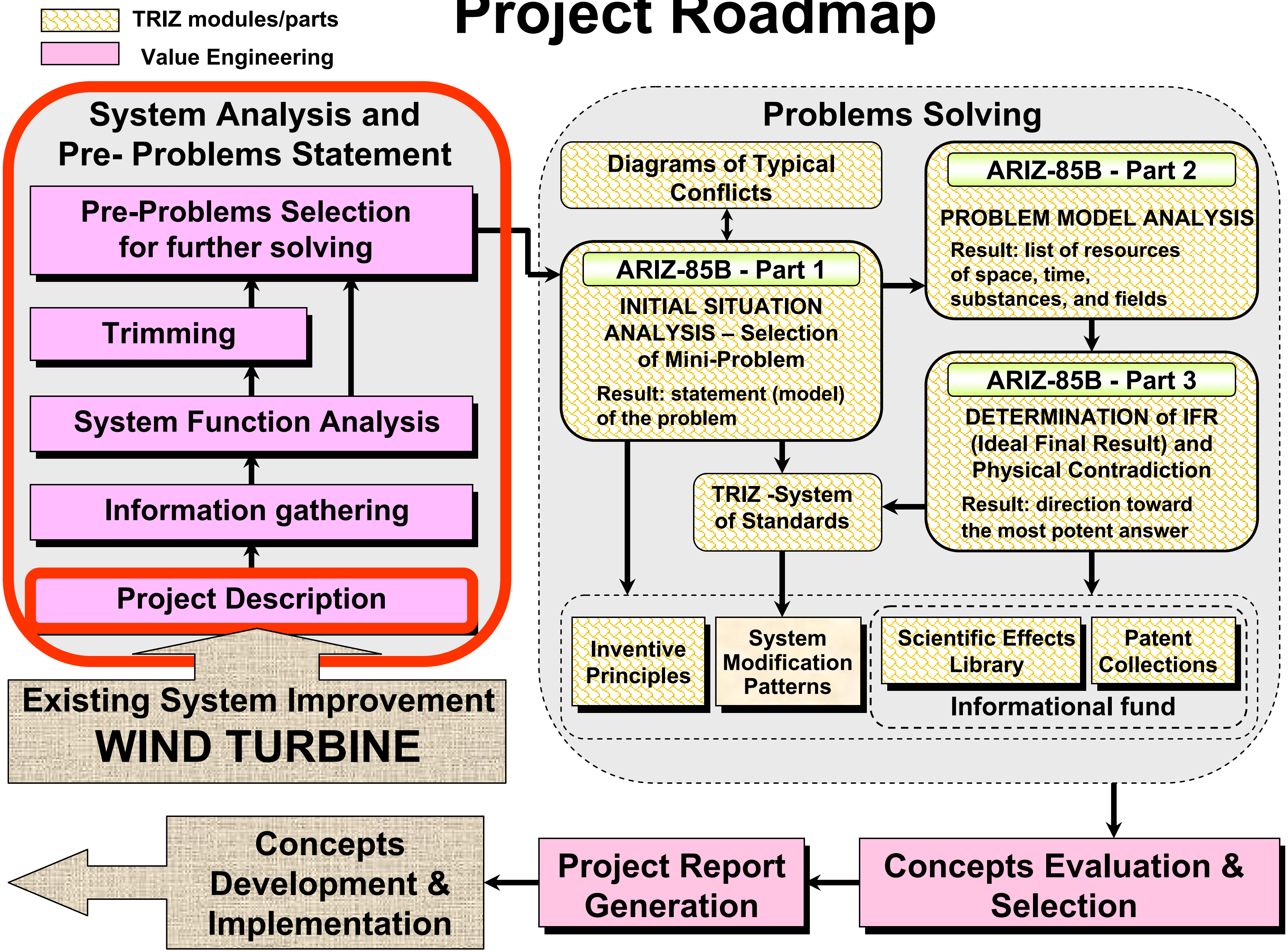
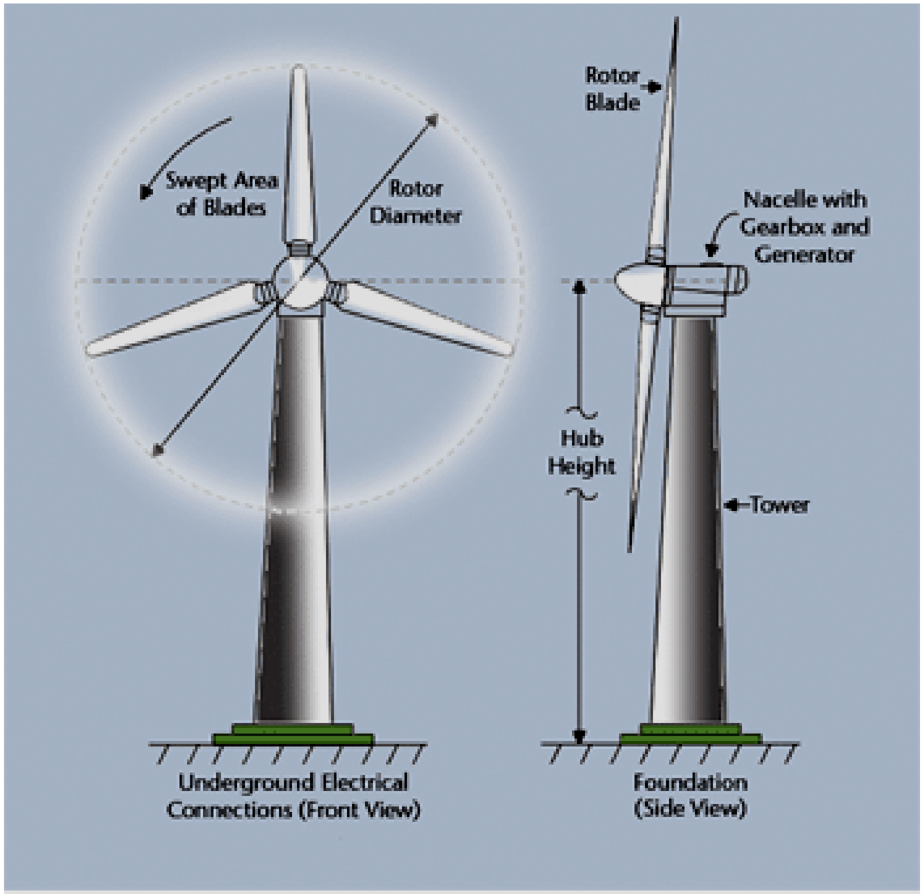


Base Wind Turbine design selection

We have selected Three-Blades Turbine as a base Turbine design for our research project.

Three-Blades Turbine are most common, sometimes it cold as a Danish Concept. These three-bladed wind turbines are operated "upwind," with the blades facing into the wind.

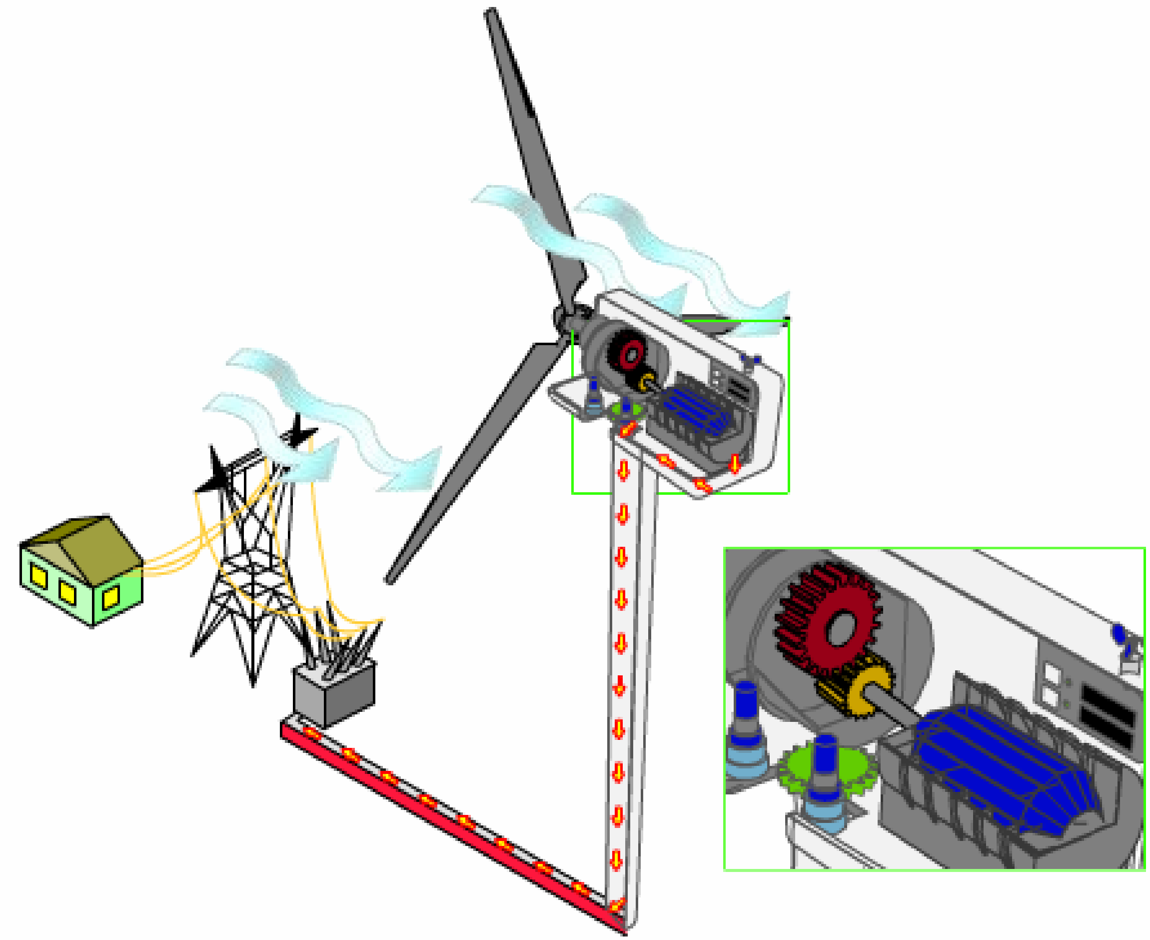


Drawing of the rotor and blades of a wind turbine, courtesy of ESN

http://europa.eu.int/comm/research/energy/nn/nn_rt/nn_rt_wind/article_1101_en.htm

Initial Situation

Wind turbine works the opposite of a fan. Instead of using electricity to make wind, a turbine uses wind to make electricity.
The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. The electricity is sent through transmission and distribution lines to a substation, then on to homes, business and schools.



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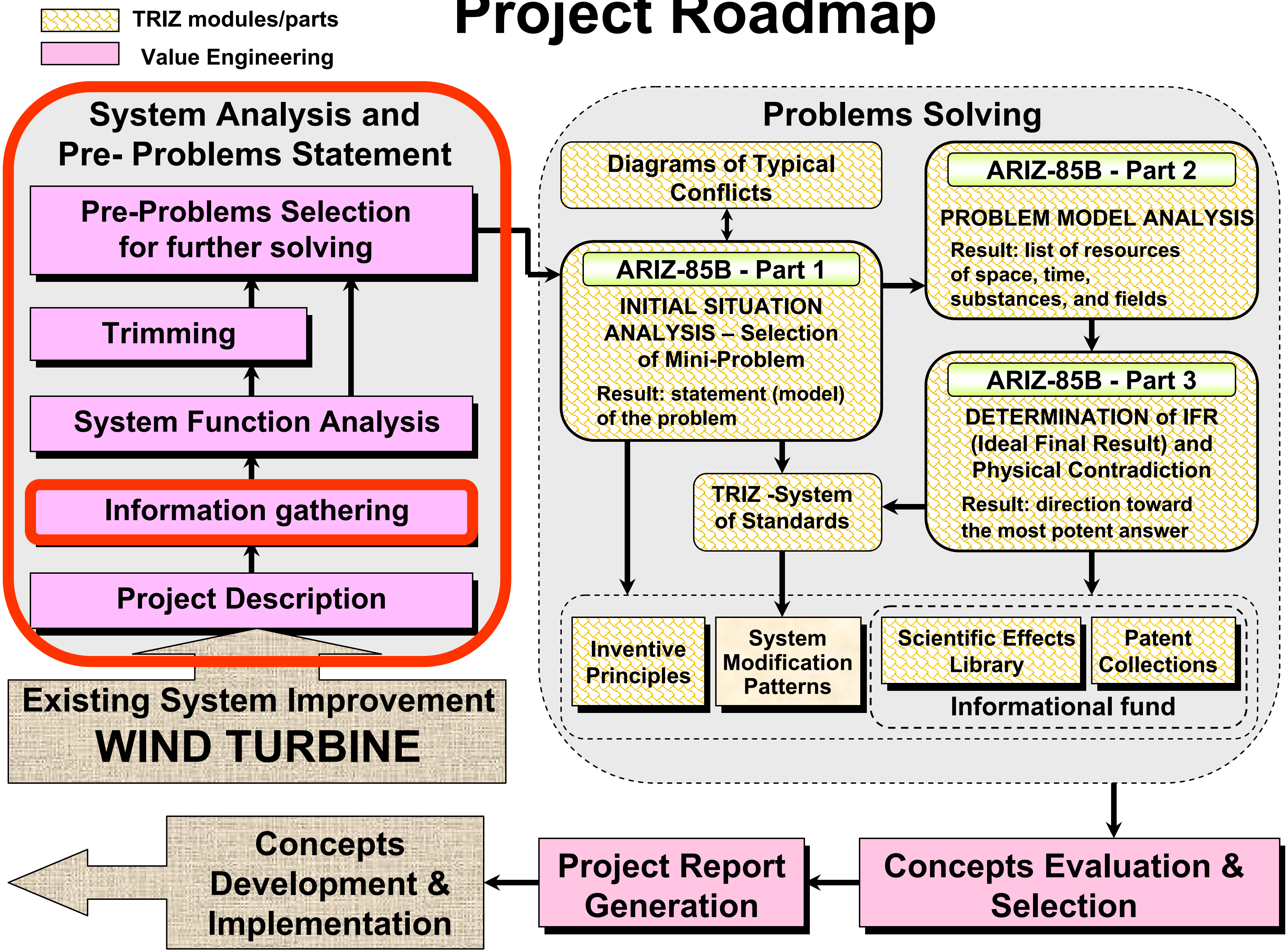
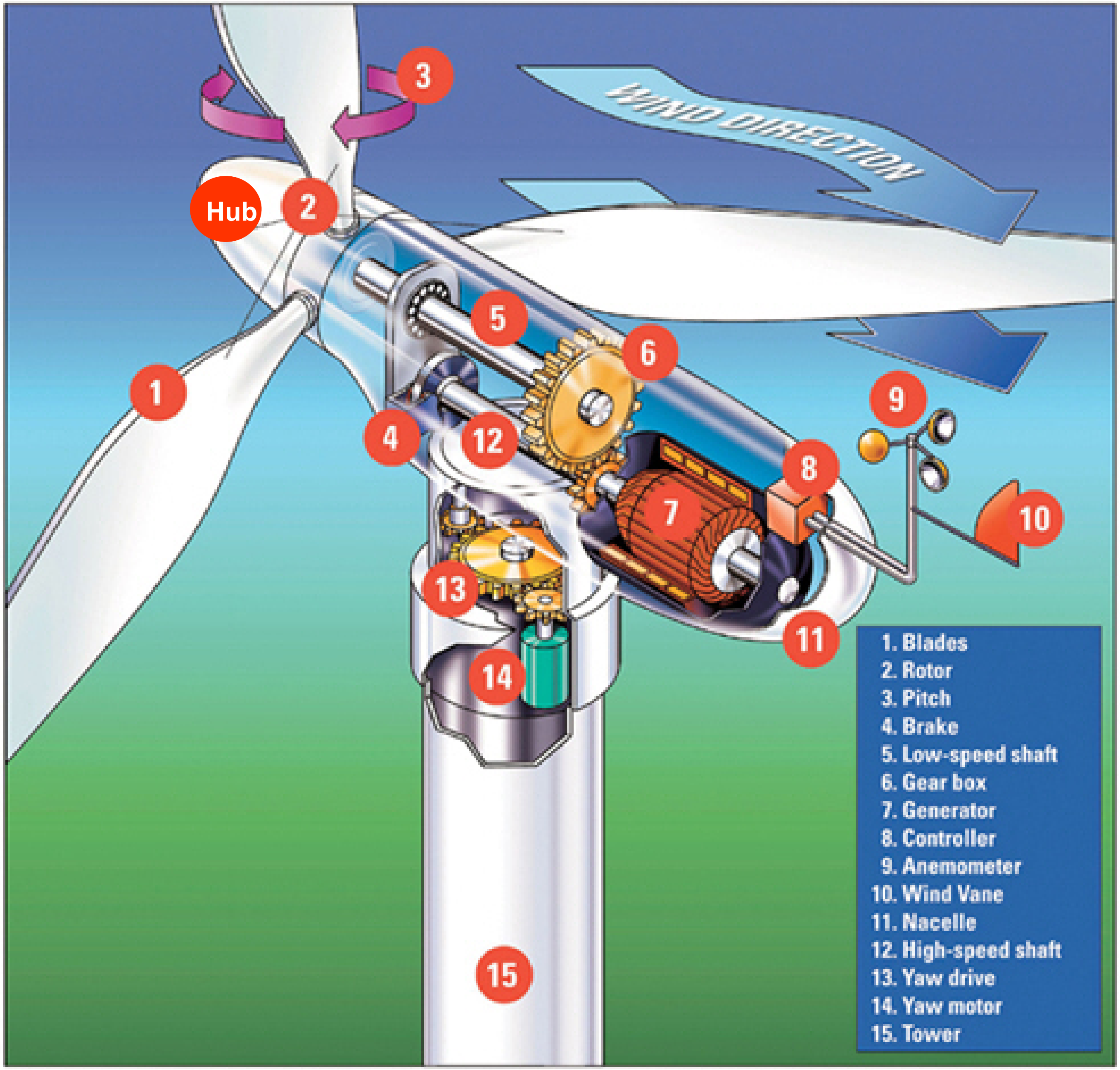


Component Stricture of the Wind turbine



Wind Turbine Components

Anemometer:

Measures the wind speed and transmits wind speed data to the controller. These are attached to the back of the nacelle. A 3-cup anemometer spins to measure the wind speed.

(Rotor) Blades:

Wind turbine blades act similar to an airplane's wing or a boat's sail. When air travels over the curved blade, a low-pressure area is created on the concave side of the blade (referred to as Bernoulli's effect) creating pressure. This pressure pushes against the blade, causing the rotational mechanical energy that drives the low speed shaft connected to the hub.
The rotor blades are the elements of the turbine that capture the wind energy and covert it into a rotational form. The profile and shape of the blade is designed for maximum efficiency and minimum noise. The turbine blades are made of fiberglass. Using stronger and more lightweight materials has allowed manufacturers to create larger blades, increasing the capacity of the turbines.

Wind Turbine Components (con.)

Brake:

A disc brake which can be applied mechanically, electrically, or hydraulically to stop the rotor in emergencies.
The mechanical brake is a physical brake, similar to a disc brake on the wheel of a car, connected to the high-speed shaft. It is used for servicing the equipment to ensure that no components start to rotate, endangering the repair worker.
This is used to stop the blades rotating in gale force winds or for maintenance purposes. It is hydraulically operated using the same principles as found in a car's disc brakes.

(Electronic) Controller:

The controller starts up the machine at wind speeds of about 8 to 16 miles per hour (mph) and shuts off the machine at about 65 mph. Turbines cannot operate at wind speeds above about 65 mph because their generators could overheat. The controller is a computer system that monitors and controls various aspects of the turbine. It has the ability to shut down the turbine if a fault occurs. Continuously monitors the condition of the wind turbine. Controls pitch and yaw mechanisms. In case of any malfunction (e.g., overheating of the gearbox or the generator), it automatically stops the wind turbine and may also be designed to signal the turbine operator's computer via a modem link.

Wind Turbine Components (con.)

Cooling system:

The cooling system is used to ensure that the components do not overheat and cause damage to themselves or any other component. A typical cooling system is either an electrical fan or a radiator system.

Gear box:

Gears connect the low-speed shaft to the high-speed shaft and increase (transform) the rotational speeds from about 30 to 60 rotations per minute (rpm) to about 1200 to 1500 rpm and drives the generator. Connects to the low-speed shaft and turns the high-speed shaft at a ratio several times (approximately 50 for a 600 kW turbine) faster than the low-speed shaft.
Almost all wind turbines (except, Variable Speed Gearless Wind Turbine) contain gearboxes, which convert the slow rotation of the shaft into the high speed required to generate electricity. The gear box is a costly (and heavy) part of the wind turbine and engineers are exploring "direct-drive" generators that operate at lower rotational speeds and don't need gear boxes.

Wind Turbine Components (con.)

Generator:

The generator is connected to the high-speed shaft and is the component of the system that converts the rotational energy of the shaft into an electrical output. Usually an off-the-shelf induction generator that produces 60-cycle AC electricity. The generator (3-phase, 690 volt) is driven by the high-speed shaft and also turns at 1,500 rpm, supplying electricity through a low voltage transformer to a high voltage transmission transformer and into Country Energy's distribution grid. In recent years, wind power has become very competitive in electrical cost production due to increased efficiencies and the increased size of the generators, with typical outputs over 500kW for newer, utility-scale systems. Usually an induction generator or asynchronous generator with a maximum electric power of 500 to 1,500 kilowatts (kW) on a modern wind turbine.

High-speed shaft:

Drives the electrical generator by rotating at approximately 1,500 revolutions per minute (RPM).

Wind Turbine Components (con.)

Hub:

For propeller-driven turbines hub is the connection point for the rotor blades and the low speed shaft. Hub captures the wind and transfers its power to the rotor. Attaches the rotor to the low-speed shaft of the wind turbine. The hub is made of cast iron and connects the turbine's blades to the main shaft. When the wind blows, the blades and hub rotate at 28 revolutions per minute (rpm). The hub and blades together weigh 8.5 tones.

Low-speed shaft:

The rotor turns the low-speed shaft at about 30 to 60 rotations per minute. Connects the rotor hub to the gearbox. Low-speed shaft is connected with large gear (ones is a component of the gearbox) and transmits rotation to it.

Wind Turbine Components (con.)

Nacelle:

The case or housing (from steel and/or fiberglass…), which is mounted on the tower and includes (encapsulates, supports, protects, covers) the gear box, low- and high-speed shafts, electrical generator, yaw system, hydraulics, controller, and brake. The nacelle can move though 360° and is turned into the wind using "yaw" motors that are controlled by the wind vane. The nacelle and equipment weigh 19 tones.

Pitch (Mechanism):

Blades are turned, or pitched, out of the wind to keep the rotor from turning in winds that are too high or too low to produce electricity. Vestas company -> Pitch control is achieved by feathering the blades.

Rotor:

The blades and the hub together are called the rotor and it rotates a low-speed shaft.

Wind Turbine Components (con.)

Tower:

Because wind speed increases with height, taller towers (it is advantageous) enable turbines to capture more energy and generate more electricity. The tower is used to support (carries) the nacelle and rotor blades (rotor).

Wind vane:

Measures wind direction and communicates with the yaw drive to orient the turbine properly with respect to the wind. Measures the direction of the wind while sending signals to the controller to start or stop the turbine.

Yaw drive:

Upwind turbines face into the wind; the yaw drive is used to keep the rotor facing into the wind as the wind direction changes. These are controlled by the information from the wind vane and ensure that the nacelle is always facing into the wind. Downwind turbines don't require a yaw drive, the wind blows the rotor downwind.

Yaw motor:

Powers the yaw drive.

Trends of the R&D efforts that have contributed to current utility-scale turbine technology

- **Improvements in the aerodynamics of wind turbine blades**, resulting in higher capacity factors and an **increase in the watts per square meter** of swept area performance factor.

- **Development of variable speed generators** to improve conversion of wind power to electricity over a range of wind speeds.

- Development of gearless turbines that **reduce the on going operating cost of the turbine.**

- The general trend is toward wind turbines with **maximum power output of 1 MW or more.** European firms -- such as Danish companies Vestas and NEG Micon -- currently have more than 10 turbine designs in the megawatt range with commercial sales.

Trends of the R&D efforts that have contributed to current utility-scale turbine technology (con.)

- **Wind turbine manufacturers optimize machines to deliver electricity at the lowest possible cost per kilowatt-hour (kWh) of energy.**

- **Development of lighter tower structures. A by-product of advances in aerodynamics and in generator design is reduction or better distribution of the stresses and strains in the wind turbine. Lighter tower structures, which are also less expensive because of material cost savings, may be used because of such advances.**

- **Smart controls and power electronics have enabled remote operation and monitoring of wind turbines. Some systems enable remote corrective action in response to system operational problems. The cost of such components has decreased. Turbine designs where power electronics are needed to maintain power quality also have benefited from a reduction in component costs.**

WIND ENERGY PRODUCTION POTENTIAL

► **Wind power is expected to grow at an annual rate of 20 % resulting in a total of about 40 000 MW of installed capacity around the world by 2004.**

► **According to recent study “Wind Force 10” wind power could generate 10 % of global electricity by 2020, and create 1,7 million jobs at the same time.**

► **International installation of 1,2 million MW of wind capacity by 2020 would generate more electricity than the entire continent of Europe consumes today.**

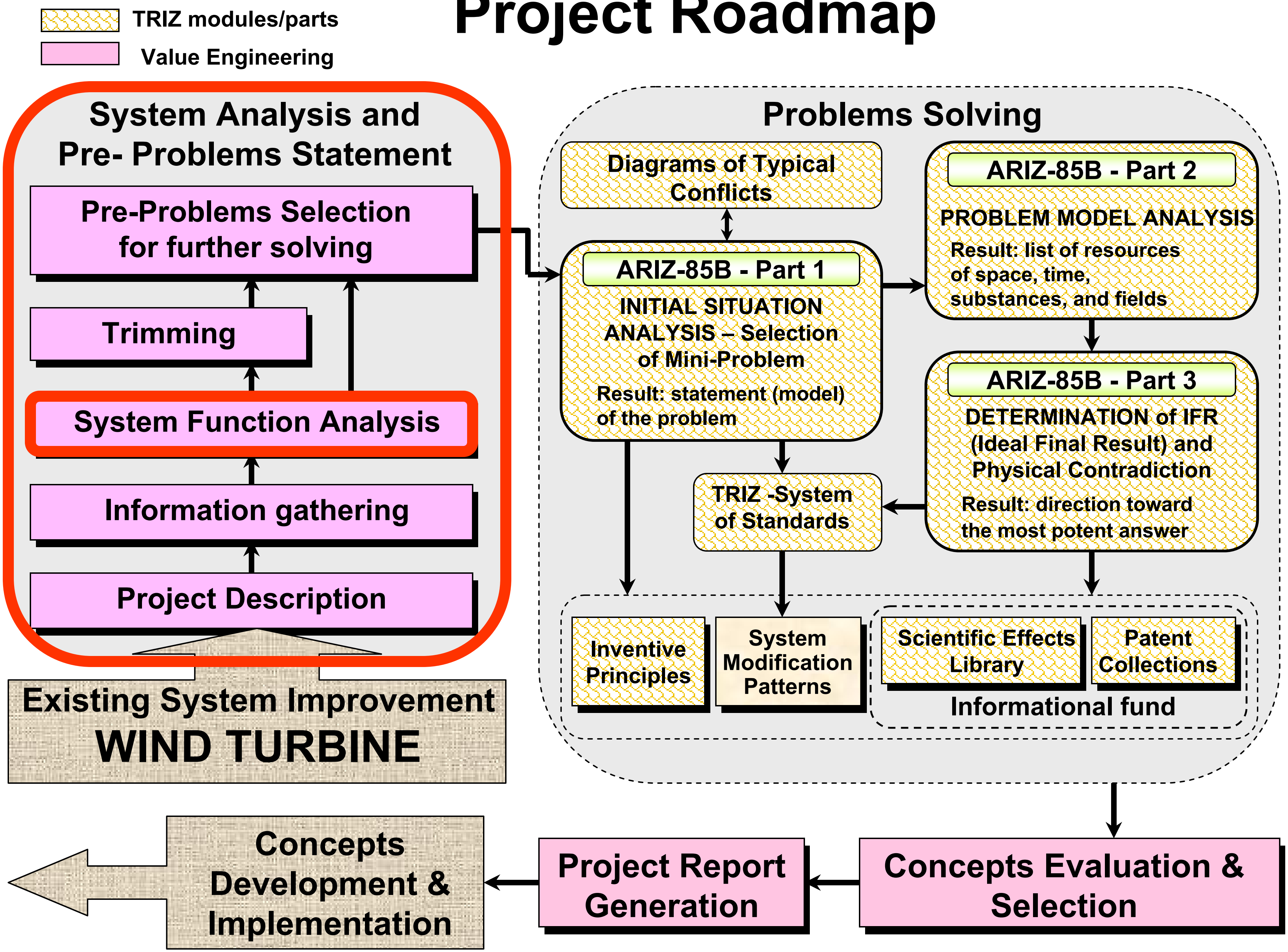
WIND ENERGY PRODUCTION POTENTIAL (con.)

► Total wind energy potential in the world is 53 trillion kWh, 17 times higher than the Wind Force 10 goal.

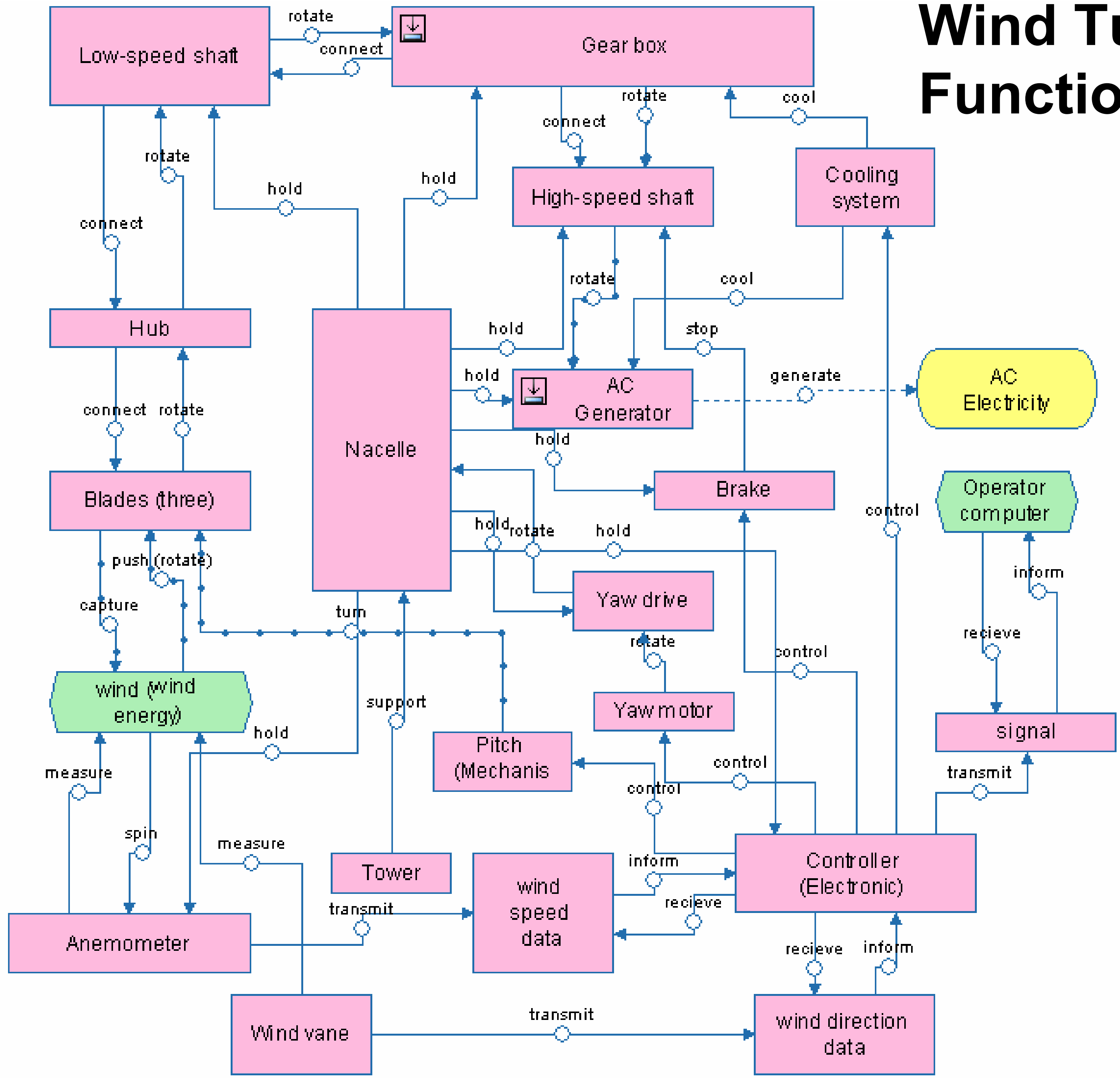
► According to the study the cost of generating electricity with wind turbines is expected to drop to 2.5 US cents/kWh by 2020, compared to the current 4.7 US cents/kWh.

► Environmental benefits of the 10 % target would be enormous – savings of 69 million tones of CO_2 in 2005, 267 millions tons in 2010 and 1780 million tones in 2020.

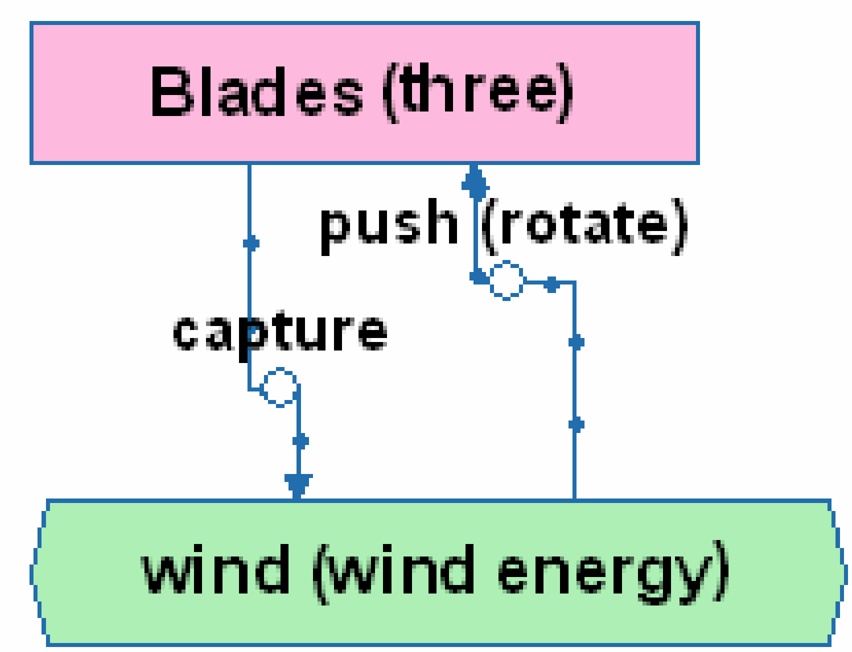
Project Roadmap

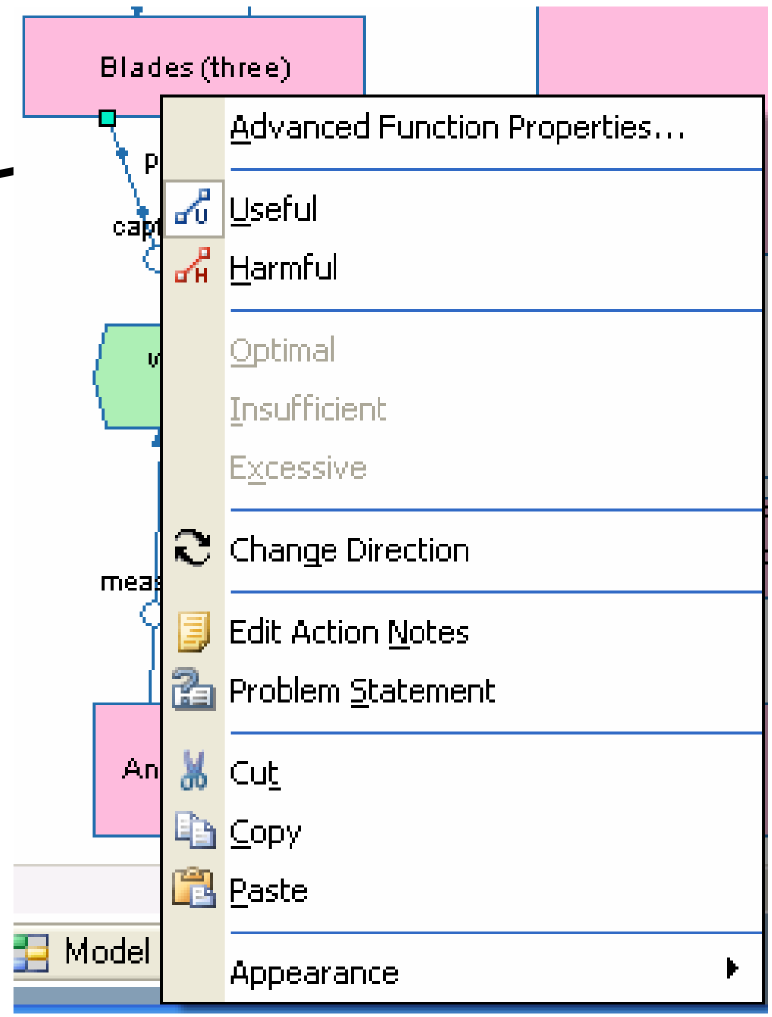


Wind Turbine -> Functional Model

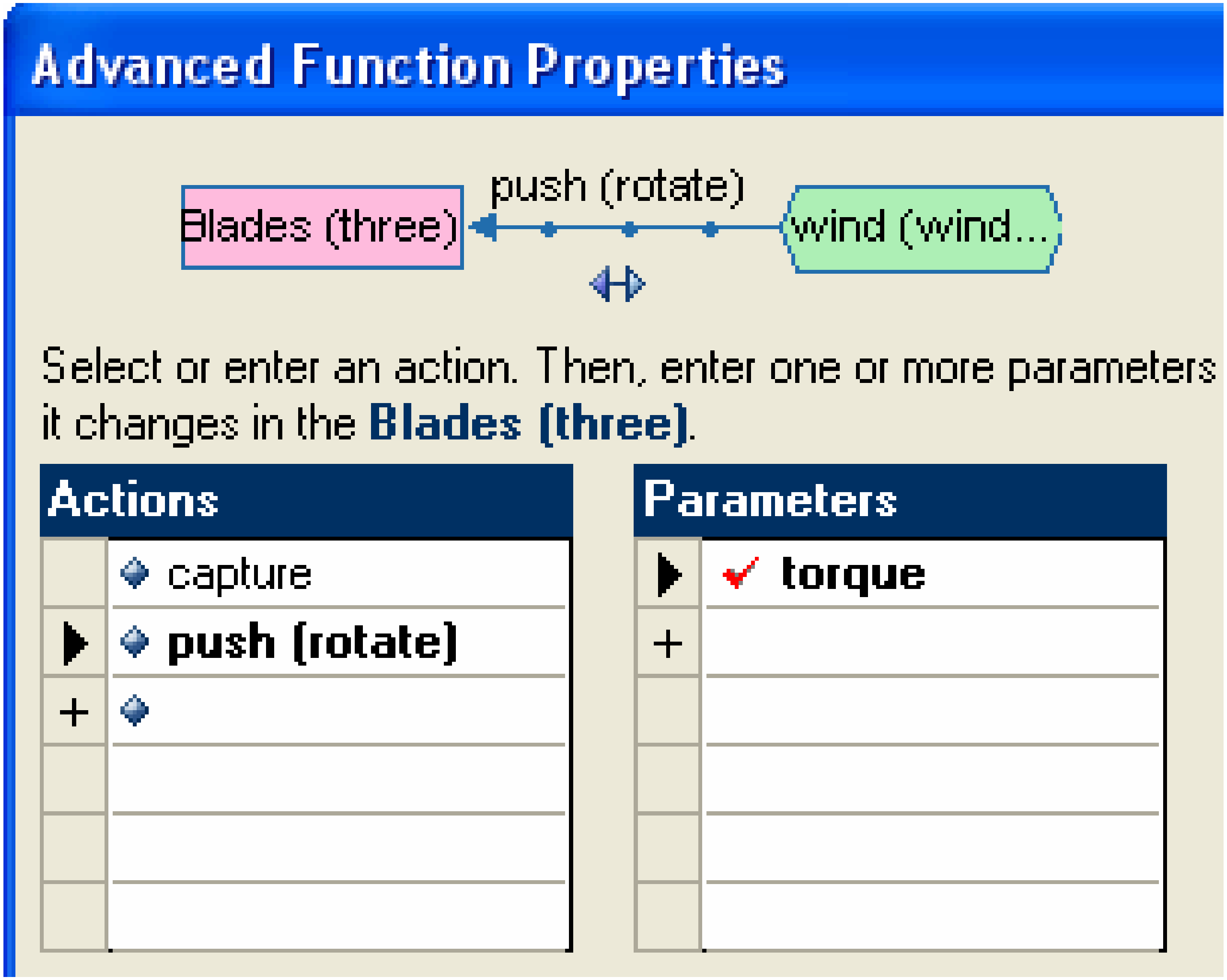


Advanced Function Properties Definition

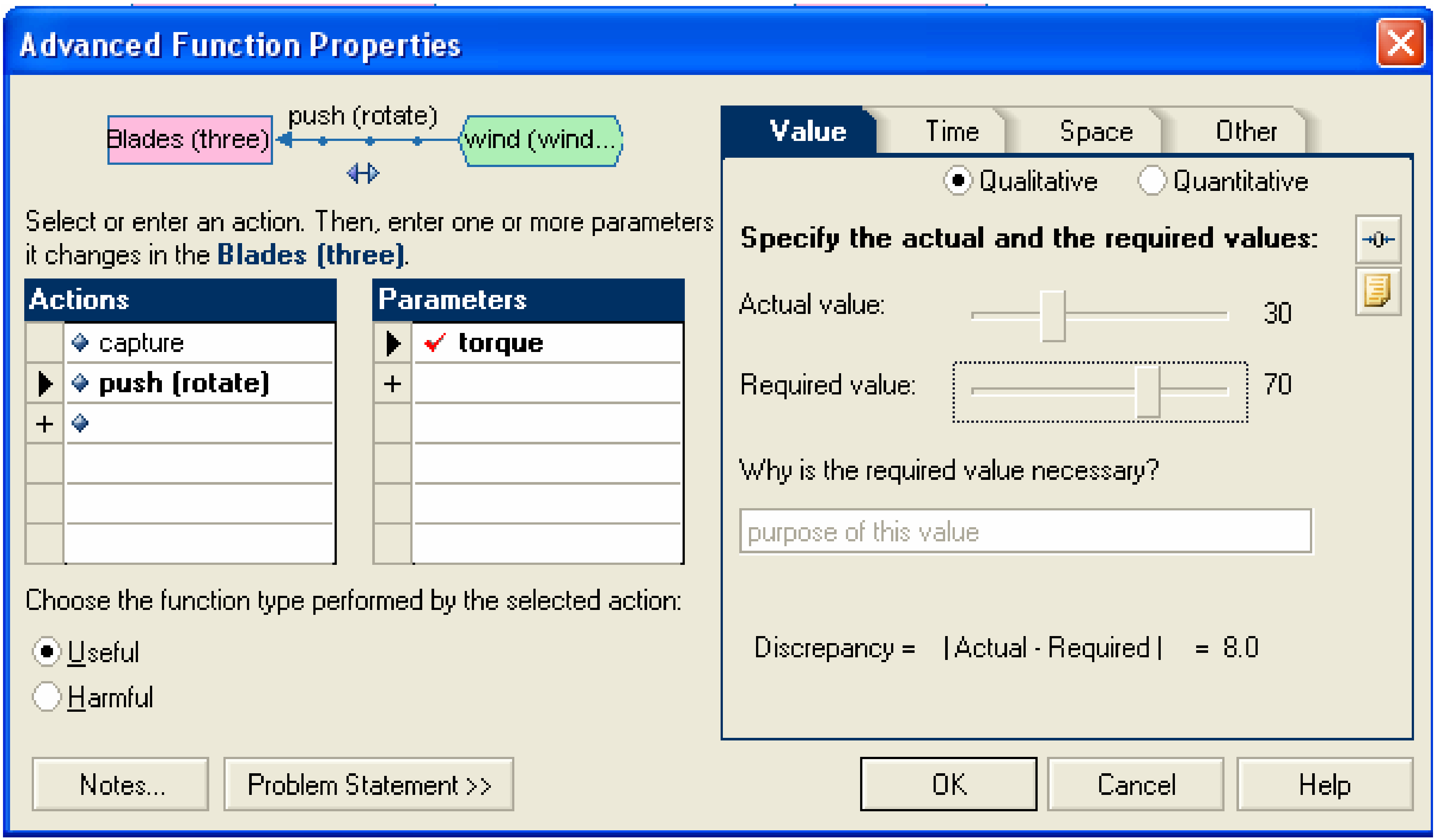




Function Parameter Definition

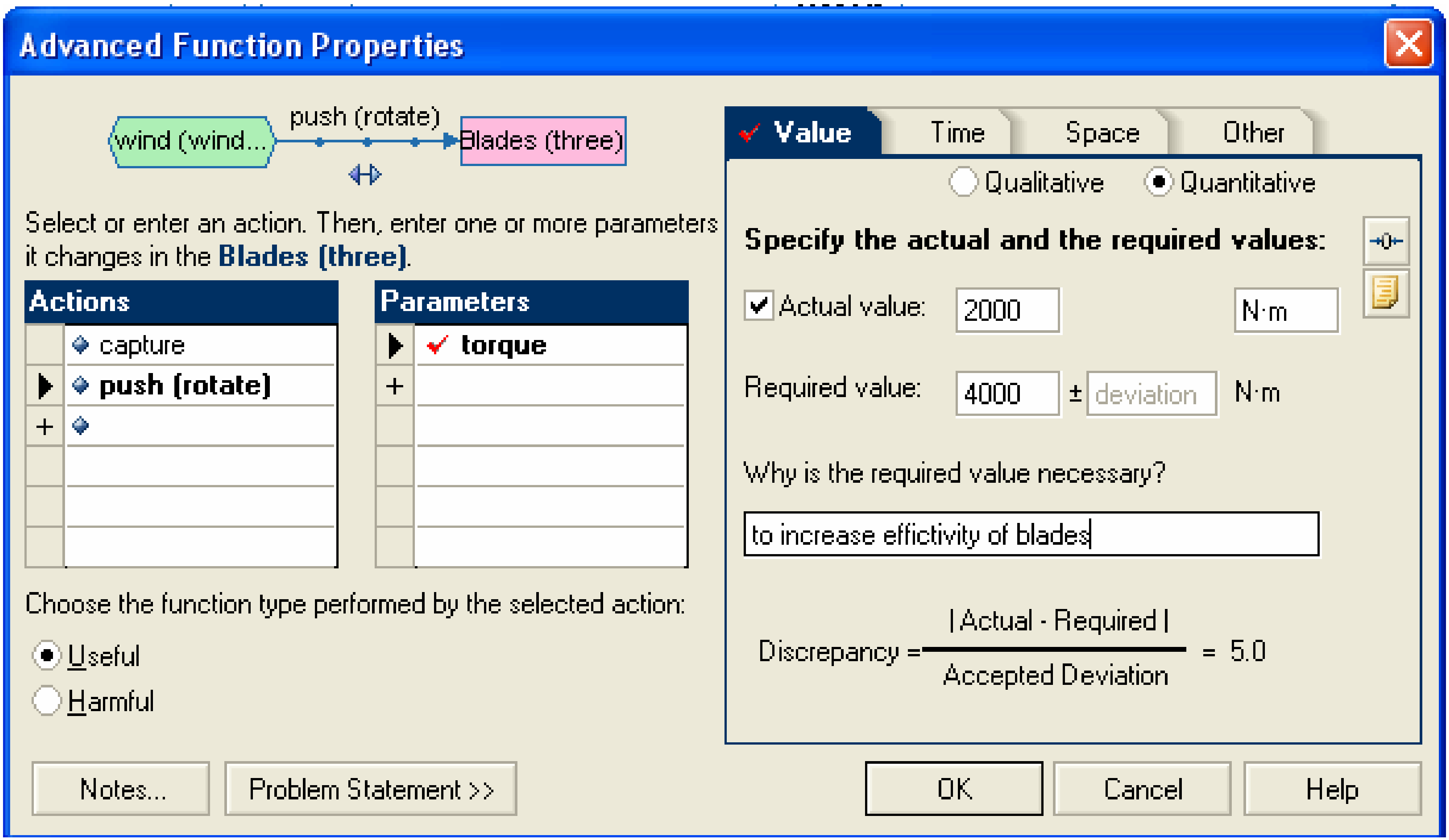


Specify the actual and the required values of defined Parameter
(Qualitative mode)

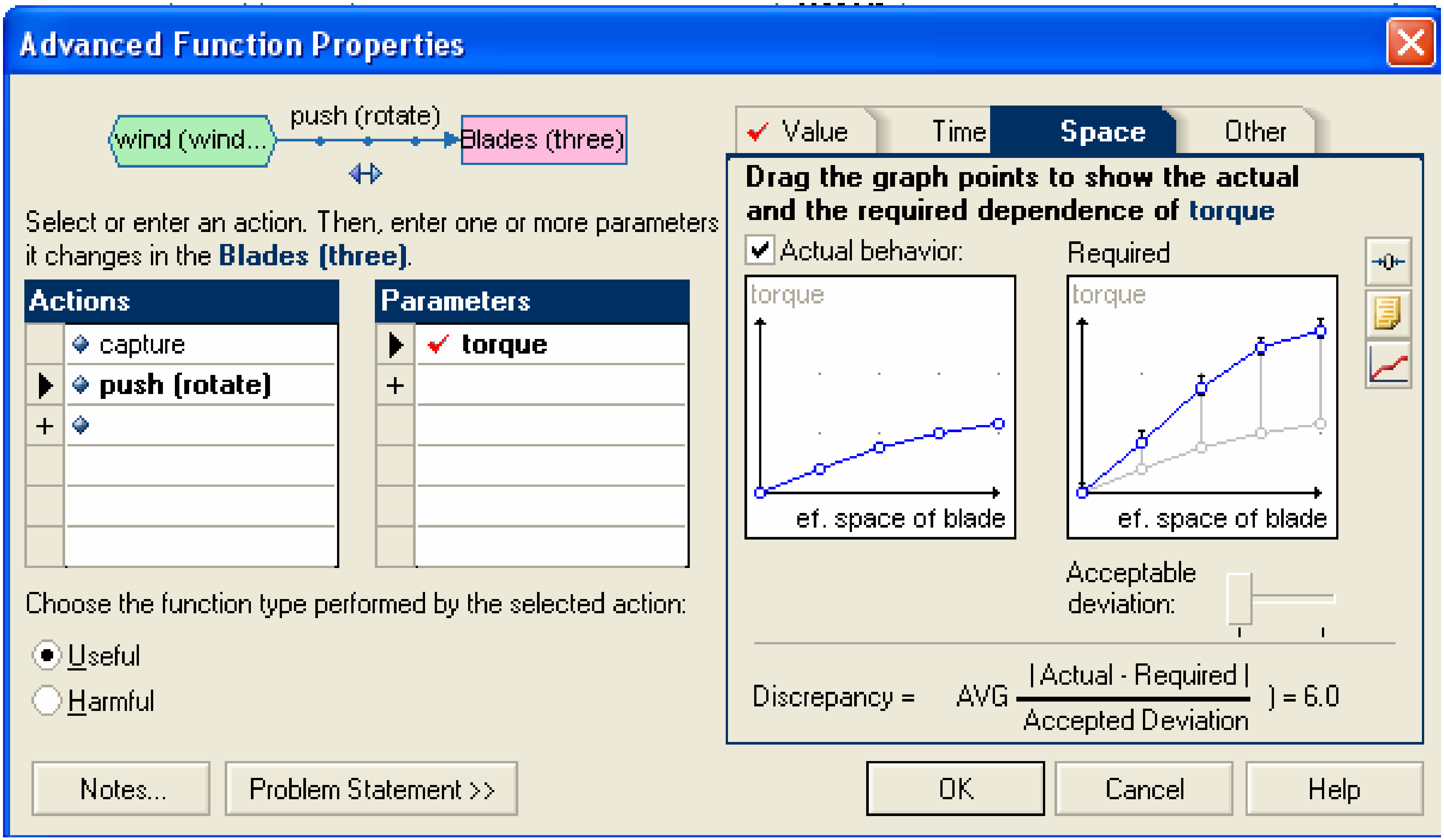


Specify the actual and the required values of defined Parameter

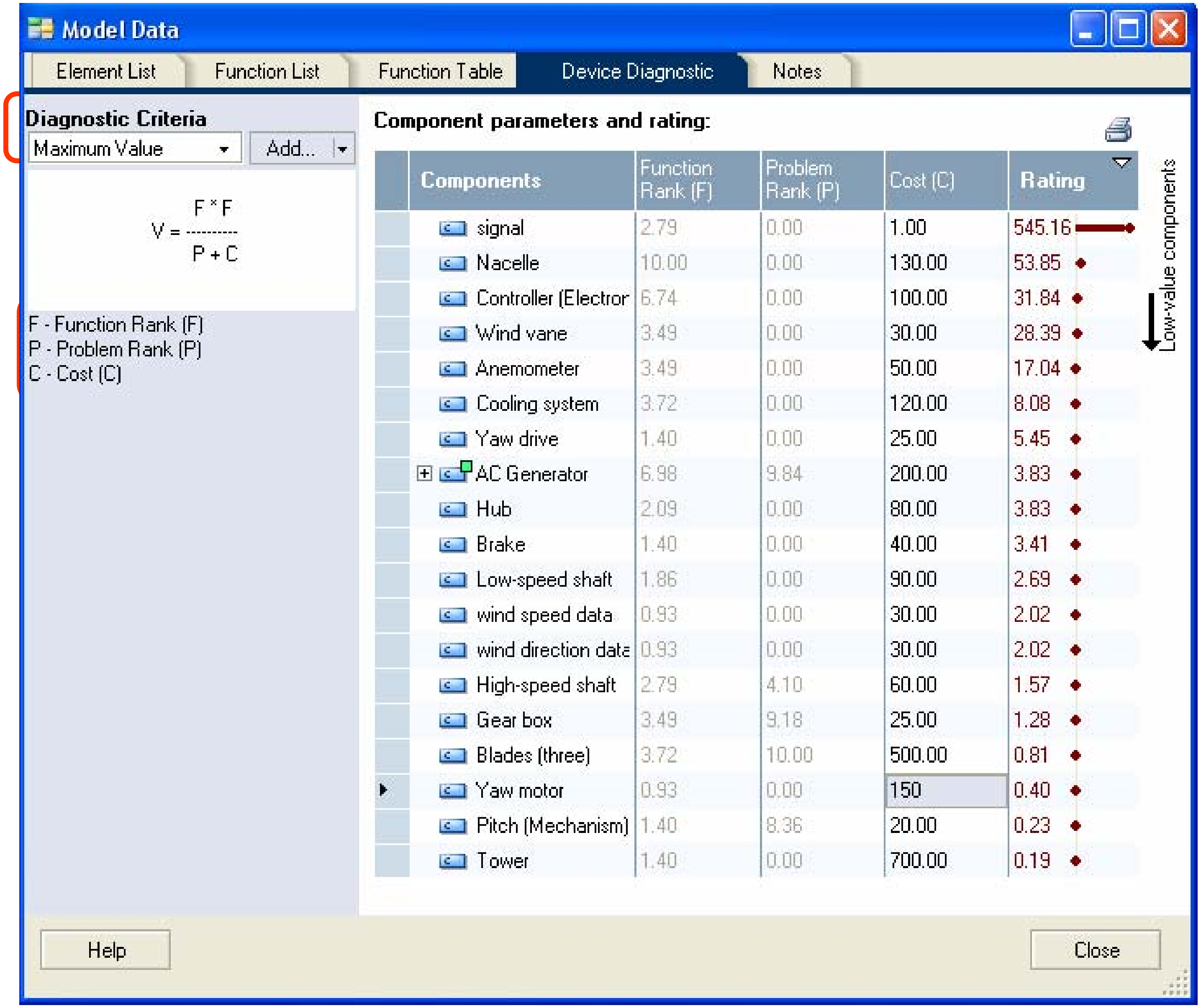
(Quantitative mode)



Create two graphs of dependence between defined parameter and one of the related parameter -> actual and required.

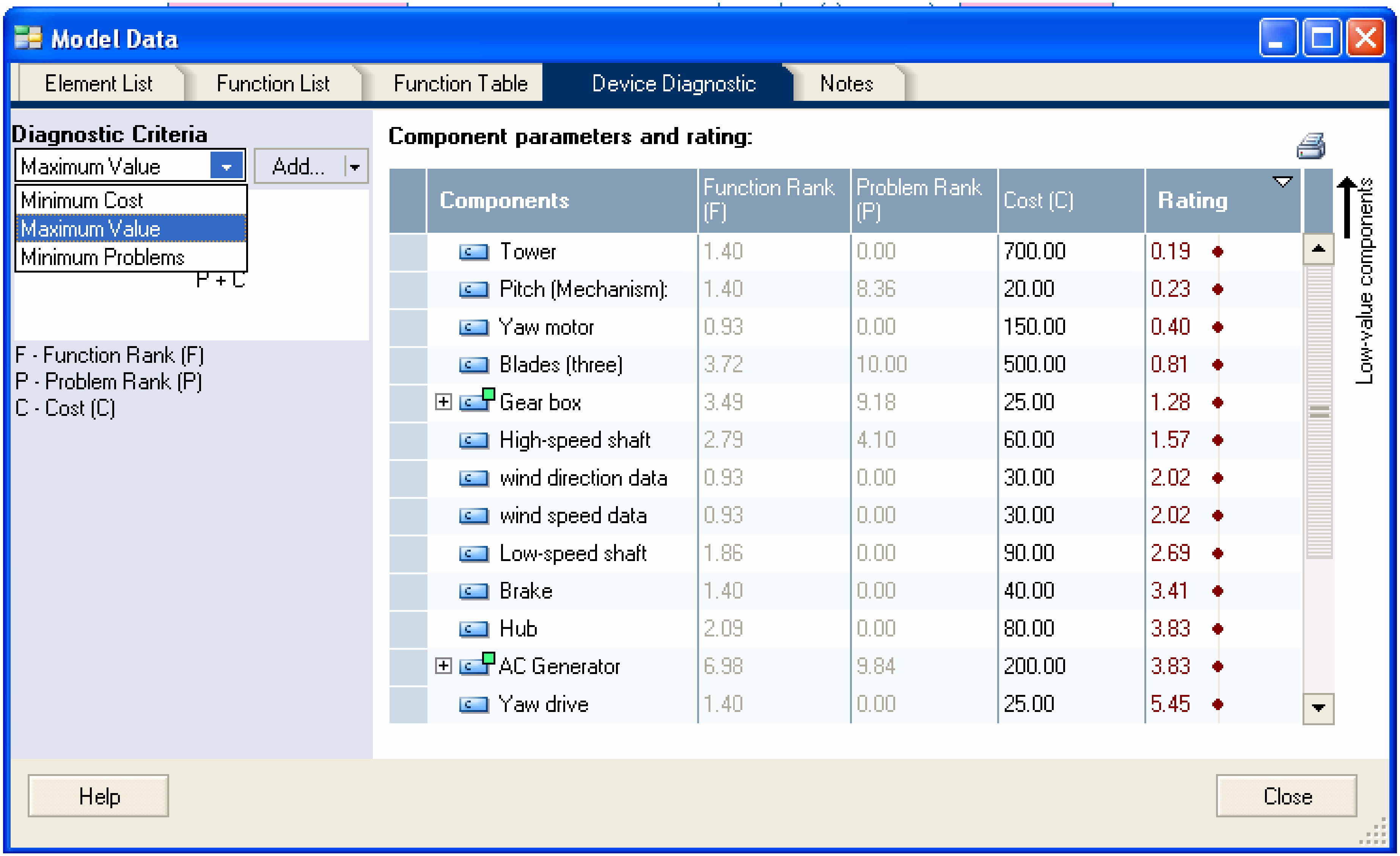


Model Data -> Device Diagnostic ->
-> Component Parameters and rating



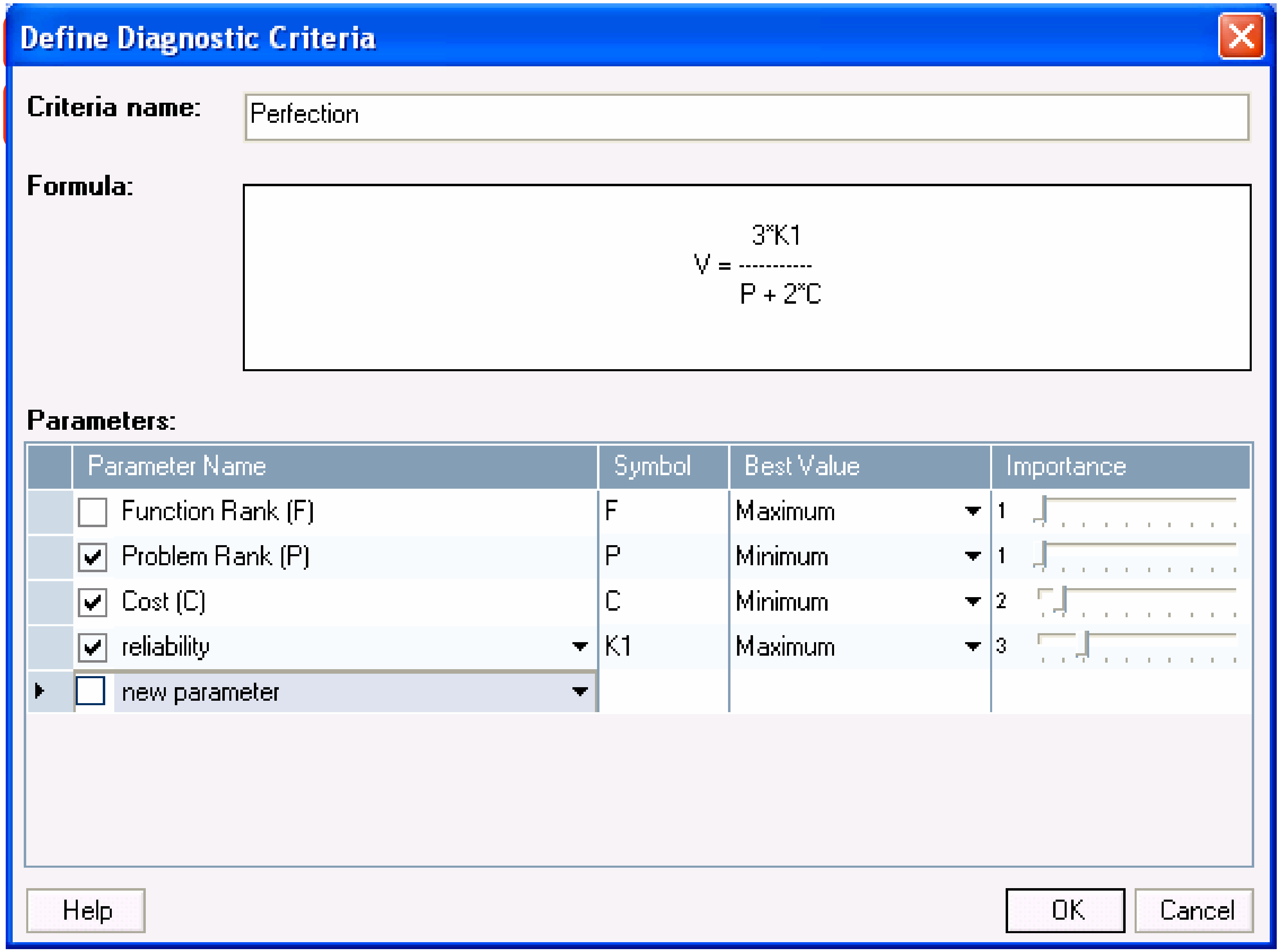
Components	Function Rank (F)	Problem Rank (P)	Cost (C)	Rating
signal	2.79	0.00	1.00	545.16
Nacelle	10.00	0.00	130.00	53.85
Controller (Electror	6.74	0.00	100.00	31.84
Wind vane	3.49	0.00	30.00	28.39
Anemometer	3.49	0.00	50.00	17.04
Cooling system	3.72	0.00	120.00	8.08
Yaw drive	1.40	0.00	25.00	5.45
AC Generator	6.98	9.84	200.00	3.83
Hub	2.09	0.00	80.00	3.83
Brake	1.40	0.00	40.00	3.41
Low-speed shaft	1.86	0.00	90.00	2.69
wind speed data	0.93	0.00	30.00	2.02
wind direction date	0.93	0.00	30.00	2.02
High-speed shaft	2.79	4.10	60.00	1.57
Gear box	3.49	9.18	25.00	1.28
Blades (three)	3.72	10.00	500.00	0.81
Yaw motor	0.93	0.00	150	0.40
Pitch (Mechanism)	1.40	8.36	20.00	0.23
Tower	1.40	0.00	700.00	0.19

Functional Analysis & Trimming -> Strategy Selection

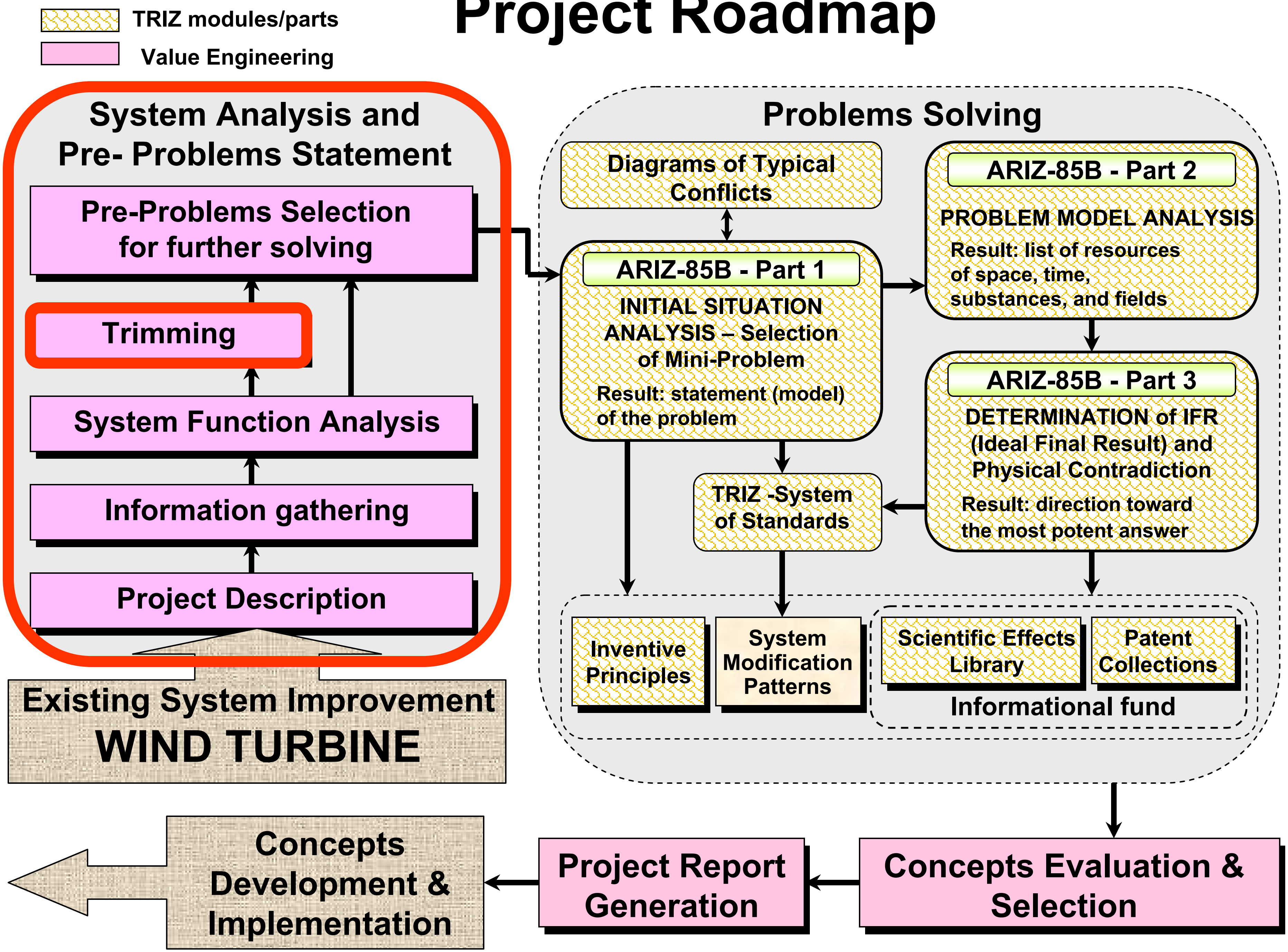


Components	Function Rank (F)	Problem Rank (P)	Cost (C)	Rating
Tower	1.40	0.00	700.00	0.19
Pitch (Mechanism):	1.40	8.36	20.00	0.23
Yaw motor	0.93	0.00	150.00	0.40
Blades (three)	3.72	10.00	500.00	0.81
Gear box	3.49	9.18	25.00	1.28
High-speed shaft	2.79	4.10	60.00	1.57
wind direction data	0.93	0.00	30.00	2.02
wind speed data	0.93	0.00	30.00	2.02
Low-speed shaft	1.86	0.00	90.00	2.69
Brake	1.40	0.00	40.00	3.41
Hub	2.09	0.00	80.00	3.83
AC Generator	6.98	9.84	200.00	3.83
Yaw drive	1.40	0.00	25.00	5.45

Functional Analysis & Trimming -> Your Own Strategy Creation



Project Roadmap



Design Simplification Strategy - Trimming Method

Radical product/process changes

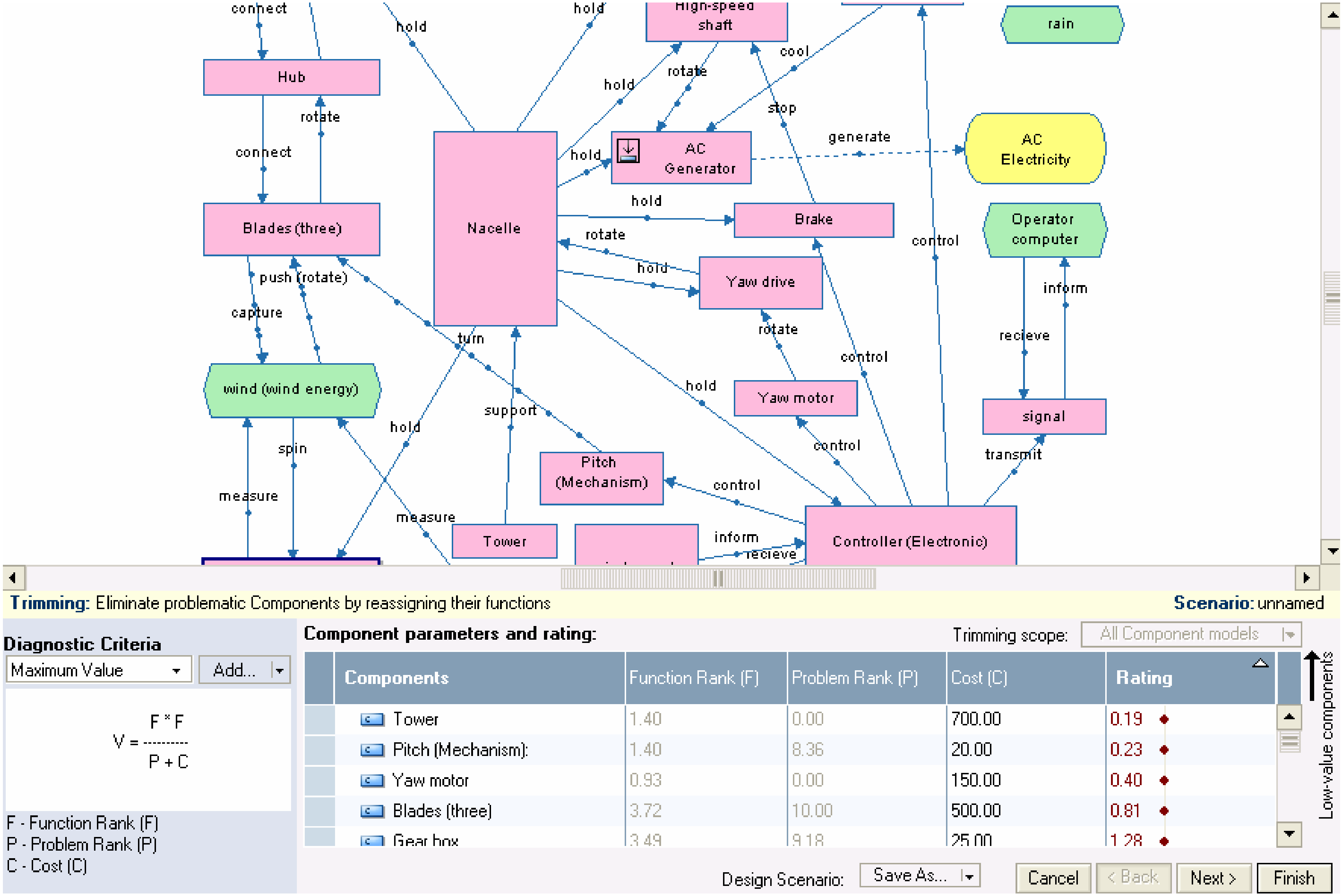
Benefits:

► Improves product/process by eliminating low value (problematic) components and redistribution their useful functions between other components.

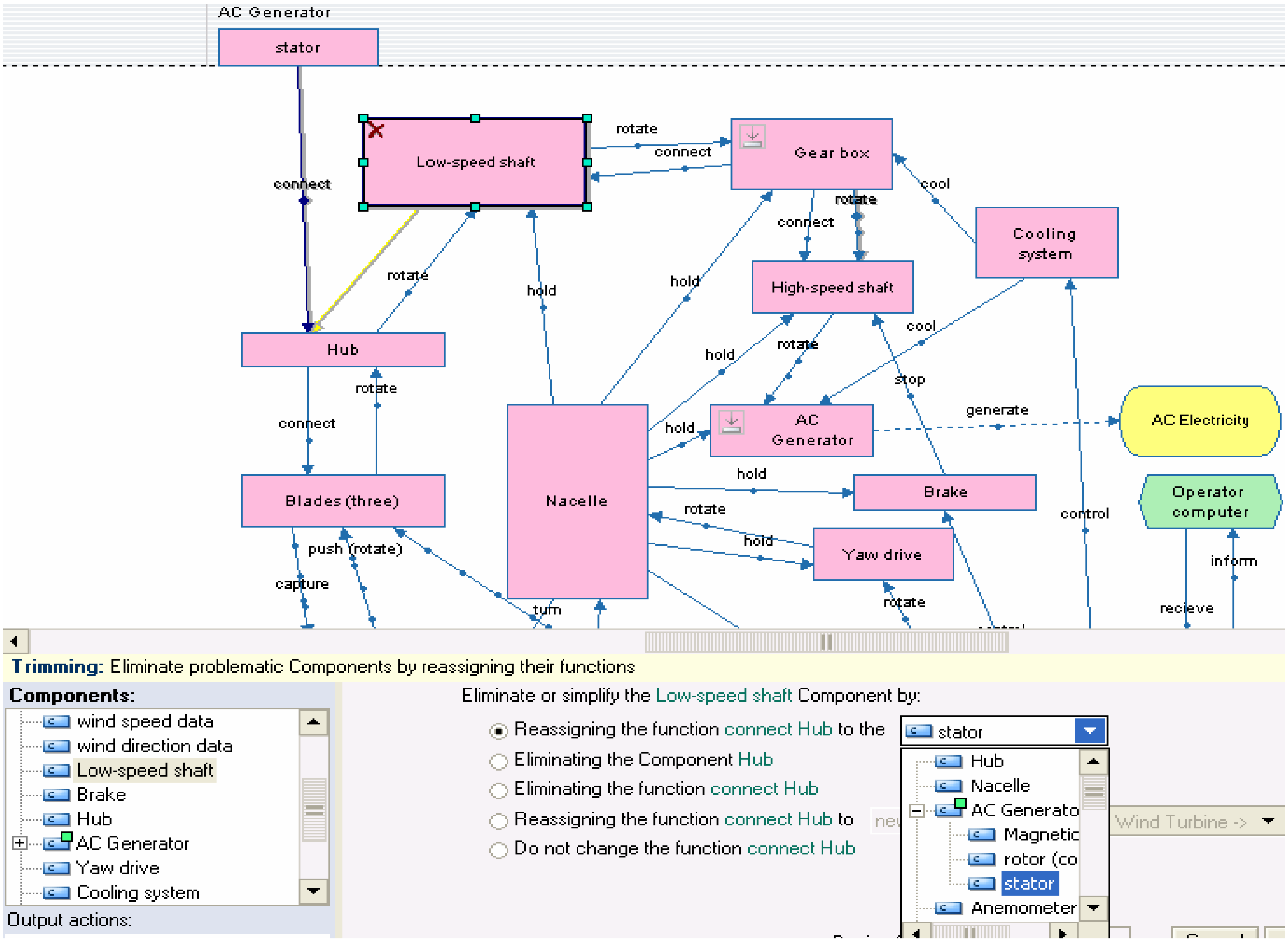
► Trimming Method simplifies and reduces the cost of user product/process, while preserving the essential functionality.

► The design variants that results from Trimming will generate different problem statements, if solved, can lead to highly innovative solutions.

First page of the Trimming Process



“Low-speed shaft” trimming

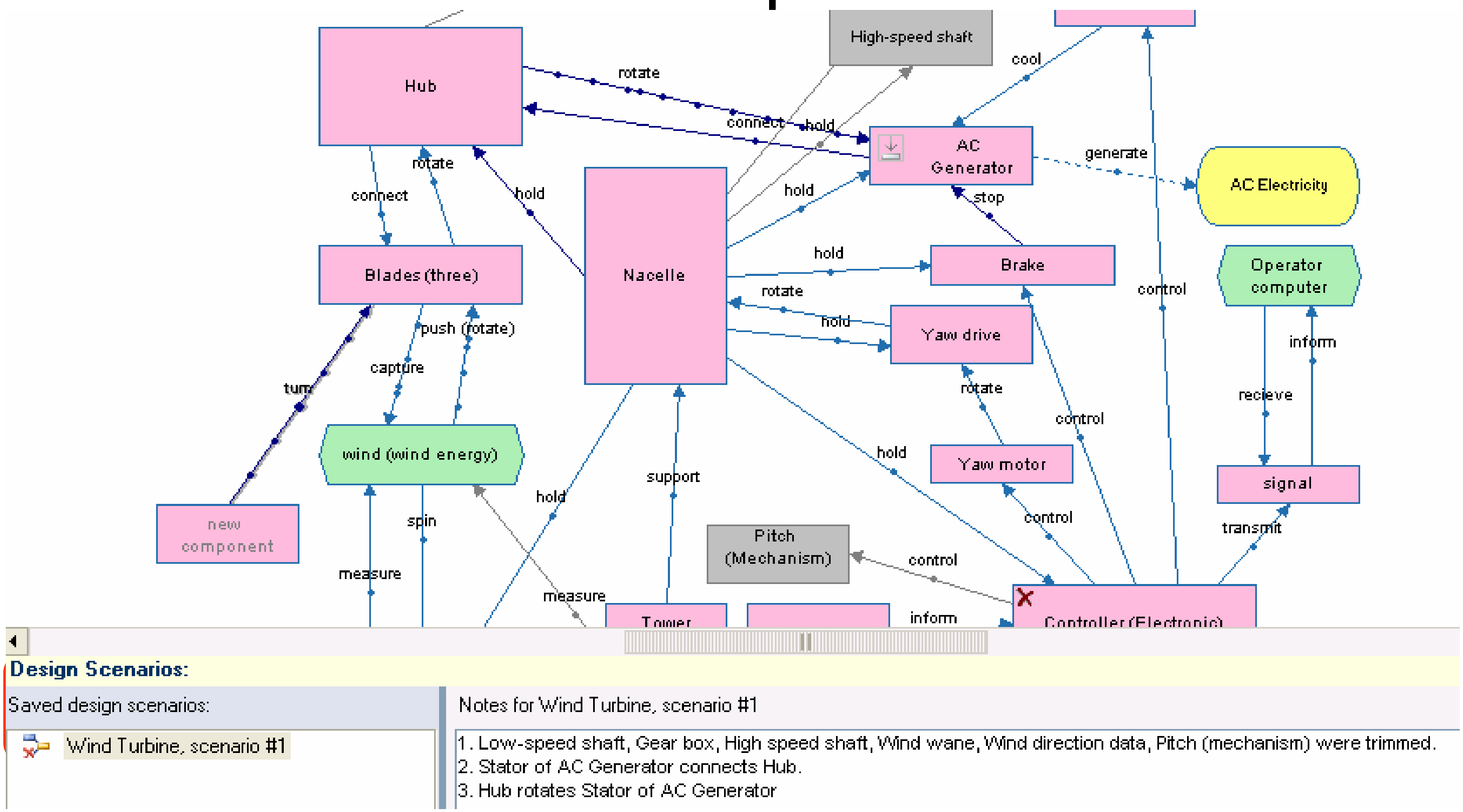


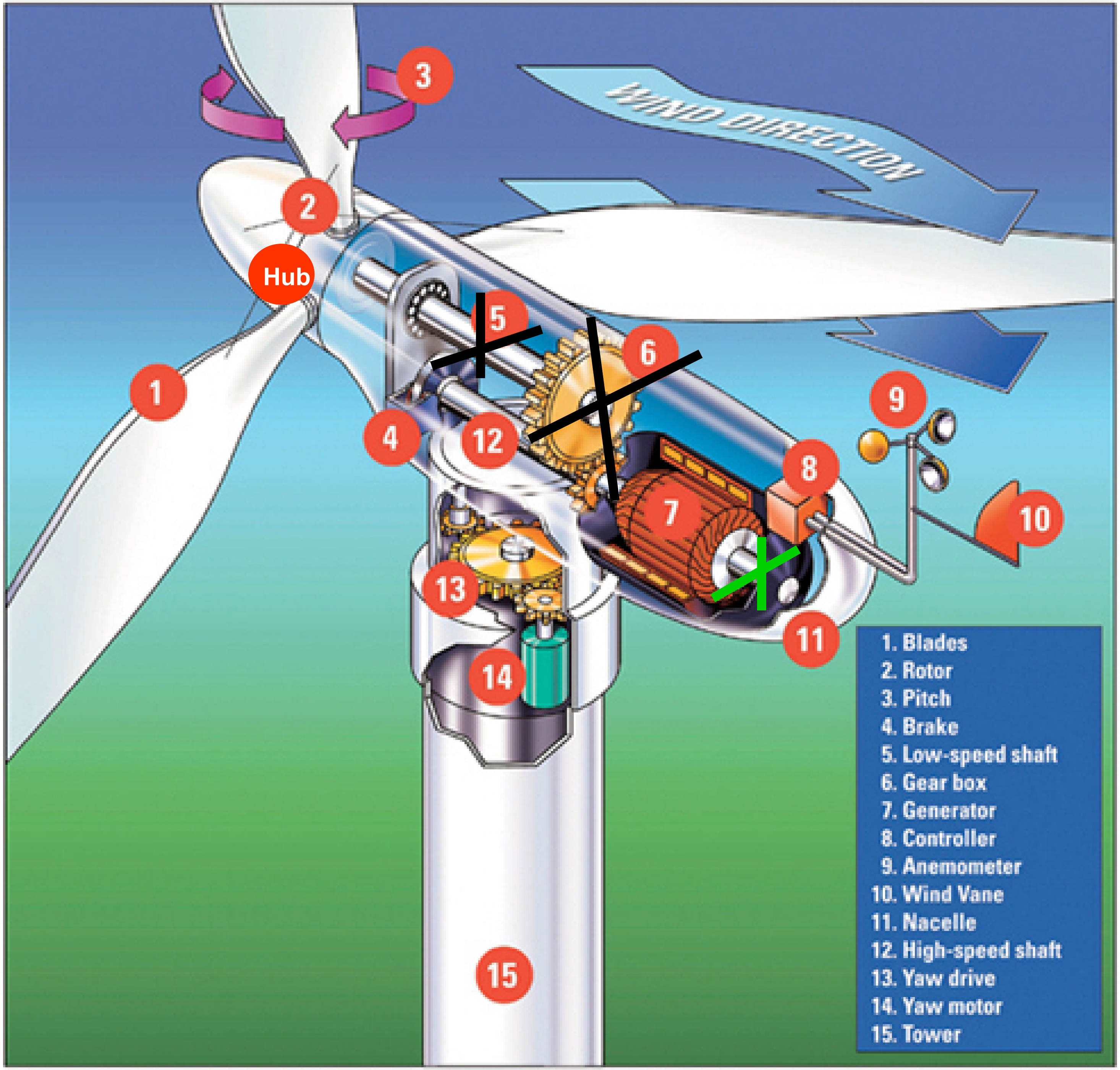
Main Trimming Results

1. Low-speed shaft, Gear box, High speed shaft, Wind wane, Wind direction data, Pitch (mechanism) were trimmed.

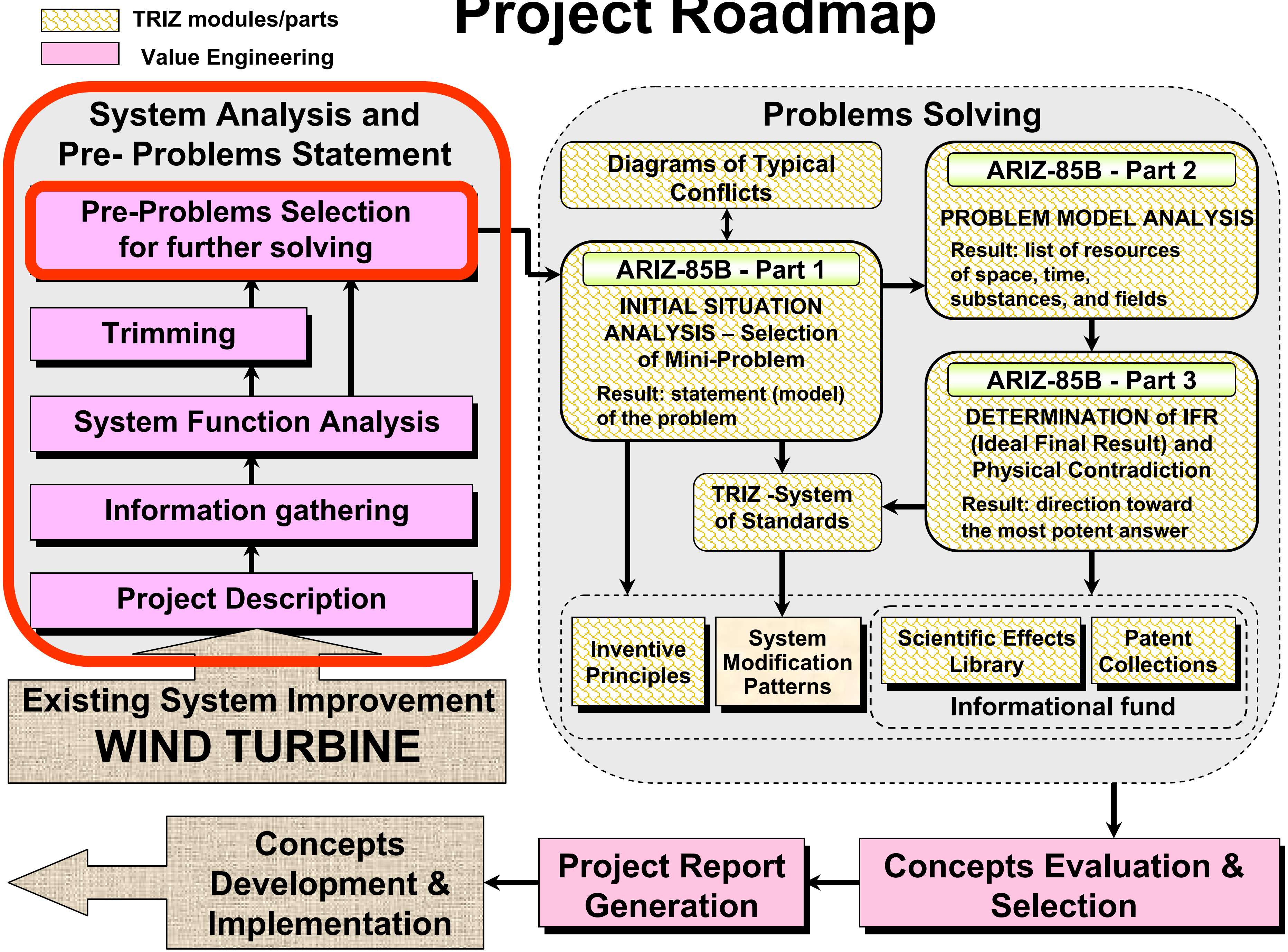
2. Stator of AC Generator connects Hub.

3. Hub rotates Stator of AC Generator




WIND DIRECTION
Hub
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1. Blades
2. Rotor
3. Pitch
4. Brake
5. Low-speed shaft
6. Gear box
7. Generator
8. Controller
9. Anemometer
10. Wind Vane
11. Nacelle
12. High-speed shaft
13. Yaw drive
14. Yaw motor
15. Tower

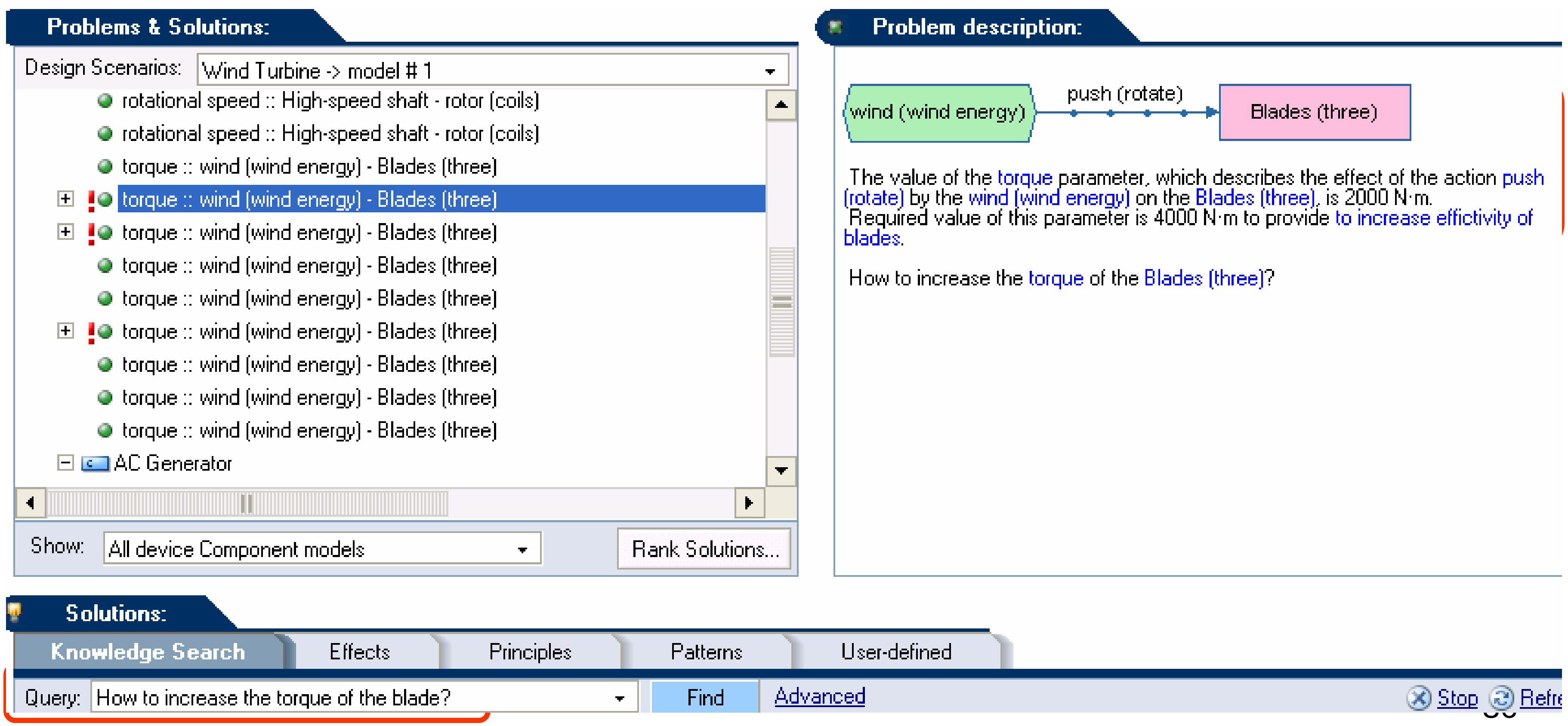
Project Roadmap



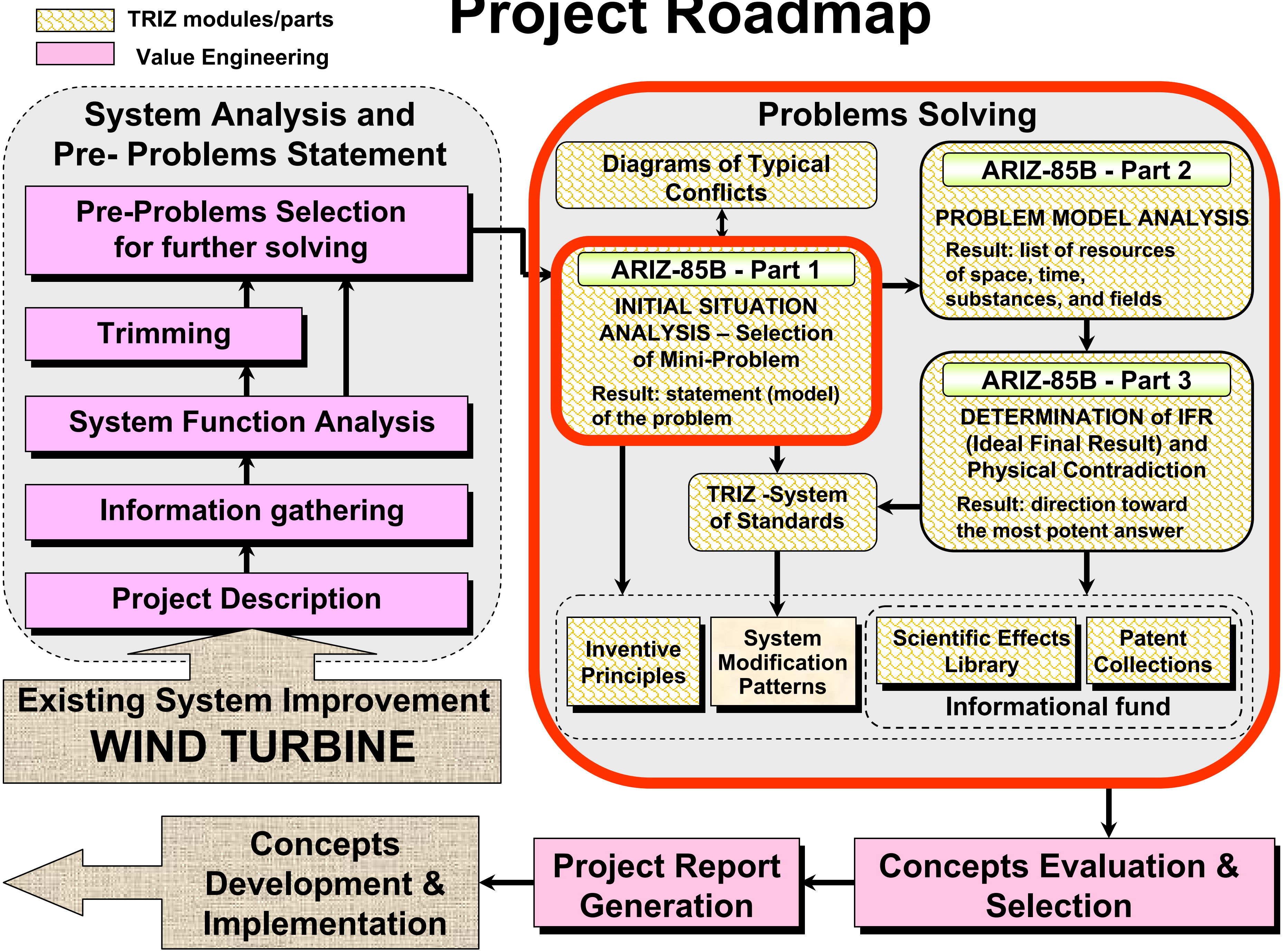
We have selected one problem (pre-problem) from 20 ones for the next stage of the project:

The value of the torque parameter, which describes the effect of the action push (rotate) by the wind (wind energy) on the Blades (three), is 2000 Nm.
Required value of this parameter is 4000 Nm to provide to increase efficiency of blades.

How to increase the torque of the Blade?



Project Roadmap



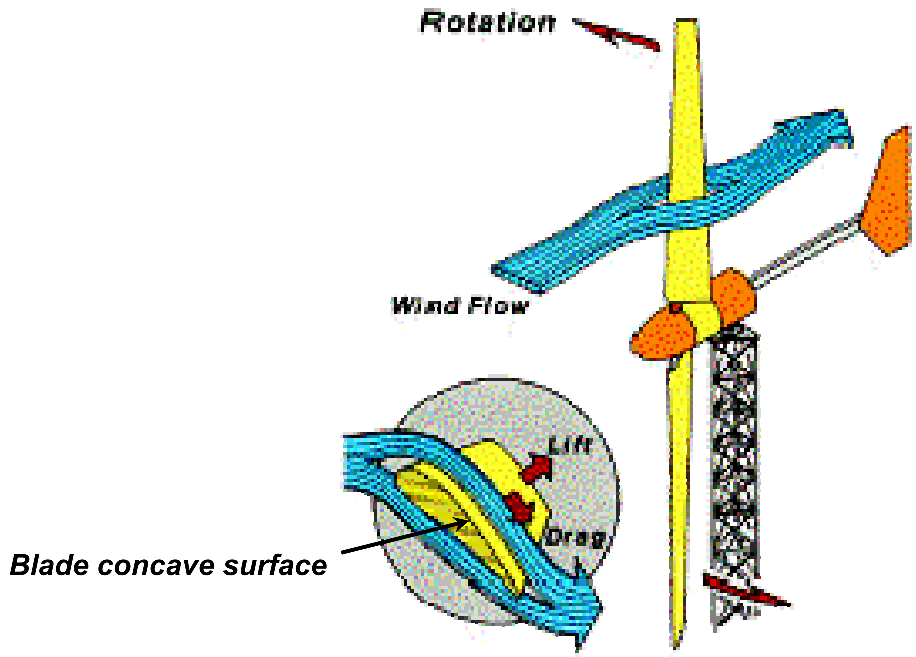
Algorithm for Inventive Problem Solving

Initial situation/pre-problem statement:

Wind flow rotates wind turbine blades/rotor (creates torque).

Three parameters determine torque of the rotor: blade length, blade concave surface area, and wind flow pressure on the blade concave surface.
Low speed of wind flow decreases rotor torque, what decreases rotor rotational speed.
It is necessary to prevent rotor rotational speed decreasing.

***Note:** speed of wind flow could not be changed – it is a supersystem element.*



Principles of Wind Turbine Aerodynamic Lift

http://www.austinschools.org/kealing/energy/reports/present/repwind.html

Algorithm for Inventive Problem Solving – Part 1.1.

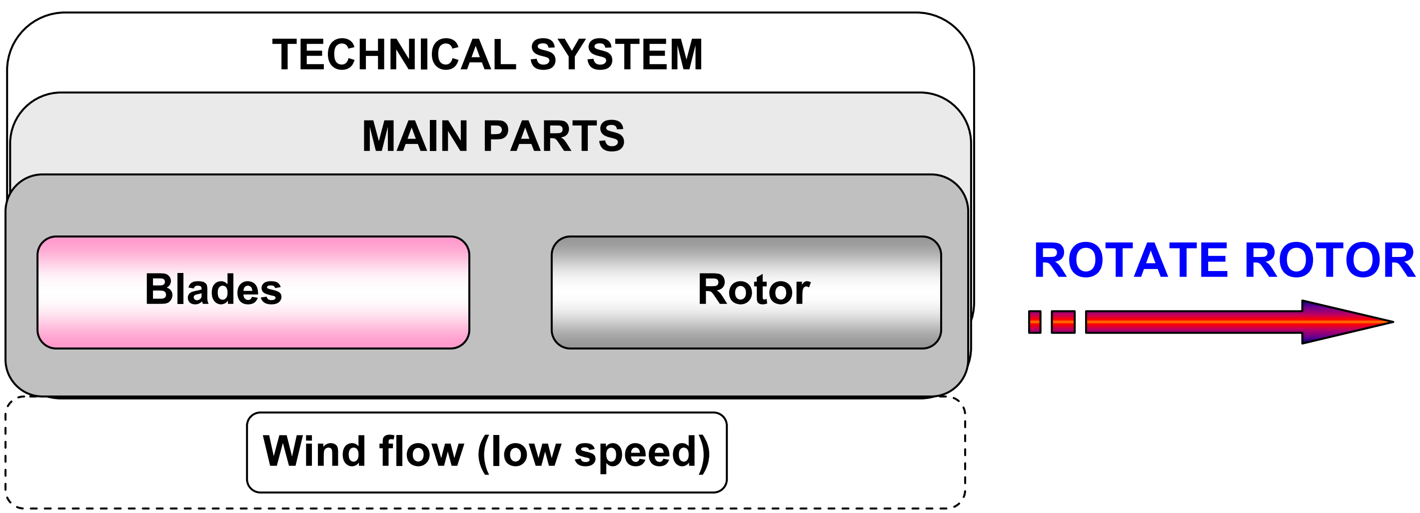
1.1. Write down conditions of a mini-problem (without special terms) as follows:

The technical system (purpose/main function of the system/product) **includes** (list main parts of the system).

The technical system to rotate rotor includes: wind flow, blades, and rotor.

Under minimal changes in the system it is required: (specify a result which should be obtained).

Under minimal changes in the system it is required: to prevent rotor rotational speed decreasing under low wind flow speed.

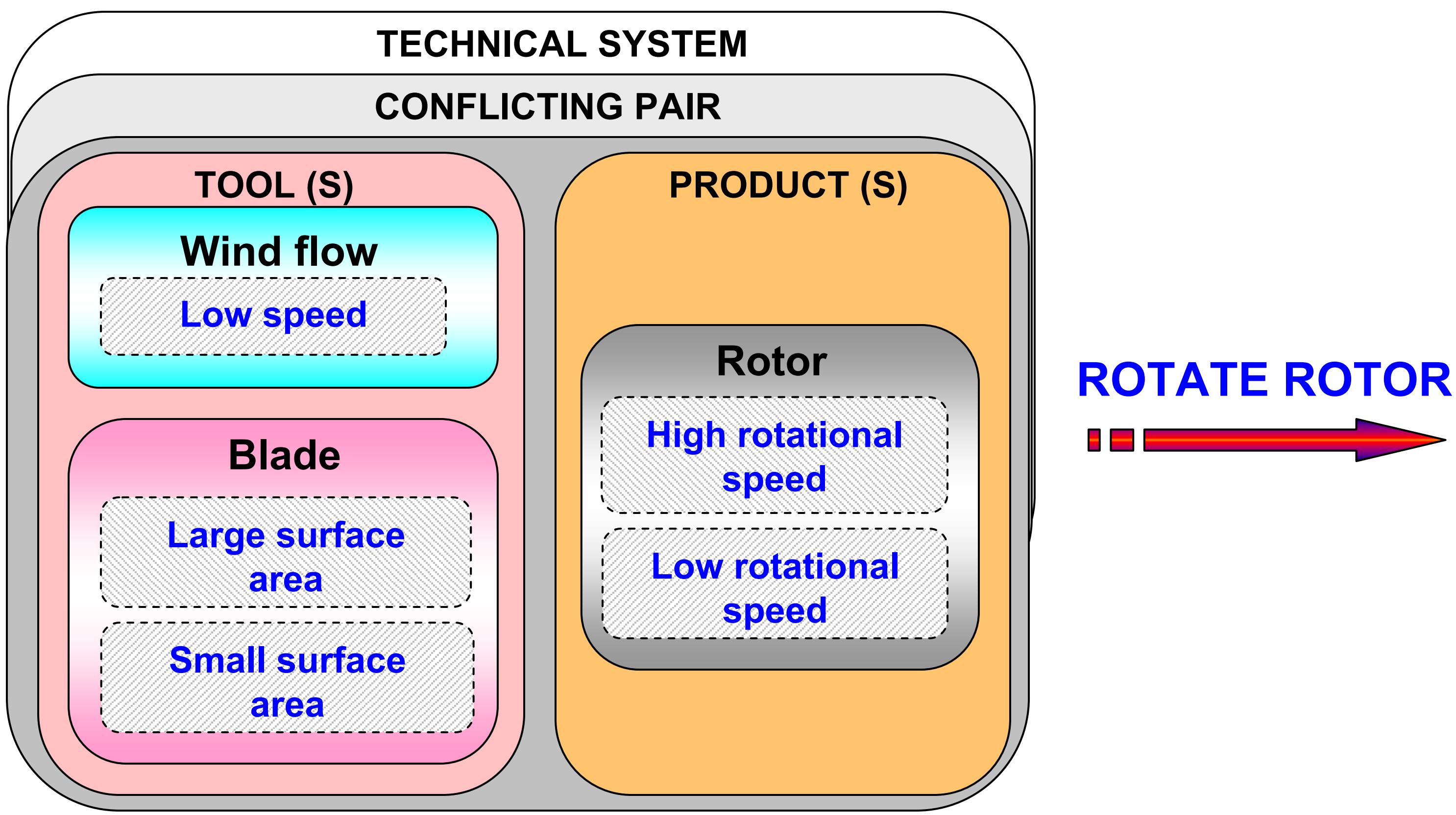


Algorithm for Inventive Problem Solving – Part 1.2.

1.2. Selection of the conflicting pair:

Product (s): ***rotor (high rotational speed, low rotational speed)***

Tools: ***wind flow (low speed), blade (large surface area, small surface area)***



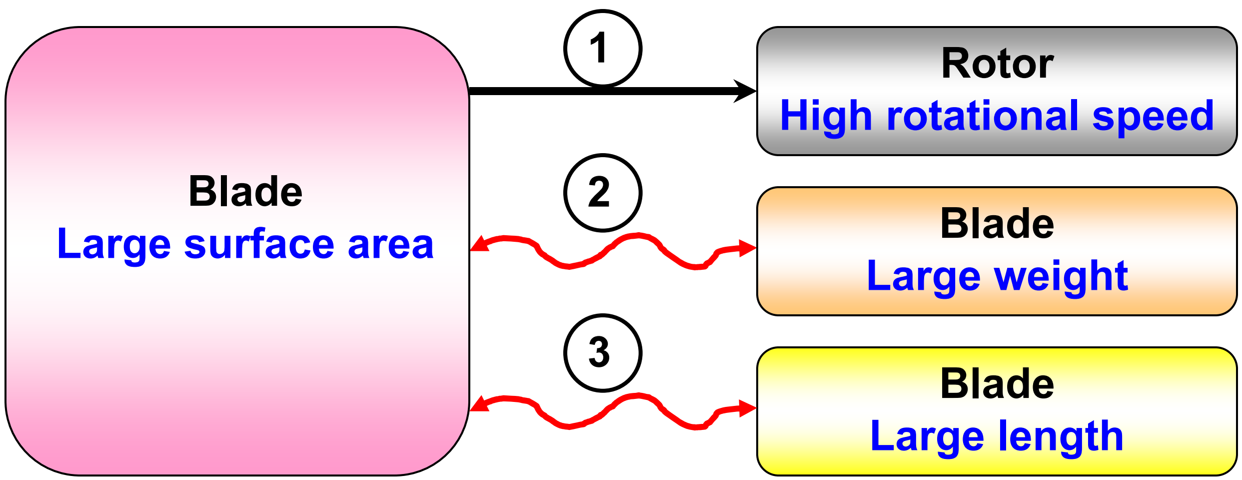
Algorithm for Inventive Problem Solving – Part 1.3.

1.3. Formulate Technical Contractions TC 1 and TC 2 using a conflicting pair and create their diagrams using the Diagrams of Typical Conflicts in Table 1.

A. Technical contradiction1 **– TC 1: (identify)**

TC 1: if there is a blade with a large surface area, the rotor rotational speed is high [1], but blade weight [2] and length [3] are increased.

B. Select/create diagram of **TC 1** using Table 1

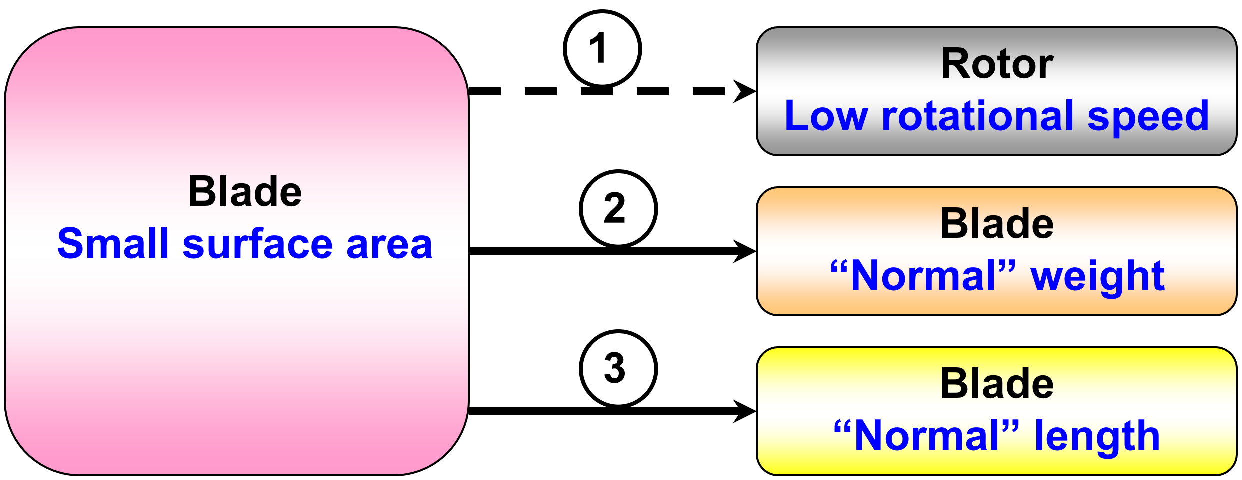


Algorithm for Inventive Problem Solving – Part 1.3.

C. Technical contradiction 2 – **TC 2: (identify)**

TC 2: if there is a blade with a small surface area, the blade weight [2] and length [3] are normal, but rotor rotational speed is low [1].

D. Select/create diagram of **TC 2** using Table 1



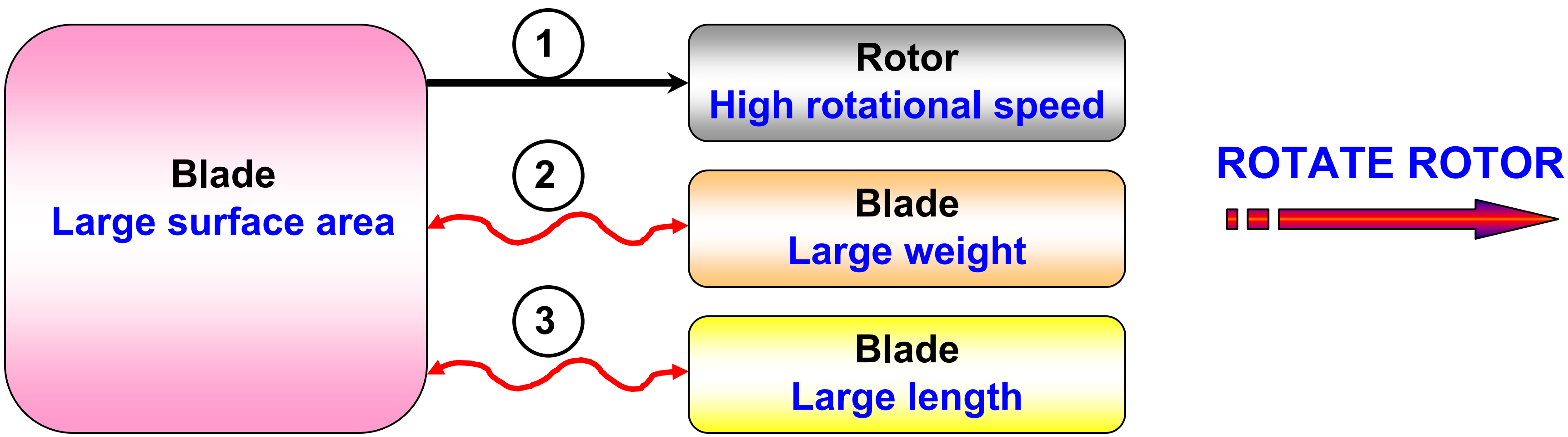
Algorithm for Inventive Problem Solving – Part 1.4.

TRIZ

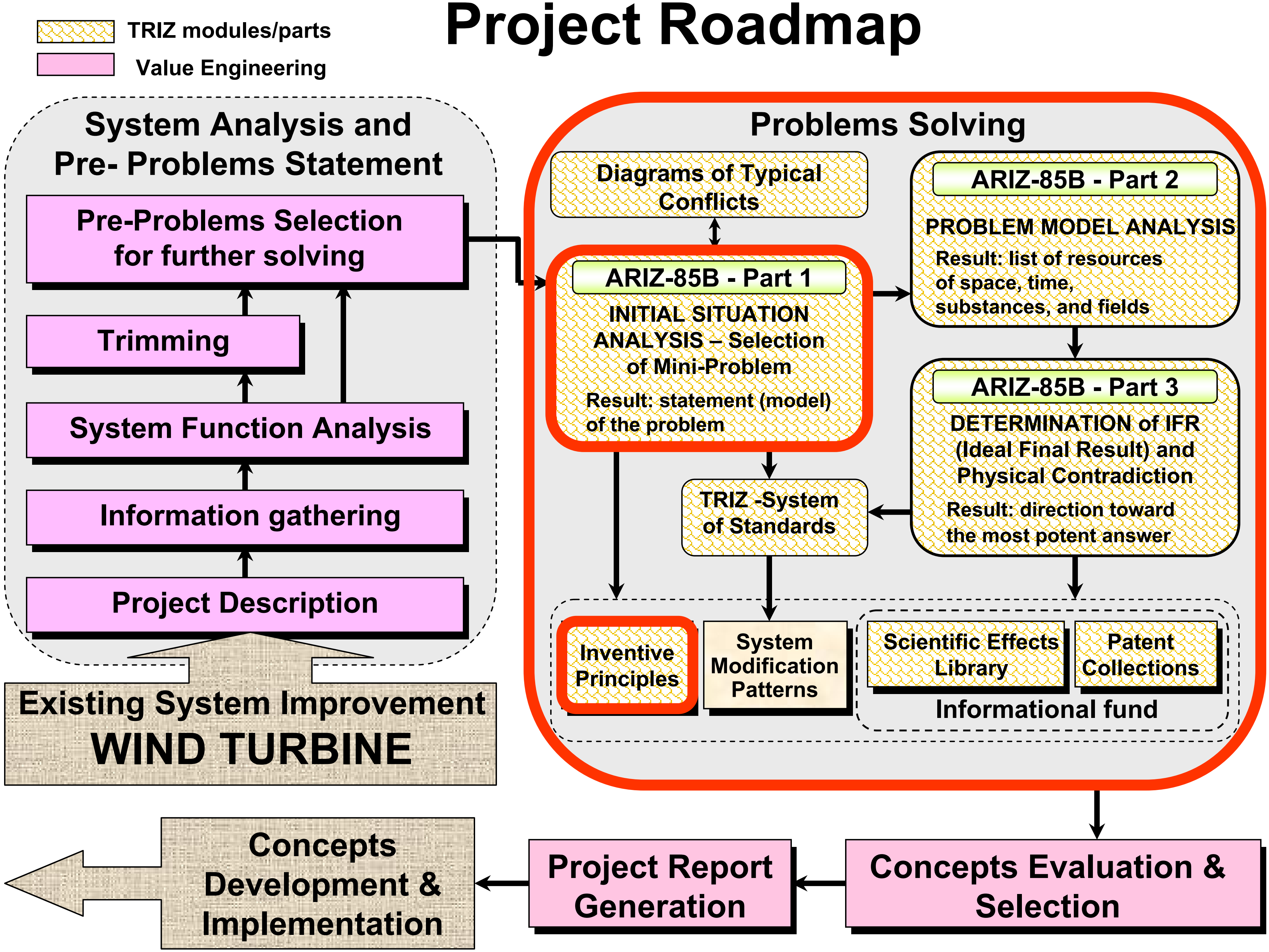
1.4. Select one conflict diagram from the two technical contradictions, (TC1 and TC2), that provides the best accomplishment of the main production process (the main function of the technical system specified in conditions of the problem).

The main function of the system is ***to rotate rotor with high rotational speed***. So, ***TC1*** should be selected: in this case ***a blade with a large surface area rotates rotor with high rotational speed***.

√ **TC1**



Project Roadmap



First Technical Contradiction
-> Recommendation # 15 – Dynamic Parts

TRIZ

First Technical Contradiction

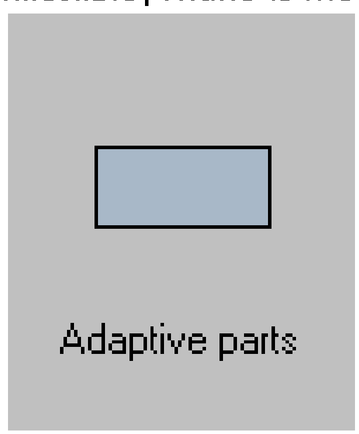
blade with a large surface area ⟺ ***blade with a large length***

Problem:

I want to	increase rotor rotational speed		
by	increasing blade surface area	Improving	area of moving object
which leads to the problem	large lenght of the blade	Worsening	length of moving object

Solution: **Dynamic parts**

- allow (or design) the characteristics of an object, external environment, or process to change to be optimal or to find an optimal operating condition,
- divide an object into parts capable of movement relative to each other,
- if an object (or process) is rigid or inflexible, make it movable or adaptable.



Technical | Physical

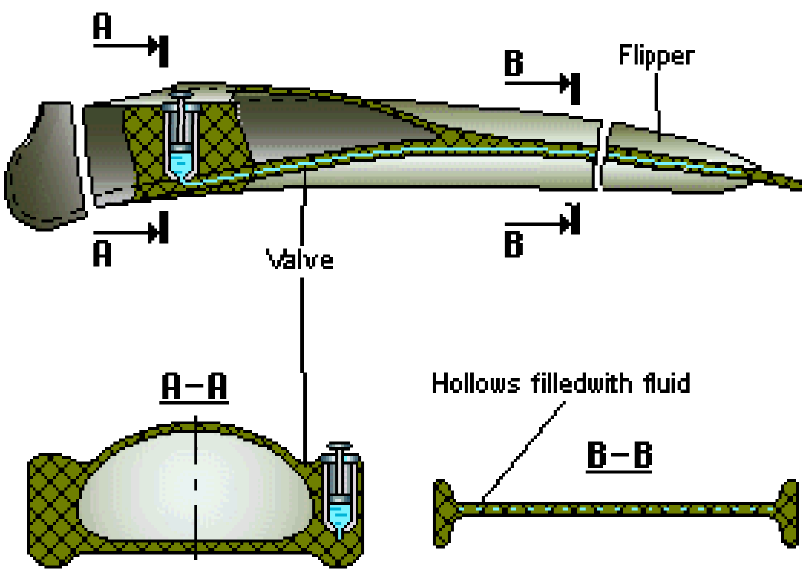
Recommendations:

- 14 - Curvature increase
- 15 - Dynamic parts
- 18 - Mechanical vibration
- 4 - Symmetry change

15 - Dynamic parts

TRIZ

Example: **Variable-rigidity flippers**



Different rigidity is required in swimming flippers under different water conditions (governed by speed and length of stay). Can an adaptive flipper be designed?

It is proposed to use the principles of flexible shells, hydraulic constructions and variability (dynamism) to improve the flipper design. One can form an enclosed longitudinal hollow in the elastic flipper material. This is filled with an non-compressible fluid whose pressure can be adjusted (on the shore or under water) using a piston valve. High pressure makes the flipper blade rigid. This can be adjusted to optimize for current swimming conditions.

SU A.c. N 317 390

You may increase rotor rotational speed by applying principle "15 - Dynamic parts" by analogy of example " Variable-rigidity flippers ".

Second Technical Contradiction
-> Recommendation # 29 – Pneumatics and Hydraulics

TRIZ

Second Technical Contradiction

blade with a large surface area ⟷ ***blade with a large weight***

Problem:

I want to	increase rotor rotational speed
by	increasing blade surface area
which leads to the problem	large weight of the blade

Improving	area of moving object
Worsening	weight of moving object

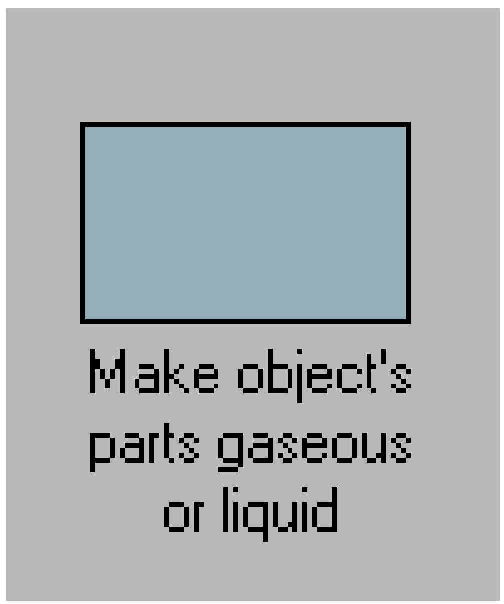
Technical | Physical

Recommendations:

- 2 - Separation
- 17 - Dimensionality change
- 29 - Pneumatics and hydraulics
- 4 - Symmetry change

Solution: **Pneumatics and hydraulics**

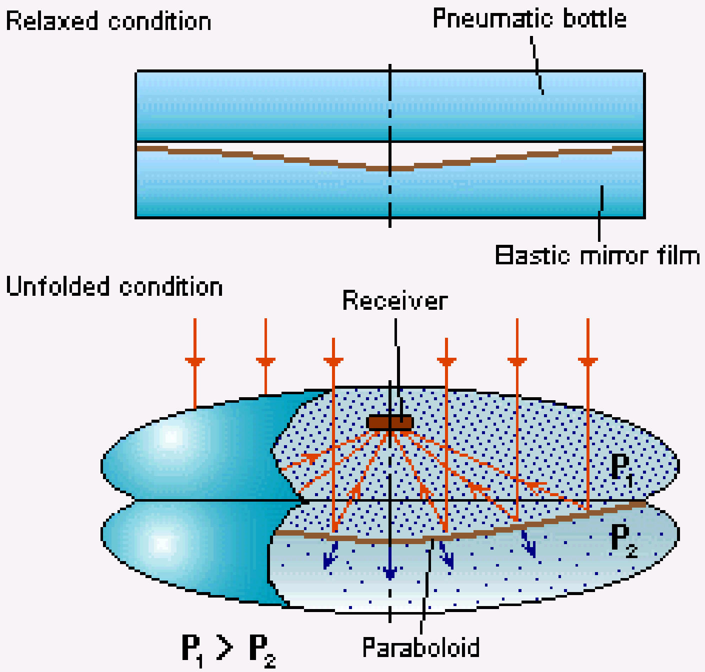
- use gas and liquid parts in an object instead of solid parts (e.g. inflatable, liquid-filled, air cushioned, hydrostatic, hydro-reactive).



29 - Pneumatics and hydraulics

TRIZ

Example: **Simple solar energy concentrator**



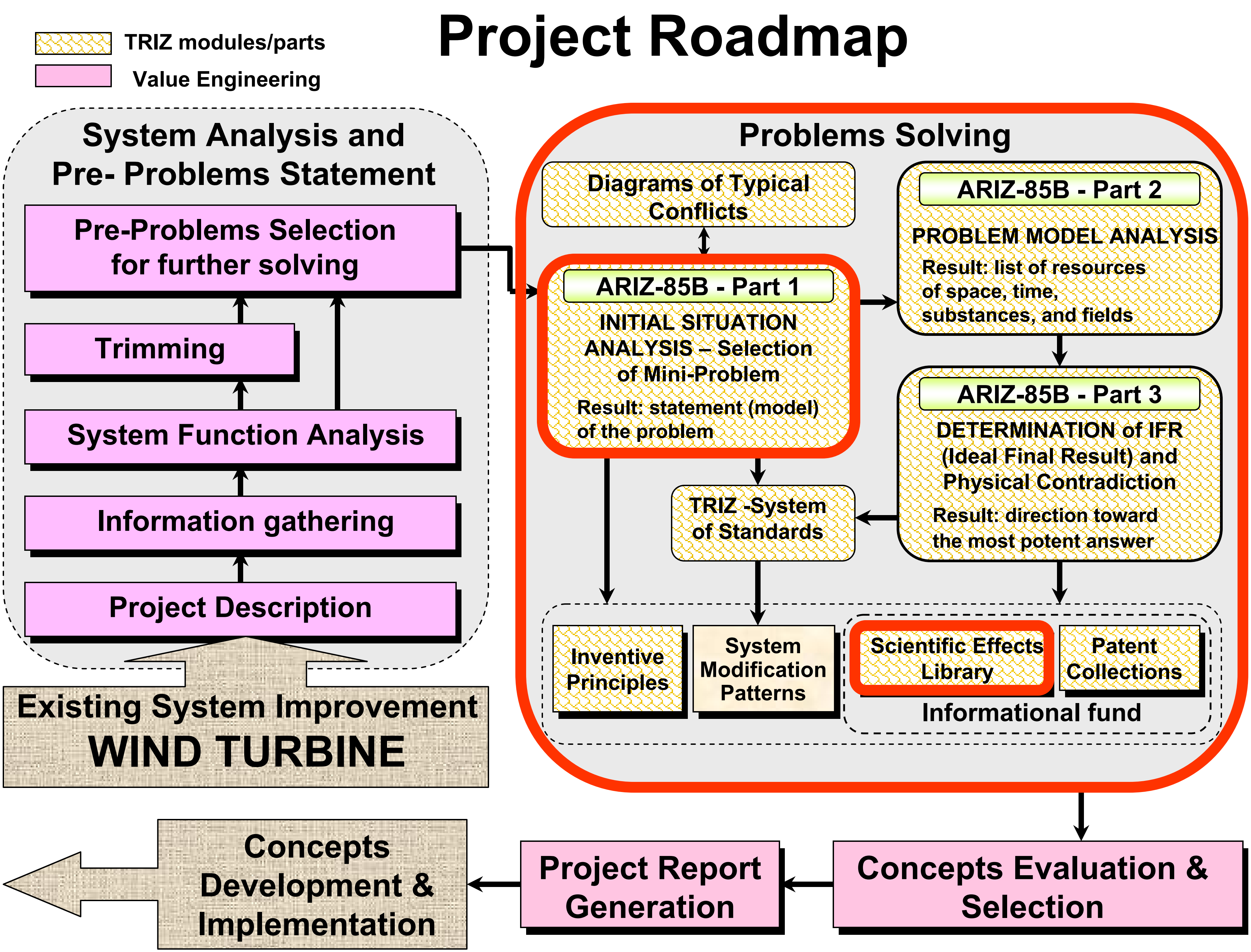
It is desirable to have a solar energy concentrator with a simple and low cost design.

It is proposed to use the principles of flexible shells, pneumatics, spheroidality and transition to another dimension to design a low cost solar collector. One can make it in the form of a pneumatic bottle (two flexible shells form two bubbles with a membrane, parabolic mirror, in between). The chambers are filled with gas, the pressure in the upper chamber being higher than in the lower one. When the chambers take shape, the pressure difference forms the parabolic surface between. Optical rays are concentrated at the receiver located at the focal point (focused by controlling the pressure difference). Using simple membranes and inexpensive resources (compressed air), makes the manufacturing and operation of this device inexpensive.

SU A.c. N 514 112

You may increase rotor rotational speed by applying principle "29 - Pneumatics and hydraulics".

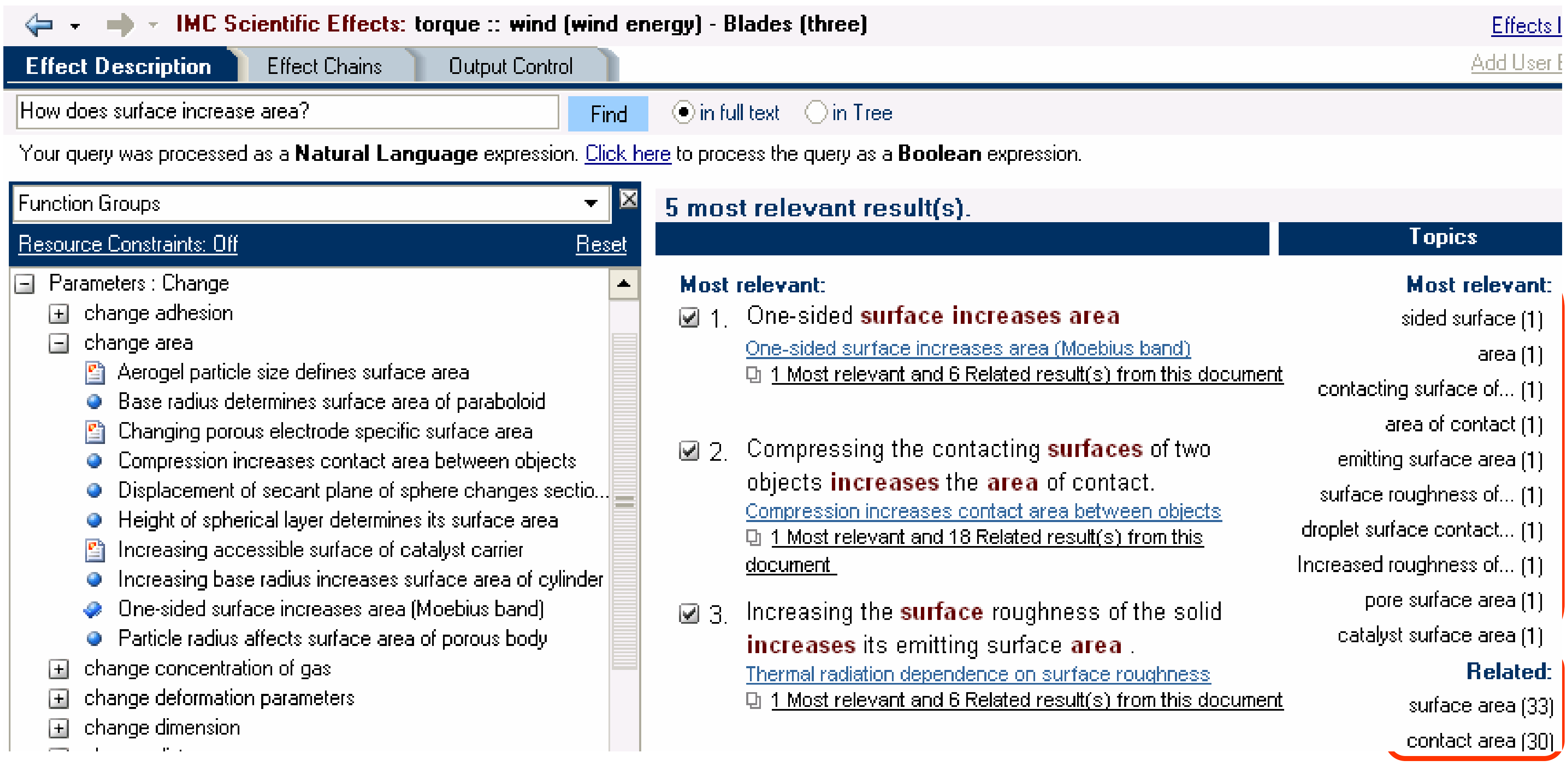
Idea: **for better synchronization with wind speed (and maybe - wind direction) and blade shape control -> some parts of blade could be made by using "Pneumatics and hydraulics".**


Project Roadmap
TRIZ modules/parts
Value Engineering
System Analysis and Pre- Problems Statement
Pre-Problems Selection for further solving
Trimming
System Function Analysis
Information gathering
Project Description
Existing System Improvement
WIND TURBINE
Problems Solving
Diagrams of Typical Conflicts
ARIZ-85B - Part 1
INITIAL SITUATION ANALYSIS – Selection of Mini-Problem
Result: statement (model) of the problem
ARIZ-85B - Part 2
PROBLEM MODEL ANALYSIS
Result: list of resources of space, time, substances, and fields
ARIZ-85B - Part 3
DETERMINATION of IFR (Ideal Final Result) and Physical Contradiction
Result: direction toward the most potent answer
TRIZ -System of Standards
Inventive Principles
System Modification Patterns
Scientific Effects Library
Patent Collections
Informational fund
Concepts Evaluation & Selection
Project Report Generation
Concepts Development & Implementation

GFIN Scientific Effects Module

Query:

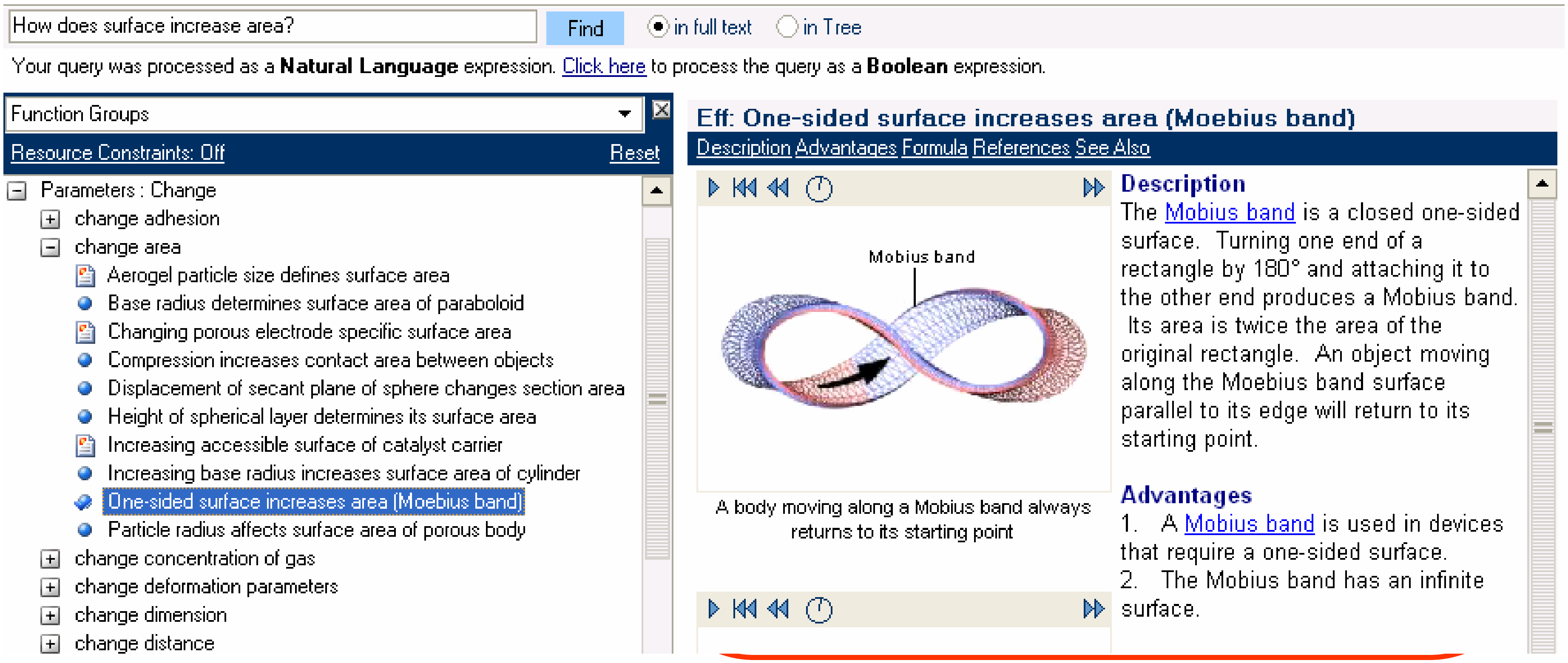
How does surface increase area?



GFIN Scientific Effects Module

Example:

One-sided surface increases area (Mobius band)



GFIN Scientific Effects Module

TRIZ

Example: Motor blade in form of Mobius strip

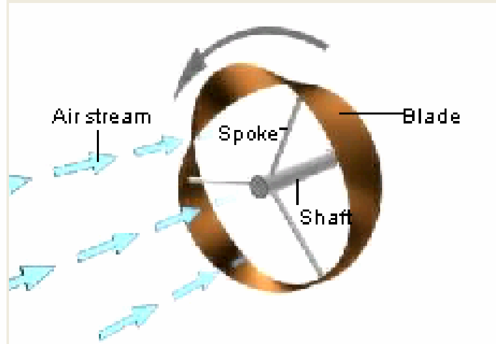
Function Groups

Resource Constraints: Off　　Reset

- Drop arm moves steering links
- Efficiency increase of mechanism
- Einstein-de Haas effect
- Force generation with rarefied gas
- Force-saving bicycle pedal
- Free-running brush Clutch
- Friction
- Friction buffer device
- Gravitational energy converter
- Heat engine for toys
- Helical projection rotates log
- Helical spring winds safety belt
- Inertia
- Motor blade in form of Mobius strip
- Motors made with springs
- Movable antenna mechanism
- One-sided surface increases area (Moebius band)
- Piezoelectric actuators rotate disk
- Piezoelectric drives rotate shaft
- Resilient crosspiece allows door opening
- Roller bearing
- Rotary actuator made of shape memory alloy
- Rotation of dielectric rotor in electrorheological suspensions
- Rotation of heavy flexible body with help of gravitation wave
- Rotation of metal ring with help of heat wave
- Screw effect
- Shaft rotational velocity change
- Sheet turning over with conveyer belt
- Sinusoidal surfaces transmit rotation

Ex: Motor blade in form of Mobius strip

Problem Solution Advantages References See Also



The air stream rotates the blade made in the form of a Mobius strip

Problem

In windmills, propellers are used to impart rotation to a shaft. The propeller blades have a complicated surface; they are difficult to fabricate.

Solution

A blade is fixed on a shaft by means of spokes. The blade is made of elastic material and has the Mobius strip form.

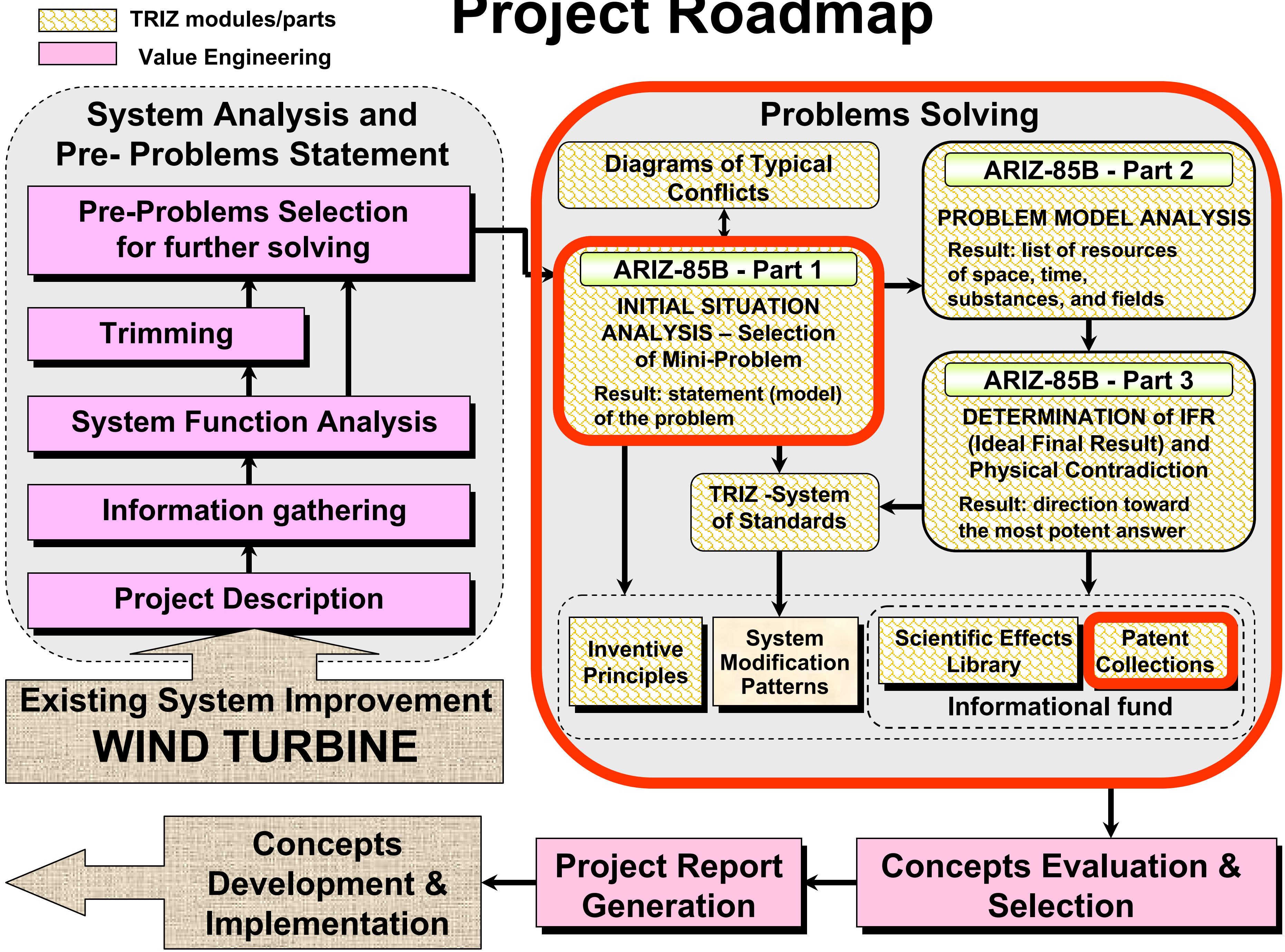
The blade is blown over by an air stream. The blade surface is located at an angle to the air stream direction. Due to this, an aerodynamic force occurs. It rotates the blade and the shaft.

The blade is fabricated from elastic material as a strip. No complicated surface contouring is required for this purpose.

Advantages

1. The propeller blade in the Mobius strip form is simple in design.
2. The blade in the Mobius strip form is easy to manufacture.
3. The blade has a low aerodynamic

Project Roadmap



GFIN Patent Collections

Query: How to increase the torque of the blades?

First selected Patent: US-20030123973 A1

TRIZ

How to increase the torque of the blades? | Find

Your query was processed as a **Natural Language** expression. Click here to process the query as a **Boolean** expression.
Click here to perform a fielded search in Patent Collections.

Patents

27 most relevant result(s).

Try synonyms: accrue accrue to augment enhance **increase** maximise maximize rise

Topics

Most relevant:

1. ...rotation direction and guiding the airflow from the path thus formed to the rear face of the blade body, so as to generate lift on the leading edge auxiliary vane and **increases** a rotating **torque** of the turbine **blade**; and the blade body...
   US-20030123973 A1 Propeller type windmill for power generation
   6 Most relevant and 82 Related result(s) from this document

2. ...vane frontwardly in the rotational direction and guiding the airflow from the formed path thus formed to the rear face of the blade body, thereby generating lift on the leading edge auxiliary vane and **increasing** a rotating **torque** of the turbine **blade**.
   US-6752595 B2 Propeller type windmill for power generation
   6 Most relevant and 92 Related result(s) from this document

3. ...rotation direction and guiding the airflow from the path thus formed to the rear face of the blade body, so as to generate lift on the leading edge auxiliary vane and **increases** a rotating **torque** of the turbine **blade**; and the blade body...
   EP-1375911 A1 PROPELLER TYPE WINDMILL FOR POWER GENERATION
   5 Most relevant and 84 Related result(s) from this document

4. The invention is to solve the problems of the prior arts, and it is an object thereof to present a washing machine capable of **increasing** the rotating **torque** of the agitating **blades** without increasing the torque of the drive motor, and capable of...
   US-20020184928 A1 Washing machine
   3 Most relevant and 111 Related result(s) from this document

5. The invention is to solve the problems of the prior arts, and it is an object thereof to present a washing machine capable of **increasing** the rotating **torque** of the agitating **blades** without increasing the torque of the drive motor, and capable of

Most relevant:

- rotating torque of... (8)
- rotating torque of... (3)
- blade retarding torque (2)
- torque of rotary... (2)
- minimum multiple of... (2)
- torque (1)
- rotation torque of... (1)
- turning torque of... (1)
- rotating torque of... (1)
- torque transmitting performance... (1)
- torque transmitting property... (1)
- strength of high... (1)

Related:

- Torque (36)
- integrated torque tube... (14)
- stirring blade torque (7)

GFIN Patent Collections

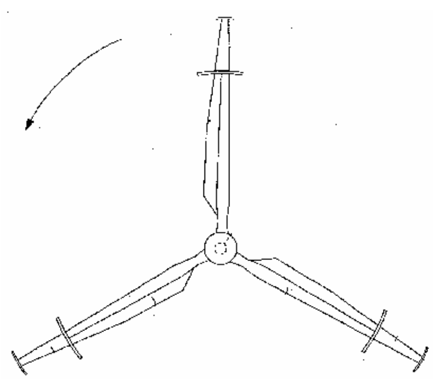
First selected Patent: US-20030123973 A1

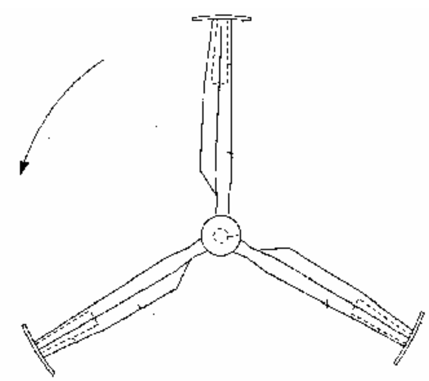
Goldfire Innovator - Patent Summary

Detail level

Less More

Publication Number	US-20030123973 A1
Title	**Propeller type windmill for power generation**
Application	This invention relates to a propeller-type wind turbine used in wind- powered electrical generation.
Task	The invention of claim 6 is the structure according to claim 5, characterized in that the blade body of each turbine blade includes a rear auxiliary vane provided at the trailing edge portion and being capable of extending and retractingrearward in the rotation direction, and a rear auxiliary vane extension-and-retraction unit for protruding the rear auxiliary vane rearward so as to increase a vane arc length.
Method	With this structure, the pitch changing guide member allows the pitch of the vane bodies to continuous with that of the tip auxiliary blades, forming a vane of a better performance.
Features	Furthermore, because the pitch addition means 11 is provided to the extension-and-retraction guide unit 9 , when the tip auxiliary blades 6 are extende from inside the blade bodies 4 , a specific rotational displacement is imparted, allowing a continuous pitch to be formed from the blade bodies 4 to the tip auxiliary blades 6 , so operation is more efficient.





GFIN Patent Collections

TRIZ

Second selected Patent: US-5902108

An object of the invention is to provide an air turbine headpiece in which a rotor can be efficiently rotated at high torque, in connection with a nozzle opening for injecting air to a turbine blade portion

Goldfire Innovator - Patent Summary

Detail level

Less | More

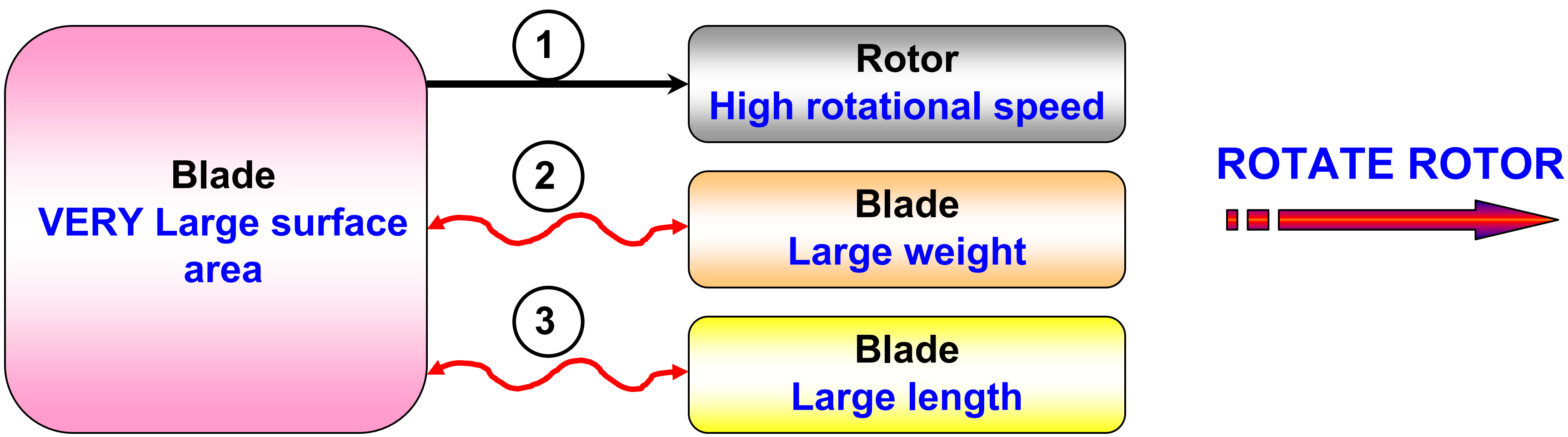
Publication Number	US-5902108
Title	Air turbine handpiece
Application	The present invention relates to an air turbine handpiece which can be usefully applied to medical treatment or the like.
Task	An object of the invention is to provide an air turbine handpiece in which a rotor can be efficiently rotated at high torque, in connection with a nozzle opening for injecting air to a turbine blade portion.
Method	In a twenty-third aspect of the invention, the head portion comprises a head body which forms the chamber, an inner housing member is attached to a interior of the chamber of the head body, a sleeve member is attached to an outer peripheral surface of the inner housing member, and an auxiliary air flow path which guides air from the first turbine blade portion to the second turbine blade portion is formed by the sleeve member and the inner housing member.
Features	According to the twenty-sixth aspect of the invention, the rotor having the first and second turbine blade portions can be produced relatively easily and economically.

Algorithm for Inventive Problem Solving – Part 1.5.

1.5. Reinforce (intensify) a conflict, specifying a limit state (action) of elements (parts).

Let's assume that instead of "a large surface area" "a very large surface area" is specified in TC 1.

√ **TC1**



Algorithm for Inventive Problem Solving – Part 1.6.

1.6. Write down a specified problem model:

A. Conflicting pair

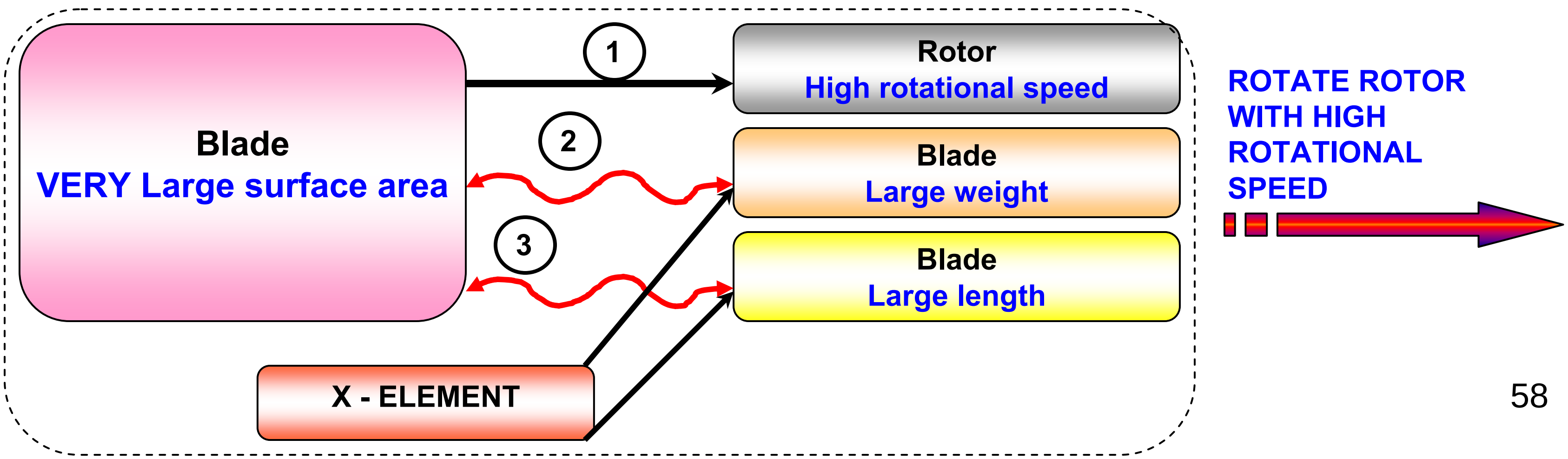
B. Blade with a very large surface area and a rotor with a high rotational speed.

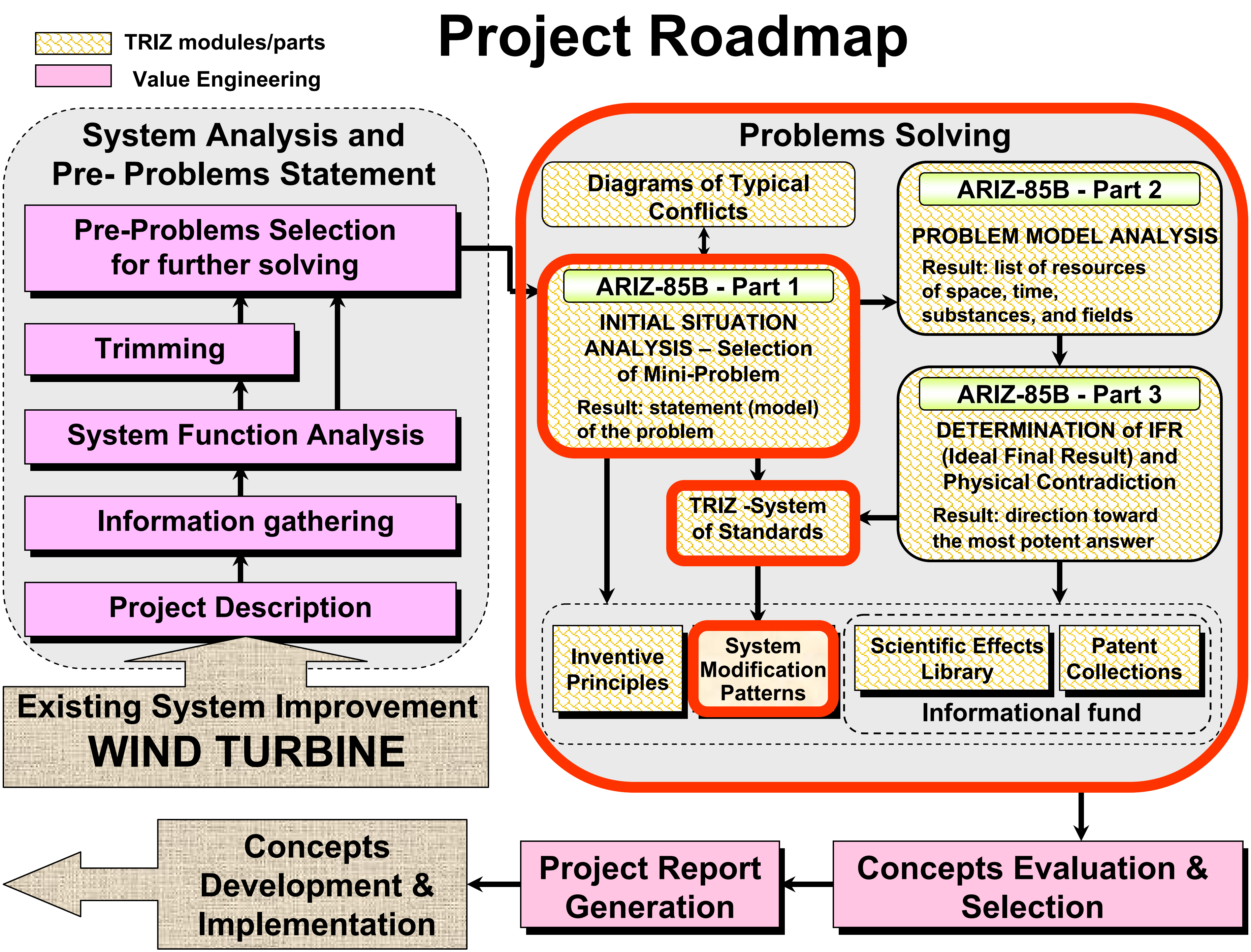
B. Reinforced (intensified) formulation of a conflict

B. Blade with a very large surface area increases the rotational speed of rotor [1], but blade weight [2] and length [3] are increased.

C. It is required to find x-element, which solves a conflict of the selected TC (to preserve, to eliminate, to improve, to provide, etc.).

C. It is required to find x-element, which preserves the ability of the blade with a very large surface area to rotate rotor with a high rotational speed would not create a large weight and length of blade.

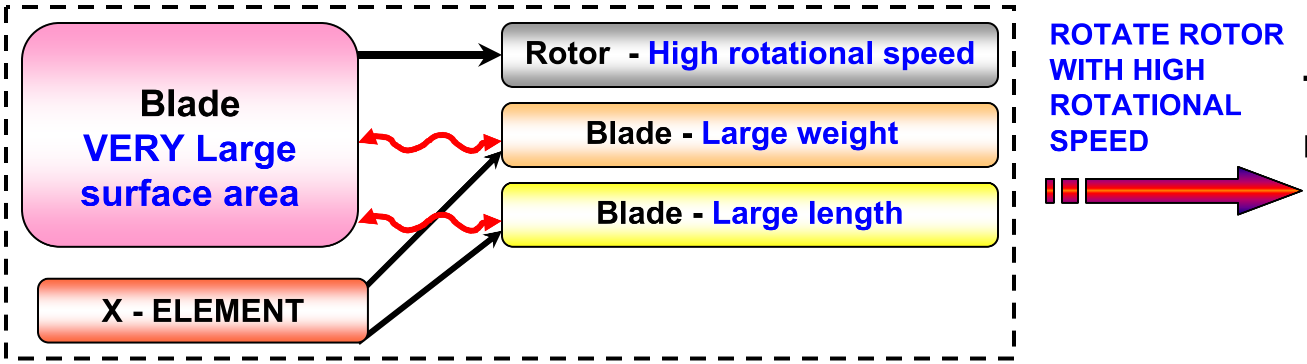




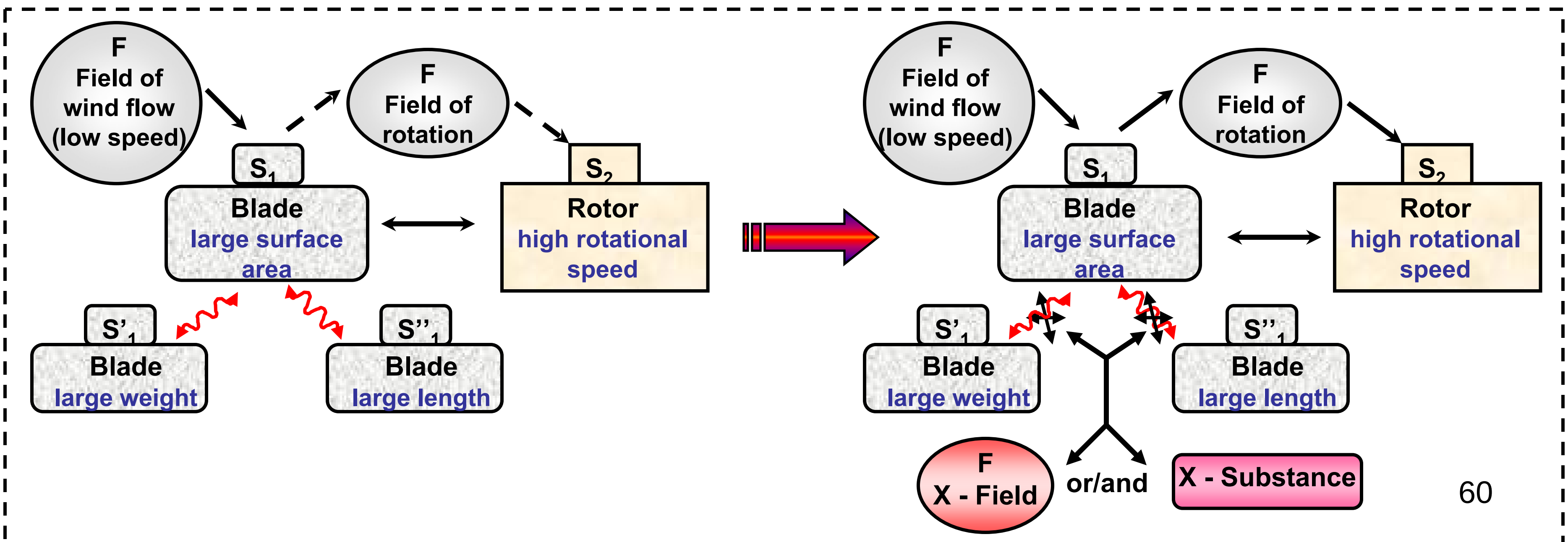
TRIZ modules/parts
Value Engineering
Project Roadmap
System Analysis and Pre- Problems Statement
Pre-Problems Selection for further solving
Trimming
System Function Analysis
Information gathering
Project Description
Existing System Improvement
WIND TURBINE
Problems Solving
Diagrams of Typical Conflicts
ARIZ-85B - Part 1
INITIAL SITUATION ANALYSIS – Selection of Mini-Problem
Result: statement (model) of the problem
ARIZ-85B - Part 2
PROBLEM MODEL ANALYSIS
Result: list of resources of space, time, substances, and fields
ARIZ-85B - Part 3
DETERMINATION of IFR (Ideal Final Result) and Physical Contradiction
Result: direction toward the most potent answer
TRIZ -System of Standards
Inventive Principles
System Modification Patterns
Scientific Effects Library
Patent Collections
Informational fund
Concepts Development & Implementation
Project Report Generation
Concepts Evaluation & Selection

Algorithm for Inventive Problem Solving – Part 1.7.

1.7. Check possibility of using of the System of Standards to solve the problem model. Transition from functional model to the Su-Field model



Transition from functional model to the Su-Field model



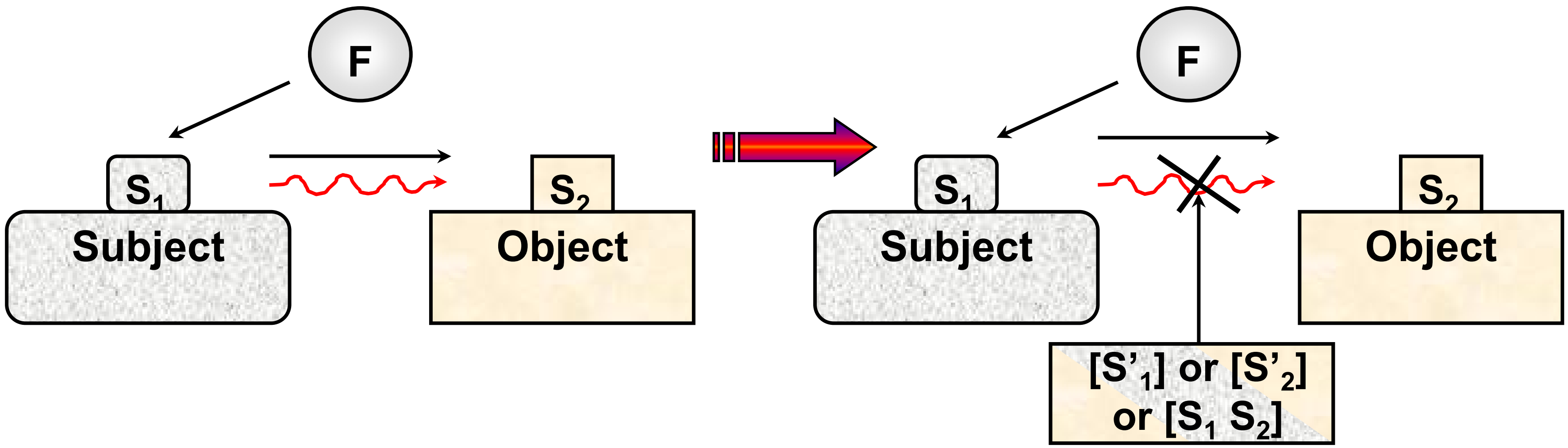
TRIZ - System of Standards: Standard 1.2.2.

TRIZ

1.2.2. Harmful interaction (function) removal by modification of the existing substances.

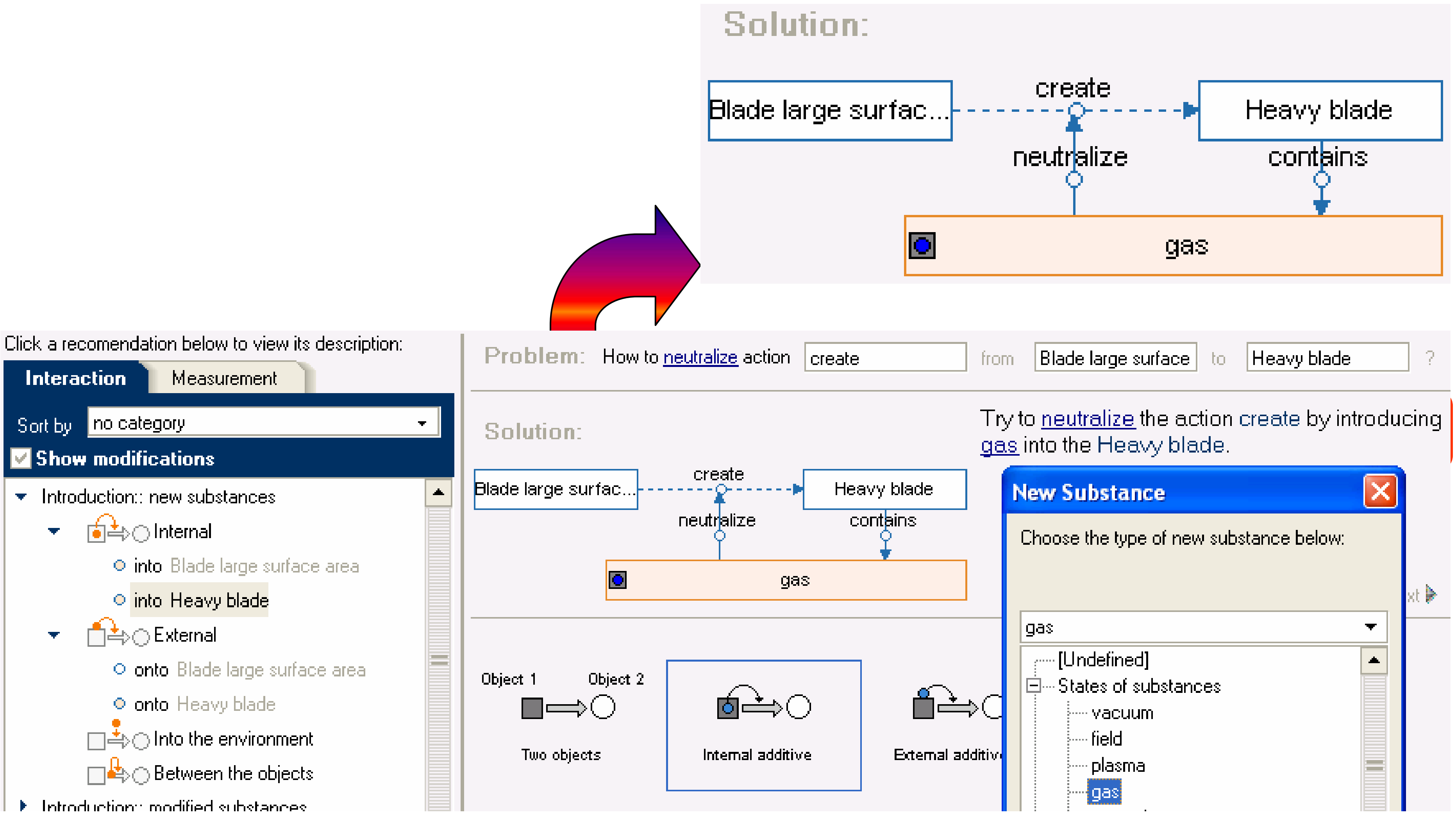
If useful and harmful actions are linked between two substances in a S-Field (direct contact of substances is not necessary to preserve and using of foreign substance is prohibited or to no purpose),

the problem could be solved by introduction of a modified third substance (modification of any existing substances, or their combinations) between those two substances.



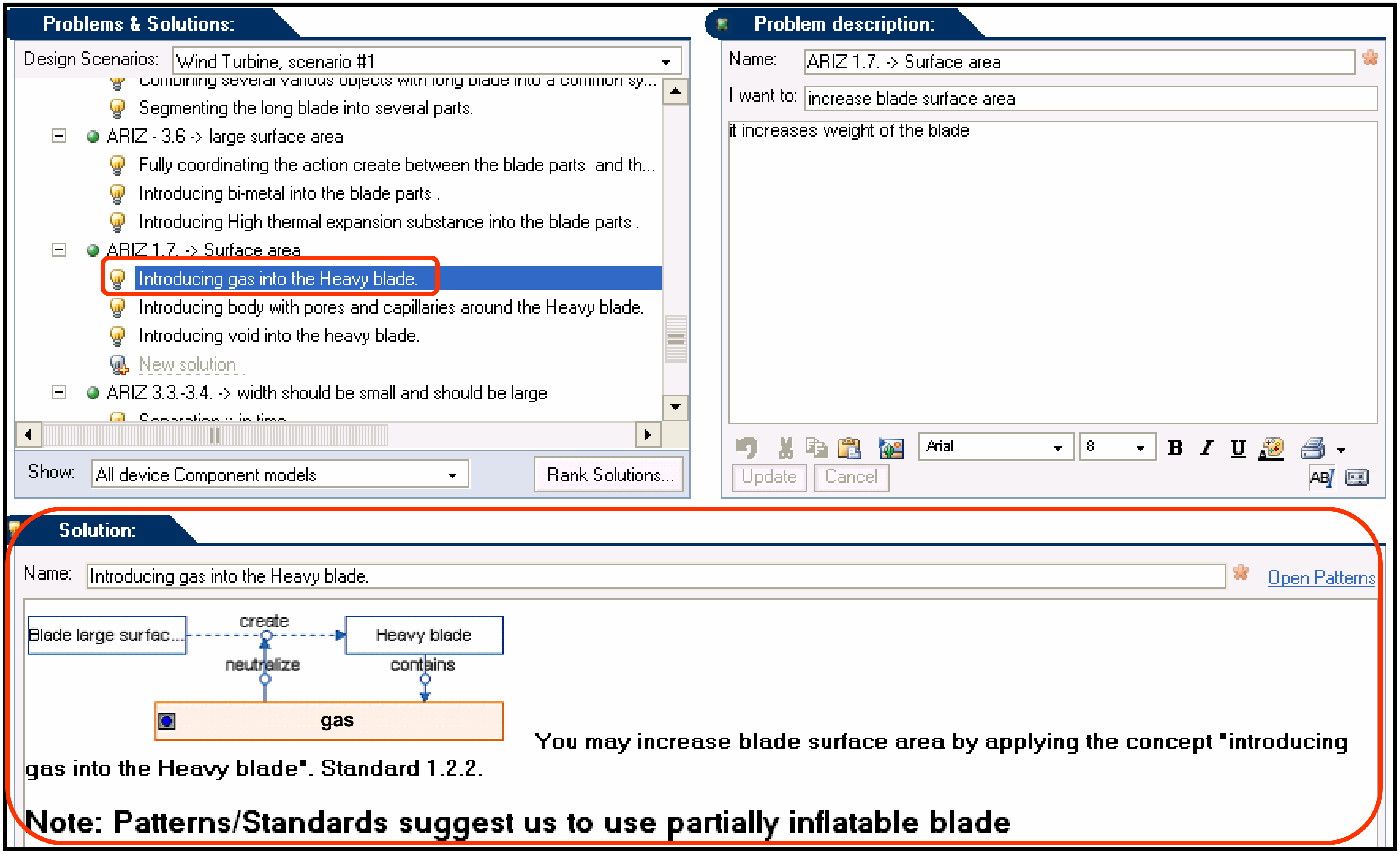
***Note:* it is clear -> the given standard orients us to use available substance-field recourses.**

GFIN System Modification Pattern Module – Standard 1.2.2

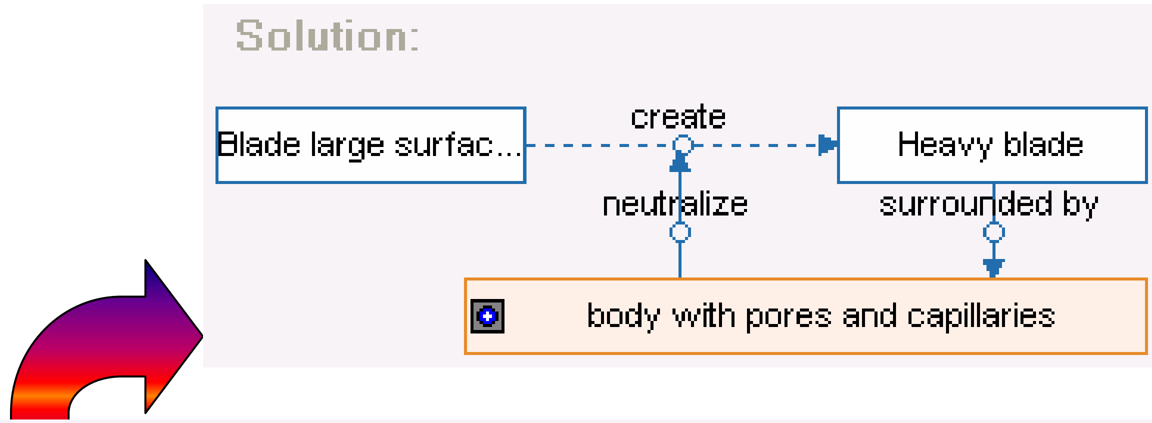


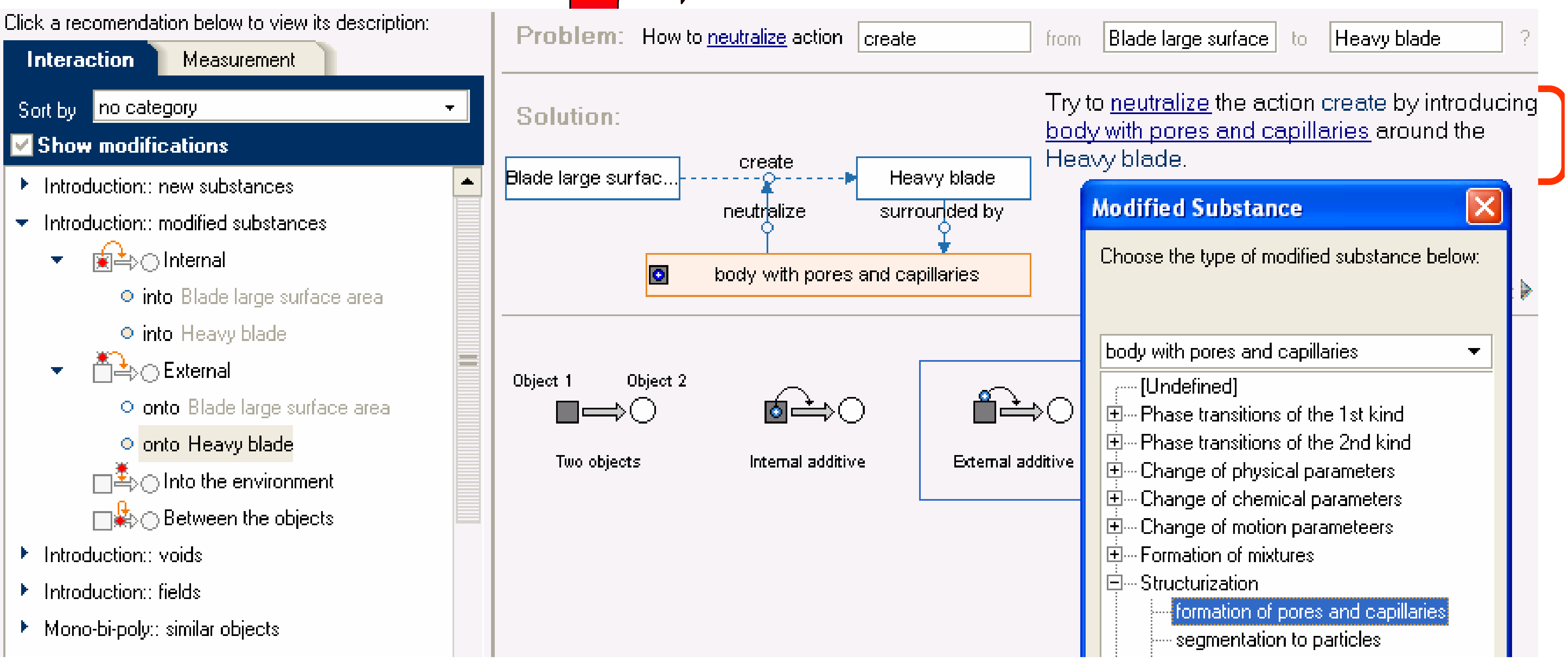
GFIN System Modification Pattern Module – Standard 1.2.2
GFIN Problem & Solution Manager

TRIZ

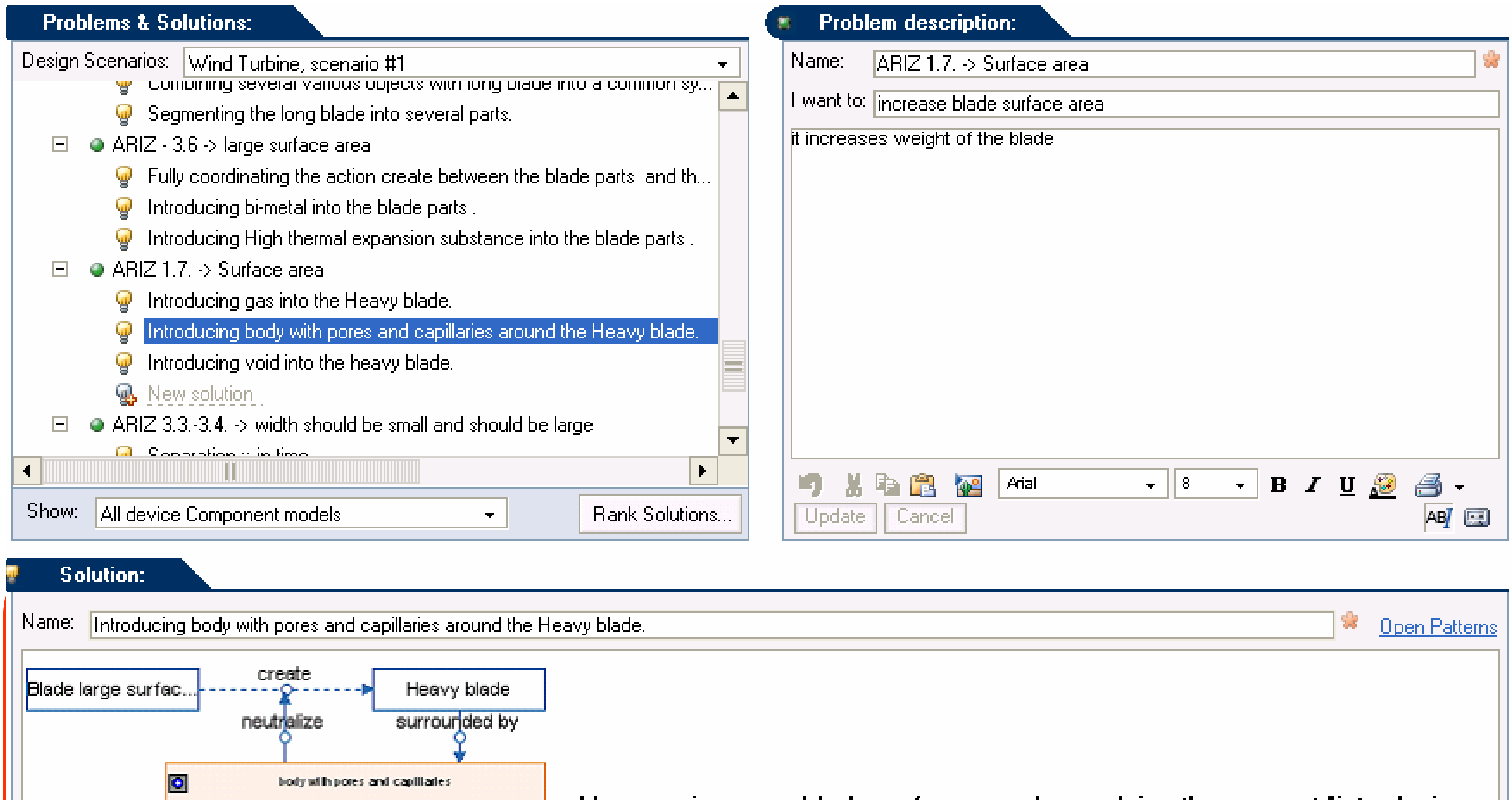


GFIN System Modification Pattern Module – Standard 1.2.2





GFIN System Modification Pattern Module – Standard 1.2.2
GFIN Problem & Solution Manager



You may increase blade surface area by applying the concept "introducing body with pores and capillaries around the Heavy blade"Standard 1.2.2.

Patterns/Standards suggest us to use for blade design pores and capillaries

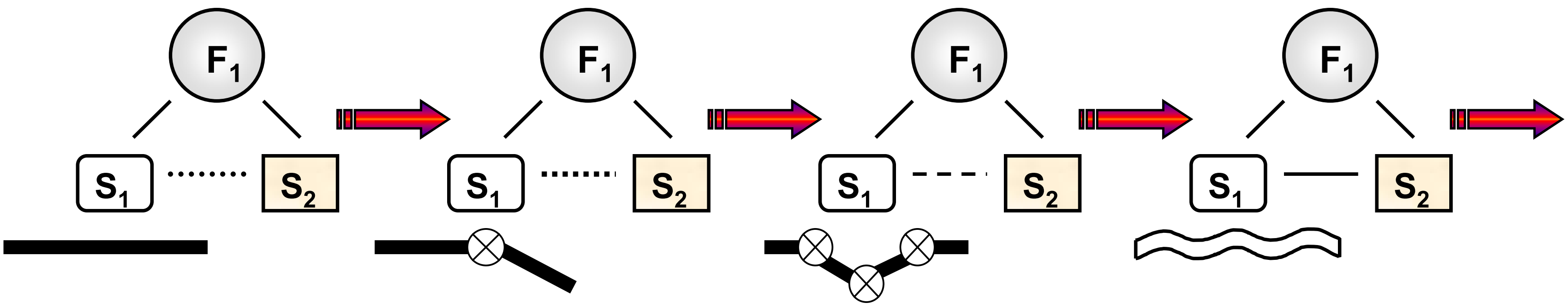
TRIZ - System of Standards: Standard 2.2.4.

2.2.4. Transition to Dynamic (flexible) S-Fields Models

Efficiency of the S-Field model could be improved by transition to dynamic (more flexible) structure of the system.

Explanations:

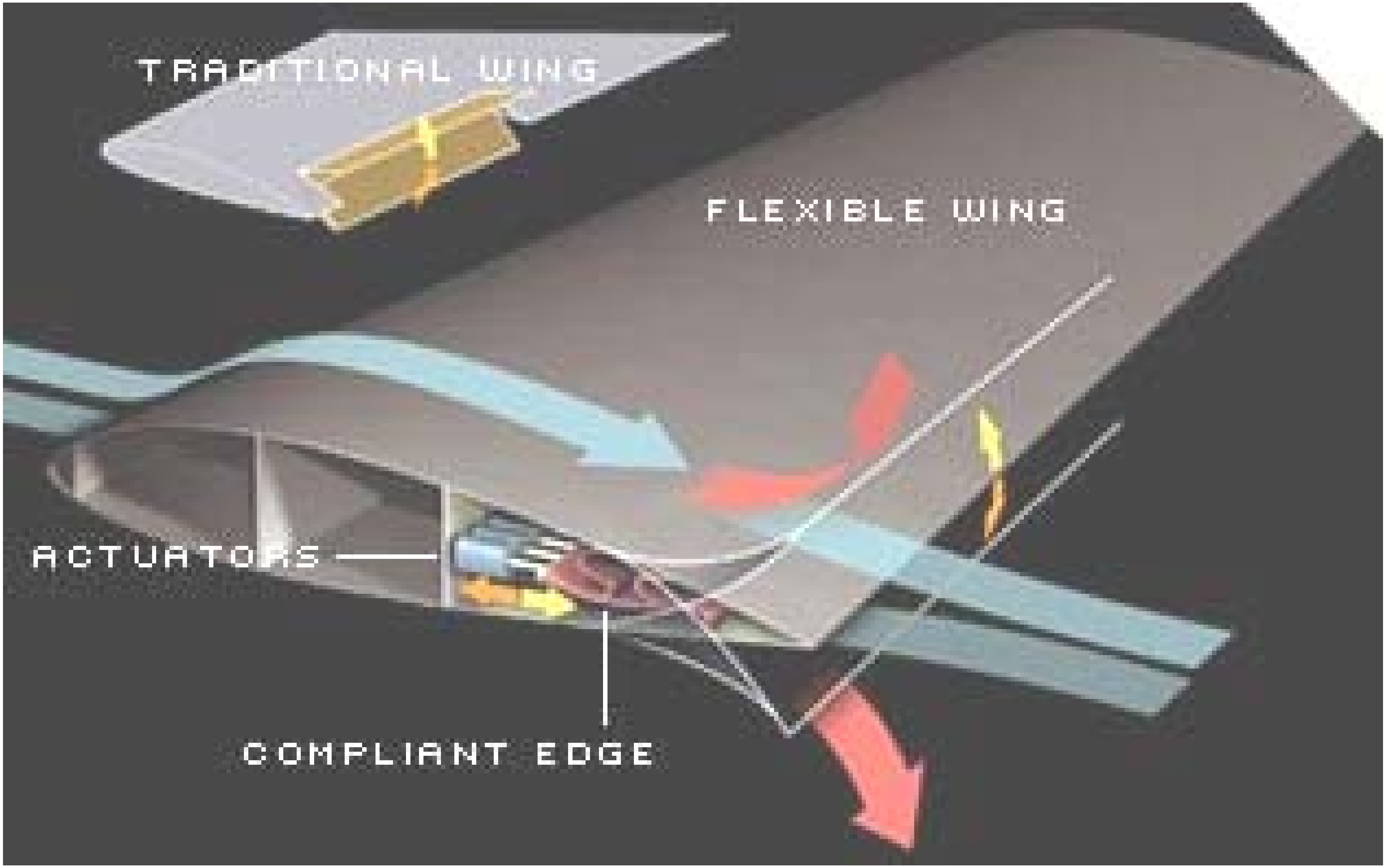
Transition to dynamic of S_1 (tool) usually starts with its breaking into two jointed parts. Further, the dynamism proceeds along the following line: joint -> many joints -> flexible S_1.



<u>Note:</u> in our case -> blade, parts of the blade, and surfaces of the blade should be flexible in the shape, in the parameters, in…

Standard 2.2.4. -> Concept

Flexible wing - blade



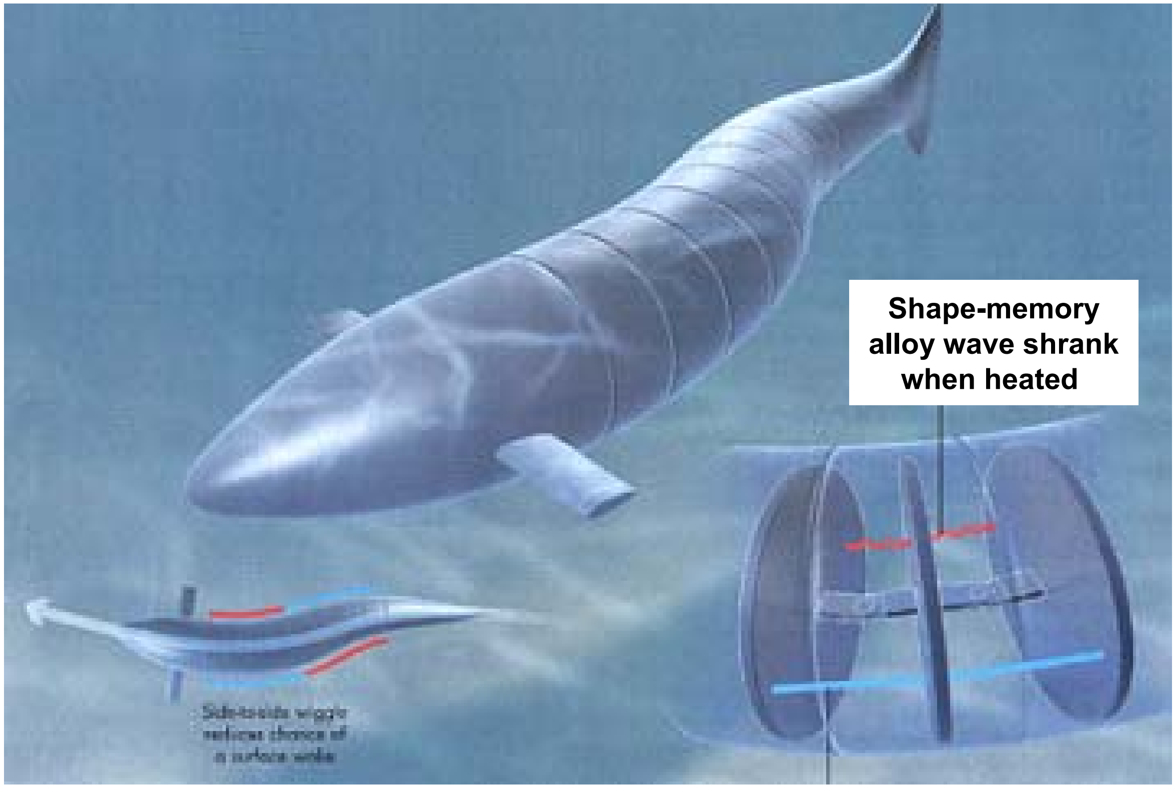
http://i.timeinc.net/popsci/images/space/space1003wing_A5_197.jpg

Standard 2.2.4. -> Concept

Flexible hull - blade

TRIZ

Metal muscles made of alloys that remember shapes are connected to evenly spaced vertebral column and shrink and expand as much as 8 percent as they're alternately heated and cooled, causing the 3-foot sub's sectioned hull (AND OUR BLADE AS WELL) to bend and flex.



Side-to-side wiggle reduces change of a surface wake

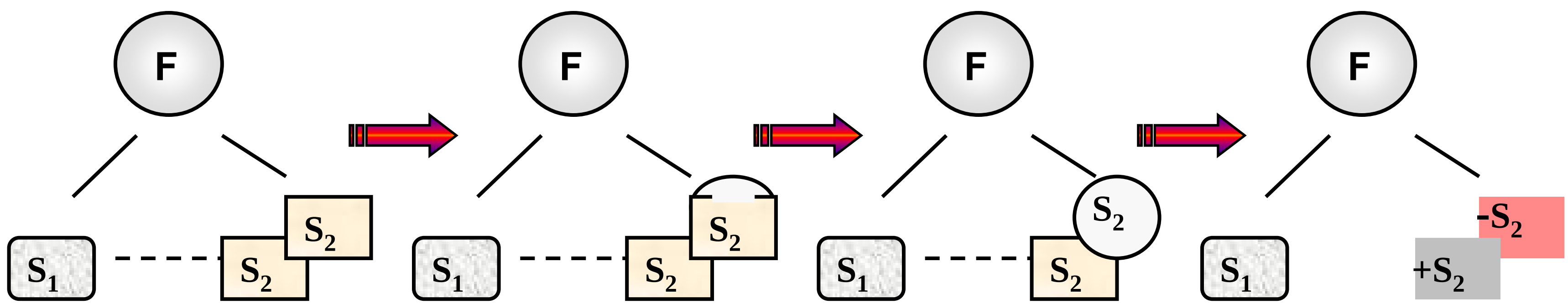
The wave returns to their natural shape when cooled

TRIZ - System of Standards: Standard 3.1.3.

3.1.3. Bi- and Poly-Systems. Development of Differences of Components

Efficiency of bi- and poly-systems systems could be improved via development of differences between their components (system transition 1-b):

- similar components with similar parameters (set of similar pencils);
- components with shifted parameters (set of color pencils);
- different components (case of drawing instruments);
- inverse combinations like “component – anti-component (pencil and eraser).



<u>Note:</u> *in our case -> blade should be divided into different parts with shifted or different parameters*

Standard 3.1.3. -> Concept

TRIZ

Doubled propeller – Doubled blades

- **The propeller is the contra rotating with a diameter of 4.5 m (14 ft 9 in).**
- **It has blades made of advanced composites and pronounced scimitar-like curvature on the leading-edge. It offers increased efficiency under high-speed cruise, and improved acoustics.**
- **There are six blades in the front propeller and eight in the rear, the latter absorbing most of the power and providing most of the thrust.**

http://www.aeronautics.ru/news/news002/news094.htm

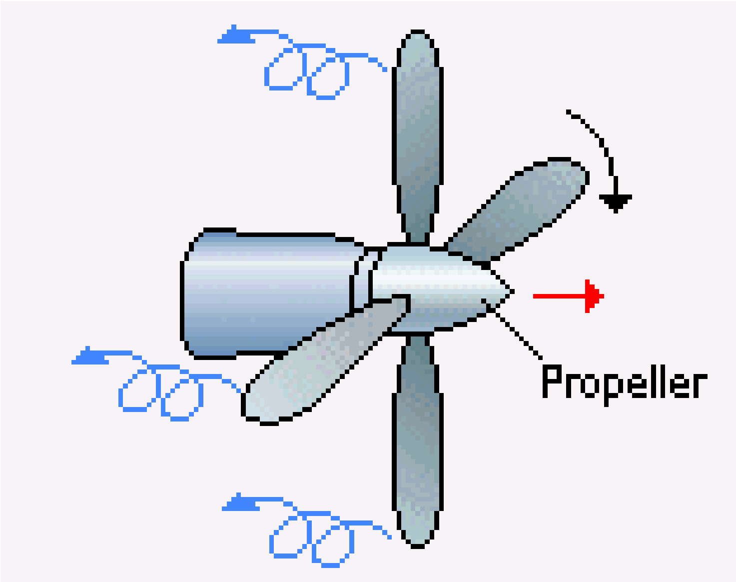
Standard 3.1.3. -> Concept

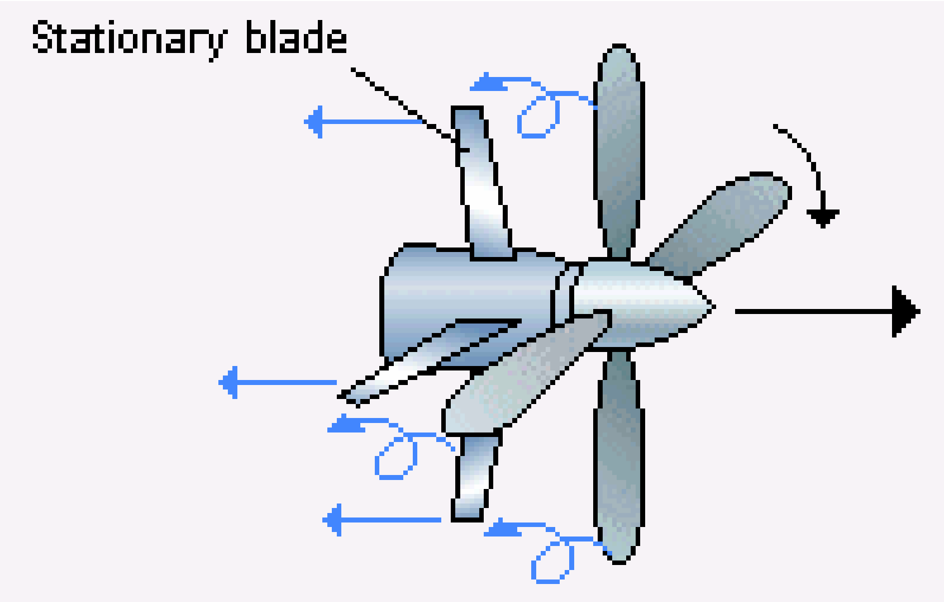
Efficient propeller – Efficient blade

A propeller produces a propulsion that drives an airborne vehicle.

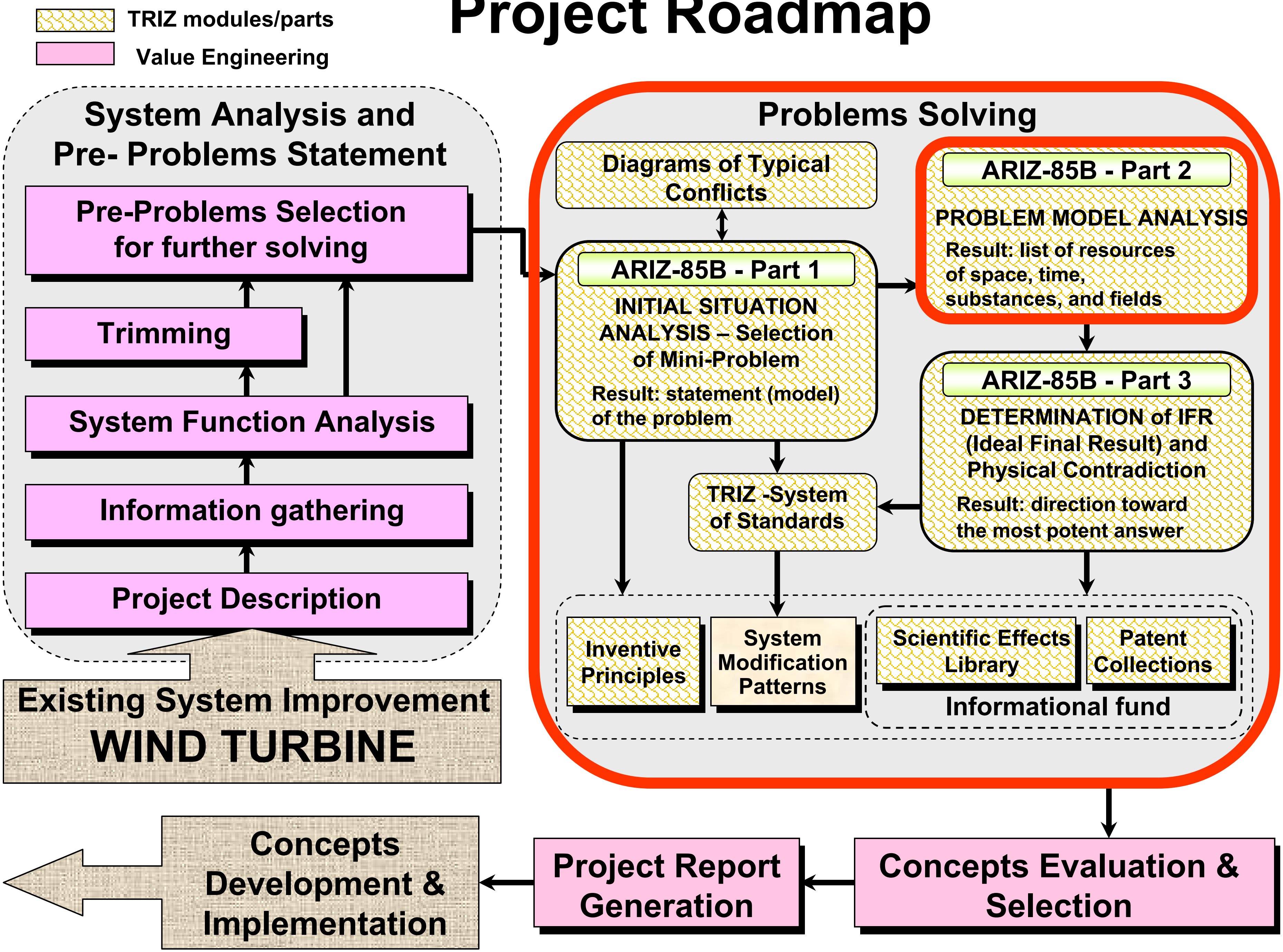
Disadvantage: This causes an air stream to be driven back, causing high turbulence. This decreases the propulsion.

It is proposed to mount two stationary blades directly behind the propeller. The two stationary blades act as an air stream stabilizer. The propeller efficiency increases by 30% as a result of the air stream ordering.





Project Roadmap



Algorithm for Inventive Problem Solving – Part 2.1.

2.1. Conflict zone (CZ) determination.

Blade body

15 large wind turbines, each capable of generating 1.8 megawatts can provide enough electricity to supply 3,329 homes.

http://www.communityenergy.biz/images/gllry_blade_event2.jpg

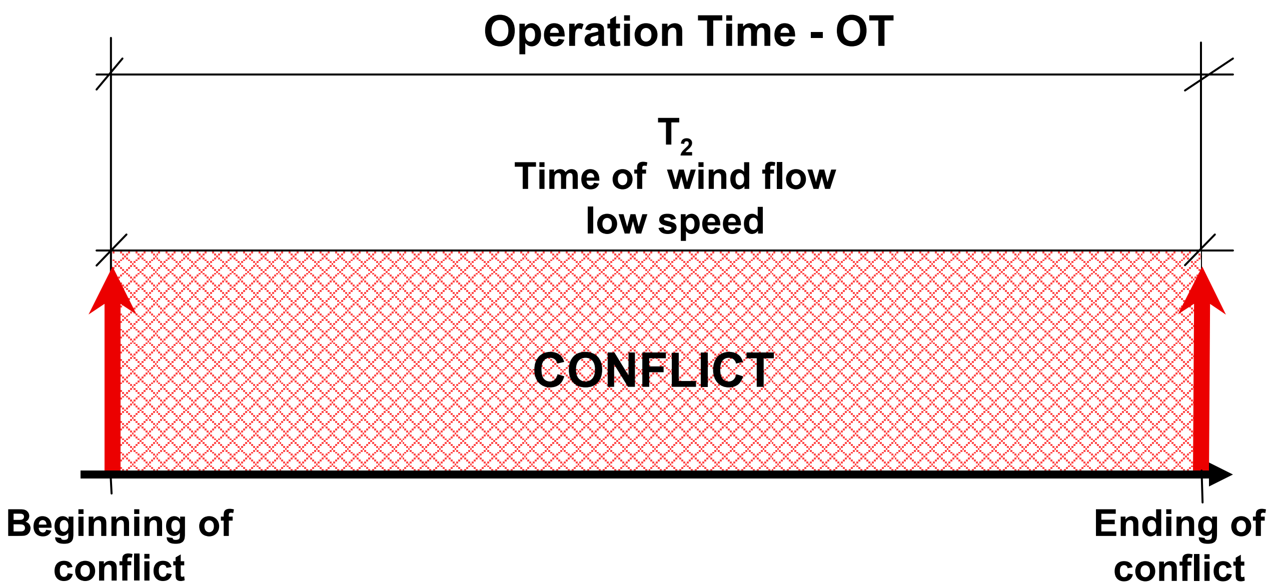
Algorithm for Inventive Problem Solving – Part 2.2.

2.2. Operation Time (OT) determination.

OT is a T_2 (conflicting time -> time of wind flow low speed)

<u>Note:</u>

In our case we don't have pre-conflicting time ->T_1 and post-conflicting time T_3 because speed of the wind flow is always low for our situation and could not be changed – it is a supersystem component.



Algorithm for Inventive Problem Solving – Part 2.3.

2.3. Determine substance-field resources (SFR).

1. Internal-System SFR:

Substances:

- ***geometry elements of the blade;***
- ***blade;***
- ***rotor;***

Fields:

- ***wind flow pressure on the blade surface;***
- ***centripetal forces;***

Parameters:

- ***weight of the blade;***
- ***length of the blade;***
- ***width of the blade;***
- ***rotational speed of the rotor;***
- ***area of the blade surface;***
- ***torque of the blade;***
- ***specific weight of blade;***
- ***shape of the blade;***
- ***blade center of gravity;***
- ***distance between rotor and earth surface;***

2. External-System Resources

Substances:

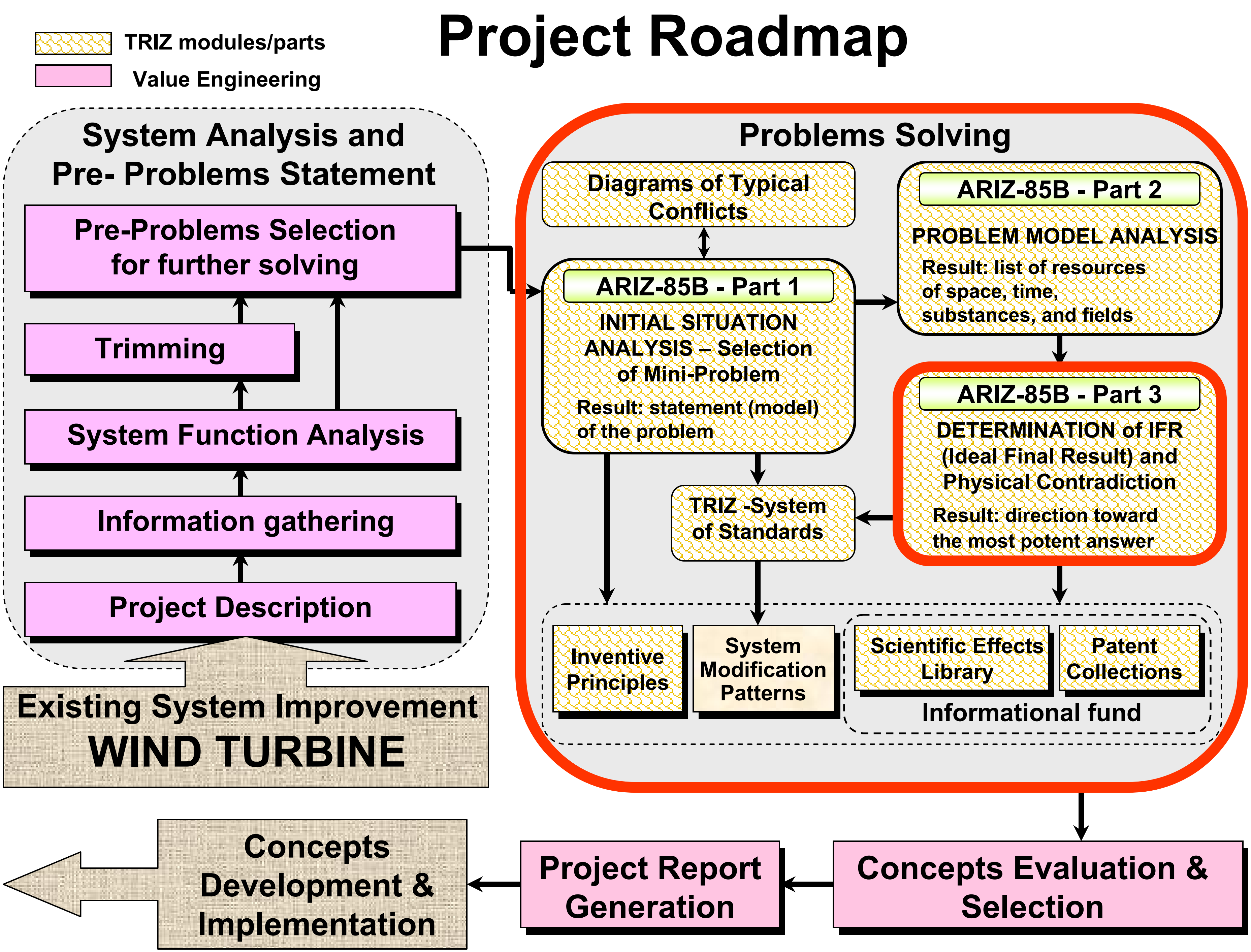
- ***air;***
- ***drops of rain;***
- ***snow;***

Fields:

- ***wind flow;***
- ***sun energy;***
- ***gravity;***

Parameters:

- ***speed of the wind flow;***
- ***direction of the wind flow;***
- ***wind flow pressure;***
- ***temperature of the air;***


TRIZ modules/parts
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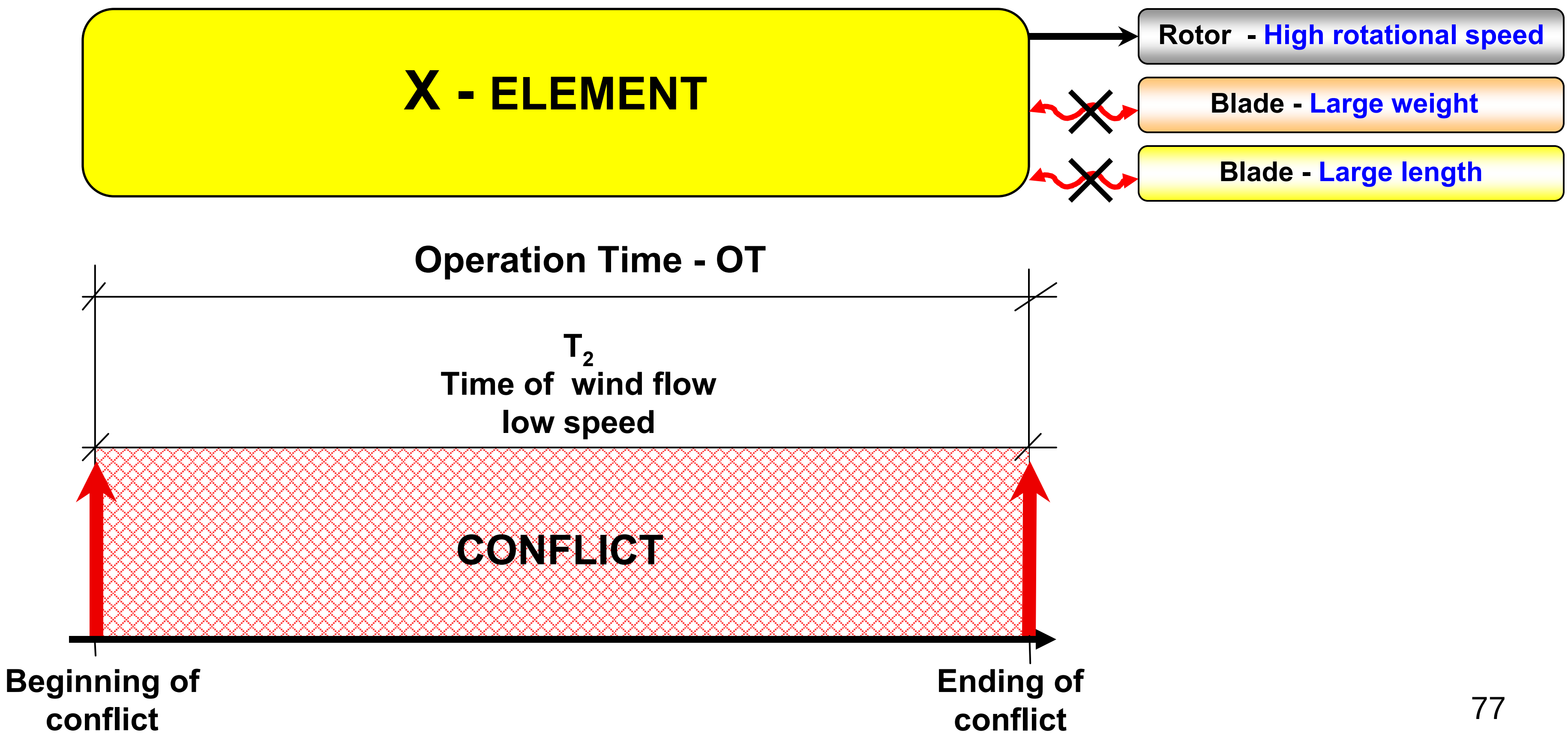
DETERMINATION of IFR (Ideal Final Result) and Physical Contradiction
Result: direction toward the most potent answer
TRIZ -System of Standards
Inventive Principles
System Modification Patterns
Scientific Effects Library
Patent Collections
Informational fund
Concepts Development & Implementation
Project Report Generation
Concepts Evaluation & Selection

Algorithm for Inventive Problem Solving – Part 3.1.

3.1. Write down a formulation of IFR-1.

X-element while not complicating the system and causing harmful phenomena eliminates large weight and large length of blade increasing during OT within CZ preserving the ability of the blade with a very large surface area to rotate rotor with a high rotational speed .

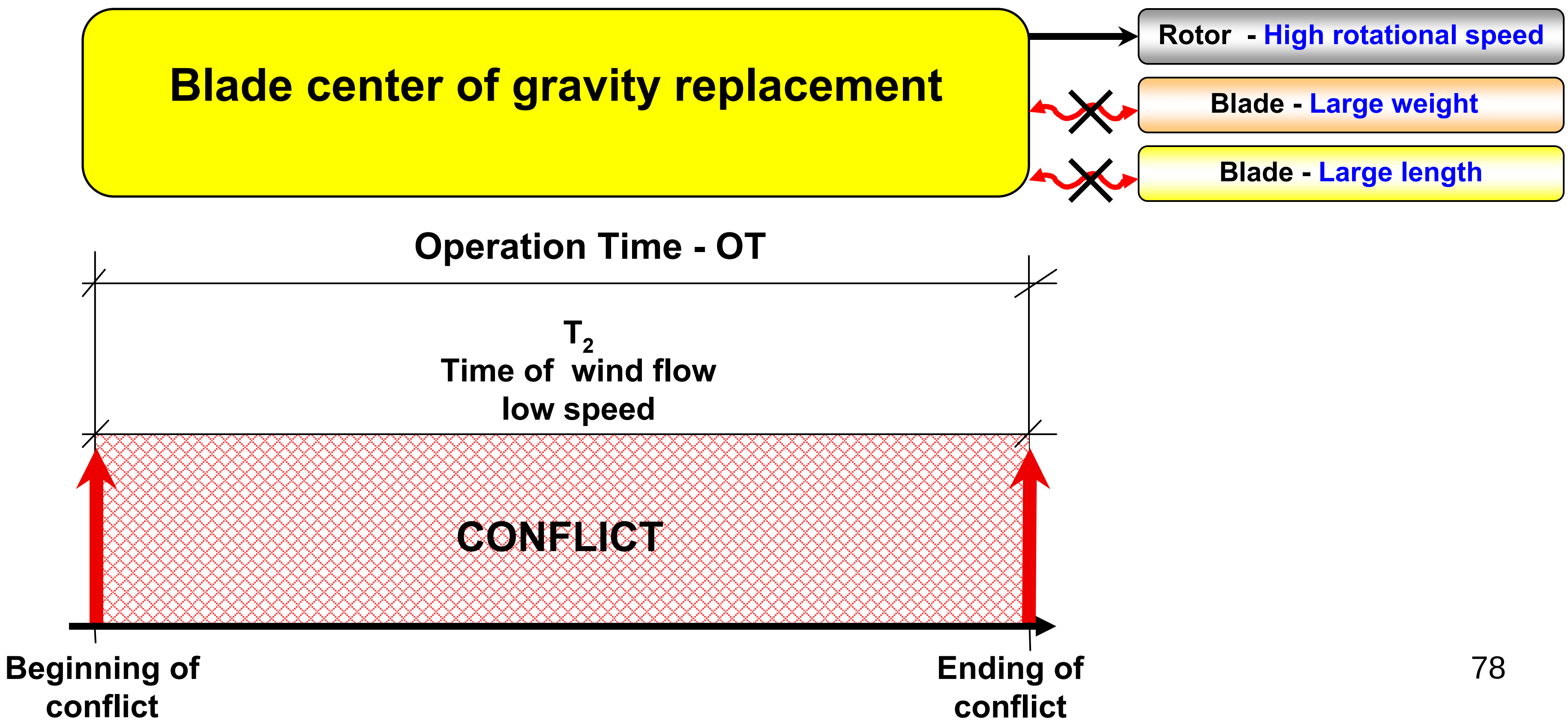


Algorithm for Inventive Problem Solving – Part 3.2.

3.2. Reinforce (intensify) a formulation of IFR-1 with additional requirements: it must not introduce new substances and fields into the system - use SFR.

Variant # 1

~~X-element~~ Blade center of gravity replacement while not complicating the system and causing harmful phenomena eliminates large weight and large length of blade increasing during OT within CZ preserving the ability of the blade with a very large surface area to rotate rotor with a high rotational speed.

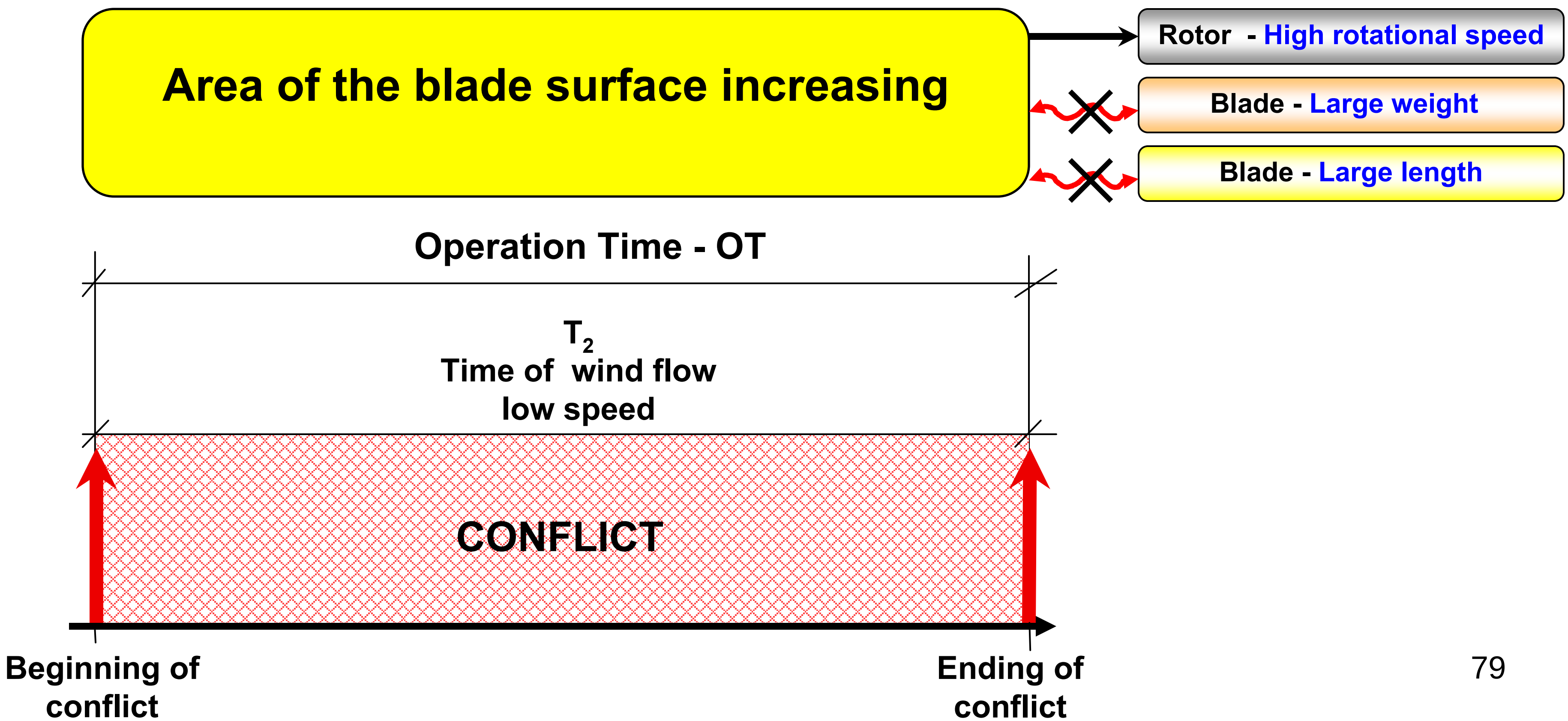


Algorithm for Inventive Problem Solving – Part 3.2.

3.2. Reinforce (intensify) a formulation of IFR-1 with additional requirements: it must not introduce new substances and fields into the system - use SFR.

__Variant # 2__

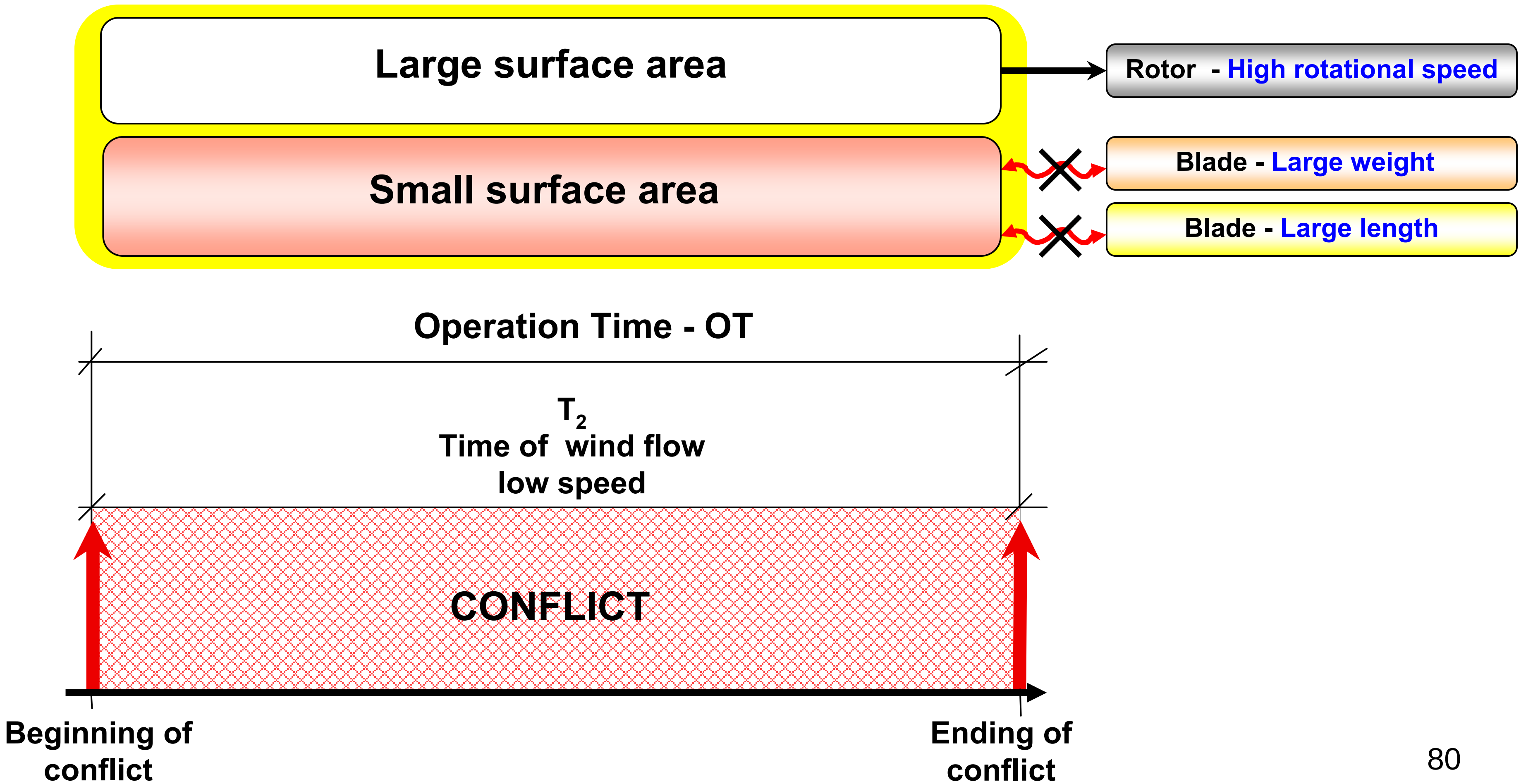
*~~X-element~~ **Area of the blade surface increasing** while not complicating the system and causing harmful phenomena eliminates large weight and large length of blade increasing during OT within CZ preserving the ability of the blade with a very large surface area to rotate rotor with a high rotational speed.*



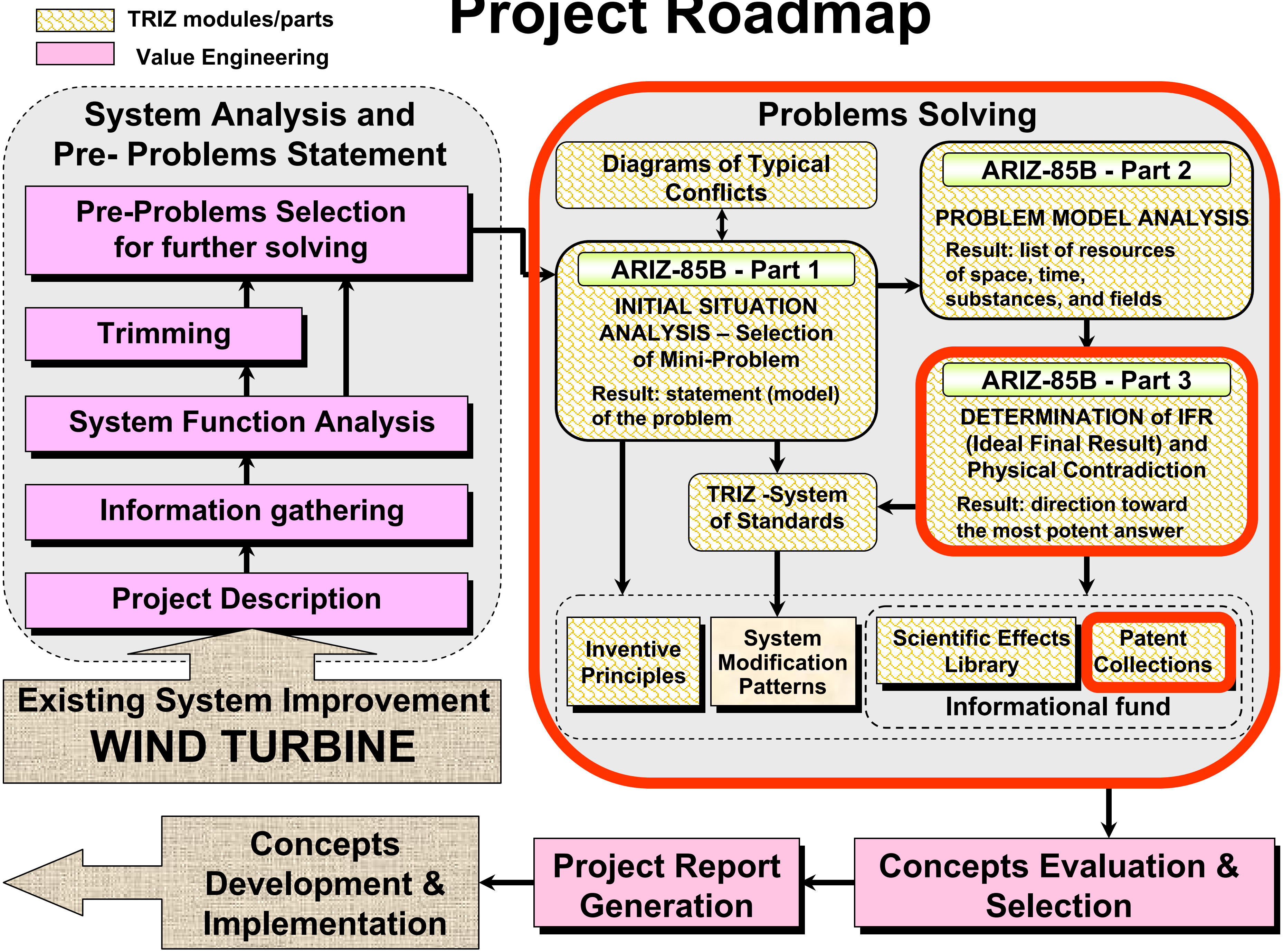
Algorithm for Inventive Problem Solving – Part 3.3.

3.3. Write down a formulation of a PC on a macro-level (variant # 2)

Blade (CZ) during OT should be with a very large surface area to rotate rotor with a high rotational speed and should be with a small surface area to prevent blade overweight and over length.



Project Roadmap



GFIN Patent Collections

TRIZ

Query: flexible turbine blade

Selected Patent: US-4291235

flexible turbine blade | Find

Your query was processed as a **Natural Language** expression. Click here to process the query as a **Boolean** expression.
Click here to perform a fielded search in Patent Collections.

Patents | 5 most relevant result(s).

Most relevant:

1. Each **flexible turbine blade** 40 is attached to one end of a turbine spar 38 as shown and tethered to an adjacent spar by turbine blade tethers 42.
   US-5040948 Coaxial multi-turbine generator
   4 Most relevant and 120 Related result(s) from this document

2. Several wind turbine designs, such as those described in U.S. Pat. Nos. 4,352,629, 6,327,957 and 5,584,655 (all of which are incorporated herein by reference) describe highly **flexible** wind **turbine blades**.
   US-20040057828 A1 Wind turbine blade deflection control system
   2 Most relevant and 119 Related result(s) from this document

3. A water turbine, comprising: (a) a turbine rotor longitudinally extending between opposed ends of the rotor; and, (b) a plurality of relatively narrow, **flexible** elongated **turbine blades** extending outwardly from said rotor for communication with a water current, wherein: (i) said blades are...
   US-20040096310 A1 Apparatus and method for generating power from moving water
   1 Most relevant and 126 Related result(s) from this document

4. FIG. 17 is a perspective view showing a swash plate actuating linear potentiometers for **flexible** control of **turbine blade** angle of incidence.
   US-4491739 Airship-floated wind turbine
   1 Most relevant and 150 Related result(s) from this document

5. As the rotational speed of the turbine increases, a component of the centrifugal force acting on the out-of-plane balance weight applies a torsional force to the outer portion of the torsionally **flexible turbine blades**, thereby twisting the blades about their radial...
   US-4291235 Windmill

Topics

Most relevant:

- flexible turbine blade (1)
- flexible wind turbine... (1)
- plurality of narrow... (1)
- flexible control of... (1)
- outer portion of... (1)

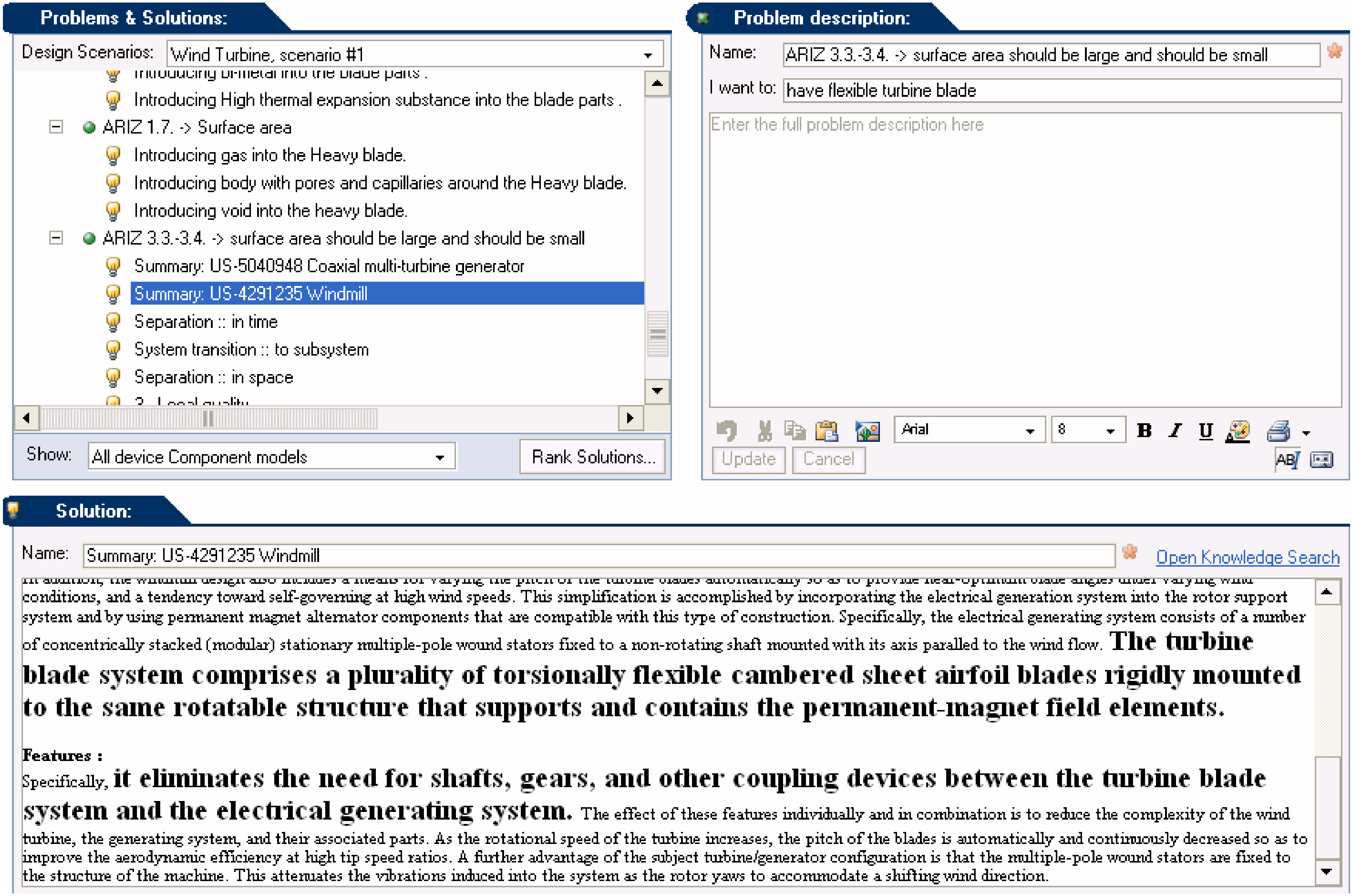
Related:

- turbine blade (97)
- flexible blade (16)
- blade (14)
- blade of wind... (8)
- permanently magnetized turbine... (6)
- flexible upper wiper... (6)
- blade of gas... (5)
- number of turbine... (3)
- jet engine turbine... (3)
- number of radially... (3)

GFIN Problem & Solution Manager

TRIZ

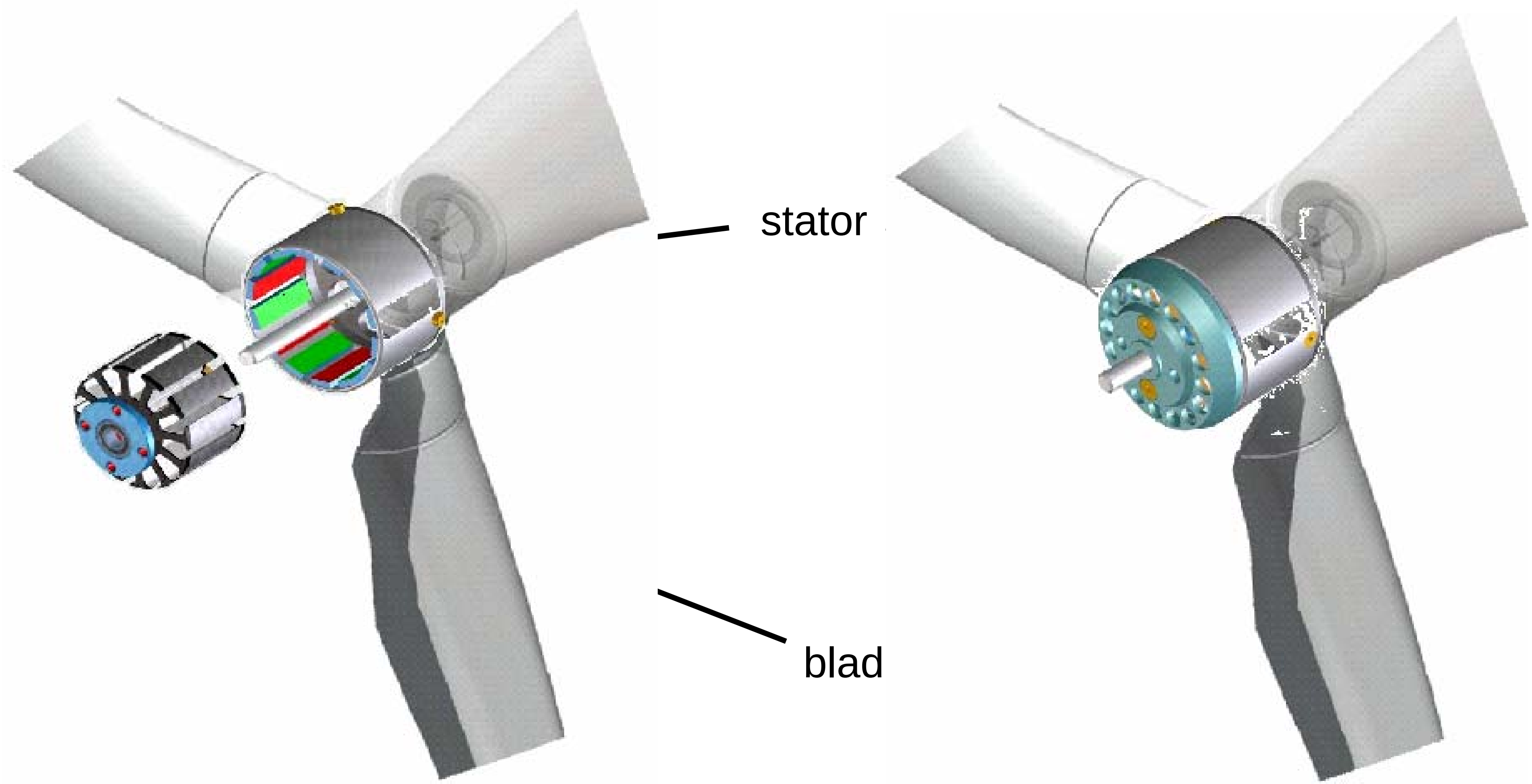
Selected Patent: US-4291235



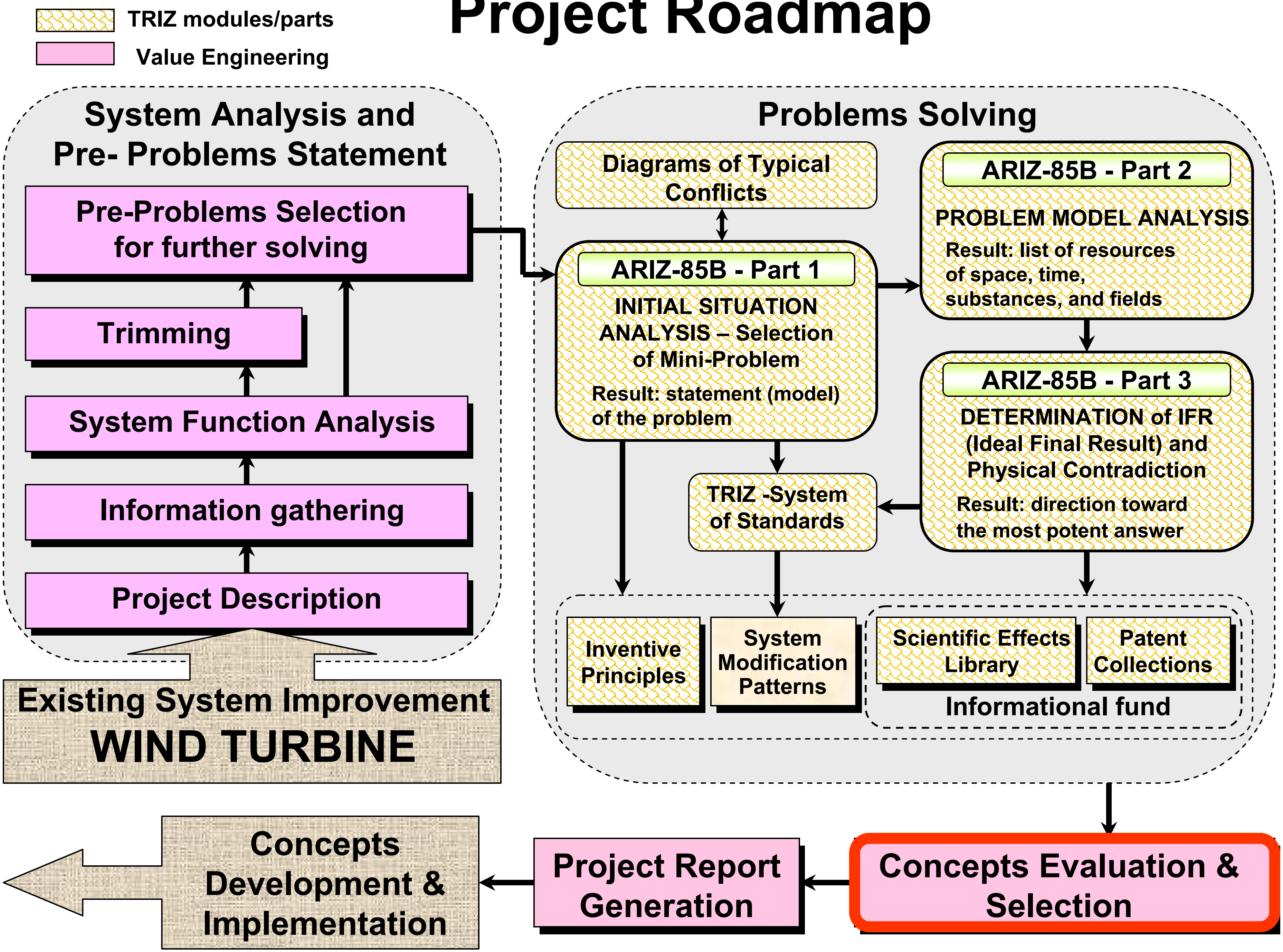
Trimming results & US Patent 4291235 -> Concept

Stator of Permanent Magnet Synchronous Generator directly connects Blades.

- Blades rotate directly Stator of Permanent Magnet Synchronous Generator. Permanent Magnet Synchronous Generator works good for variable blades rotational speed.
- Low-speed shaft, high-speed shaft, gear box, and other coupling devices between the turbine blade system and the electrical generating system are



Project Roadmap



Concepts Evaluation & Selection

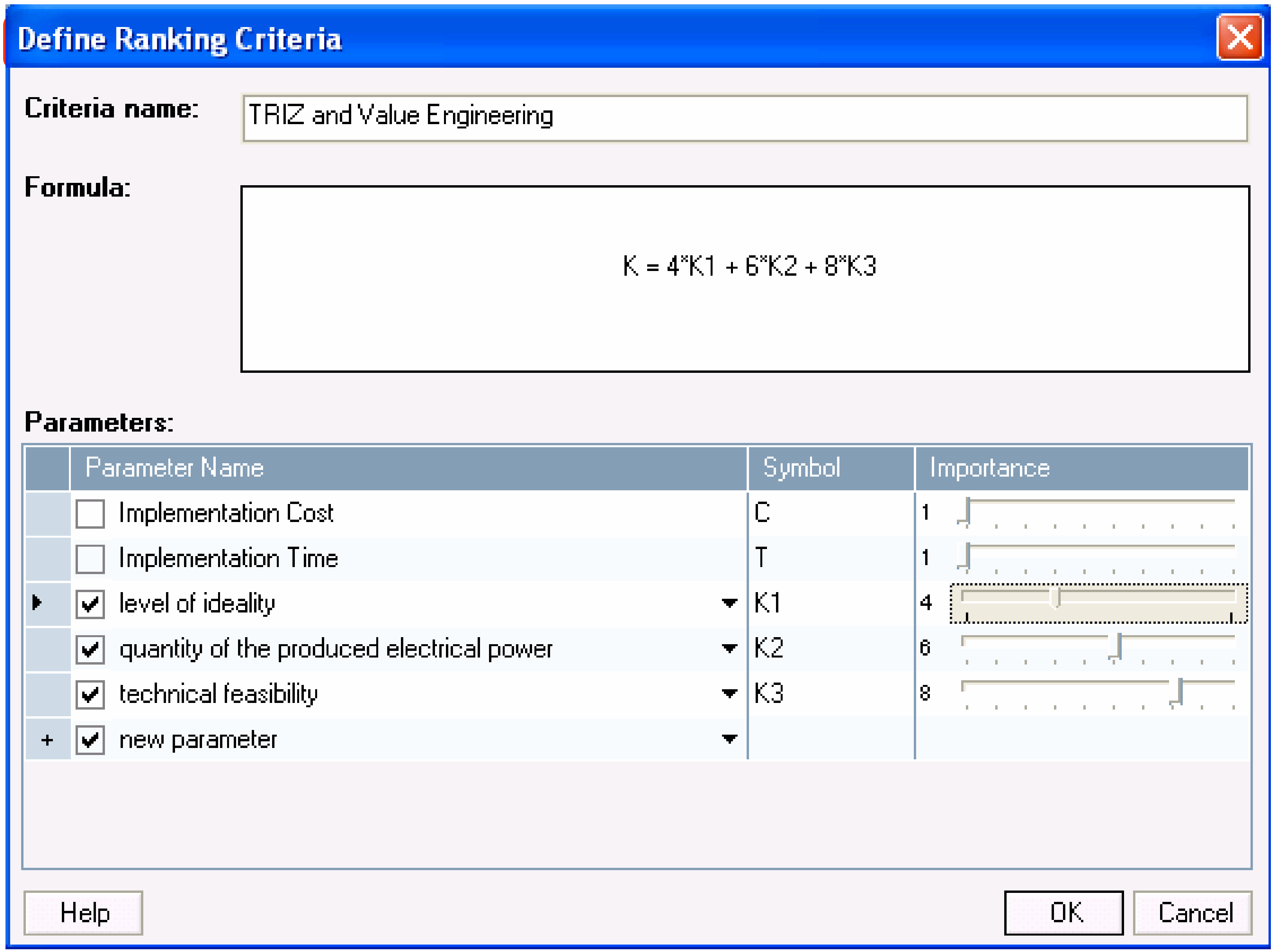
TRIZ

We have created 32 available solutions for farther development by using TRIZ, Value Engineering, and Informational Fund (Scientific Effects Library, Patent Collections, WEB based information), including:

from the Inventive Principles (Inventive Principles Module):	**9**
from the Effect Library (Effects Module):	**2**
from the System of Standards (System Modification Patterns Module):	**12**
from Patent Collections and WEB based information:	**9**

Solutions
⊞ Improve functionality solutions
⊟ Simplify design solutions
14 - Curvature increase
15 - Dynamic parts
4 - Symmetry change
29 - Pneumatics and hydraulics
One-sided surface increases area (Moebius band)
Motor blade in form of Mobius strip
Summary: US-5902108 Air turbine handpiece
Summary: US-20030123973 A1 Propeller type windmill for power generation
⊟ Solutions for user-defined problems
Introducing gas into the Heavy blade.
Introducing body with pores and capillaries around the Heavy blade.
Introducing void into the heavy blade.
Making the long blade flexible.
Making the long blade flexible.
Creating protrusion on the long blade.
Segmenting the long blade into several parts.
Combining several various objects with short blade into a common system.
Introducing one new object into the blade large surface area.
Fully coordinating the action create between the blade parts and the large s
Introducing bi-metal into the blade parts .
Introducing High thermal expansion substance into the blade parts .
Summary: US-5040948 Coaxial multi-turbine generator

Ranking Strategy Creation



Solution Ranking

TRIZ

Ranking Criteria: TRIZ and Value Engineering | Edit... | **Formula:** K = 4*K1 + 6*K2 + 8*K3 | ☑ **Qualitative**

Rank Solution for: All device Component models | Solution Filter: Off | ☑ Show Indicators

Solutions	level of ideality (K1)	quantity of the produced electrical power (K2)	technical feasibility (K3)	Rank Better
Introducing body with pores and capillaries around th	-1.00	-1.00	1.00	-2.00
Making the long blade flexible.	1.00	1.00	1.00	18.00
Making the long blade flexible.	1.00	1.00	1.00	18.00
Segmenting the long blade into several parts.	1.00	1.00	1.00	18.00
Introducing one new object into the blade large surfa	0.00	0.00	0.00	0.00
Summary: US-5040948 Coaxial multi-turbine generatc	0.00	0.00	0.00	0.00
Separation :: in time	0.00	0.00	0.00	0.00
Introducing gas into the Heavy blade.	1.00	1.00	0.00	10.00
Introducing void into the heavy blade.	1.00	1.00	0.00	10.00
Combining several various objects with short blade in	1.00	1.00	0.00	10.00
Introducing bi-metal into the blade parts .	1.00	1.00	0.00	10.00
3 - Local quality	1.00	1.00	0.00	10.00
System transition :: to subsystem	1.00	1.00	0.00	10.00
Introducing High thermal expansion substance into tl	1.00	1.00	-1.00	2.00
System transition :: to subsystem	1.00	1.00	-1.00	2.00
Separation :: in space	1.00	1.00	-1.00	2.00
Creating protrusion on the long blade.	-5.00	-1.00	-5.00	-66.00
Fully coordinating the action create between the blac	5.00	1.00	-5.00	-14.00
⊟ General Solutions				
Efficient propeller - Standard 3.1.3. and GFIN Systerr	1.00	1.00	5.00	50.00
Some Concepts based on trimming scenario # 1 and	5.00	1.00	5.00	66.00
Doubled propeller - Standard 3.1.3. and GFIN Systei	5.00	1.00	5.00	66.00
Flexible wing - Standard 2.2.4. and GFIN System Moı	1.00	1.00	0.00	10.00
Flexible hull - Standard 2.2.4. and GFIN System Moc	1.00	1.00	0.00	10.00
New solution				

Solution Rank Summary

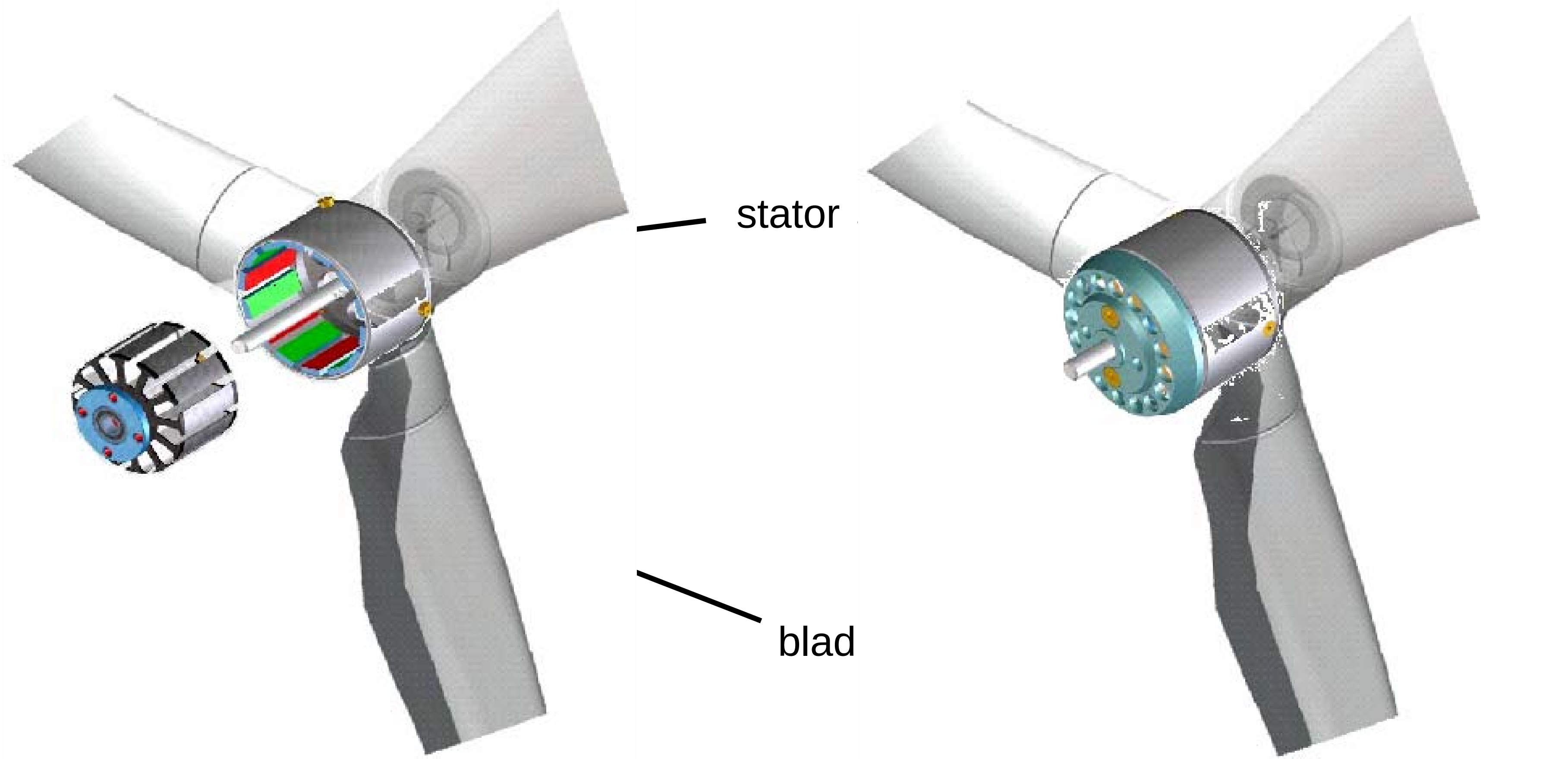
In total, 6 concepts were ranked as high level available solutions, having the ranking equal or higher than 10, including:

#	Title of Concept	Ranking code
1.	Stator of Permanent Magnet Synchronous Generator directly connects Blades	66
2.	Doubled propeller – Doubled blades	66
3.	Efficient propeller - Stream stabilizer	50
4.	Blade in form of Mobius strip	18
5.	Variable-rigidity flipper - blade	18
6.	Flexible Wing - Blade	10

Best Solutions

1. Stator of Permanent Magnet Synchronous Generator directly connects Blades.

- **Blades rotate directly Stator of Permanent Magnet Synchronous Generator. Permanent Magnet Synchronous Generator works good for variable blades rotational speed.**
- **Low-speed shaft, high-speed shaft, gear box, and other coupling devices between the turbine blade system and the electrical generating system are**



Best Solutions

2. Doubled Propeller – Doubled Blades.

- **The propeller is the contra rotating with a diameter of 4.5 m (14 ft 9 in).**
- **It has blades made of advanced composites and pronounced scimitar-like curvature on the leading-edge. It offers increased efficiency under high-speed cruise, and improved acoustics.**
- **There are six blades in the front propeller and eight in the rear, the latter absorbing most of the power and providing most of the thrust.**

http://www.aeronautics.ru/news/news002/news094.htm

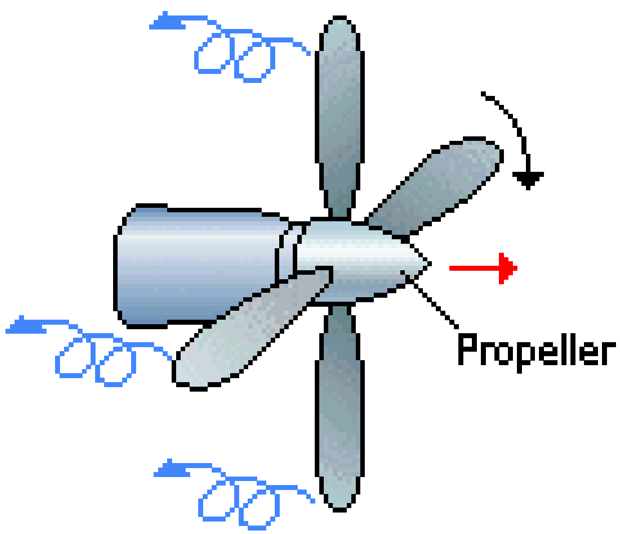
Best Solutions

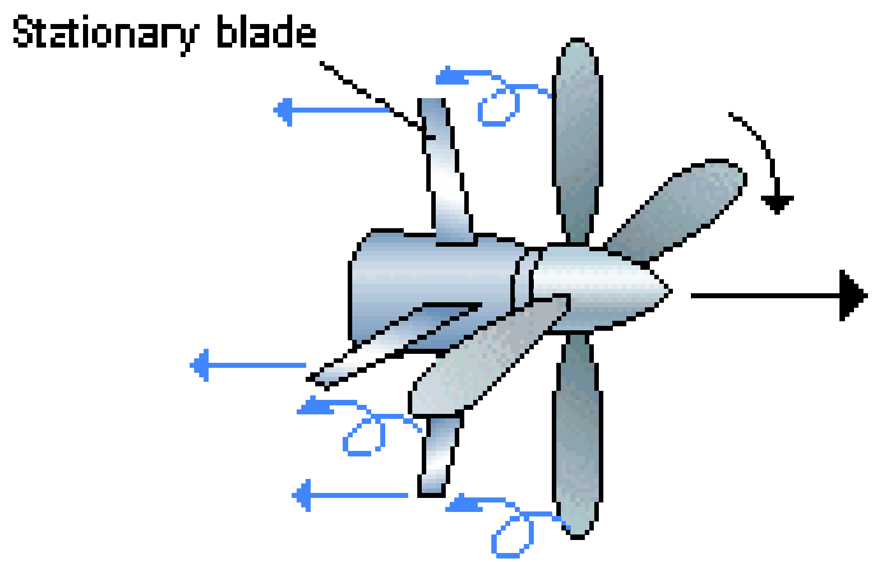
3. Efficient propeller – Efficient blades.

A propeller produces a propulsion that drives an airborne vehicle.

<u>Disadvantage:</u> This causes an air stream to be driven back, causing high turbulence. This decreases the propulsion.

<u>It is proposed</u> to mount two stationary blades directly behind the propeller. The two stationary blades act as an air stream stabilizer. The propeller efficiency increases by 30% as a result of the air stream ordering.





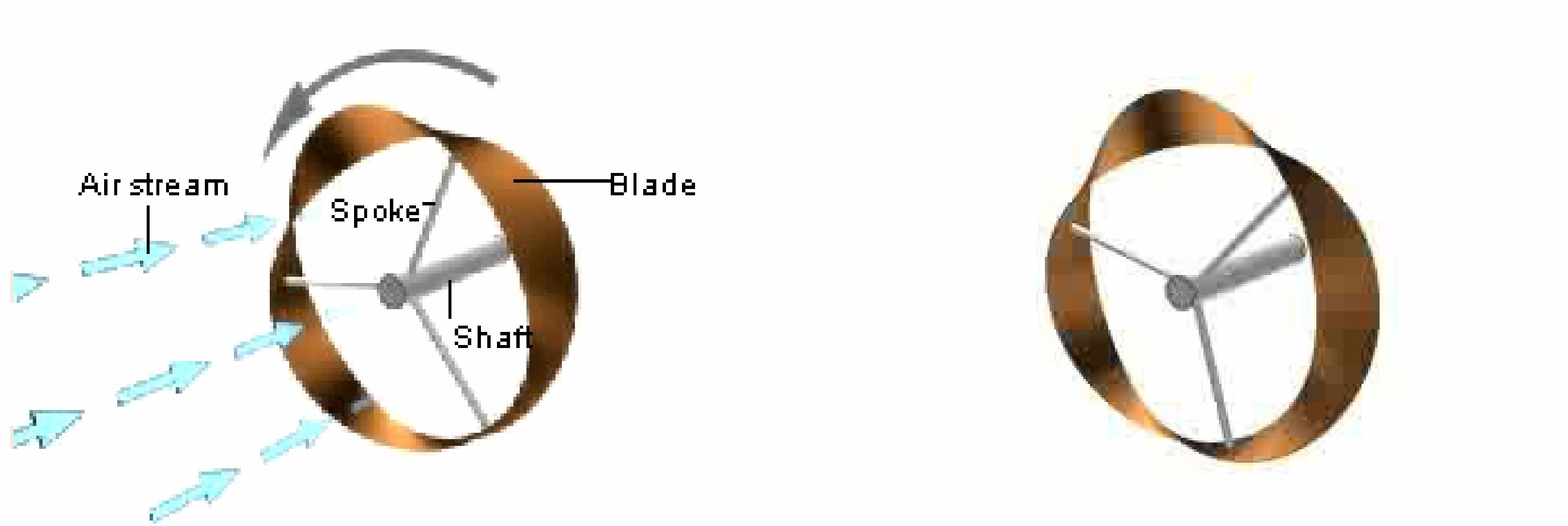
Best Solutions

4. Blade in form of Mobius strip.

A blade is fixed on a shaft by means of spokes. The blade is made of elastic material and has the Mobius strip form.

Advantages:

1. **The propeller blade in the Mobius strip form is simple in design.**
2. **The blade in the Mobius strip form is easy to manufacture.**
3. **The blade has a low aerodynamic resistance and increases the windmill efficiency.**



The air stream rotates the blade made in the form of a Mobius strip

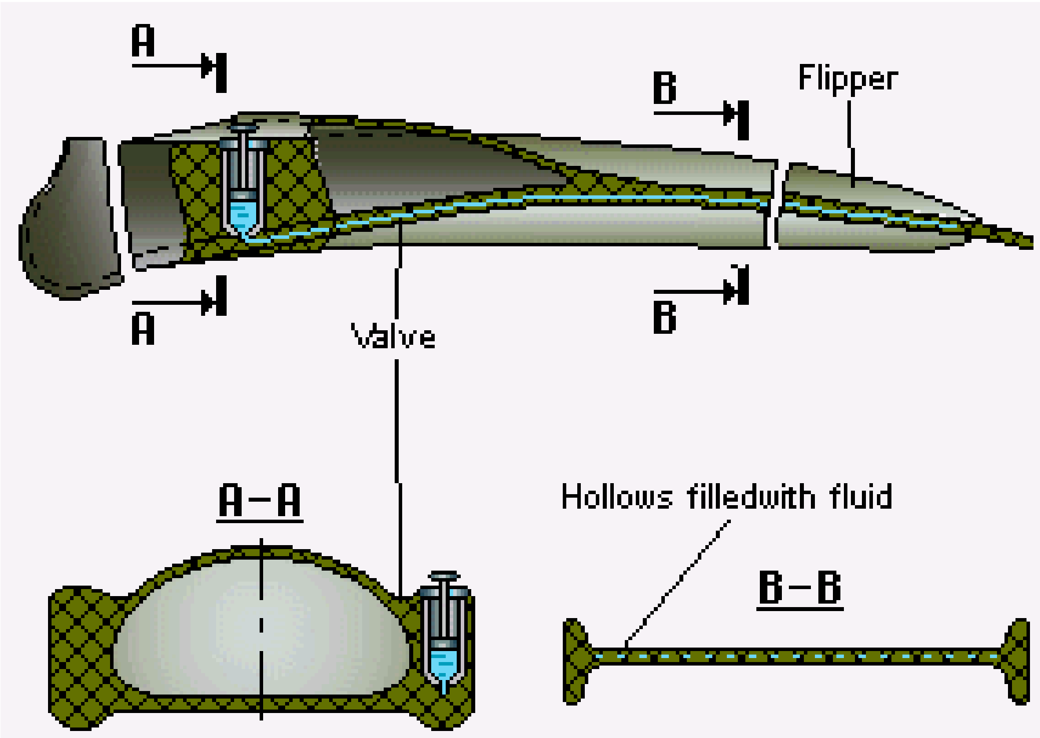
Best Solutions

5. Variable-rigidity flipper - blade.

Different rigidity is required in swimming flippers under different water conditions (governed by speed and length of stay).

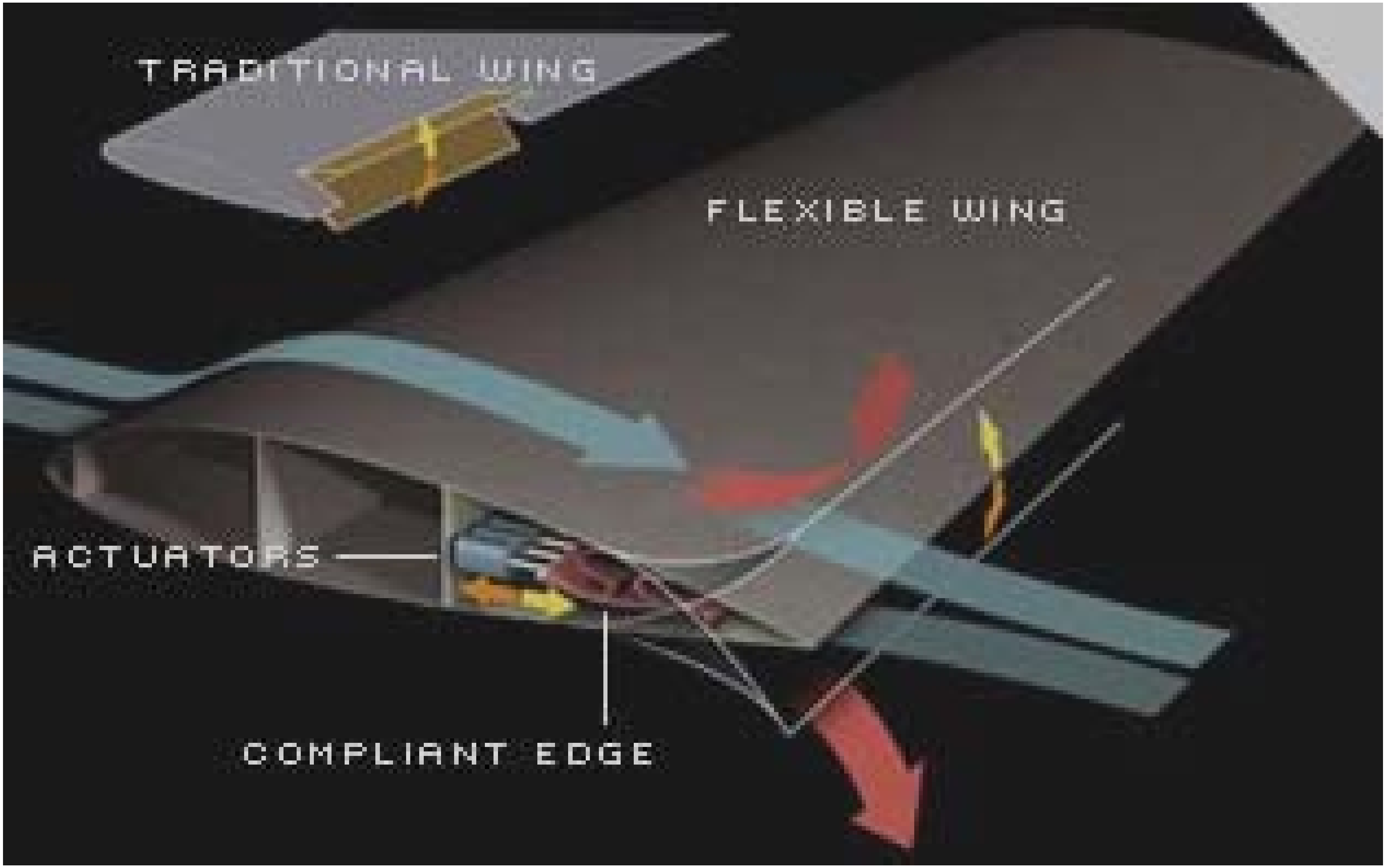
<u>It is proposed:</u>

to use hydraulic constructions and variability (dynamism) to improve the flipper design. One can form an enclosed longitudinal hollow in the elastic flipper material. This is filled with an fluid whose pressure can be adjusted using a piston valve. High pressure makes the flipper blade rigid. This can be adjusted to optimize for current swimming (wind) conditions



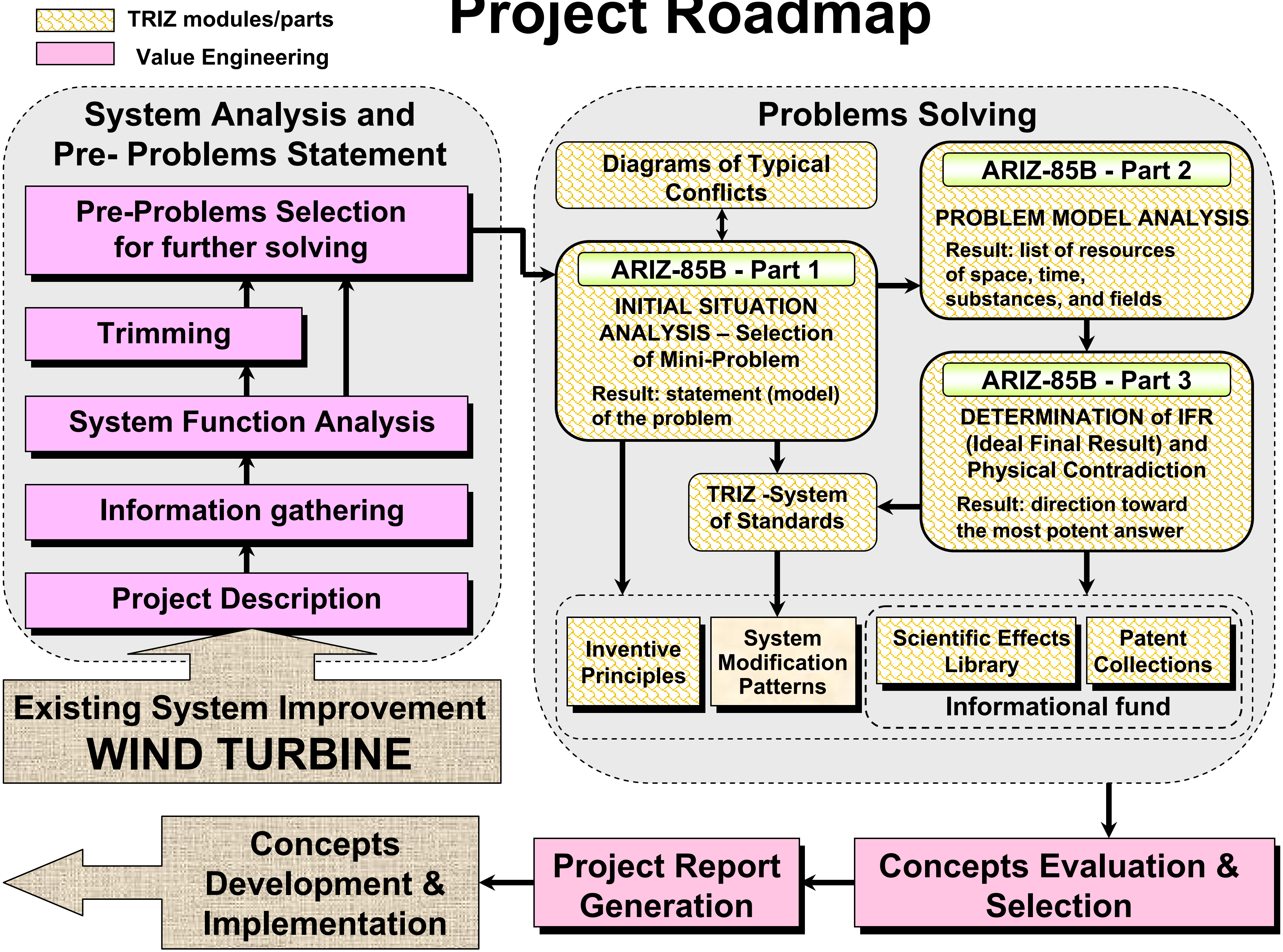
Best Solutions

6. Flexible wing - blade.



http://i.timeinc.net/popsci/images/space/space1003wing_A5_197.jpg

Project Roadmap



This repeatable process overcomes common TRIZ deployment challenges by showing a workflow and methodology for how to get started working on a problem with TRIZ, how to complement TRIZ with Value Methodologies for problem identification, and how to leverage internal and external knowledge sources to accelerate concept identification.

Thank you very much

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