Academia Romana -Comitetul Român de Istoria si Filsofia Ştiinţei şi Tehnicii (CRIFST)
Divizia de Logica Metodologie si Filozofia Stiintei (DLMFS)
Societatea Nationala Nuclearelectrica SA
Simpozionul Despre riscuri in stiinta si tehnica
19 mai 2022

Despre sistemele de energie, transformarile și riscurile lor

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Secretar DLMFS
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Informatii suplimentare in lucrarea
Dan Șerbănescu, Natural reactors and man-made reactors Similarities, differences, lessons for last generations of nuclear reactors *Reactoare naturale și reactoare create de omAsemănări, diferențe, lecții pentru reactorii artificiali de ultima generație*
DOI: 10.13544/RG.2.4.55459
https://www.researchgate.net/publication/360654035_Natural_reactors_and_man-made_reactors_Similarities_differences_lessons_for_last_generations_of_nuclear_reactors

19 mai 2022

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Inginer fizician Institutul Energetic Moscova Diploma de merit premiul I si propunere de continuare tema speciala ca doctorand (1979)
dr.ing. in inginerie nucleaara ICEFIZ/IFIN HH (1987)

Tema tezei Metode de corelare a defectelor provocate de cresterea sigurantei in functionare a unei centrale nucleare, coordonator prof dr. Ionel Purica,
Ihttps://www.researchgate.net/publication/294856257_Metode_de_corelare_a_defectelor_provocate_de_cresterea_sigurantei_in_functionare_a_unei_centrale_nucleare

Expert in cadrul Departamentului de Securitate Nucleara
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Profile research ID www.researcherid.com/rid/B-9590-2012

·EXPERIENTA
43 de ani in domeniul nuclear:

- ***constructie CNE, fabricatie echipamente CNE, pregatire si autorizare operatori CNE, proiectare CNE, autorizare CNE – punere in functoiune si functionare CNE Cernavoda u1 si u2, dezafectare, analize de risc; la nivel national 28 ani , evaluari de securitate nucleara Cernavoda si programe noi de centrale nucleare (SMR)***
- ***international 12 ani (CE-staff member 6 ani analize risc & dezafectare CNE Koziodui 1-4,PBMR Ltd 6 ani sef proiect PRA reactor generatie IV)***

ACTIVITATI

- ***Membru titular din 2014 si din 2019 secretar interimar al Diviziei de Logica si Modele in Stiinta (DLMFS) din cadrul Comitetului Roman de Istoria si Filozofia Stiintei si Tehnicii (CRIFST)– Academia Romana***
- ***Membru ESREDA – European Safety, Reliability & Data Association.***
- ***Consultant tehnic extern in proiecte IAEA si CE - securitate nucleara, tehnologii inovative, calculatoare quantice-roboti , analize de risc***
- ***Colaborator extern ("full academic scope"-) la conducerea de teze de doctorat in domeniul nuclear Universitatea Politehnica Bucuresti. Autor al cursului de master de analize de risc nuclear in cadrul programului Seneca, UBP-Facultatea Energetica, 1996-2000***
- ***Coordonator teze de doctorat asupra modelarii sistemelor energetice nationale si a securitatii alimentarii cu energie la Universitatea Tehnica Delft (2007-2010) si Universitatea Kaunas (2007-2010) cu colaborari ulterioare cu Brookhaven National Laboratory si Lithuanian Energy Institute .***
- ***Redactor sef (contract) domeniul risc industrial Safety Science - Elsevier (2009-2011)***
- ***Autor si coautor de carti si lucrari in domeniul securitatii nucleare si analizelor de risc, modelarea in fizica si energetica nucleara***

- Pe baza modelării prezentate în lucrări anterioare a **sistemelor energetice ca fiind sisteme complexe, care în forma lor optimă sunt autoreglabile, cu reacții de tip cibernetic multidimensional (hypercibernetic) si dezvoltate fractalic pe diverse niveluri,** se consideră transformările lor și implicațiile acestora.

- **Se definesc parametrii minimali ce caracterizează aceste transformări, ca și parametrul ce indică direcția acestora, precum și conexiunea acestora cu noțiunea de risc**. Evaluările diverselor stări și transformări ale sistemelor energetice cuprind **nu numai sussele, ci și reteau dependenta de acestea, pâna la utilizatori și feedbackul acestora**.

- **Aceste transformari și provocări sunt evaluate din perspectiva implicațiilor lor, context în care se utilizează noțiunea de risc**. Întrucât noțiunea de risc are accepțiuni diverse se precizează acceptiunea considerată in aceste evaluări și se fac referințe la posibilele abordări în ceea ce privește definiția de risc abordată.

A. INTRODUCERE

B. METODE

B1 – METODE CURENTE "TRADITIONALE"
B2 – METODE ANALIZE DE RISC – EXTENSII CAS
B3 – METODE ANALIZE DE IMPACT CE
B4 - GENERALIZARI METODE NOI - CATS

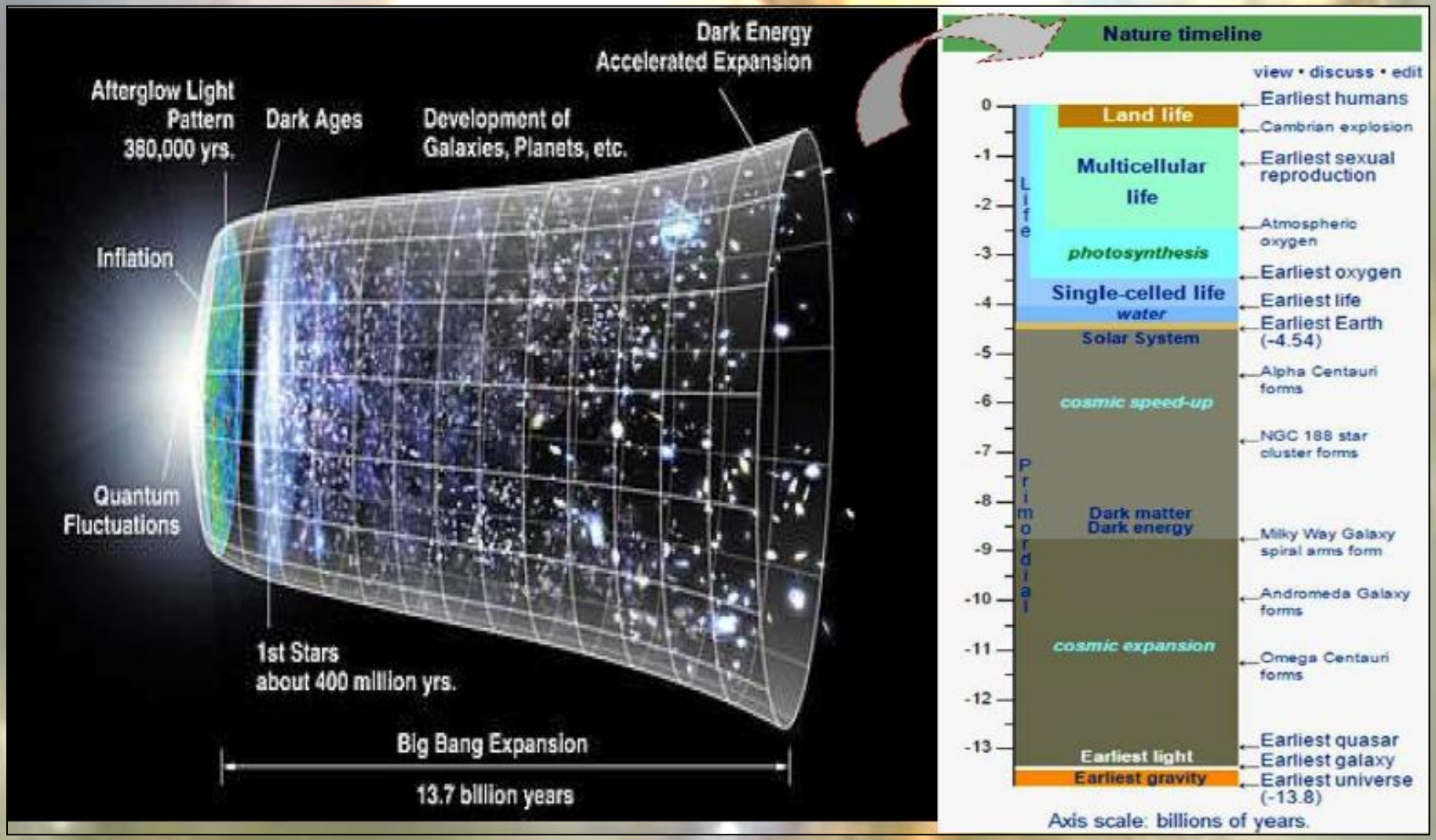
C. EXEMPLE – STUDII DE CAZ

D. IN LOC DE CONCLUZII

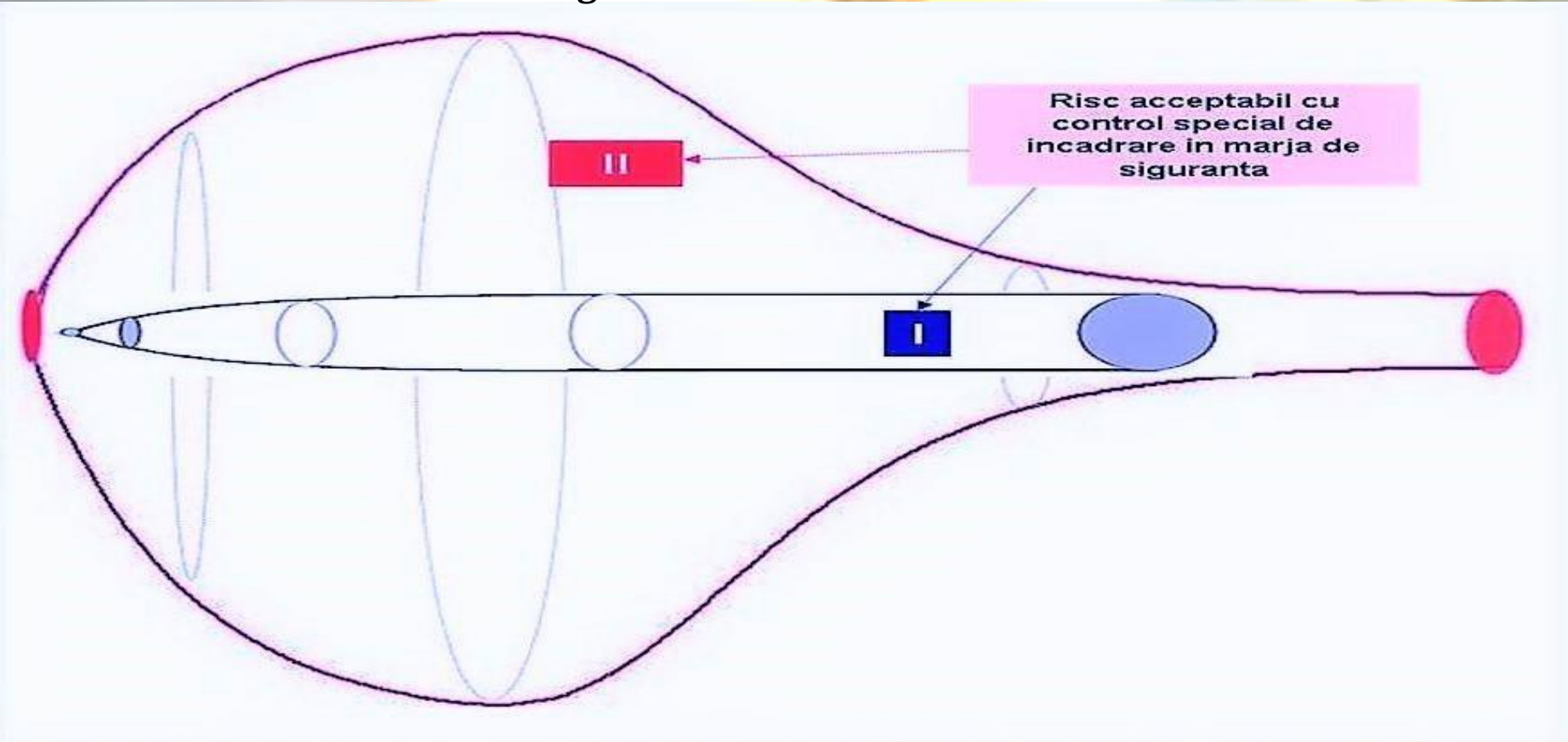
A.INTRODUCERE

- **Sistemele de energie ca sisteme ale intregului**
- **Sistemele de energie in contextul riscurilor civilizatiei**
- **Sisteme de energie si riscurile asociate**

• Sistemele de energie ca sisteme ale intregului



- **Sistemele de energie in contextul riscurilor civilizatiei**



Categoria I de cazuri – riscuri definite pentru sisteme cu modelare umana "standard" conform intelegerii actuale a factorului uman in tehnica/stiinta

Categoria II de cazuri (A,B,C) – riscuri definite in diverse scenarii de evolutie / interferenta uman – inteligenta artificiala- alt tip de inteligenta

Kardashev / Sagan scale civilization levels

- **Sisteme de energie si riscurile asociate**

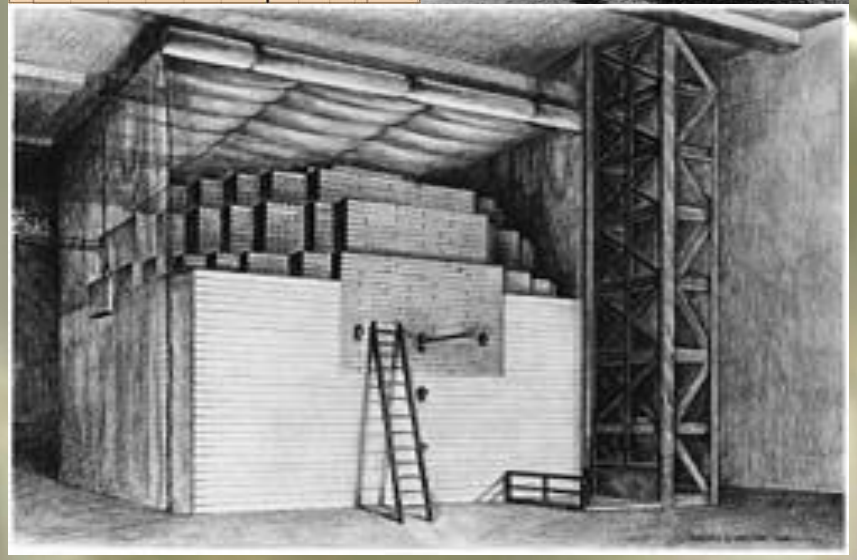
Type	Tera watts	Level of used energy	Comments
I	4×10^{4} - 4×10^{5}	Solar insolation to earth	Existing Earth level cca 4×10^{3} possible to reach type I in 100-200 years
II	4×10^{17}	Energy radiated by its own star	Few thousands years
III	4×10^{28}	Energy on the scale of its own galaxy	One million years

Group I Cosmic level	
[redacted]	
Group II Energy sources	
D-D fusion energy possible from worlds oceans	10^{31}
100-megaton H-bomb	10^{17}
Fission one ton of Uranium	10^{15}
Yearly solar emission	10^{17}
Burning a million tons of coal	10^{16}
Energy available from earth's fossil fuels	10^{23}
Exploding volcano (Krakatoa)	10^{16}
Thunderstorm	10^{14}
Group III Natural phenomena / significant human achievements	
Earth moving in orbit	10^{33}
Cretaceous-Tertiary extinction theory meteorite	10^{23}
Exploding volcano (Krakatoa)	10^{19}
Severe earthquake (Richter 8)	10^{18}
E = mc2 of 1 gram	10^{14}
Energy to put the space shuttle in orbit	10^{13}
Energy used in one year per capita U.S.	10^{12}

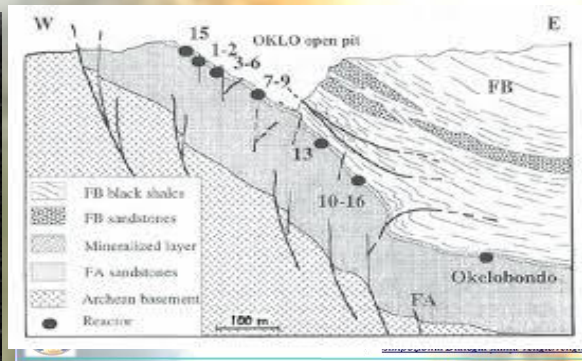
• Sisteme de energie si riscurile asociate

Type	Energy used	Energy density	Risk associated	Main features	Comments
0	1	2	3	4	5
I	Fusion	H	M	Conversion of matter-for instance helium into energy	For instance 280 kg of hydrogen into helium per second = cca 8.9×106 tons/year
	Antimatter-matter collisions	H	H	Entire rest mass of the particles converted toradiant energy.	Energy released per mass = cca four orders of magnitude greater than from nuclear fission
	Renewable energy	L	L	Solar cells Earth ground based	Very limited impact (VLI)
		L	L	Wind ground based	VLI
		L	L	Hydro	VLI
		M	M	Earth space based solar satellites	Possible to lead to type I if all the solar power is used
II	Earth star/solar space	H	H	Star/solar space based solar satellites	Earth based stations
	Stellar mass into a black hole	H	VH	Feed stellar mass into a black hole	Collect photons emitted by the accretion disc
	Penrose process	H	VH	Penrose process	Capture photons escaping from the accretion disc, reducing a black hole's angular momentum
	Star lifting	VH	VH	Remove a substantial portion of a star's matter	The process to remove portion of a star's matter is done in a controlled manner.
	Recycled antimatter	VH	VH	Antimatter as industrial byproduct	Antimatter as industrial byproduct of engineering processes - for ex star lifting and recycled
	Absorb fraction of stars in a large number of stars	VH	VH	Absorb fraction of the output of each star.	In multiple-star systems absorb fraction of the output of each star
III	Sources for type II for more galaxies	VH	VH	ditto II but applied to all stars of one or more galaxies	As per type II
	Black holes energy	VH	CT	Use the energy released from black holes	Black holes at the center of many galaxies
	White holes energy	VH	CT	from collecting the matter propelling outwards	White holes provide energy from collecting the matter propelling outwards
	Gamma ray bursts	CT	CT	Capture energy of gamma-ray bursts	Capture energy of gamma-ray bursts - power source
	Quasars	CT	CT	Emissions from quasars comparable to small active galaxies	Emissions from quasars comparable to small active galaxies -power source

CHICAGO PILE 1942-1943



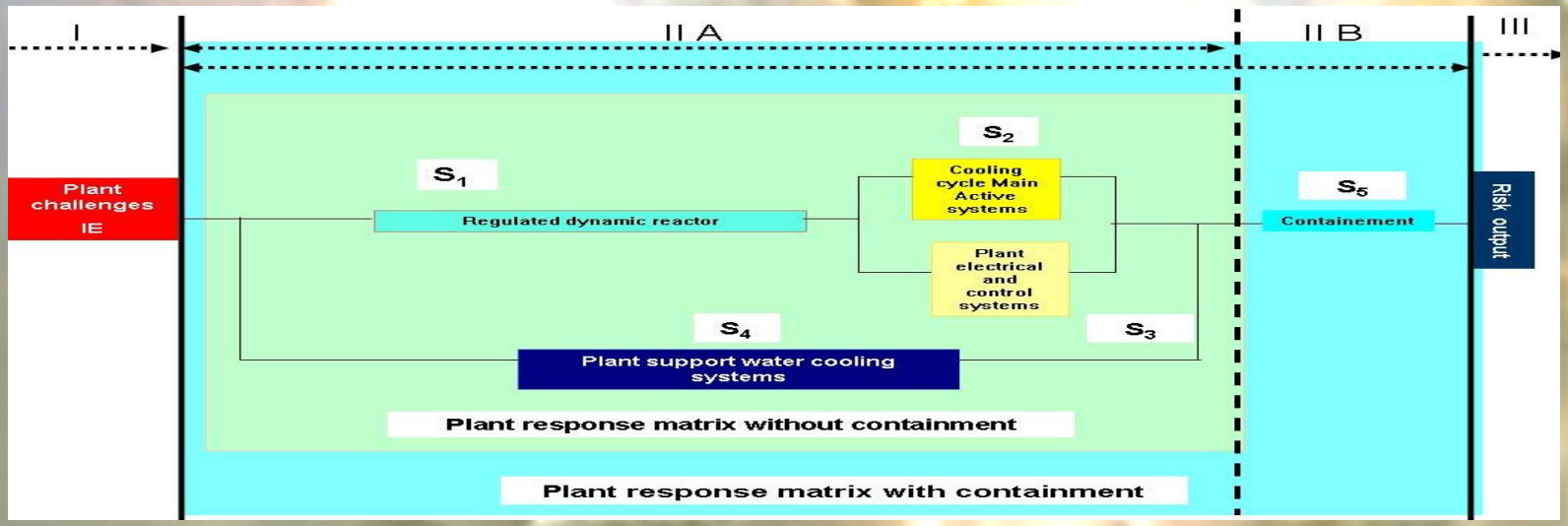
OKLO GABON CCA 2 BLN YEARS AGO

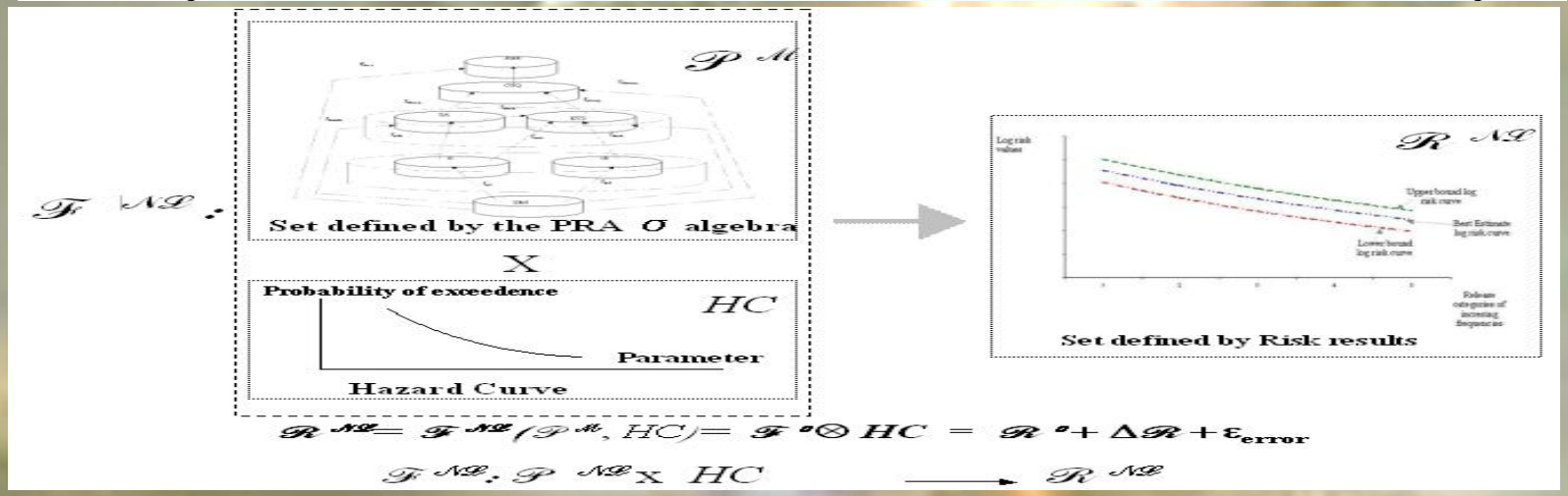


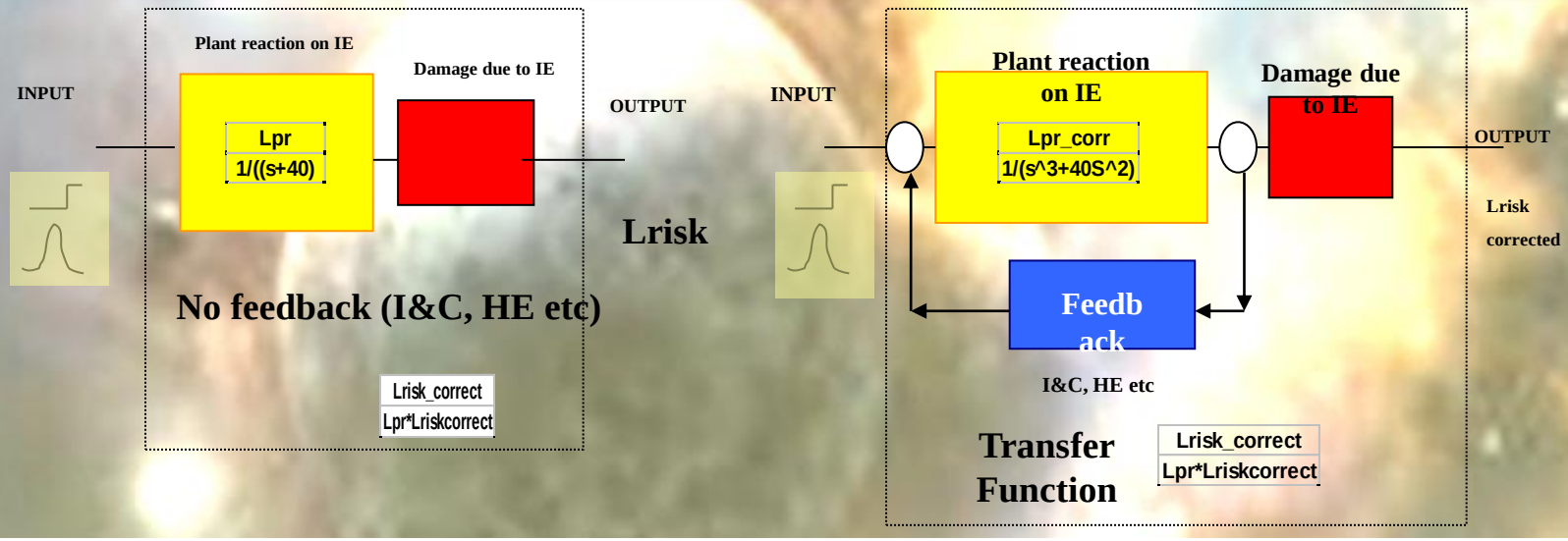
Sisteme Apoietice Complexe Energetice - naturale

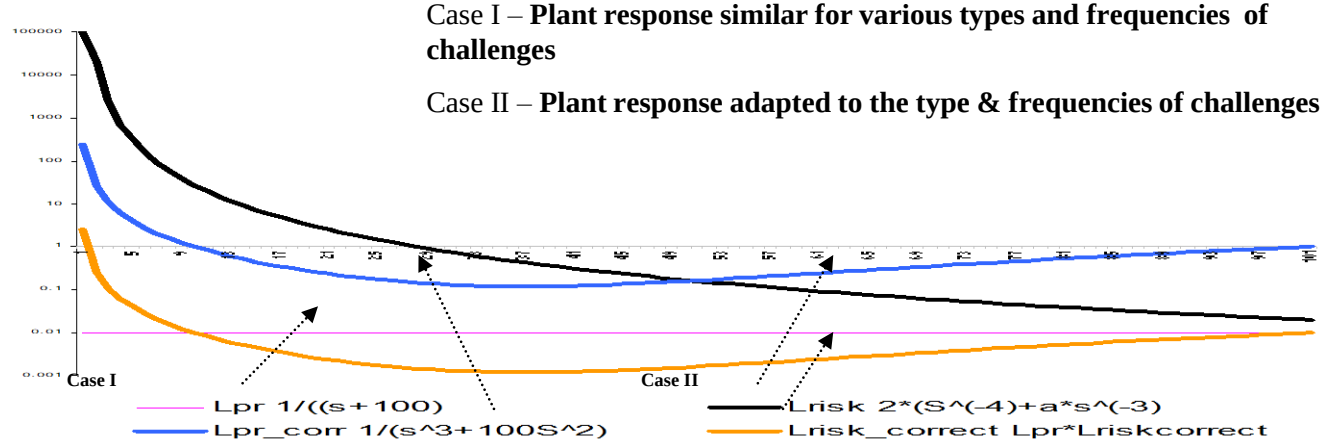
B. METODE

B1 ANALIZE DE RISC - METODE EXISTENTE "TRADITIONALE"

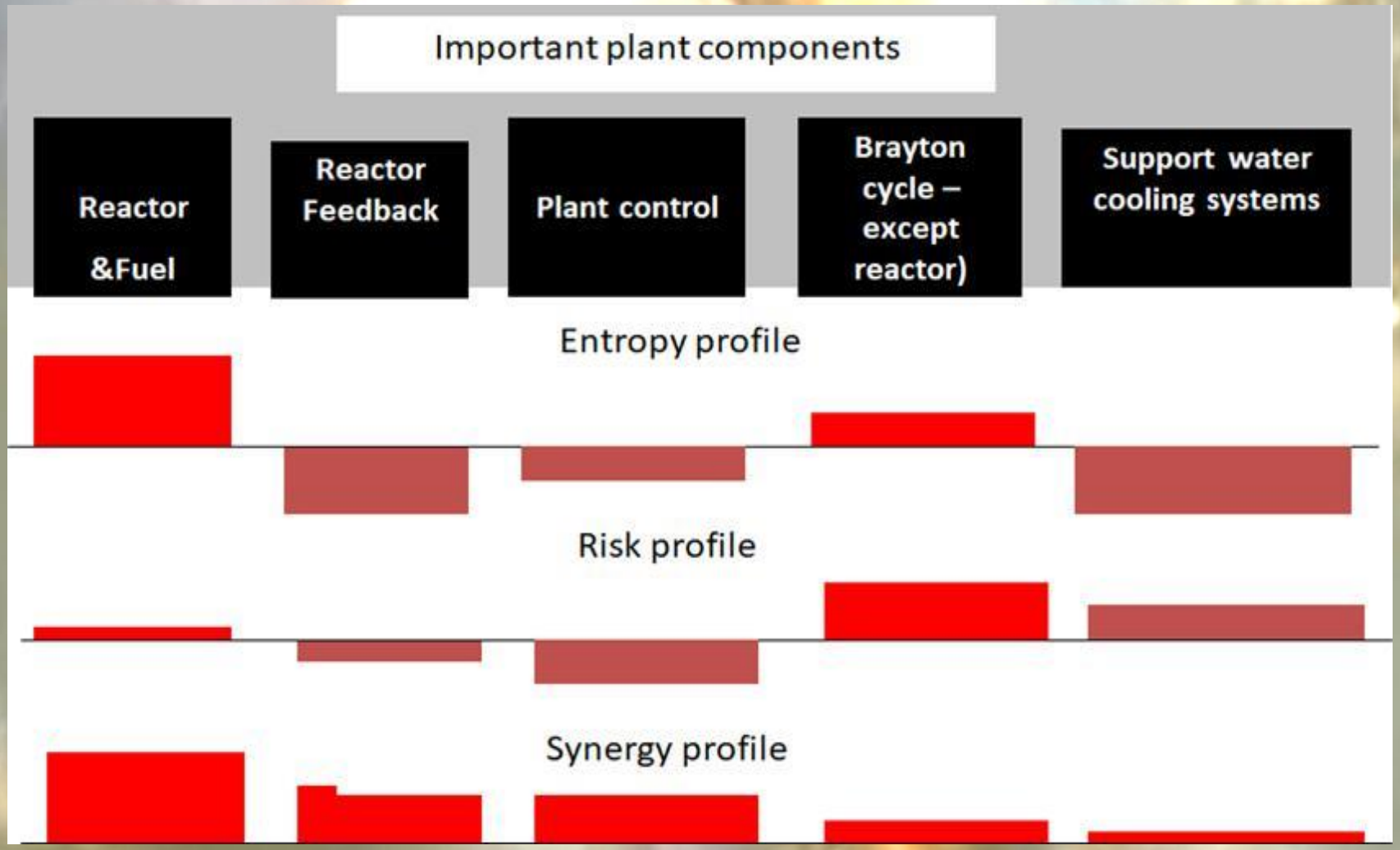

I
II A
II B
III
Plant challenges IE
S1
Regulated dynamic reactor
S2
Cooling cycle Main Active systems
Plant electrical and control systems
S3
S4
Plant support water cooling systems
Plant response matrix without containment
Plant response matrix with containment
S5
Containement
Risk output


Set defined by the PRA algebra
X
Probability of exceedence
Parameter
HC
Hazard Curve
Set defined by Risk results



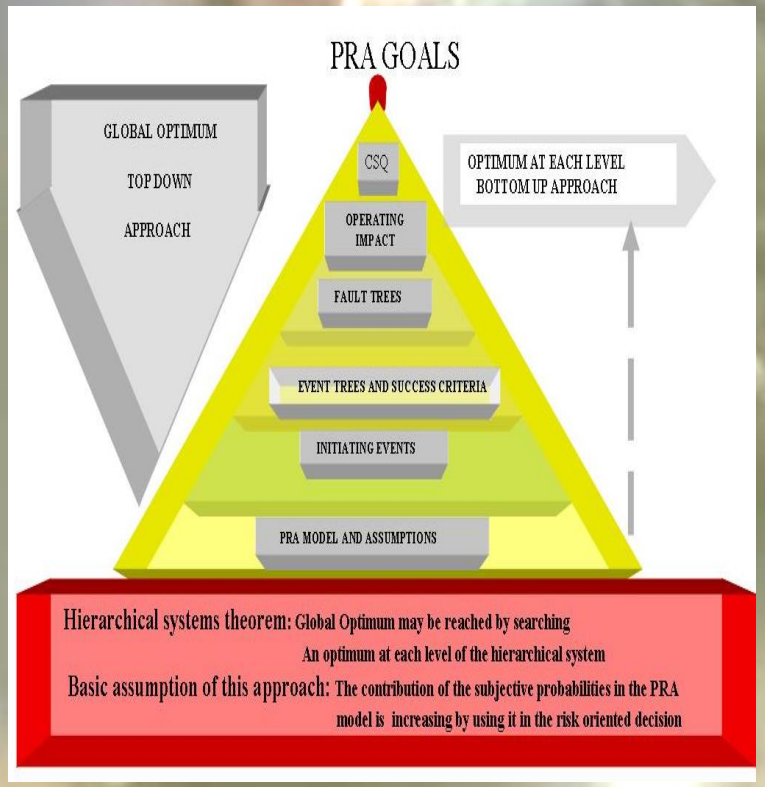


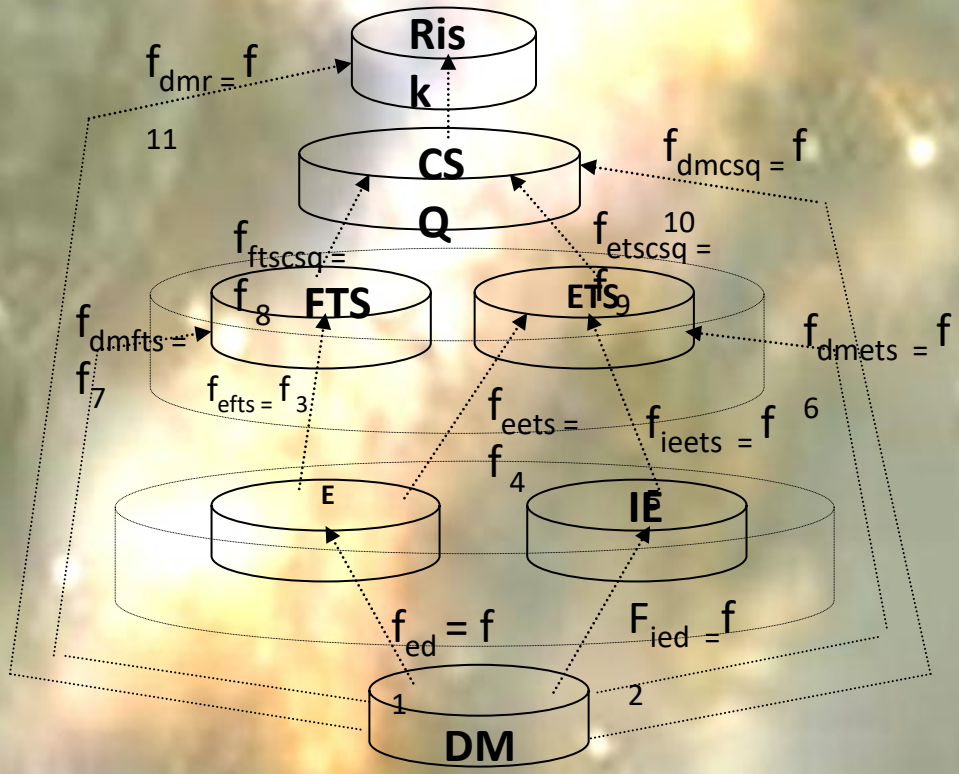
NPP as a cybernetic risk producing machine


Important plant components
Reactor &Fuel
Reactor Feedback
Plant control
Brayton cycle – except reactor)
Support water cooling systems
Entropy profile
Risk profile
Synergy profile

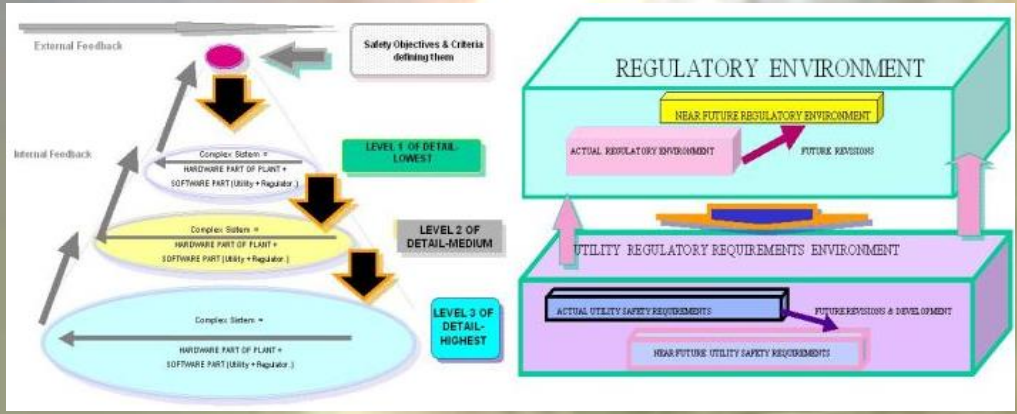
A CAS model leads to the problem of building a sigma algebra for a risk model. If we consider the sigma algebras defined as in the figure, then a norm may be defined, and the norm used is usually called risk. This model corresponds to the level of physical interfaces of the CAS (CAS level 1) The methods to find a solution complying with the Pareto type limits leads to faster, easier to model and less work intensive models in case that integrated PRA tools are used, as defined in the other previous communicated results, which are mainly based on the use of a series of logical switches for a single unique model.

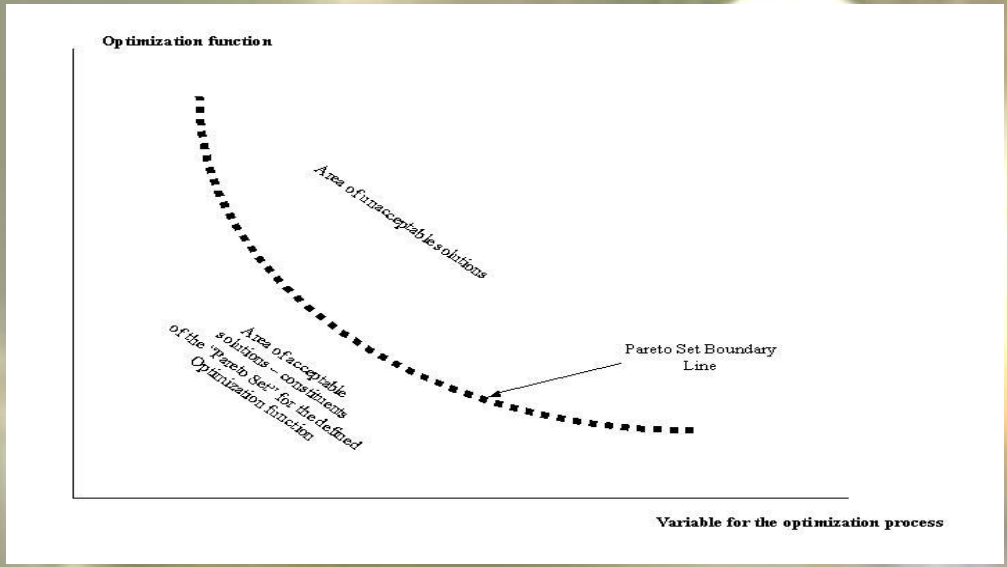
PRA is a 3 S method: Systemic, Structured and Systematic





Some important methodological aspects



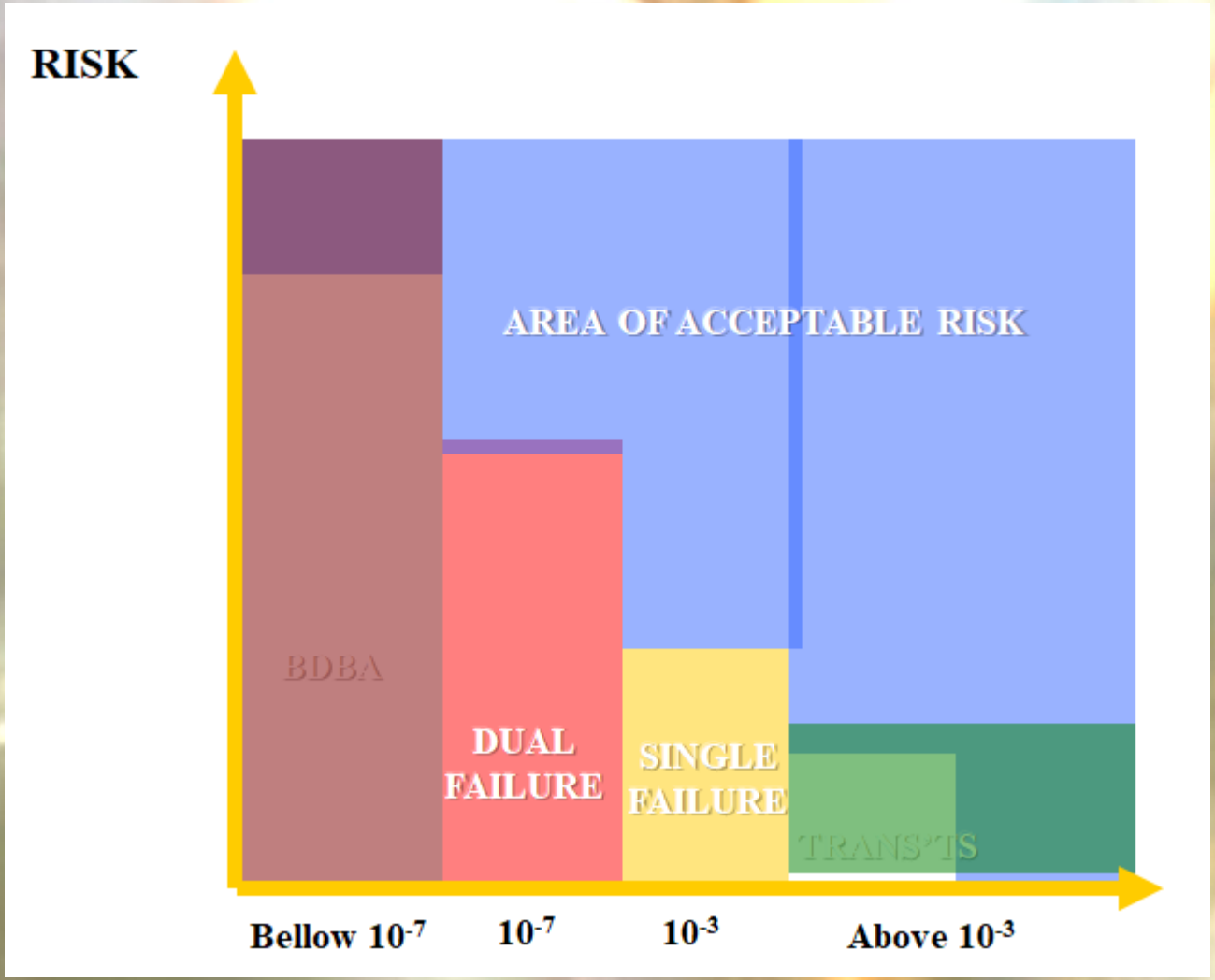


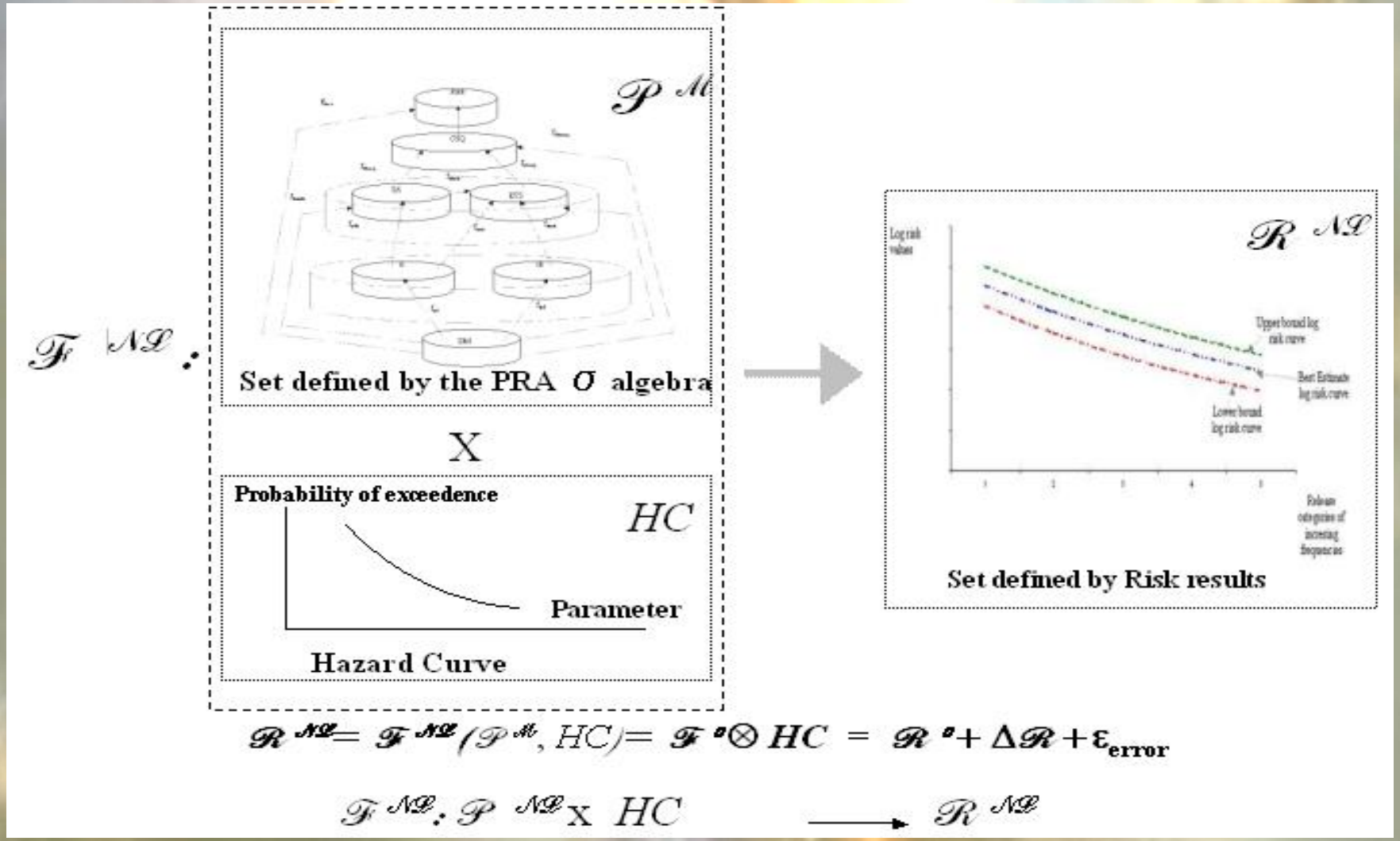
CAS potentially described by hierarchical systems theory and the basis for decisions is done using Risk Data Base capable to support living changes and continuous use.

The methodology has to be compliant with a set of requirements, which assure its adequacy for Risk Informed Decisions.

One main starting point is to consider the risk as a norm for hierarchical systems

For such tasks the objectives defined have to comply with a Pareto type curve

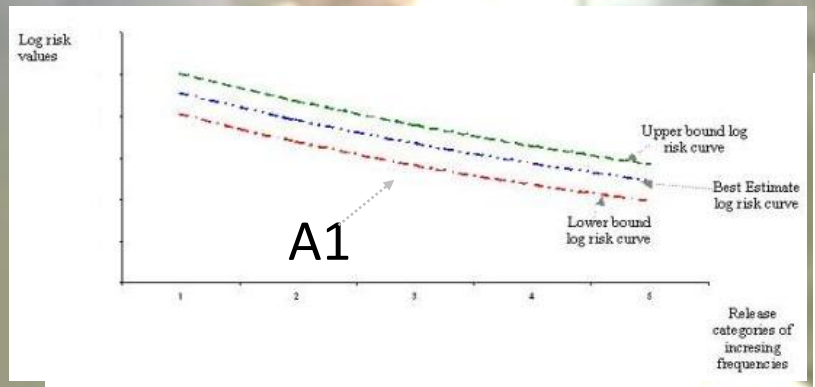

RISK
AREA OF ACCEPTABLE RISK
BDBA
DUAL FAILURE
SINGLE FAILURE
TRANS'TS
Bellow 10^{-7}
10^{-7}
10^{-3}
Above 10^{-3}

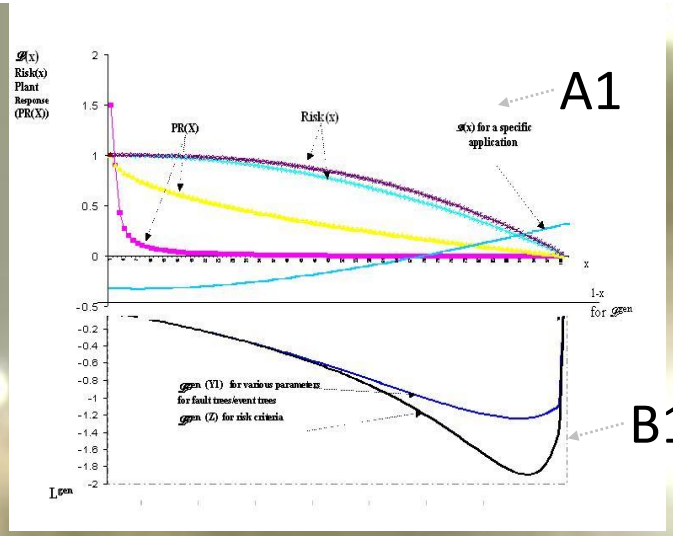


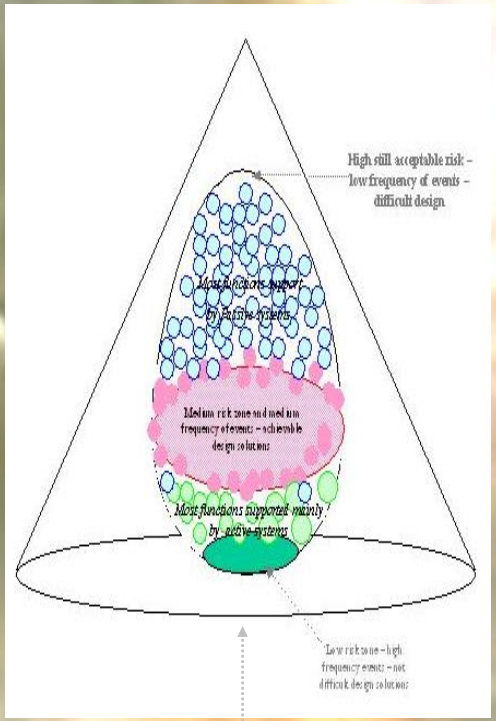
$$\mathcal{R}^{\mathcal{NL}} = \mathcal{F}^{\mathcal{NL}}(\mathcal{P}^{\mathcal{M}}, HC) = \mathcal{F}^{0} \otimes HC = \mathcal{R}^{0} + \Delta\mathcal{R} + \varepsilon_{error}$$

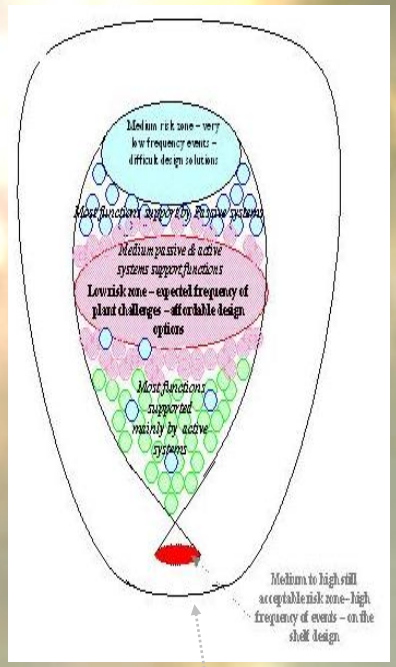
$$\mathcal{F}^{\mathcal{NL}} : \mathcal{P}^{\mathcal{NL}} \times HC \longrightarrow \mathcal{R}^{\mathcal{NL}}$$

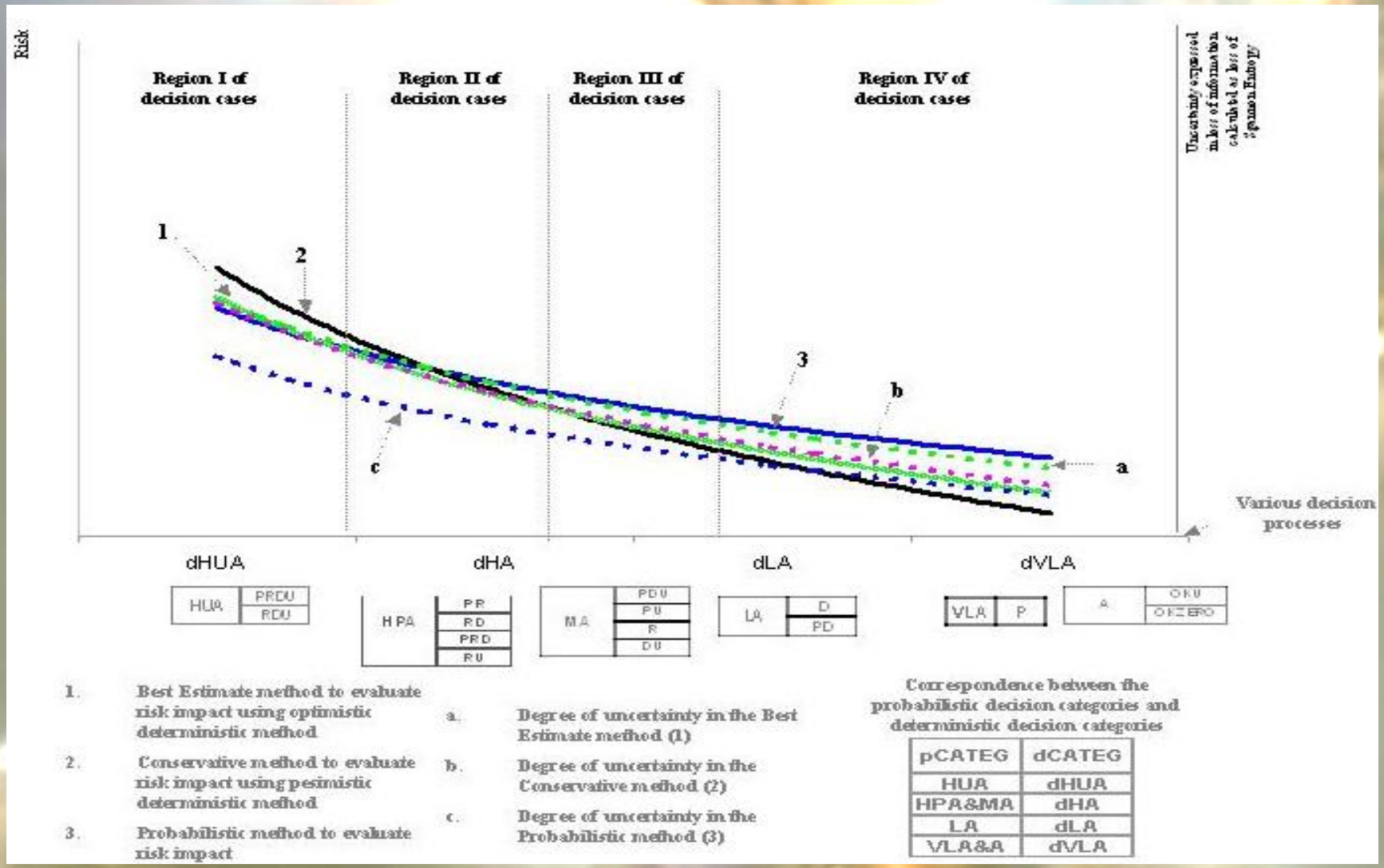
The solutions of optimization for objective functions complying with a Pareto type of limit is of type A or of type B (if the limitations are considered in the optimizations process), where 1 or 2 relate to bi or 3 dimensional representation.

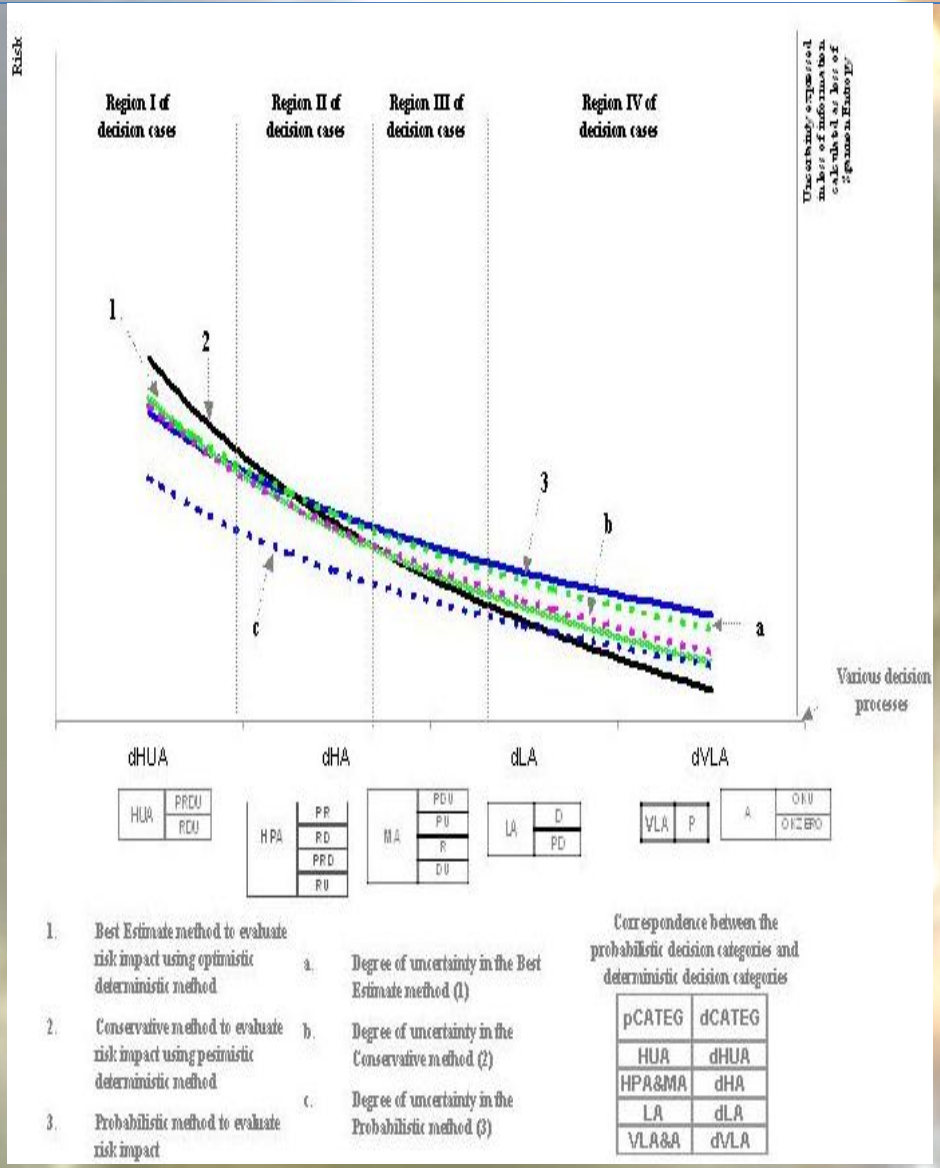









Risk
Region I of decision cases
Region II of decision cases
Region III of decision cases
Region IV of decision cases
Uncertainty expressed in loss of information calculated as loss of "gamma Entropy"
1
2
3
a
b
c
Various decision processes
dHUA
dHA
dLA
dVLA
HUA
PRDU
RDU
HPA
PR
RD
PRD
RU
MA
PDU
PU
R
DU
LA
D
PD
VLA
P
A
OKU
OKZERO
1. Best Estimate method to evaluate risk impact using optimistic deterministic method
2. Conservative method to evaluate risk impact using pesimistic deterministic method
3. Probabilistic method to evaluate risk impact
a. Degree of uncertainty in the Best Estimate method (1)
b. Degree of uncertainty in the Conservative method (2)
c. Degree of uncertainty in the Probabilistic method (3)
Correspondence between the probabilistic decision categories and deterministic decision categories
pCATEG
dCATEG
HUA
dHUA
HPA&MA
dHA
LA
dLA
VLA&A
dVLA



- If the decision is aimed at evaluating high foreseen risk situations above the acceptable limits, then the deterministic pessimistic statements will lead to the most conservative decision, even if that will happen under less credibility than for the probabilistic ones. But by other reasons than technical ones, the deterministic based decisions could be expected.

- If the decision is aimed at evaluating high or moderate foreseen risk situations below the acceptable limits, then there will be no difference between the very pessimistic way of thinking, an optimistic one or a probabilistic one except the fact that the probabilistic one will have more credibility, which could make it the most probable choice for the decision.

- If the decision is aimed at evaluating low and very low foreseen risk situations below the acceptable limits, then it will be based on the probabilistic approach, giving the fact that it generates the most conservative results with highest credibility. Evaluation of risk impact using extensive sensitivity cases is one of the key issues to support the probabilistic type of thinking and its more extensive use in decision process. This is integrated in the verification and validation process, of which independent review and benchmarking play a very important role in confirming the truth value of probabilistic statements.

Secvente de impact / Metode de decizie	Principiul abordarii precaute Precautionary principle PREC PREC	Principiul deliberarii Deliberative Principle DELIB	Principiul deciziei pe baza informatiilor de risc Risk Informed Decision Making RIDM
Ridicat	**Se poate astepta cea mai conservativa decizie facuta cu prioritate maxima, atunci** cand **Interfata internationala slaba**, chiar si singura, si **cu atat mai mult daca are loc atunci cand si coomunicarea este slaba**, iar **incertitudinea** asupra situatiei pe teren **este mare**	**Se poate astepta ca o dezbatere cu partile implicate sa aiba loc cu prioritate maxima,** daca **Interfata internationala este ridicata**, chiar si singura, si cu atat mai mult daca are loc atunci cand si **comunicarea este buna, chiar si daca incertitudinea asupra situatiei pe teren este mare**	**Se poate astepta o decizie bazata pe evaluarea riscului sa fie luata cu prioritate maxima, cu sprijinul grupului GLERUNR**, in conditiile unei interfete **internationale bune**, a existentei unor rezultate de analiza confirmate de criteriul de succes pe centrele luate in consideratie, chiar si **in conditiile unor incertitudini asupra situatiei pe teren**
Mediu	**Se poate astepta cea mai conservativa decizie facuta cu prioritate medie, atunci** cand **Interfata internationala slaba**, in timp ce **monitorarea** cu criteriul sau de succes pentru centrele / laboratoarele autorizate **si coordonarea/verificarea monitorarii sunt slabe**	**Se poate astepta ca o dezbatere cu partile implicate sa aiba loc cu prioritate medie, cu suport din partea grupului de analize GLERUNR si cu o** comunicarea buna, chiar si daca interfata internationala nu este foarte buna, iar **rezultatele analizelor conform criteriilor de succes** al centrelor/laboratoarelor si **incertitudinea** asupra situatiei pe teren **sunt de nivel mediu**	
Scazut	**Se poate astepta cea mai conservativa decizie facuta cu prioritate scazuta, atunci** cand **Interfata internationala este puternica**, chiar daca a esuat comunicarea, in timp ce **monitorarea** cu criteriul sau de succes pentru centrele / laboratoarele autorizate **si** coordonarea/verificarea monitorarii **sunt slabe**	**Se poate astepta ca o dezbatere cu partile implicate sa aiba loc cu prioritate scazuta, cu suport din partea grupului de analize GLERUNR, in conditiile in care nu se activeaza SNSMU,** interfata internationala nu este foarte buna, iar **rezultatele analizelor conform criteriilor de succes** al centrelor/laboratoarelor si **incertitudinea** asupra situatiei pe teren **sunt de nivel mediu**	
Foarte Scazut		**Se poate astepta ca o dezbatere cu partile implicate sa aiba loc cu prioritate foarte mica, in conditiile in care interfata internationala si comunicarea sunt foarte bune, iar monitorarea conform criteriilor de** succes al centrelor/laboratoarelor si coordonarea acesteia sunt la nivel scazut	

TRAN	Acceptance is dependent on transparency rather than on elaborate definitions of te objective functions. Most risks could be expected to be accepted/assumed if the process was transparent
DELIB	Acceptance is dependent on the existence of a deliberation process for the objective functions. Risks could be accepted / assumed as a result of deliberations
PRECP	Acceptance is expected because the decision is taken top down in a very conservative manner. The risks could be accepted / assumed as a result of legal actions
RIDM	Acceptance is expected based on evaluation of objective functions and various approahes in evaluation of risks for various actors perspectives

Case A	Highly controversial and emotional issue specially from public perspective. No risks accepted by public, no common agreement between the other two actors and sigificant diffculties to evaluate risk or other value functions	Highly radioactive waste management
Case B	No major controversy on the issue and possile reach of acceptance for all actors but in a local area / country and no major diffculties to evaluate risk or other value functions	Carbon emissions
Case C	Agreement on some - safety /risk related aspects of the issue but possile problems in the implementation for all actors on the globe and no problems to evaluate risk or other value functions	Climate change and carbon emissions and/or use of various energy scenarios capable to cope with that

Complex Apoietic Systems (CAS)

- **In other words autopoiesis means "self-production" (self-creation or production) and expresses a fundamental complementarity between structure and function.**
- **An autopoietic machine is a machine organized (defined as a unity) as a network of processes of production (transformation and destruction) of components which:**
  - **through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them;**
  - **and constitute it (the machine) as a concrete unity in space in which they (the components) exist by specifying the topological domain of its realization as such a network.**

CAS coevolution is being performed at three levels
• (Bio) Physical level – at the level of the physical part of the system components and structure
• (Bio) Social level – at the level of the system interface with society and other system defined as environment
• Mythicosocial level – at the level of concept, objectives and general philosophical interpretation of the CAS issues

Complex Systems (CS) are systems with specific features	
1	The system is characterized by the fact that the interrelations between its elements/components create a synergetic effect, which actually makes the system unique. The interactions are of short distance between elements or of long distance (in space and time)
2	The existing relationships in a CS a defined by the existence of feedback loops, which results in a dynamic system structure, with constant nonlinear interfaces.
3	CS are interacting with the environment, being open to the exchange of energy and information.
4	No part of a CS can contain the whole and therefore no part can assure the control of the whole CS. This could lead to specific tools for controlling it, like for instance distributed control, hierarchical control and/or external to the CS unitary control. However
5	CS elements are CS themselves and are highly adaptive, which introduces another difficulty in the choice of the modelling tools.
6	CS have a historical hysteresis characteristic, in the sense that they have a history and that leads to an effect known as “the butterfly effect”, i.e. a small change in time and space will impact on the future history of the whole CS or to a completely different component that the one that had the initial change. However, even if the interrelations of the components are nonlinear they comply with the cause and effects law in this specific manner. The concept of linearity and nonlinearity apply to the models defined for CS and it is one of the important modelling issues.
7	CS have boundaries difficult to define, which has a high impact on the content of their models and their own changing dynamics and flexibility.

Complex Apoietic Systems (CAS)
were introduced by the works of (Maturana 1980)

They have the specific features additionally to the generic CS ones, sometimes refining the generic CS features. CAS are systems, for which an autopoietic mechanism can be defined, leading to the system possibility not only to self regulate, but also to recreate itself, as follows

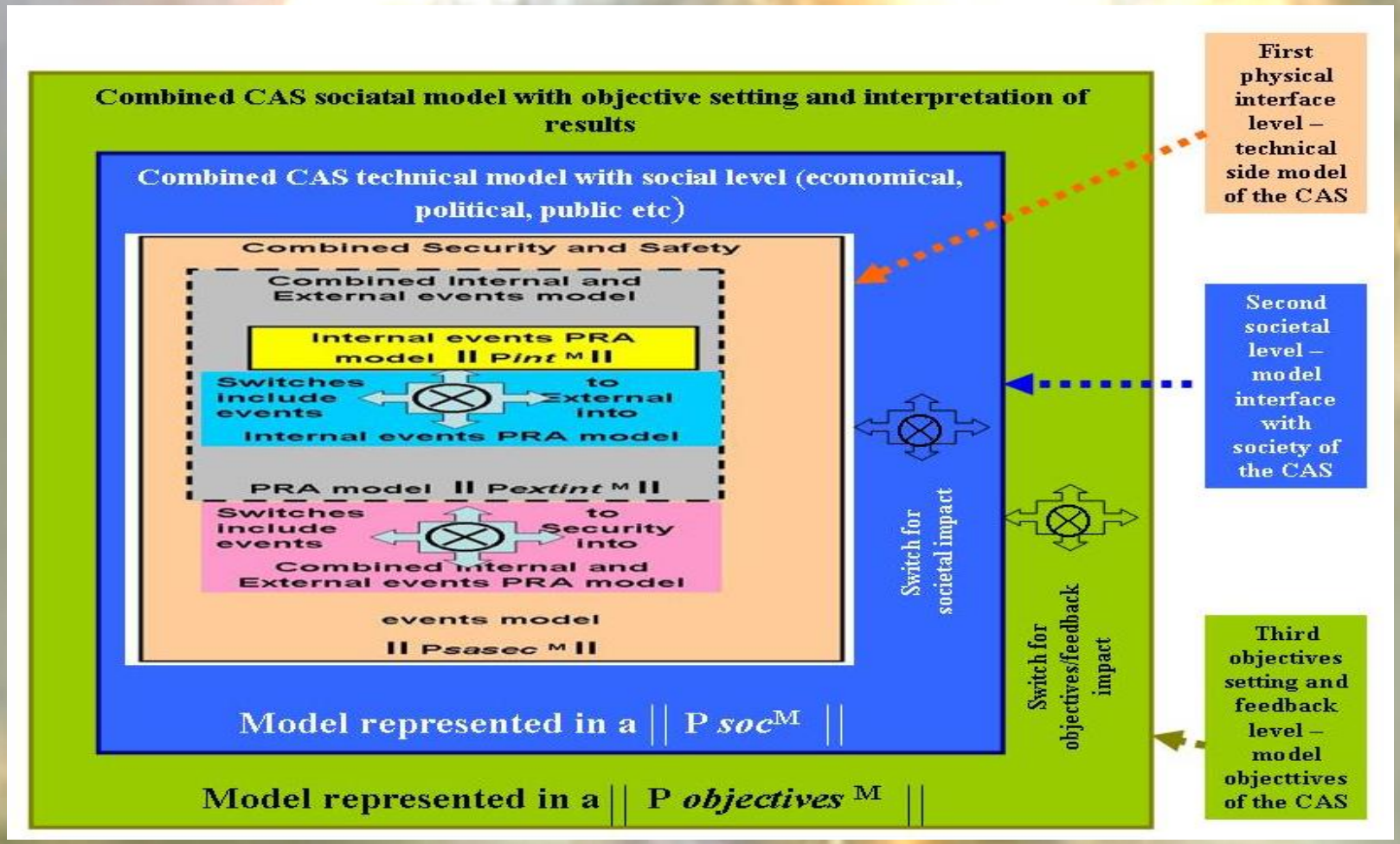
1	**The system boundaries have to be clearly defined at any moment in time**
2	**The system has to have components, being themselves CS**
3	**The cause – effect law interactions have to be operable.**
4	**The system boundaries have to be self produced by the system, as well as**
5	**The system components**
6	**The rest of the components should be also be able for most of them to be self produced by the system**

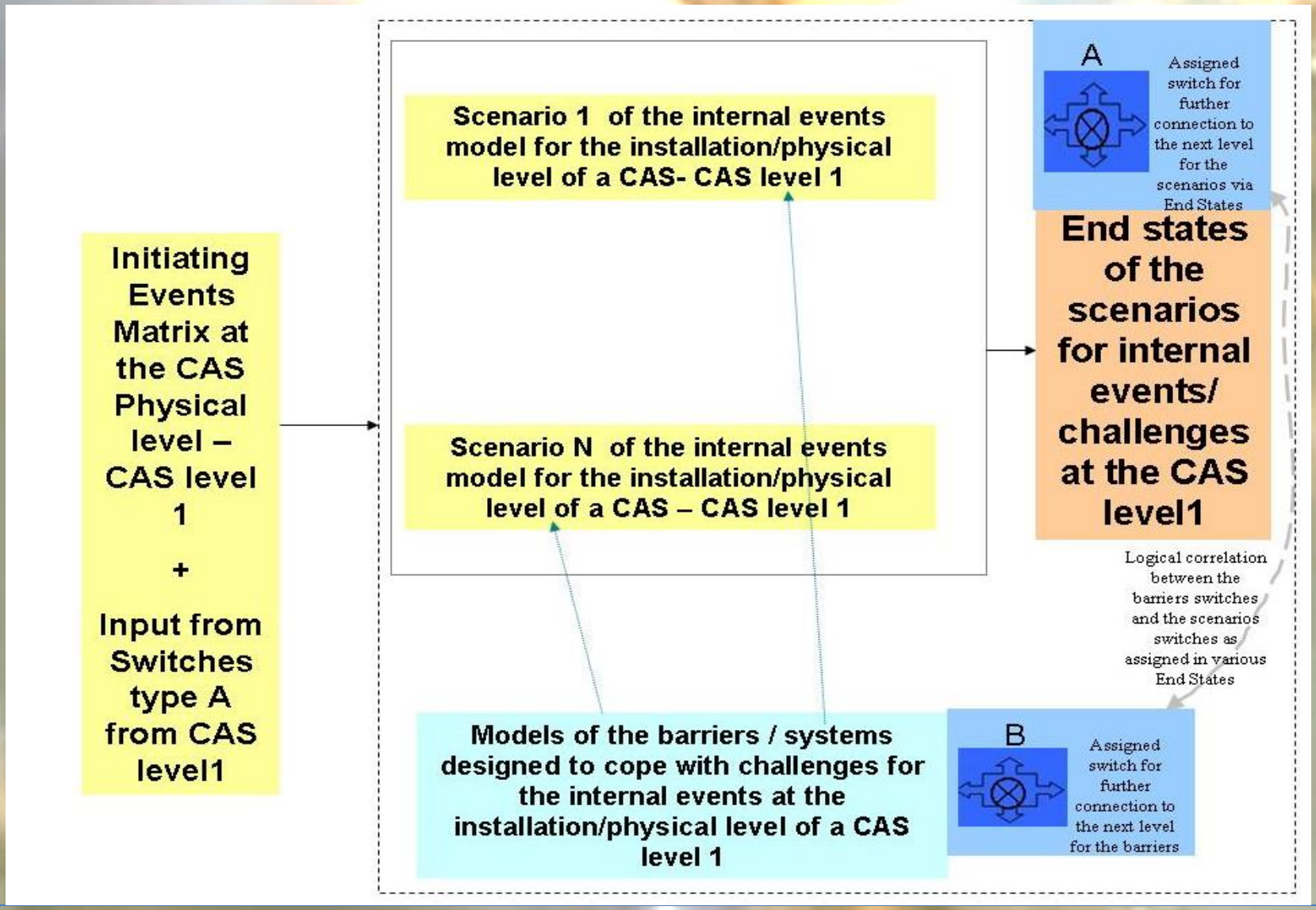
Model requests for CAS Risk	
1	The model has to be developed on a basis of risk as a multiple yet convergent in a 3+1 hierarchical system, where 1 indicates the feedback loop.
2	The risk measures have to be defined with various norms: classical, considering uncertainty etc
3	Implementation of meaningful use of the risk notion for decisions has to be based not only on risk-benefit approach, but also on considering various goals adopted by various partners
4	The risk theory has to be based on developing a model on the hierarchical system norm approach
5	A set of rules has to be defined for the use of model by various categories of users
6	The objective and subjective models have to be defined in the model in a non conflicting method
7	Scenarios with catastrophic failure of the whole theory behind the base line of the model have to be considered and defined.

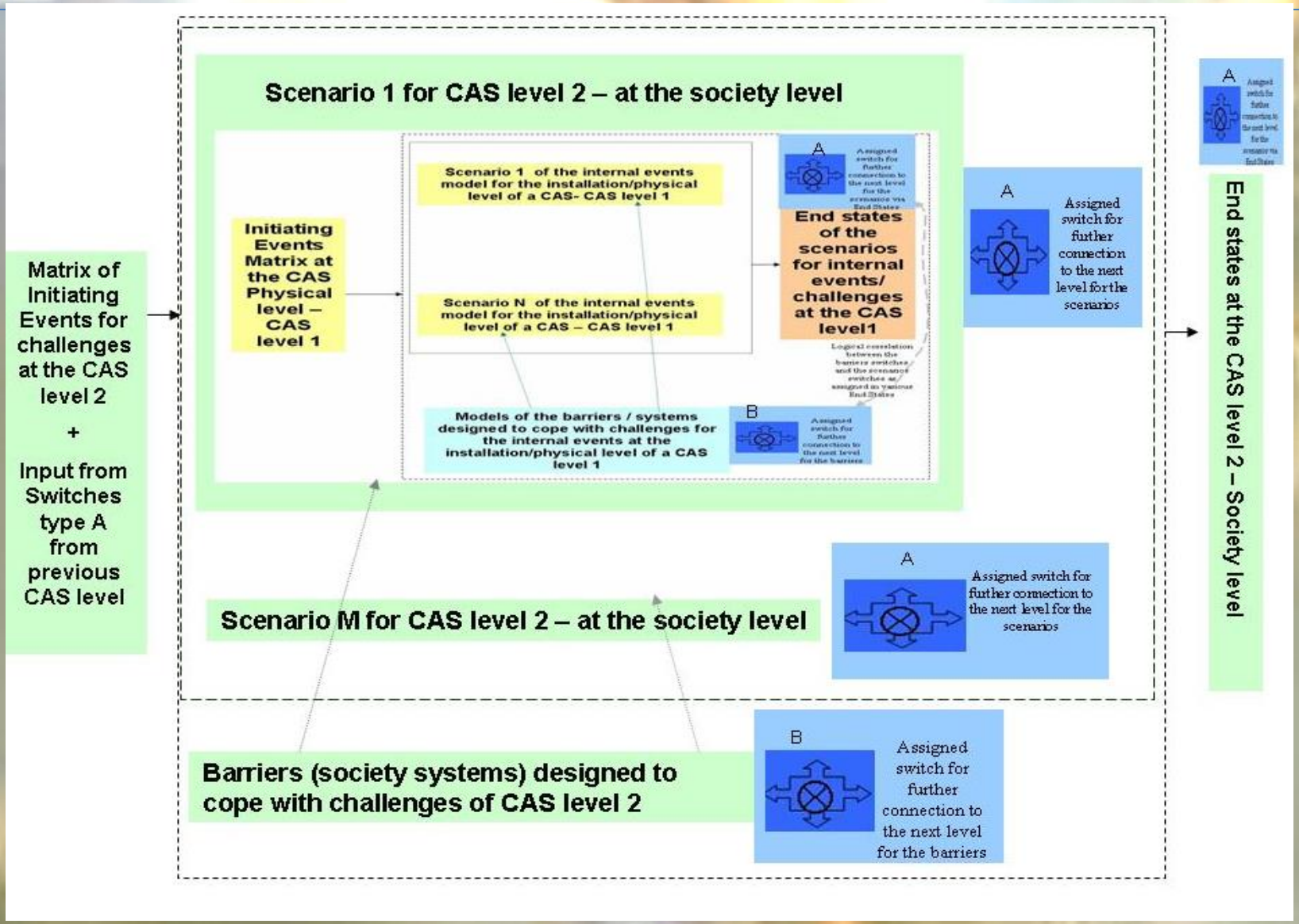
	Requirements to the method - Risk Analysis
1	To be systemic, systematic and structured
2	To be able to define structures of dynamic cybernetic interrelations between components with random character of challenges combined with intentional challenges and to solve nonlinear dynamic models, by defining what linearity means for a CAS
3	To define the system as a whole, as being a result of the synergetic interfaces of its components and to define also the CAS interface with the environment
4	To have a solution for the system control (like for instance distributed control, hierarchical control and/or external to the CS unitary control) and system management based on predefined objectives, as for instance energy/substance balance or risk impact. Definition of objective functions for CAS like energy balance, information balance, system safety or security, system risk metrics etc. is very important and needs tested and/or testable methods directly or by benchmark exercises.
5	To have a model and adequate method to solve the specifics of the cause–effect issue for a CAS, which is an aspect connected in its turn to others like definition of linearity, uncertainty and system structure modelling.
6	To be able to develop models and methods, which are dynamic themselves and with high flexibility in defining initial and boundary conditions.

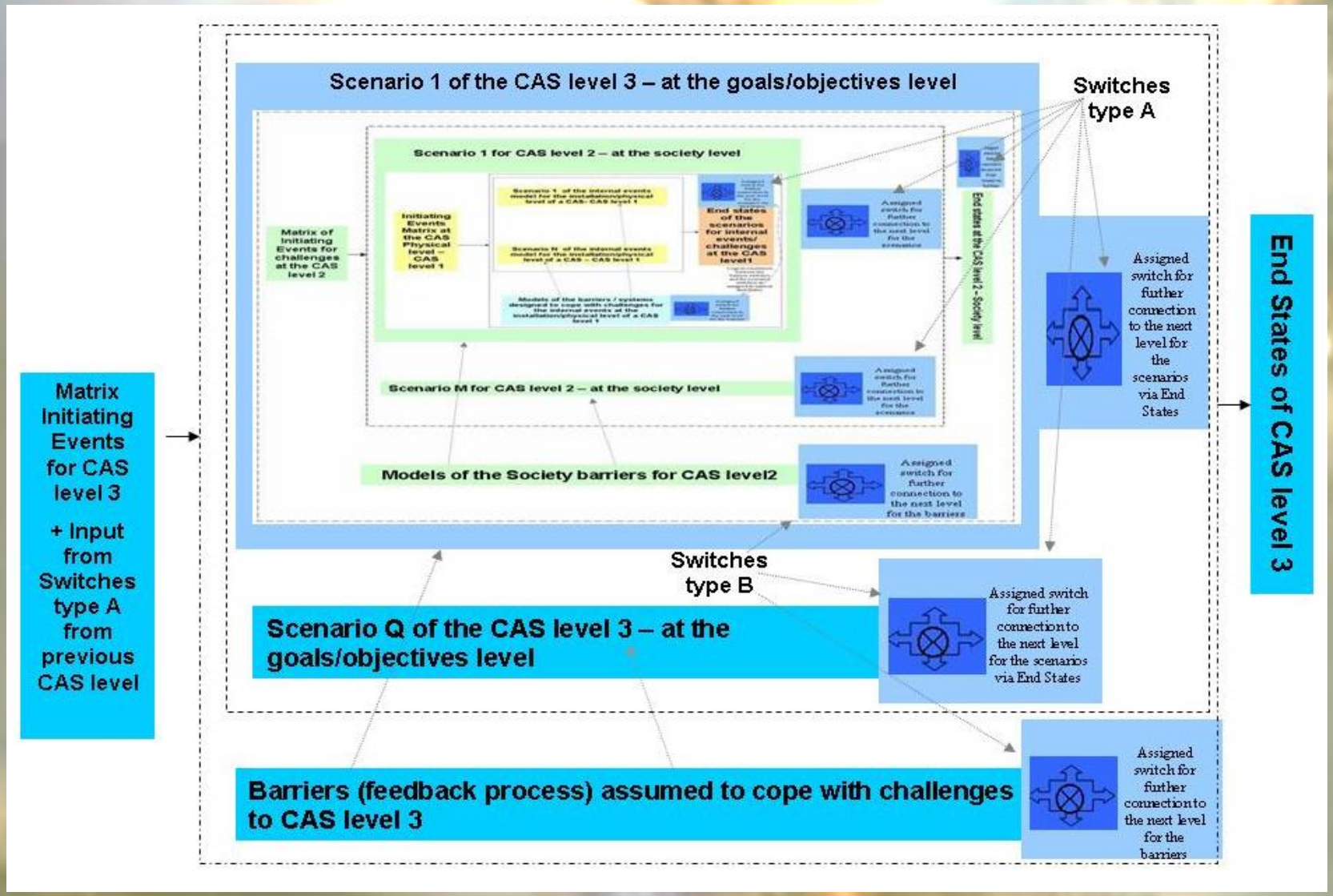
PRA/PSA model Some important aspects

Sample representation of the interconnection between various model layers and modules




Initiating Events Matrix at the CAS Physical level – CAS level 1
+
Input from Switches type A from CAS level1
Scenario 1 of the internal events model for the installation/physical level of a CAS- CAS level 1
Scenario N of the internal events model for the installation/physical level of a CAS – CAS level 1
Models of the barriers / systems designed to cope with challenges for the internal events at the installation/physical level of a CAS level 1
A
Assigned switch for further connection to the next level for the scenarios via End States
End states of the scenarios for internal events/ challenges at the CAS level1
Logical correlation between the barriers switches and the scenarios switches as assigned in various End States
B
Assigned switch for further connection to the next level for the barriers


Matrix of Initiating Events for challenges at the CAS level 2
+
Input from Switches type A from previous CAS level
Scenario 1 for CAS level 2 – at the society level
Initiating Events Matrix at the CAS Physical level – CAS level 1
Scenario 1 of the internal events model for the installation/physical level of a CAS- CAS level 1
Scenario N of the internal events model for the installation/physical level of a CAS – CAS level 1
End states of the scenarios for internal events/ challenges at the CAS level1
Models of the barriers / systems designed to cope with challenges for the internal events at the installation/physical level of a CAS level 1
A
Assigned switch for further connection to the next level for the scenarios
B
Scenario M for CAS level 2 – at the society level
Barriers (society systems) designed to cope with challenges of CAS level 2
Assigned switch for further connection to the next level for the barriers
End states at the CAS level 2 – Society level


Scenario 1 of the CAS level 3 – at the goals/objectives level
Switches type A
Scenario 1 for CAS level 2 – at the society level
Matrix of Initiating Events for challenges at the CAS level 2
Initiating Events Matrix at the CAS Physical level – CAS level 1
End states of the scenarios for internal events/ challenges at the CAS level1
Scenario M for CAS level 2 – at the society level
Models of the Society barriers for CAS level2
Assigned switch for further connection to the next level for the barriers
Assigned switch for further connection to the next level for the scenarios via End States
Matrix Initiating Events for CAS level 3
+ Input from Switches type A from previous CAS level
Switches type B
Scenario Q of the CAS level 3 – at the goals/objectives level
Assigned switch for further connection to the next level for the scenarios via End States
Barriers (feedback process) assumed to cope with challenges to CAS level 3
Assigned switch for further connection to the next level for the barriers
End States of CAS level 3

B 3 ANALIZE DE RISC

METODE DIN ANALIZE DE RISC ALE CE

CAS level 2,3 sample results
Evaluation is done using risk metrics as defined for standardized PRA for a CAS level 1 against other weighting factors

Item code	Model components	CAS Level 3 TCO Method RITOCAS using ARC	CAS Level 3 TCO RITOCAS not using ARC	CAS Level 3 TCO Screenein g methods A,B,C (Serbanes cu 2005)
PUBL1 *	Public challenges manageable by the existing system of public interface	H	H	H
PUBL2 *	Public challenges NOT manageable by the existing system of public interface	H	H	H
POL1 *	Political challenges manageable by the existing political system features	H	H	H
POL2 *	Political challenges NOT manageable by the existing political system features	H	H	H
ECON1 *	Economical challenges manageable by the existing economical system	H	H	H
ECON2 *	Economical challenges NOT manageable by the existing economical system	H	H	H
SBC1 *	Security challenges manageable by existing security systems	M	M	M
SBC2 *	Security challenges NOT manageable by existing security systems	M	M	M
EXTEV ***	External events challenges	M	M	M
BR **	System breaks leading to possible contamination	M	M	M
COOL **	Support cooling water systems failures	L	M	M
HE **	Support high energy CAS part failures	L	M	M
CONT **	Last barrier to the containment release - containment	M	M	M

<u>Main results including sensitivity calculations</u>

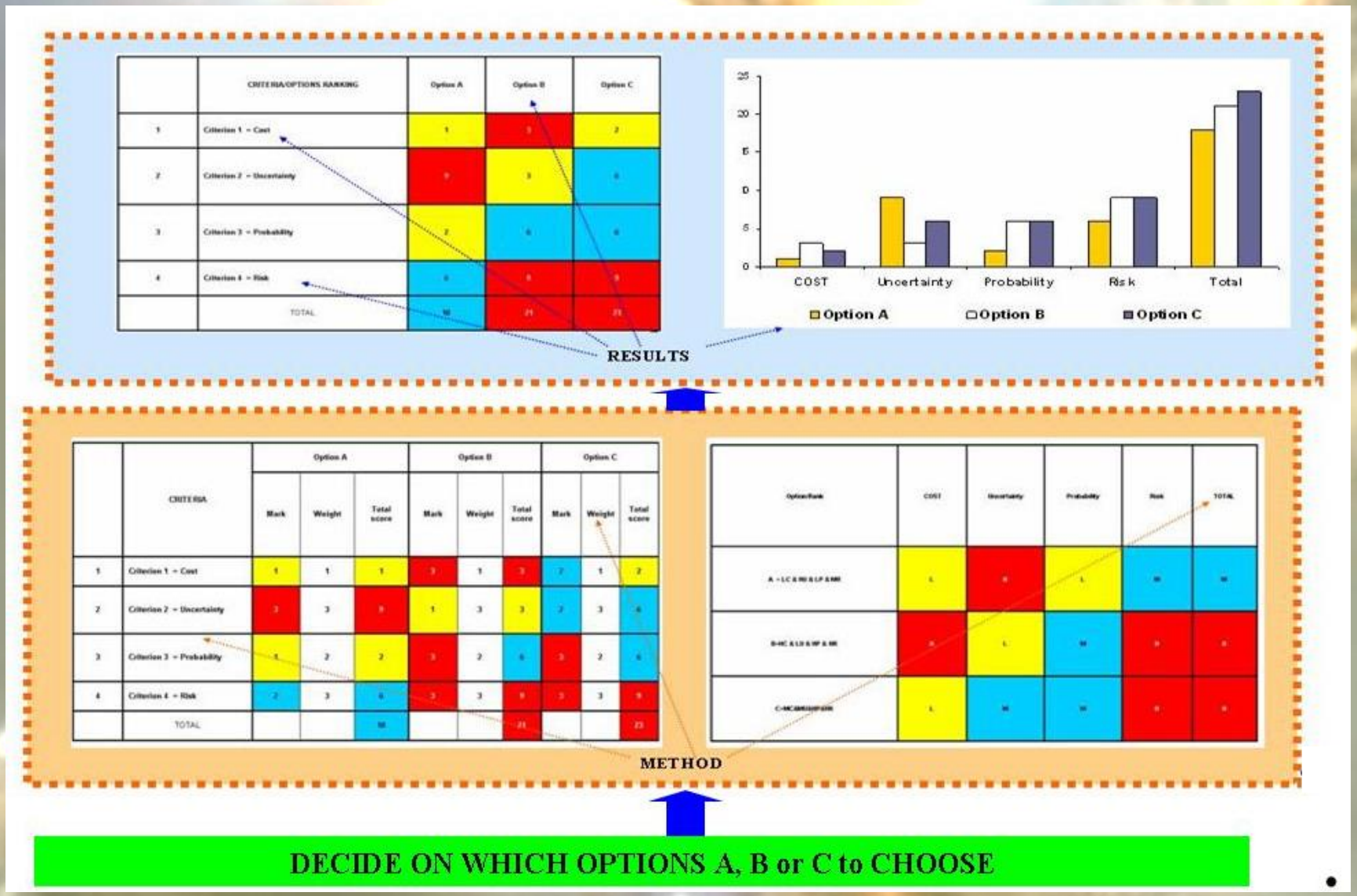
The important contribution to the final conclusions of comparing contributors to risk of societal aspects, in all methods used for comparison

The higher contribution of both security type of challenges (with and without barriers designed) by comparison with the internal safety aspects of a given energy source

A very high potential for comparisons and better decision making support for more than one energy source reviewed if a CAS level2 and 3 is analyzed

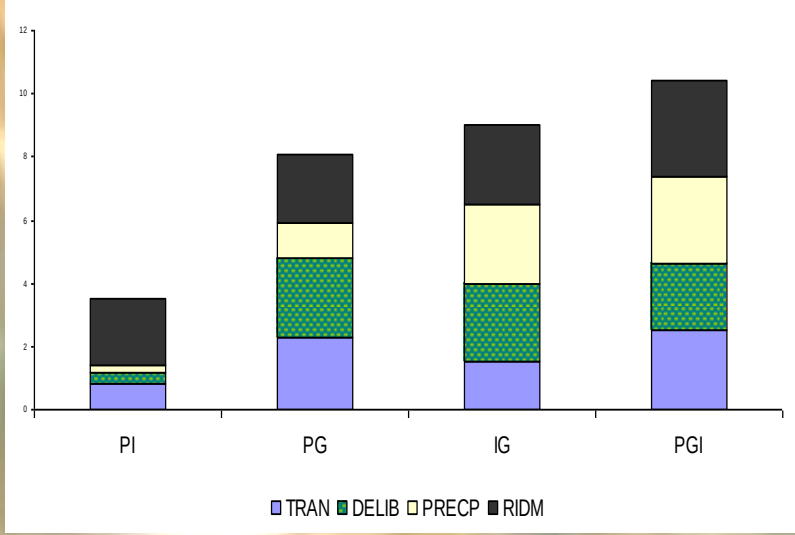
The versatility of the unique CAS levels 1, 2, 3 model for more than one energy source for on-line (living multiple energy source and safety-security model in an integrated unique model) operation. This feature is extremely useful for the use of the method to support decision making.

Very good possibilities of connecting the model with extended external risk related databases for on-line support to decision making process, a process which could be defined as "Living PRA for a CAS system".

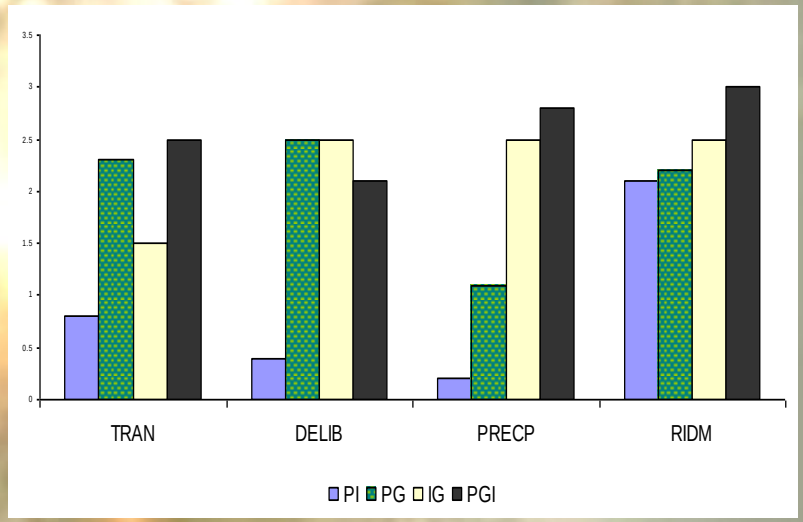

CRITERIA/OPTIONS RANKING
Option A
Option B
Option C
1
Criterion 1 = Cost
2
Criterion 2 = Uncertainty
3
Criterion 3 = Probability
4
Criterion 4 = Risk
TOTAL
COST
Uncertainty
Probability
Risk
Total
Option A
Option B
Option C
RESULTS
CRITERIA
Mark
Weight
Total score
METHOD
DECIDE ON WHICH OPTIONS A, B or C to CHOOSE

Model/method	Code	public	industry	government	support/feedback and tools
Transparency and accountability	TRAN				
Deliberation for risk governance	DELIB				
Precautionary Principle	PRECP				
Risk informed decision making.	RIDM				

Low applicablity	Hgh applicablity	Medium applicability	Able to adpat /reflect the needs



Model/method	Code	PI	PG	IG	PGI
Transparency and accountability	TRAN				
Deliberation for risk governance	DELIB				
Precautionary Principle	PRECP				
Risk informed decision making.	RIDM				



Model/method	Code	public	industry	government	support/feedback and tools
Transparency and accountability	TRAN				
Deliberation for risk governance	DELIB				
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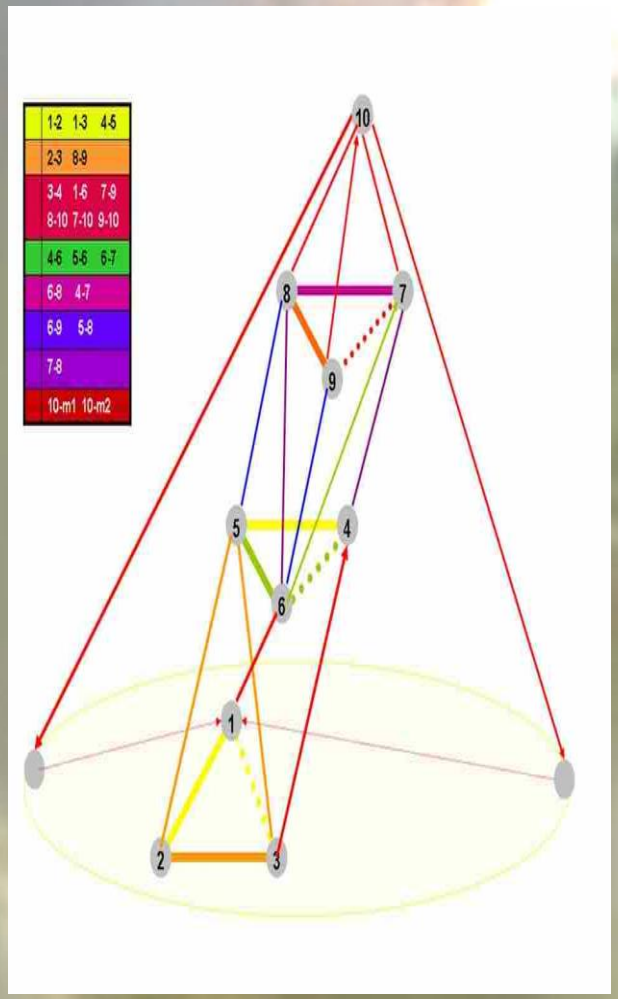
Low applicablity	Hgh applicablity	Medium applicability	Able to adpat /reflect the needs

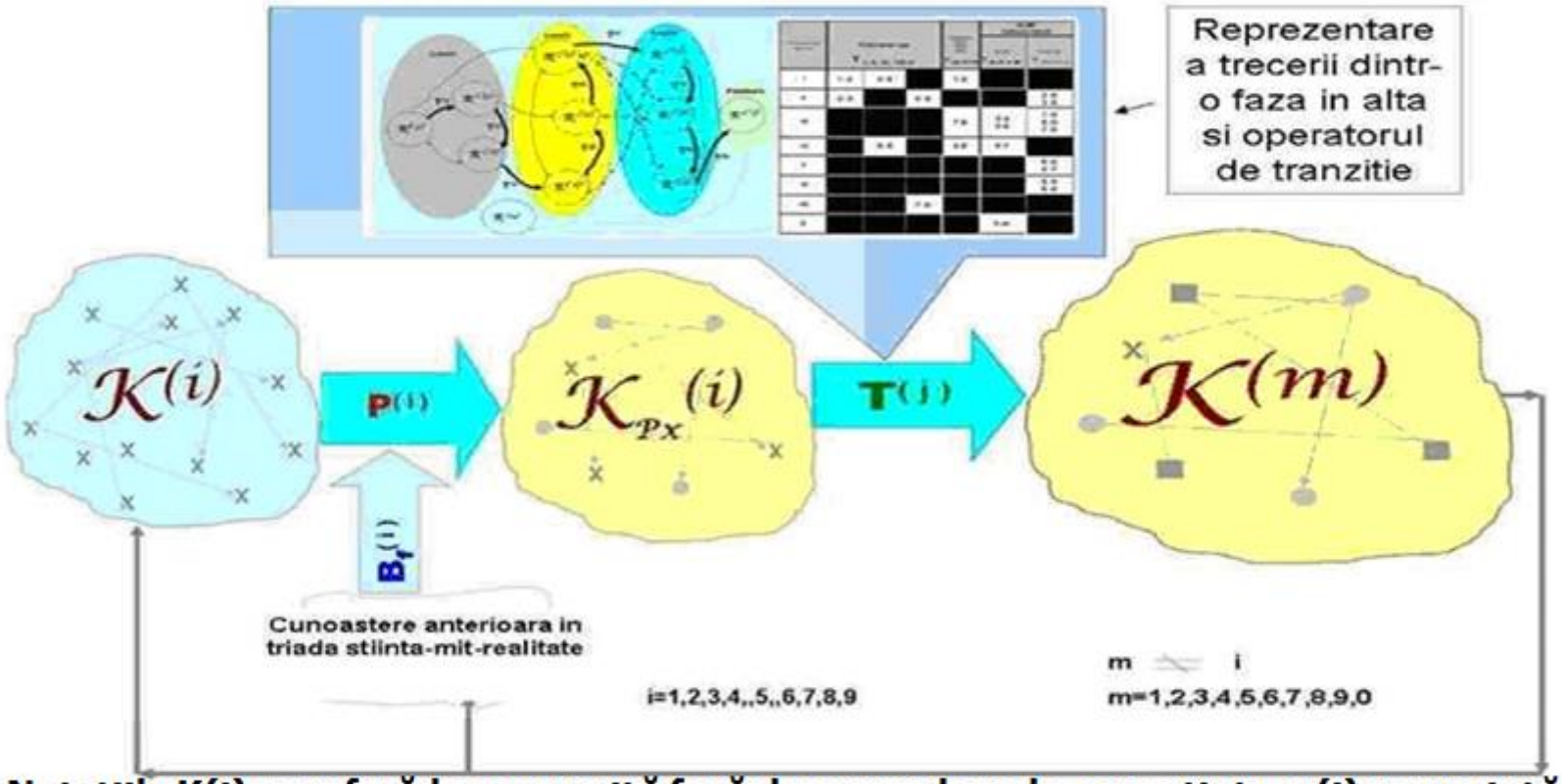
Model/method	Code	PI	PG	IG	PGI
Transparency and accountability	TRAN				
Deliberation for risk governance	DELIB				
Precautionary Principle	PRECP				
Risk informed decision making.	RIDM				

B 4 ANALIZE DE RISC

GENERALIZARI ALE MODELELOR DE RISC CAS / CATS



1-*A*	Definirea necesității	Avem o sursă unică de cunoaștere
2-*B*	Clarificarea diferențelor	Baza științei(lor) și a trăsăturilor sale / lor ca o abordare duală
3-*C*	Dezvoltarea principalelor 'unelte'	Crearea unei noi științe / revoluționarea uneia existente ca fiind guvernată de o abordare din trei- unghiuri de vedere (posibil – imposibil - probabil)
4-*D*	Verificarea stabilității elementelor definitorii pentru știința respectivă - teorii etc.	Durabilitatea unui element metodologic (teorie etc) așa cum rezultă din robustețea sa la paradoxuri
5-*E*	Identificarea principalelor convingeri care impiedică evoluția	Fiecare fază definită în cheie istorică a respectivei științe este alimentată de anumite convingeri / credințe și intuiții
6-*F*	Rafinarea cunoștințelor dobândite și imbunătățirea eficienței utilizării lor	Fiecare teorie trebuie să aibă un grad de utilitate în cadrul științei respective și al societății
7-*G*	Încercarea de a unifica metode pentru obținerea unor rezultate mai bune	Cunoașterea absolută și cea relativă
8-*H*	Gestionarea cunoștințelor acumulate	Existența și / sau introducerea / modificarea de ierarhii și conexiuni între diversele teorii ale unei științe conduc către nevoia de a avea unelte cât mai bune de gestionare a edificiului.
9-*I*	Încercarea continuă de a rezolva probleme nerezolvate și de a extinde cunoașterea	Nevoia de neînfrânat de a atinge noi niveluri de perfecțiune și înțelegere, ca o cauză continuă, latentă, de reîncepere a întregului proces de la zero.



Notațiile K(i) se referă la o anumită fază de acumulare de cunoștințe, p(i) reprezintă probabilitatea de trecere dintr-o fază în alta, iar T(i) se referă la operatorul de tranziție dintr-o structură de cunoaștere în alta.

systems

Subquantic	SQ=SYS7
Quantic	Q =SYS8
Molecular	M =SYS9
Molecular life	ML=SYS1
Planetary	P =SYS2
Planetary life	PL =SYS3
Planetary life intelligent	**PLI =SYS0**
Galaxy	G =SYS4
Cosmic	C =SYS5
Cosmic life	CL =SYS6
Cosmic intelligent	**CLI =SYS10**

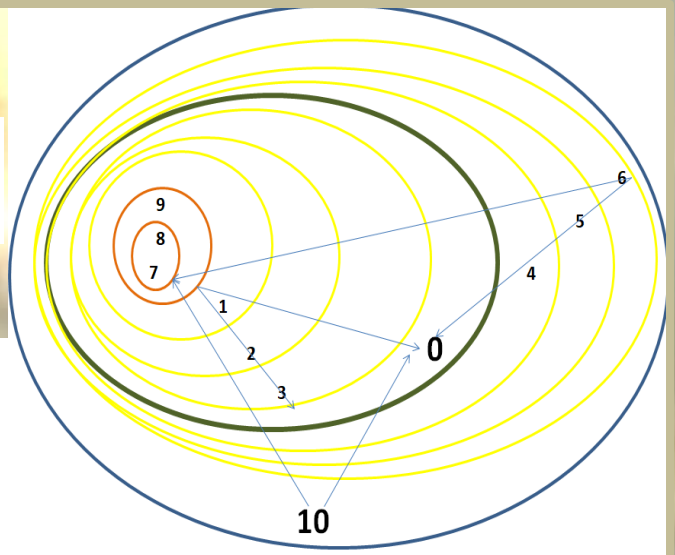
For one given case

$$s^{(k)} = \sum_{l=0}^{8} \sigma_l^{(k)} + \sum_{l=0}^{8} \omega * i_l^{(k)}$$

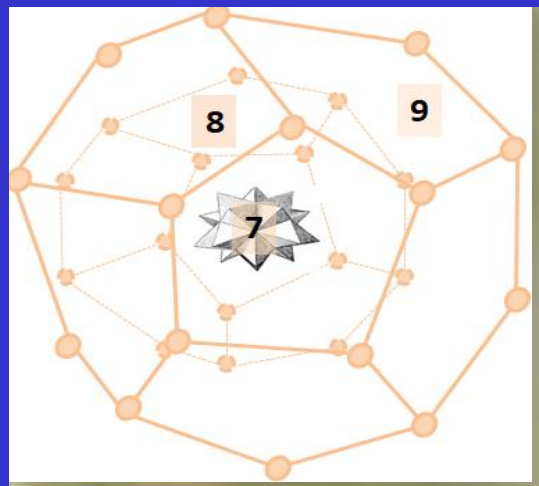
$$E^{(k)} \equiv \sum_{l=0}^{8} E_l^{(k)} i_l^{(k)}$$

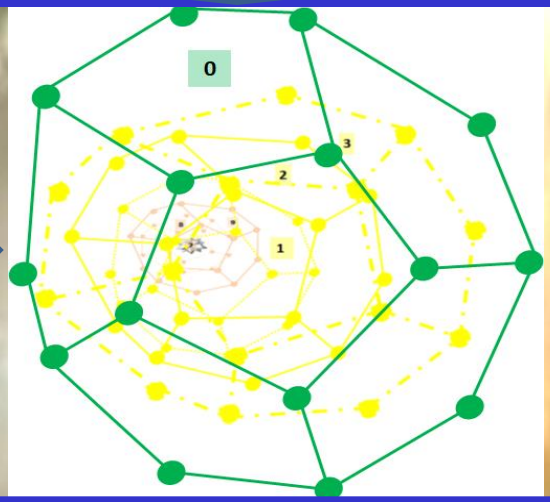
$$m^{(k)} \equiv \sum_{l=0}^{8} m_l^{(k)} i_l^{(k)}$$

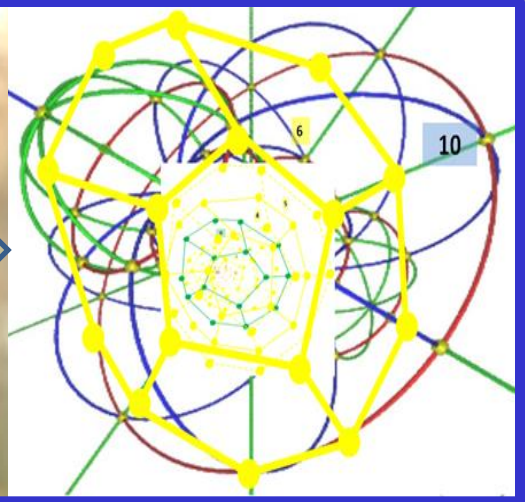
$$\psi^{2\,(k)} \equiv \sum_{l=0}^{8} \psi^{2}{}_l^{(k)} i_l^{(k)}$$



spacestates







Principle 3: KP is asymptotically stable and complete. However the resultant final structure of this process, which is a CAS, may not be known by its detailed phenomenological characteristics, nor predicted, but rather known for its dominant syzygies.

The invariants are called syzygies and they are in the format described by (1) and (2)

$$\text{Gen [NES]} = [\text{EnTh EnI Sy Em NInCx Fr}] \quad (1)$$

$$\text{Syzygy [NES]} = f\ (\text{Gen[NES]}) \quad (2)$$

There are some specific generators (in the sense of syzygy theory) for a K(i) structure built for NES:

- Exergy (Ex) of a NES (defined as the maximum useful work possible during a process that brings the system into equilibrium with a heat reservoir), as a measure of the efficiency of an energy conversion process. This generator has some specific characteristics:
  - It is conserved only when all processes of the system and the environment are reversible
  - It is destroyed whenever an irreversible process occurs.
- Entropy in a thermodynamic (EnTh) interpretation as a measure of disorder
- Information entropy (EnI) (as a measure of knowledge limits themselves)

Principle 3 (cont'd)

- Synergy (Sy) as a measure of a resultant set of features for a NES appearing from the existence and interaction of all systems and subsystems, leading to a set of characteristics for the whole NES than exist in the sum of its parts
- Emergence (Em) from one level to another (in the example for NES presented from SQ to CSU) a process in which larger entities, patterns, and regularities arise through interactions among smaller or simpler entities that themselves do not exhibit such properties and evolve to new levels.
- Nonlinearity (even for simple systems) and/or complexity (NlnCx) of NES as sources of chaotic structure and behavior
- Features of CAS—fractals type of structure (Fr) of NES and K(i) knowledge topological structures built for them.

The physical meaning of the dominating syzygies, defining the phase change of ES (NES and MMES) is that they are a triadic set of characteristics of the state of the ES/syzygies and are:

Energy (E)
Mass (m)
Entropy (ψ)

$$E^{(k)} = E_0^{(k)} + \sum_{j=1}^{8} E_j^{(k)} * z_j^{(k)} \quad (3)$$

$$m^{(k)} = m_0^{(k)} + \sum_{j=1}^{8} m_j^{(k)} * z_j^{(k)} \quad (4)$$

$$\psi^{(k)} = \psi_0^{(k)} + \sum_{j=1}^{8} \psi_j^{(k)} * z_j^{(k)} \quad (5)$$

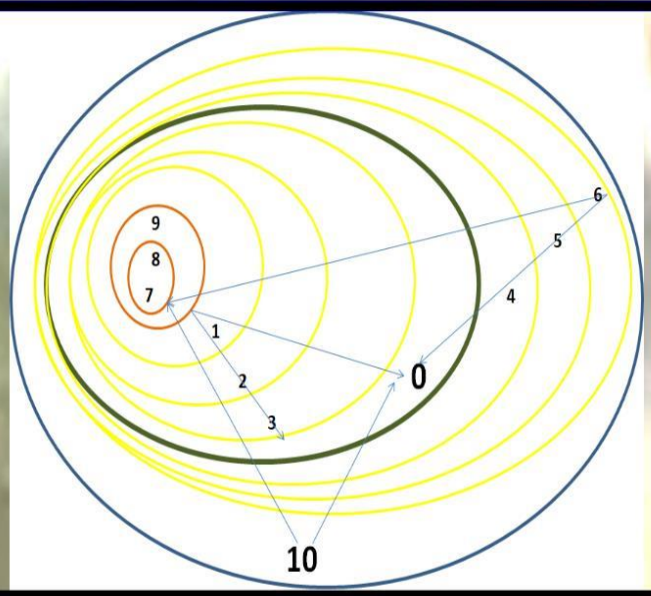
These are optimal descriptors of each ES states where:

- E_0, m_0, ψ_0 –and $E_1^{(k)}*i_1^{(k)}$; $m_1^{(k)}*i_1^{(k)}$ $\psi_1^{(k)}*i_1^{(k)}$ (Noted for the states 0 and 1) define the term called real energy/mass/entropy; examples of energy in such states are the energies perceived at Earth level by a human observer (including such as NES_Oklo), defining the Real Reality.
- indexes 2 and 3 the simple complex part (for the states 2 and 3); examples of states of this type are the paranormal phenomena, energies, information channels perceived by a human observer becoming part of the observed object, defining the Intuition Reality of the second level Realm (cosmic) and
- the rest of components are the hyper-complex part (for the states 4–8); examples are states of paradoxical situations coming from other realities and totally unexplainable for a human observer, but managing them by **enantiotropy feedback chain (entropy of states of the triadic ES)** and they are our connection to the Universe Realm and diverse realities (Universes) – A triadic set of syzygies defined the set of Realities

$$R^{(k)} = R_0^{(k)} + \sum_{j=1}^{k} R_j^{(k)} * i_j^{(k)} \qquad (6)$$

CATS (1) Energy Systems at various levels

Type of energy systems	Abbreviation	Notation as per Figure
Sub quantic	SQ	7
Quantic	Q	8
Molecular	M	9
Molecular life	ML	1
Planetary	P	2
Planetary life	PL	3
Planetary life intelligent	PLI	0
Galaxy	G	4
Cosmic	C	5
Cosmic life	CL	6
Cosmic Intelligent	CLI	10



$$E^{(k)} \equiv \sum_{l=0}^{8} E_l^{(k)} i_l^{(k)}$$

$$m^{(k)} \equiv \sum_{l=0}^{8} m_l^{(k)} i_l^{(k)}$$

$$\psi^{2(k)} \equiv \sum_{l=0}^{8} \psi^{2}{}_l^{(k)} i_l^{(k)}$$

$$E_{ini}^{(k)}(t) = \sum_{l=0}^{8}\left(\left(m_l^{(k)}(t) * c^2\right) * \psi^{((k)^2)} * i_l^{(k)}\right)$$

m - mass

C - speed of light

ψ^2 – entropy; ψ^2 is expressed in general as information entropy, but being actually a matrix of elements describing the entropies at various levels and for various types of energy systems.

- **The full expression of the multilevel energy system of CATS type, for any system is considered as above**
- **The transitions from one state to another for a given system and from one system to another take place in accordance with a transformation matrix governed by self-regulating mechanisms described by a general form of cybernetics (Hypercybernetics)**

$$E^{(k)} \equiv \underbrace{E_0^{(k)} i_0^{(k)} + E_1^{(k)} i_1^{(k)}}_{01} + \underbrace{E_2^{(k)} i_2^{(k)} + E_3^{(k)} i_3^{(k)}}_{23} + \underbrace{E_4^{(k)} i_4^{(k)} + E_5^{(k)} i_5^{(k)} + E_6^{(k)} i_6^{(k)} + E_7^{(k)} i_7^{(k)} + E_8^{(k)} i_8^{(k)}}_{4\text{-}8}$$

Real energy — Complex energy — Hypercomplex energy

C. EXEMPLE – STUDII DE CAZ

Studii de caz

A. **Intercompararea riscurilor** pentru diverse sisteme de energie (terestră, în accepțiunea curentă) și soluții de căutare cu unele exemple pentru asigurarea unei securitaăți și rezilienţe energetice locale/regionale

B. **Transformarile unor sisteme de energie cu componente biologice** la provocări externe (cazul COVID)

C. **Riscurile inovării în sistemele energetice**, cu exemple din domeniul nuclear

A.Intercompararea riscurilor pentru diverse sisteme de energie (terestră, în accepțiunea curentă) și soluții de căutare

cu unele exemple pentru asigurarea unei securități și rezilience energetice locale/regionale si evaluari de risc in sisteme complexe

CAZ A1 SECURITATEA ENERGETICA

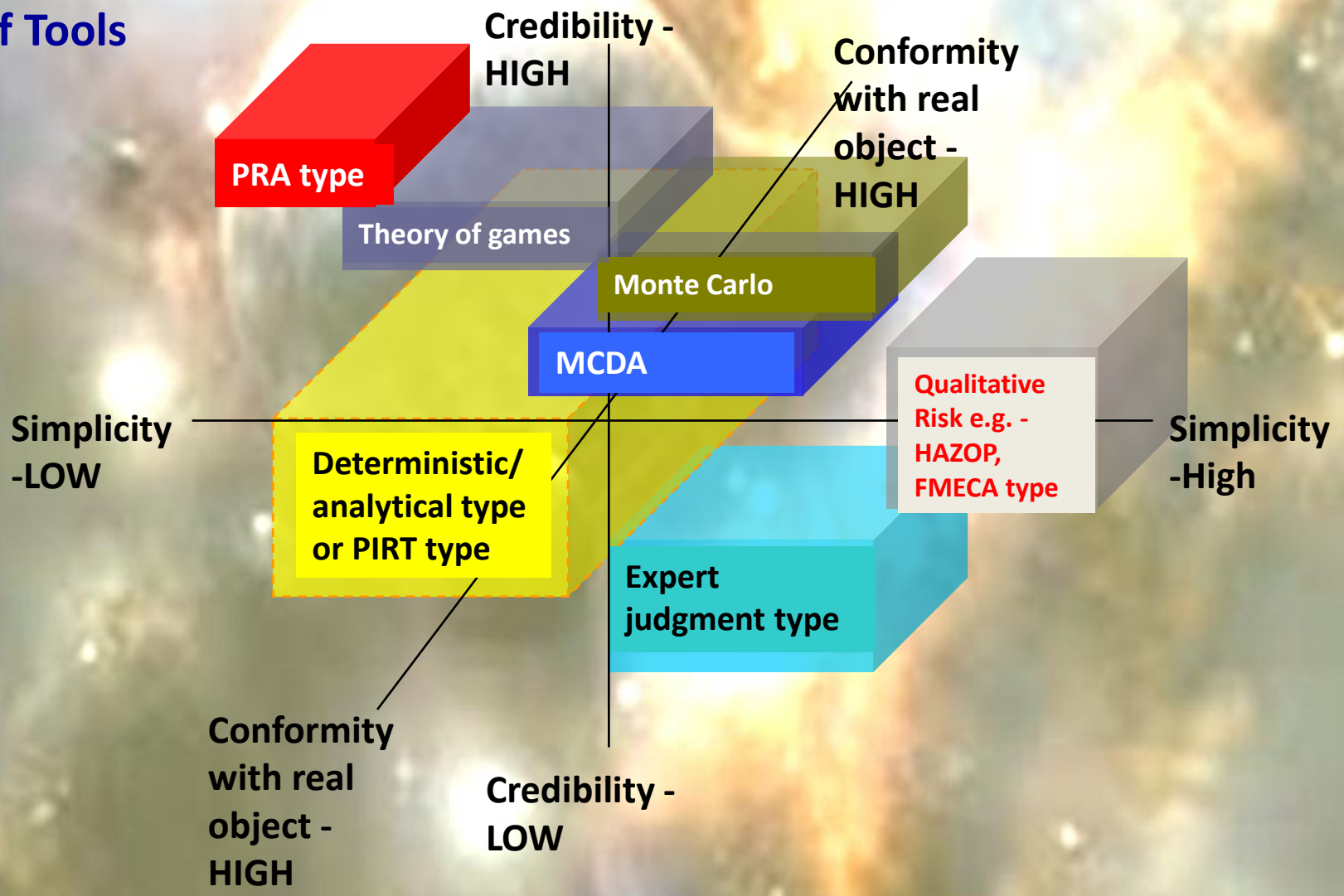
- **MODEL CLASIC si CAS**
- **METODE 1-3**

Scenarii orientate spre asigurarea securitatii energetice- REZILIENTA / ROBUSTETEA

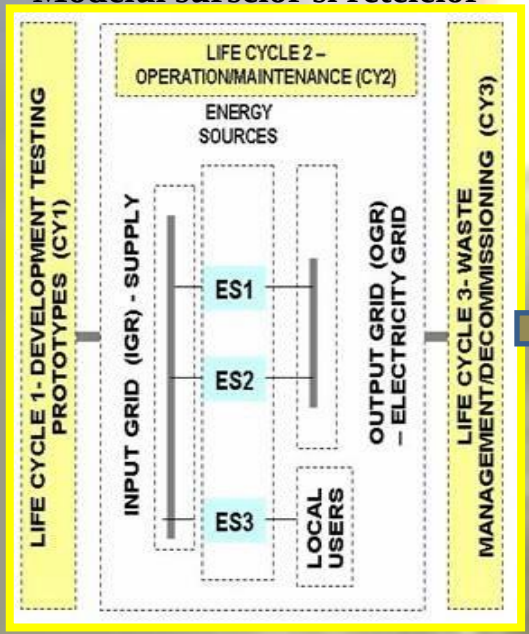
Exprimata de exemplu prin capacitatea de a supravietui in regim apropiat de normal dupa orice fel de provocari

sistemelor nationale, regionale

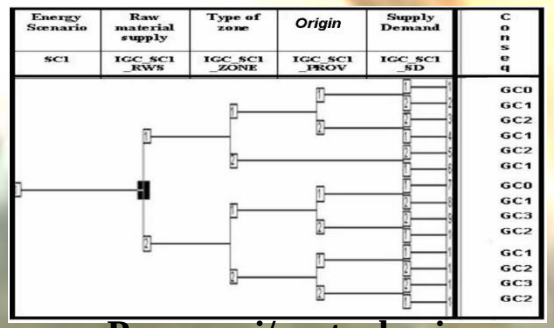
Map of Tools


Credibility - HIGH
Conformity with real object - HIGH
PRA type
Theory of games
Monte Carlo
MCDA
Simplicity -LOW
Deterministic/ analytical type or PIRT type
Qualitative Risk e.g. - HAZOP, FMECA type
Simplicity -High
Expert judgment type
Conformity with real object - HIGH
Credibility - LOW

Modelul surselor si retelelor



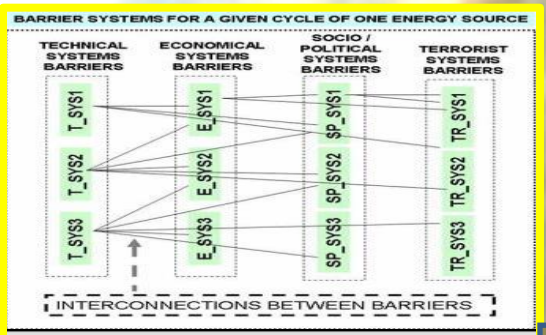
Conditii initiale



Provocari/perturbari

IE_ES1_CY2_SP1	Initiating Event SP1 for SC1 ES1 Cy2
IE_ES1_CY3_SP1	Initiating Event SP1 for SC2 ES1 CY3
IE_ES2_CY1_SP1	Initiating Event SP1 for SC2 ES2 Cy2
IE_ES2_CY2_SP1	Initiating Event SP1 for SC3 ES2 Cy2
IE_ES3_CY2_SP1	Initiating Event SP1 for SC3 ES3 Cy2
IE1_ES1_CY2_E1_0	IE ES1_0 for SC1 ES1 Cy2
IE1_ES1_CY2_E1_1	IE ES1_1 for SC1 ES1 Cy2
IE1_ES1_CY2_E1_2	IE ES1_2 for SC1 ES1 Cy2
IE1_ES1_CY2_T1_0	IE T1_0 for SC1 ES1 Cy2
IE1_ES1_CY2_T1_1	IE T1_1 for SC1 ES1 Cy2
IE1_ES1_CY2_T1_2	IE T1_2 for SC1 ES1 Cy2

Interfete interne



	T1	T2	T3	E1	E2	E3	SP1	SP2	SP3
T1	1	0	0	1	0	0	0	0	0
T2	0	1	0	1	1	1	1	1	1
T3	0	0	1	1	1	1	1	1	1
E1	1	1	1	1	0	0	0	1	1
E2	0	1	1	0	1	0	1	1	1
E3	0	1	1	0	0	1	1	1	1
SP1	0	1	1	0	1	1	1	0	0
SP2	0	1	1	1	1	1	0	1	0
SP3	1	1	1	1	1	1	0	0	1

	SURV3 MCS				
6	ES1_CY3_E_SYS1	GC2_SF	IE_SC1_ES2_CY3_TR1		
31	ES2_CY3_E_SYS1	ES2_CY3_E_SYS_SWSF	GC2_SF	IE_SC1_ES2_CY3_TR1	
33	ES2_CY3_SP_SYS1	ES2_CY3_SP_SYS_SWSF	GC2_SF	IE_SC1_ES2_CY3_TR1	
45	GC2_SF	IE_SC1_ES2_CY3_TR1	IGR_CY3_E_SYS1	IGR_CY3_E_SYS_SWSF	
77	GC2_SF	IE_SC1_ES2_CY3_TR1	OGR_CY3_SP_SYS1	OGR_CY3_SP_SYS_SWSF	
78	GC2_SF	IE_SC1_ES2_CY3_TR1	OGR_CY3_E_SYS1	OGR_CY3_E_SYS_SWSF	
95	ES1_CY3_E_SYS1	GC1_SF	IE_SC1_ES2_CY3_TR1		
436	GC2_SF	IE_SC1_ES2_CY3_TR2	IGR_CY3_SP_SYS1	IGR_CY3_SP_SYS_SWSF	
442	ES2_CY3_SP_SYS1	ES2_CY3_SP_SYS_SWSF	GC2_SF	IE_SC1_ES2_CY1_TR2	
2651	ES3_CY3_SP_SYS1	ES3_CY3_SP_SYS_SWSF	GC1_SF	IE_SC1_ES2_CY3_T2	
2669	ES1_CY3_E_SYS2	GC1_SF	IE_SC1_ES2_CY3_T2		
3811	ES2_CY3_E_SYS1	ES2_CY3_E_SYS_SWSF	GC0_SF	IE_SC1_ES2_CY3_T1	
4141	ES1_CY3_SP_SYS2	ES1_CY3_SP_SYS_SWSF	GC2_SF	IE_SC1_ES2_CY3_TR2	
6952	ES3_CY3_SP_SYS2	ES3_CY3_SP_SYS_SWSF	GC0_SF	IE_SC1_ES2_CY3_T1	
10834	ES1_CY3_T_SYS1	ES1_CY3_T_SYS2	ES3_CY3_T_SYS_SWSF	GC0_SF	IE_SC1_ES2_CY3_T1
587	ES2_CY3_E_SYS1	ES2_CY3_E_SYS_SWSF	GC2_SF	IE_SC1_ES2_CY1_TR2	
588	ES2_CY3_E_SYS1	ES2_CY3_E_SYS_SWSF	GC2_SF	IE_SC1_ES2_CY2_TR2	

	Components and their occurrence / failure impact for a SS system SURV3 (as defined in Table 1)	Rank of Impact	Confidence in results	Group of impact
	Failure of the barrier defined by System 2 of TR type, for ES2 in cycle CY1	H	L	I – HL
A	Failure of the barrier defined by System 2 of SP type, for ES2 in cycle CY2	H	L	
	Failure of the barrier defined by System 2 of T type, for ES1 in cycle CY2	H	L	
	Failure of the barrier defined by System 2 of E type, for ES1 in cycle CY3	H	M	II – HM
B	Occurrence of an IE (Challenge) to OGR of TR2 type in cycle CY2	H	M	
	Failure of the barrier defined by System 1 of TR type, for ES1 in cycle CY1	H	M	
	Occurrence of an IE (Challenge) to OGR of T2 type in cycle CY2	M	L	III – ML
C	Failure of the barrier defined by System 1 of T type, for OGR in cycle CY2	M	L	
	Failure of the barrier defined by System 2 of T type, for ES3 in cycle CY1	M	L	
	Initial consequence of worst type (GC3)	H	H	IV – HH
D	Failure of the barrier defined by System 2 of SP type, for ES1 in cycle CY1	H	H	

		SURV3 IMP	Impact rank	Uncertanty results	Groups
137	ES2_CY1_TR_SYS2	Failure of System 2 ES2 TR Cy1	H	L	I=HL
159	IGR_CY2_E_SYS2	Failure of System 2 IGR E Cy2	H	L	
166	ES2_CY2_SP_SYS2	Failure of System 2 ES2 SP Cy2	H	L	
167	IE_SC1_OGR_CY3_SP2	IE SP2 for SC1 OGR Cycle3	H	L	
285	ES1_CY2_T_SYS2	Failure of System 2 ES1T Cy2 considering switches	H	L	
35	ES1_CY3_E_SYS2	Failure of System 2 ES1 E Cy3	H	M	II=HM
39	IE_SC1_OGR_CY2_TR2	IE TR2 for SC1 OGR Cycle2	H	M	
145	ES3_CY1_TR_SYS1	Failure of System 1 ES3 TR Cy1	H	M	
180	ES1_CY1_E_SYS1	Failure of System 1 ES1 E Cy1 considering switches	H	M	
115	IE_SC1_OGR_CY2_T2	IE T2 for SC1 OGR Cycle2	M	L	III=ML
116	IE_SC1_IGR_CY2_T2	IE T2 for SC1 IGR Cycle2	M	L	
258	OGR_CY2_T_SYS1	Failure of System 1 OGR T Cy2	M	L	
292	ES3_CY1_T_SYS2	Failure of System 2 ES3 T Cy1	M	L	
3	GC3_SF	Weight of chossing GC3	H	H	IV=HH
98	ES3_CY2_SP_SYS_SWSF	Split fraction not considering switches for failure of Systems ES3 SP Cy2	H	H	

SES - General[2] Survivability Group (SES - GSG)	Short Description of General Survivability Group	SES - Specific Survivability Subgroup Combination of categories defined in Table 2 (Binning)
SURV 0	Very Low Impact leading to no significant follow up corrective actions needed (NCO)	T0 E0 E1 T1
SURV 1	Small Impact leading to Minor follow up corrective actions needed (CO1)	E2 T2 E0T1 E0E1 E0T1 E0T0 E0T1 E1T0
SURV 2	Medium Impact leading to Some Important follow up corrective actions needed (CO2)	E1E2 E1T1 E1T2 E2T1
SURV 3	High Impact leading to Major follow up corrective actions needed (TCO)	E2T2

	Components and their occurrence / failure impact for a SES state of type SURV3 (as defined in Table 1)	Rank of Impact	Confidence in results	Group of impact
	Failure of the barrier defined by System 2 of TR type, for ES2 in cycle CY1	H	L	I - HL
A	Failure of the barrier defined by System 2 of SP type, for ES2 in cycle CY2	H	L	
	Failure of the barrier defined by System 2 of T type, for ES1 in cycle CY2	H	L	
	Failure of the barrier defined by System 2 of E type, for ES1 in cycle CY3	H	M	II - HM
B	Occurrence of an IE (Challenge) to OGR of TR2 type in cycle CY2	H	M	
	Failure of the barrier defined by System 1 of TR type, for ES1 in cycle CY1	H	M	
	Occurrence of an IE (Challenge) to OGR of T2 type in cycle CY2	M	L	III - ML
C	Failure of the barrier defined by System 1 of T type, for OGR in cycle CY2	M	L	
	Failure of the barrier defined by System 2 of T type, for ES3 in cycle CY1	M	L	
	Initial condition of worst type (GC3)	H	H	IV - HH
D	Failure of the barrier defined by System 2 of SP type, for ES1 in cycle CY2	H	H	

Challenge consists of a failure of barrier 2 of socio- political type for ES1, i.e. nuclear (e.g. failure of reaching consensus between government, industry and public regarding the continuation of nuclear power plant prediction (cycle 2). In this scenario, the decision-maker could shut down the nuclear plant, but this could have serious repercussions to the entire survivability of the whole energy system, as nuclear is one of the important sources of the energy mix. However, this could lead to even worse public reaction when they will realize that their everyday lives may be drastically changed due to lack of electricity. Thus, as this scenario is of high-risk and high confidence, the decision-maker may have no other choice but to speedily re-open dialogue with the public to seek consensus on the best course of action

CAZ A2 ANALIZE RISC DIVERSE SISTEME ENERGETICE 1

- **MODEL CLASIC si CAS**
- **METODE 1-3**

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Indicators to compare risk expressions, grouping, and relative ranking of risk for energy systems: Application with some accidental events from fossil fuels

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ABSTRACT

The comparative assessment of risk issues related to different energy systems across their steps in the fuel/life cycle is highly challenging due to the large variety of heterogeneous risk expressions, and is further complicated by the difficulty in grouping different criteria of evaluation for ranking purposes. Based on our previously developed set of 17 Risk Characterization Indicators (RCIs) to measure different risk facets, a PRA-based logic-related grouping and ranking methodology to compare and rank risks from different energy technologies is illustrated and applied. The application takes into account three fossil fuels (coal, natural gas, and oil) using selected illustrative examples in open-source form, chosen from the database ENSAD (Energy-related Severe Accident Database). The events are processed with the RCIs and ranked according the proposed methodology. The RCIs can be used either for (1) analysis of single events, (2) for comparison of events with similar characteristics, (3) for comparison of different energy technologies based on aggregated values, and (4) within Multi-Criteria Decision Analysis (MCDA) to rank events and energy chains. The benefits and limits of the energy risks comparative methodology are discussed, considering its potential to support the management of energy-related risks.

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1. Introduction

This paper focuses on the validation of a set of Risk Characterisation Indicators (RCIs), which have been developed to assist in the comparison of energy risk expressions from different energy systems. Its principal aim is to demonstrate the methodology to group the RCIs and subsequently to rank events to which they are applied.

The present work brings further what already was initiated in (Colli et al., 2008), enhancing the set of RCIs with an innovative grouping and ranking approach based on PRA-related concepts and logic.

Summary information from few selected events from the ENSAD (Energy-related Severe Accident Database – continuously maintained and extended by the Paul Scherrer Institut) database is used to validate the process (Burgherr and Hirschberg, 2008; Burgherr et al., 2004; Hirschberg et al., 2004). They cover accidental events (not terrorist attacks) of significant outcomes, such as explosion/fire in fixed facilities and in pipelines, from the coal, natural gas, and oil chains, for the extraction, treatment, and regional transportation stages of the fuel cycle. The results obtained are discussed in view of the existing literature on fossil fuels.

In addition, two alternative evaluation paths for the RCIs are introduced and evaluated on the base of the same group of ENSAD cases in comparison with the main method in the paper.

To be complete, the presented methodology needs the evaluation of the quality of the process. This will be obtained through the evaluation and quantification of the uncertainty of the process, based on the contribution of the various uncertainties coming from each single step performed. This part is under development.

The paper is divided into eight sections. After the introduction, Section 2 recalls relevant information about the set of RCIs (Colli et al., 2008). Section 3 gives a theoretical description of the innovative grouping and ranking methodology. Section 4 applies the risk comparative methodology to a selected number of accidental events affecting fossil fuels extracted from the ENSAD database. Section 5 discusses the results obtained for the single steps of the fuel cycle with possibility of analysis. Section 6 shows the overall relative ranking of risks among the natural gas and the oil chains, validating the results on the base of existing literature. Section 7 presents other two evaluation paths, both based on the amount of electricity production for each of the involved coal, natural gas, and oil chains. In conclusion, general considerations are introduced, based on the validity, benefits, and limits of the methodology.

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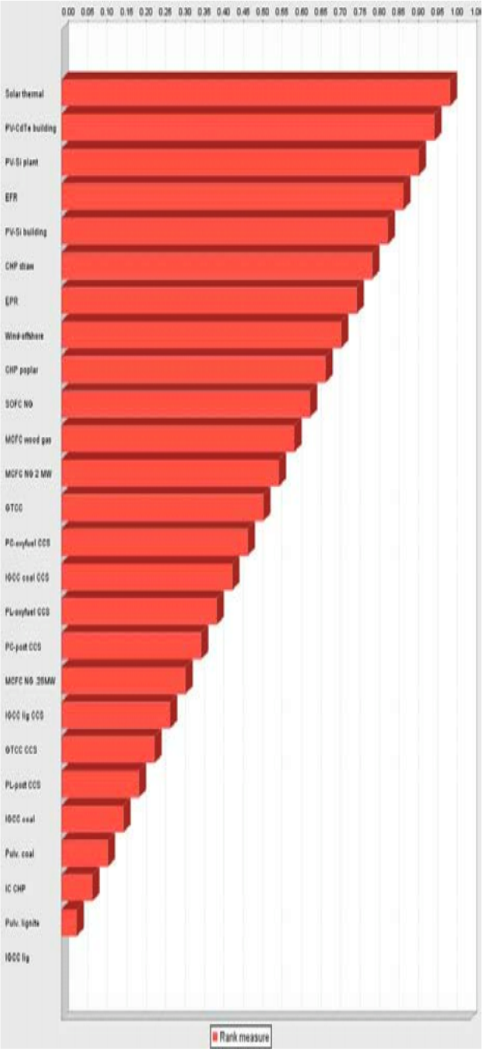
Figure 12 - The Ranking Graph and Ranking Table screens.



Ranking list

Rank	Short name	Long name
1	Solar thermal	Solar Thermal, Parabolic Trough
2	PV-CdTe building	Photovoltaic, CdTe, Building integrated
3	PV-Si plant	Photovoltaic, Silicon, Plant size
4	EFR	European Fast Reactor
5	PV-Si building	Photovoltaic, Silicon, Building integrated
6	CHP straw	Combined Heat & Power, Wheat Straw
7	EPR	European Pressurized Reactor
8	Wind-offshore	Wind Turbines, Offshore
9	CHP poplar	Combined Heat & Power, Poplar
10	SOFC NG	Solid Oxide Fuel Cell, Natural Gas
11	MCFC wood gas	Molten Carbonate Fuel Cell, Wood Gas
12	MCFC NG 2 MW	Molten Carbonate Fuel Cell, Natural Gas
13	GTCC	Gas Turbine Combined Cycle
14	PC-oxyfuel CCS	Pulverized Coal Steam Plant, oxyfuel carbon capture
15	IGCC coal CCS	Integrated Gasification Combined Cycle, Coal, carbon capture
16	PL-oxyfuel CCS	Pulverized Lignite Steam Plant, oxyfuel carbon capture
17	PC-post CCS	Pulverized Coal Steam Plant, post-combustion carbon capture
18	MCFC NG .25MW	Molten Carbonate Fuel Cell, Natural Gas
19	IGCC lig CCS	Integrated Gasification Combined Cycle, Lignite, carbon capture
20	GTCC CCS	Gas Turbine Combined Cycle, carbon capture
21	PL-post CCS	Pulverized Lignite Steam Plant, post-combustion carbon capture
22	IGCC coal	Integrated Gasification Combined Cycle, Coal
23	Pulv. coal	Pulverized Coal (PC) Steam Plant
24	IC CHP	Internal Combustion Cogeneration
25	Pulv. lignite	Pulverized Lignite (PL) Steam Plant
26	IGCC lig	Integrated Gasification Combined Cycle, Lignite

Close | Contact | Technology Descriptions

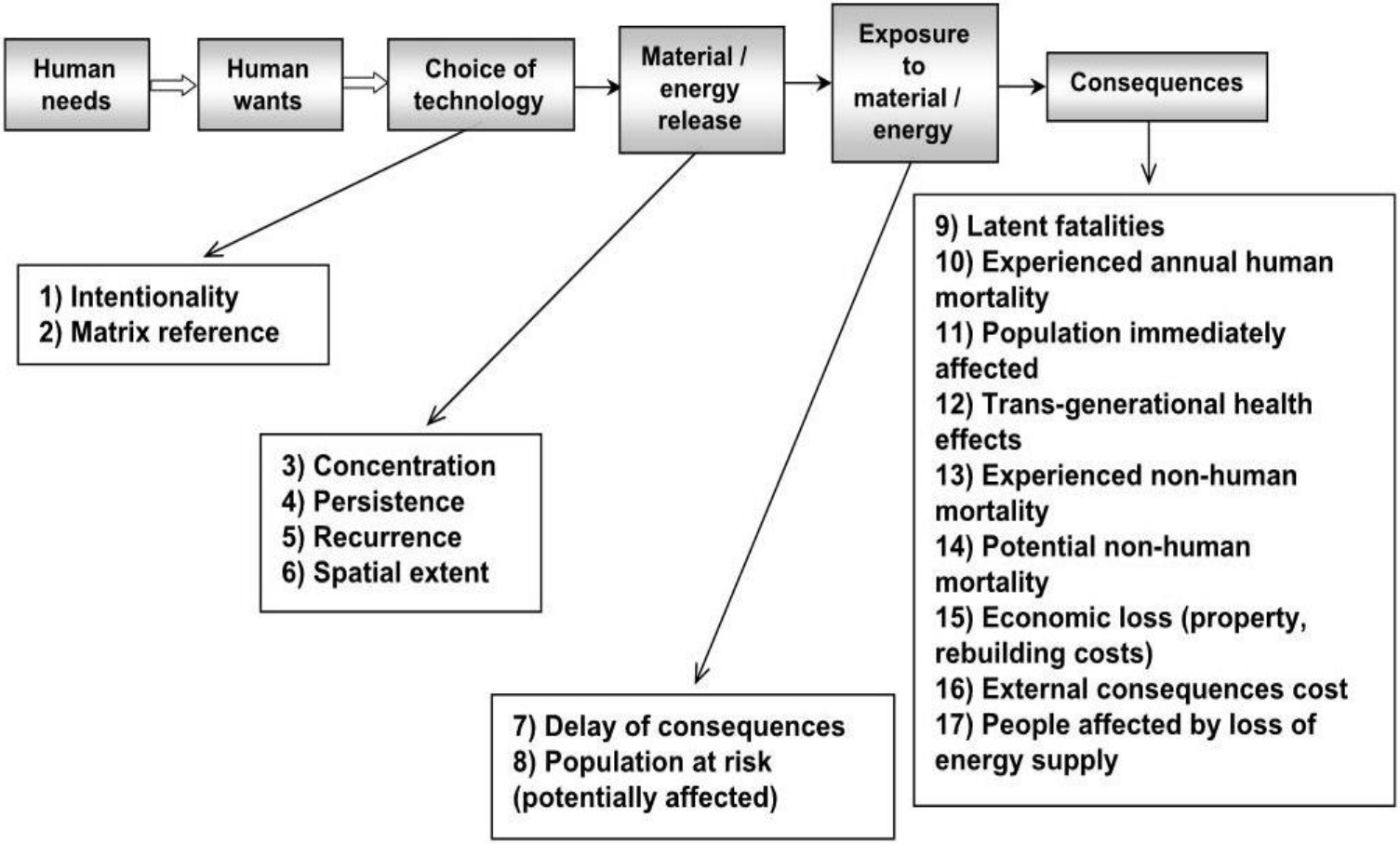
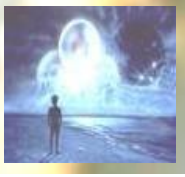


Fig. 1. Causal structure for energy systems and the linked set of RCIs.

CAZ A3 ANALIZE RISC DIVERSE SISTEME ENERGETICE 2

- **MODEL CLASIC si CAS**
- **METODE 1-3**



PRA-Type Study Adapted to the Multi-crystalline Silicon Photovoltaic Cells Manufacture Process

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ABSTRACT: The paper presents a Probabilistic Risk Assessment type (PRA-type) study developed by the Institute of Energy of the Joint Research Centre of the European Commission (JRC-IE) for non-nuclear energy applications and adapted to the manufacture process for multi-crystalline silicon solar cells production. The study is in the context of a project, which is part of a PhD study that aims to develop a methodology to compare risks across different energy systems. Risk assessment and risk data collection efforts are under way in most energy sectors (nuclear, fossil, hydropower), making possible comparisons easier. The photovoltaic (PV) sector, as a new rapidly growing energy technology, offers opportunities for assessing possible risks mainly based on the quantity of dangerous chemicals used, but there seems to be a lack of reported information on its risk events. This situation makes it difficult to analyze the impact of the PV technology, especially if the attention is on human health. Therefore, other well-known methods to assess the safety level of PV manufacturing facilities, such as PRA, can be used to assess corresponding risk levels. The PRA methodology allows to evaluate preliminary quantification figures for failure frequencies, and to demonstrate the possible advantages in identifying the failure scenarios of the process itself, so that countermeasures can be considered. This paper presents first a detailed analysis of the PV manufacture process, conducted at a methodological level (knowledge of the single processes at every step, with chemicals introduced, and resulting as reaction products) as well as at a technical level (machinery involved, auxiliary systems). Next, on this basis, an event tree and fault tree model are constructed and the corresponding analysis performed, using data available from generic chemical industry data-bases. The results of this analysis show that it is possible to quantify the frequency of failures of such processes leading to health challenges and also to identify the scenarios leading to those end states. Even if the figures resulting from the existing models based on the information available so far indicate that such probabilities are unlikely in comparison with other industries, nevertheless the results indicate the existence of weak links. Such weak points could lead to possible health threats. The benefits of using such approaches in conjunction with other design tools are clear when performing risk reviews before events happen. Such an application would be in line with the best practice on these issues from other industrial fields (aviation, aero-space, nuclear, some other chemical processes). The use of such models in the framework of risk comparison could complement the data collected to support the development of the knowledge database on risks for various energy sources.

1 INTRODUCTION

Although the world's PV industry is still new when compared to other traditional energy sectors, PV is already now considered to be among the major renewable energy technologies of the future, with a positive growth rate for the coming years, and offering the benefits of an increasing number of jobs in Europe. The growth of PV is expected to be boosted also by the decision of the Council of the European Union in March 2007; "a binding target of a 20% share of renewable energies in overall EU energy consumption by 2020" (Council of the European Union 2007) has been agreed, which will also affect PV through the implementation of national programs.

However, in parallel to the high growth rate in the PV sector, there is a real need to increase attention also to the possible proportionate rise in risks. Risk considerations are necessary for both existing and for new technologies, and the PV sector shall thus not be excluded.

PV electricity generation is a zero-emission process regardless of which technology (materials and manufacturing process) is used, but the production processes of solar modules involve chemical substances, which, like in any other industrial process, can pose a threat to occupational safety, in terms of ess is very small (ECN 2007) compared to other chemical process industries, thus the possible related risk is also more limited.

Table 2. Output chemical substances from the multi-crystalline photovoltaic cell manufacture process into analysis. The information for hydrogen fluoride, nitrogen, ammonia, nitric acid, and solvents is considered in Table 1 and not repeated.

Substance	Indication of danger according to Directive 67/548/EEC (updated version Directive 92/32/EEC)	Associated risk
Sodium hydroxide (NaOH)	C: Corrosive	Severe burns.
Nitrogen dioxide NO_X (NO2)	T+: Very toxic	Toxicity.
Chlorine (Cl_2)	T: Toxic N: Dangerous for the environment	Toxicity, skin burns.
Diphosphorus pentoxide (P_2O_5)	C: Corrosive	Skin irritation, severe burns, harmful if inhaled.
Tetrafluoro silane (SiF_4)	Not classified	Toxicity.
Fluorine (F_2)	T+: Very toxic C: Corrosive	Fire, toxicity, severe burns.
Silicon dioxide (SiO_2)	Not classified	Toxicity.
Fluorosilicic acid (H_2SiF_6)	C: Corrosive	Severe burns.

3 METHODOLOGY

3.1Main features of the model and method used

The modelling of the process using the risk type approach is based on the standards used by the nuclear industry as shown in (NUREG2300) adapted to the specificity of the photovoltaic manufacturing process.

In order to perform this adaptation a series of assumptions and clarifications are needed. Previous work, showed in (Serbanescu et al. 2008) and (Serbanescu 2006), clarifies how the PRA process can be performed in other areas than the nuclear field and identifies which are the main challenges. However in this paragraph a short list of the main features of the model and the steps of the method are presented.

The target of the PRA modelling for the photovoltaic manufacturing facilities is to support the assessment of the corresponding risk levels of the process, the potential weak links and possible future improvements.

An attempt has been made to describe the installation phases, as shown in Figure 1. However, due to the limited information accessible in open source, the results obtained will have relevance only from the point of view of highlighting the methodology and identifying relative importance and ranking of various issues between them.

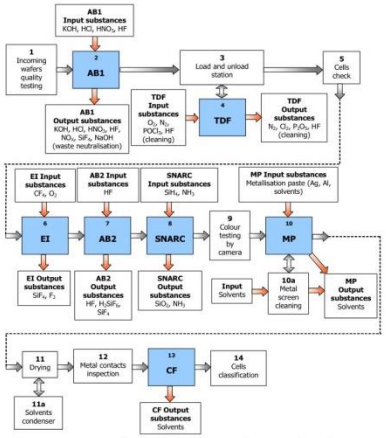

Figure 1. The multicrystalline silicon photovoltaic cells manufacture process. The highlighted boxes are those including the processes which required special modeling due to the chemical substances involved. The codes are: AB=acid bath, TDF=tube diffusion furnace, EI=edge isolation, SNARC=silicon nitride anti-reflective coating, MP=metallization process, CF=contact firing.

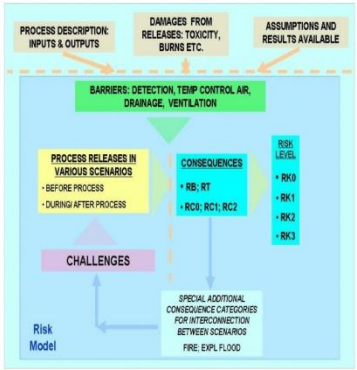

Figure 2. Main Flow of a quantitative risk analysis. For the explanation of consequences and risk categories see Table 3.

The main flow of the PRA methodology used for this case is shown in Figure 2. The process of developing the PRA model is based on process descrip-

happened and various barriers (represented in the upper horizontal bar) fail to protect the installation.

The description of the failure of barriers is performed in a set of trees defining the manner the barrier can fail to perform its function, as represented in Figures 7 and 8.

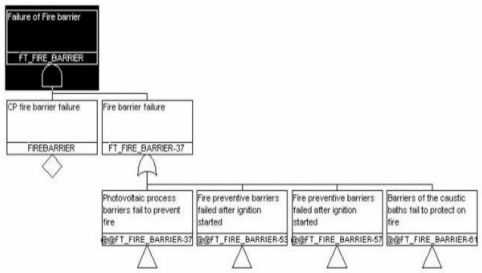

Figure 7. Sample fault tree for a barrier

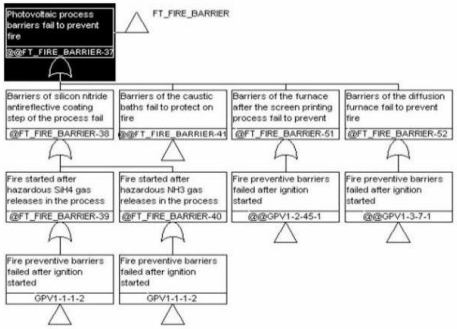

Figure 8. Sample Fault tree for a barrier

The frequency of initiating events is calculated in PRA using either results from existing database of failures (if that exists) or by developing special type of fault trees for the IE frequency calculation (if there are no data on IE). A sample for such fault trees built in our case is represented in Figures 9, 10, 11, 12, 13 and 14.

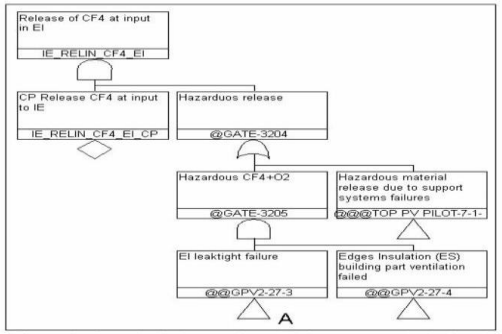

Figure 9. Sample fault tree for a IE frequency calculation. The top event considered covers the release of CF4 at input of the edge isolation (EI) process. Branch A is further developed as shown in the following Figure 10.

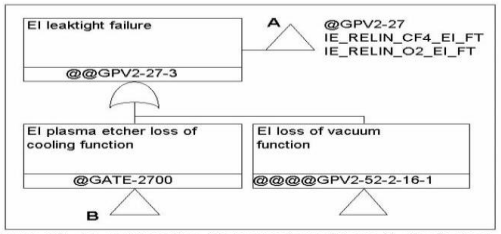

Figure 10. As continuation from previous Figure 9, the further development of branch A is presented. The path along branch B is shown in the following Figure 11.

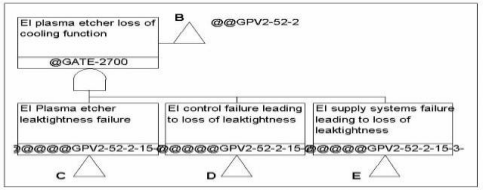

Figure 11. Development of branch B as from Figure 10. Further investigation is needed for gates C, D, and E. The progress is shown in the following Figure 12, 13 and 14.

CATEGORY OF CONTRIBUTOR	CONTRIBUTOR	Rank of the impact of a given contributor to the end states								
		RB	RT	RC0	RC1	RC2	RK0	RK1	RK2	RK3
RELEASE AT INPUT OF PROCESS	SILANE	L	L	L	L	M	L	L	L	M
	OTHER FLAMABLE	L	L	L	L	M	L	L	M	M
	OTHER NON FLAMMABLE	M	M	M	M	L	M	M	L	L
RELEASE AT OUPUT OF PROCESS	SILANE	M	M	L	M	H	L	M	M	H
	OTHER FLAMABLE	M	M	L	M	H	L	M	M	H
	OTHER NON FLAMMABLE	L	L	M	M	H	M	M	L	L
AREA EVENTS	SEISMIC	L	L	NA	NA	M	NA	NA	L	L
	FLOOD	VL	VL	VL	VL	L	VL	VL	L	L
	FIRE	L	L	VL	VL	H	VL	VL	M	H
	EXPLOSIONS	L	L	VL	VL	H	VL	VL	M	H
INTERNAL PROCESS DESIGN ELEMENTS	LEAKTIGHNESS & VACUUM	L	L	L	L	M	L	L	M	L
	SUPPORT SYSTEMS	L	L	L	L	M	L	L	M	L
	HUMAN ERRORS	L	L	L	L	M	L	L	M	L
	OTHER	L	L	L	L	L	VL	VL	L	L
BARRIERS AS PROVIDED SO FAR TO PROTECT FROM DAMAGES DUE TO EVENTS / RELEASES	DETECTIOIN OF RELEASE/SPILL	M	M	L	M	M	L	M	M	L
	CLEANING ACTIONS TO PREVENT/LIMIT RELEASE/SPILL	M	M	M	L	M	M	L	M	L
	NEUTRALIZATION AFTER PROCESS TO PREVENT	L	L	L	L	M	L	L	M	L
	VENTILLATION OF RELEASE	L	L	L	L	M	L	L	M	M
	FIRE AND EXPLOSION BARRIERS	NA	NA	NA	NA	H	NA	NA	M	H
	DRAINAGE OF SPIL	M	M	M	L	M	M	L	M	M

Figure 15. Main results of the PRA for photovoltaic manufacturing process.

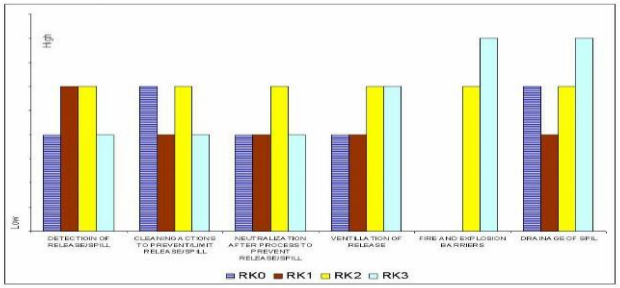

Figure 16. Main results of the PRA study for the specific PV manufacturing process, showing the level of contribution to risk of various barriers and systems. Cleaning actions and drainage of spill have the highest contribution to the low risk category RK0, while the highest input for high risk categories RK2 and RK3 comes from ventilation, fire and explosion, and drainage.

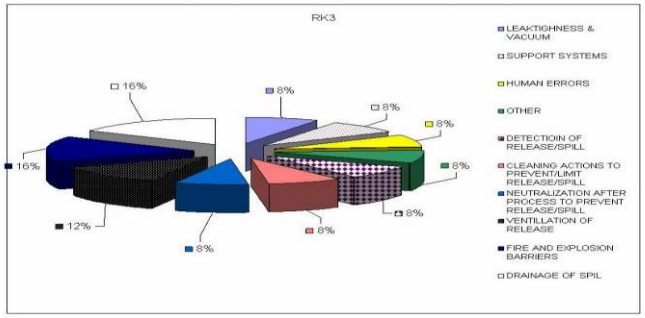

Figure 17. Detailed information concerning the contributors to RK3, as from Figure 16. No really dominant contribution is shown, even if the highest percentage is shared by fire and explosion barriers, and drainage of spill.

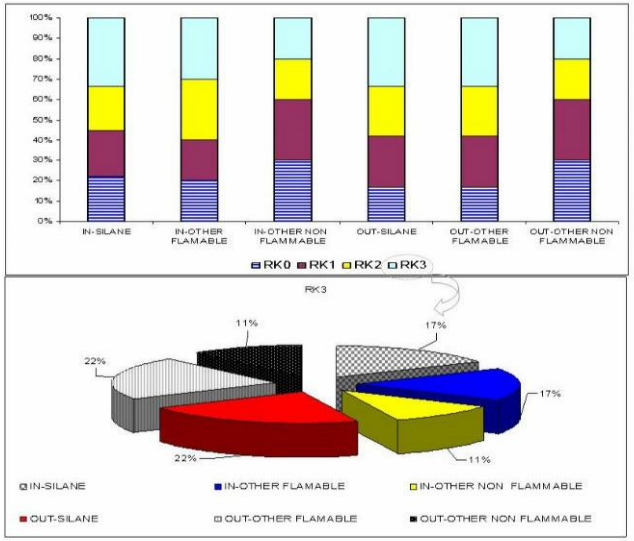

Figure 18. Main results of the PRA for photovoltaic manufacturing process showing the risk contribution of silane in comparison with other flammable and non-flammable substances. Non-flammable substances give the highest contribution to the low risk category RK0, while for the high risk category RK3 the situation is dominated by silane and flammable substances.

Methodology - Details on the model (2)

- **Event Tree for** a MUPSA model.
- **The model was built** based on real case.
- It **includes IE scenarios and end states**.
- The **Headings are defined by Fault Trees**
- **Use of logical conditions (NOR gates) and logical elements (called Switch elements) specific for each call of a certain Heading in an Event Tree**.
- **The logical switches assure the development of SUPSA to MUPSA, as illustrated in detail** in the literature

CAZ A4 ANALIZE RISC CNE

MODEL CLASIC si CAS

METODE 1-5

Methodology - Details on the model (2)

- **Event Tree for** a MUPSA model.
- **The model was built** based on real case.
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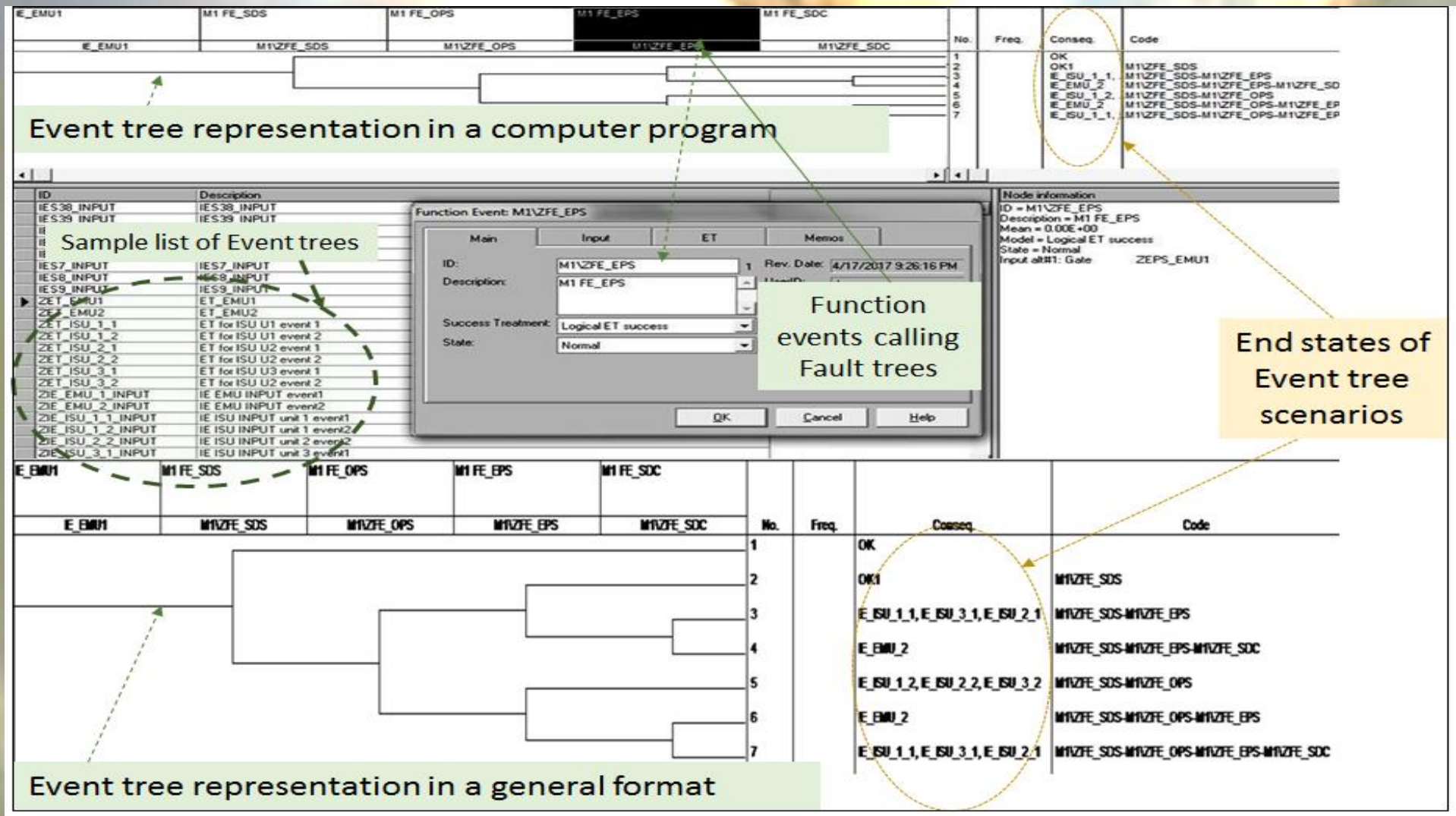
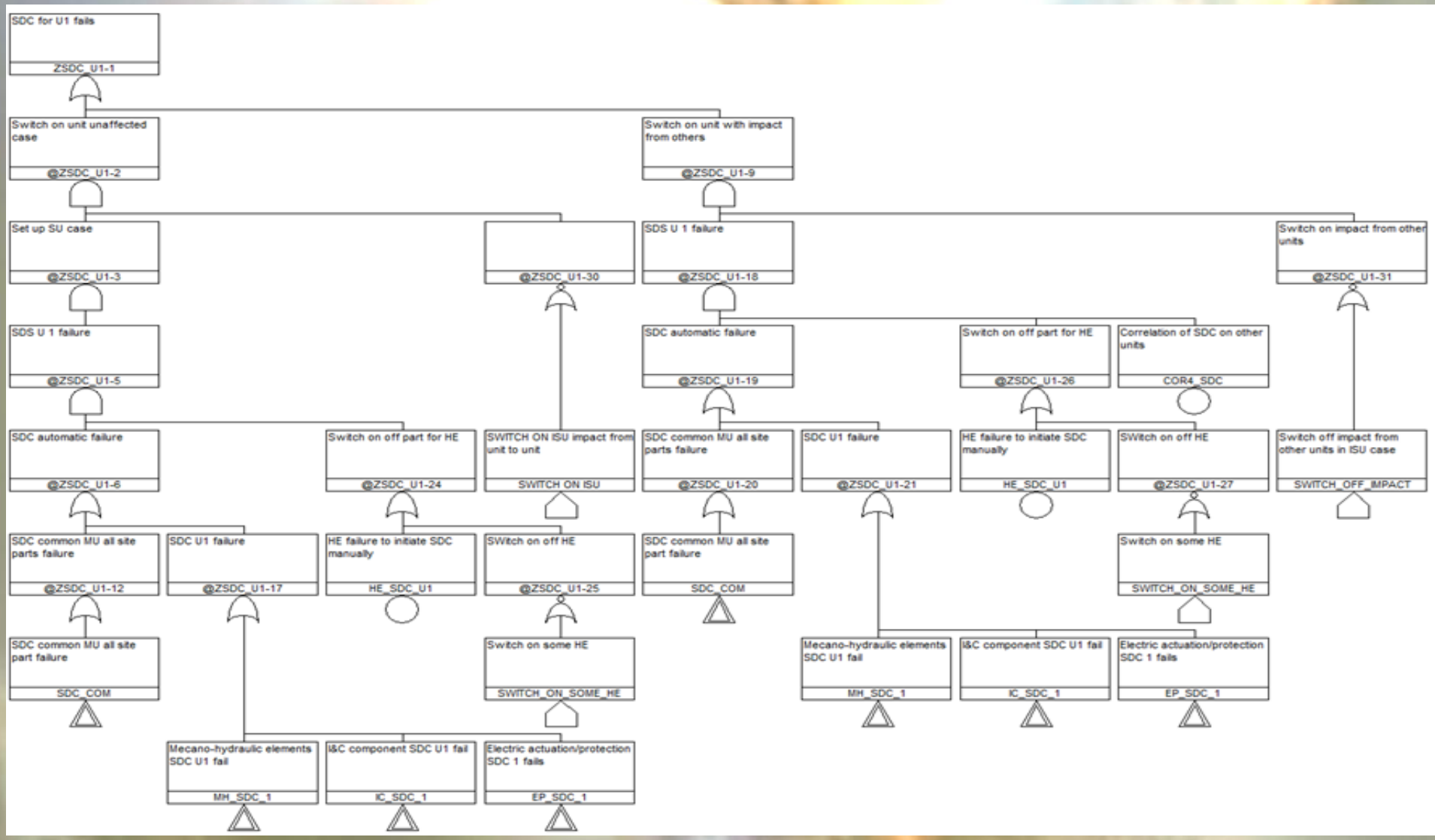

Event tree representation in a computer program
Sample list of Event trees
Function events calling Fault trees
End states of Event tree scenarios
Event tree representation in a general format


SDC for U1 fails
ZSDC_U1-1
Switch on unit unaffected case
ZSDC_U1-2
Switch on unit with impact from others
ZSDC_U1-9
Set up SU case
ZSDC_U1-3
ZSDC_U1-30
SDS U 1 failure
ZSDC_U1-18
Switch on impact from other units
ZSDC_U1-31
SDS U 1 failure
ZSDC_U1-5
SDC automatic failure
ZSDC_U1-19
Switch on off part for HE
ZSDC_U1-26
Correlation of SDC on other units
COR4_SDC
SDC automatic failure
ZSDC_U1-6
Switch on off part for HE
ZSDC_U1-24
SWITCH ON ISU impact from unit to unit
SWITCH ON ISU
SDC common MU all site parts failure
ZSDC_U1-20
SDC U1 failure
ZSDC_U1-21
HE failure to initiate SDC manually
HE_SDC_U1
SWitch on off HE
ZSDC_U1-27
Switch off impact from other units in ISU case
SWITCH_OFF_IMPACT
SDC common MU all site parts failure
ZSDC_U1-12
SDC U1 failure
ZSDC_U1-17
HE failure to initiate SDC manually
HE_SDC_U1
SWitch on off HE
ZSDC_U1-25
SDC common MU all site part failure
SDC_COM
Switch on some HE
SWITCH_ON_SOME_HE
SDC common MU all site part failure
SDC_COM
Switch on some HE
SWITCH_ON_SOME_HE
Mecano-hydraulic elements SDC U1 fail
MH_SDC_1
I&C component SDC U1 fail
IC_SDC_1
Electric actuation/protection SDC 1 fails
EP_SDC_1
Mecano-hydraulic elements SDC U1 fail
MH_SDC_1
I&C component SDC U1 fail
IC_SDC_1
Electric actuation/protection SDC 1 fails
EP_SDC_1

COR1H_ISU_	COR2_EPS	COR4_SDC	EPS_COM	EPS_U1	HE_SDC_U1	IE_ISU_1_2	MH_SDC_1							
COR1H_ISU_	COR2_EPS	COR4_SDC	EPS_COM	EPS_U1	HE_SDC_U1	IE_ISU_1_2	SDC_COM							
COR1H_ISU_	COR2_EPS	COR4_SDC	EPS_COM	EPS_U1	EP_SDC_1	HE_SDC_U1	IE_ISU_1_2							
COR1H_ISU_	COR2_EPS	COR4_SDC	EPS_COM	EPS_U1	HE_SDC_U1	IC_SDC_1	IE_ISU_1_2							
COR2_EPS	COR4_SDC	EPS_COM	EPS_U1	HE_SDC_U1	M2\HE_EPS	M2\HE_SDC	M2\SDC_COM	SDC_COM						
COR1H_ISU_	COR2_EPS	COR4_SDC	EPS_COM	EPS_U1	HE_SDC_U1	IE_ISU_1_2	MH_SDC-ALL							
COR1H_ISU_	COR2_EPS	COR4_SDC	EPS_COM	EPS_U1	EP_SDC-ALL	HE_SDC_U1	IE_ISU_1_2							
COR2_EPS	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	EP_SDC-ALL	EP_SDS_3	HE_SDC_U1	HE_SDC_U3	IE_ISU_3_1				
COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OTHER_H	EPS_COM	EPS_U1	EP_SDC_1	HE_SDC_U1	IC_SDS_1	IE_EMU_1	M1\HE_EPS	M1\HE_SDS	M1\MH_SDS	MH_SDS	
COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OTHER_H	EPS_COM	EPS_U1	EP_SDS	HE_SDC_U1	IC_SDS_1	IE_EMU_1	M1\EP_SDS	M1\HE_EPS	M1\HE_SDS	MH_SDC_1	
COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OTHER_H	EPS_COM	EPS_U1	EP_SDS_1	HE_SDC_U1	IC_SDC_1	IE_EMU_1	M1\HE_EPS	M1\HE_SDS	M1\MH_SDS	MH_SDS	
COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OTHER_H	EPS_COM	EPS_U1	EP_SDS	HE_SDC_U1	IC_SDC_1	IE_EMU_1	M1\EP_SDS	M1\HE_EPS	M1\HE_SDS	MH_SDS_1	
COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OTHER_H	EPS_COM	EPS_U1	HE_SDC_U1	IC_SDS	IE_EMU_1	M1\HE_EPS	M1\HE_SDS	M1\IC_SDS	MH_SDC_1	MH_SDS_1	
COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OTHER_H	EPS_COM	EPS_U1	EP_SDC_1	EP_SDS	EP_SDS_1	HE_SDC_U1	IE_EMU_1	M1\EP_SDS	M1\HE_EPS	M1\HE_SDS	
COR2_EPS	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	HE_SDC_U1	HE_SDC_U3	IC_SDS_3	IE_ISU_3_1	MH_SDC_1	MH_SDC_3			
COR2_EPS	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	HE_SDC_U1	HE_SDC_U3	IC_SDC_3	IE_ISU_3_1	MH_SDC_1	MH_SDS_3			
COR2_EPS	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	HE_SDC_U1	HE_SDC_U3	IC_SDC_1	IE_ISU_3_1	MH_SDC_3	MH_SDS_3			
COR2L_ISU_	COR2_EPS	COR2_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U2	EP_SDC_2	HE_SDC_U1	HE_SDC_U2	IE_ISU_2_1	MH_SDC_1	MH_SDS_2		
COR2L_ISU_	COR2_EPS	COR2_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U2	EP_SDS_2	HE_SDC_U1	HE_SDC_U2	IE_ISU_2_1	MH_SDC_1	MH_SDC_2		
COR2L_ISU_	COR2_EPS	COR2_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U2	EP_SDC_1	HE_SDC_U1	HE_SDC_U2	IE_ISU_2_1	MH_SDC_2	MH_SDS_2		
COR2_EPS	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	EP_SDC_1	EP_SDS_3	HE_SDC_U1	HE_SDC_U3	IE_ISU_3_1	MH_SDC_3			
COR2_EPS	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	EP_SDC_3	EP_SDS_3	HE_SDC_U1	HE_SDC_U3	IE_ISU_3_1	MH_SDC_1			
COR2_EPS	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	EP_SDC_1	EP_SDC_3	HE_SDC_U1	HE_SDC_U3	IE_ISU_3_1	MH_SDS_3			
COR1H_ISU_	COR1_ISU_I	COR2_EPS	COR3H_ISU_IE	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	HE_SDC_U1	HE_SDC_U3	IC_SDS-ALL	MH_SDC-ALL		
COR1H_ISU_	COR1_ISU_I	COR2_EPS	COR3H_ISU_IE	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	HE_SDC_U1	HE_SDC_U3	IC_SDC-ALL	MH_SDS-ALL		
COR1H_ISU_	COR1_ISU_I	COR2_EPS	COR3H_ISU_IE	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	EP_SDC_3	HE_SDC_U1	HE_SDC_U3	IC_SDC_1	MH_SDS-ALL	
COR1H_ISU_	COR1_ISU_I	COR2_EPS	COR3H_ISU_IE	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	EP_SDS-ALL	HE_SDC_U1	HE_SDC_U3	IC_SDC_3	MH_SDC_1	
COR1H_ISU_	COR1_ISU_I	COR2_EPS	COR3H_ISU_IE	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	EP_SDC_1	HE_SDC_U1	HE_SDC_U3	IC_SDC_3	MH_SDS-ALL	
COR1H_ISU_	COR1_ISU_I	COR2_EPS	COR3H_ISU_IE	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	EP_SDS-ALL	HE_SDC_U1	HE_SDC_U3	IC_SDC_1	MH_SDC_3	
COR1H_ISU_	COR1_ISU_I	COR2_EPS	COR3H_ISU_IE	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	HE_SDC_U1	HE_SDC_U3	IC_SDS-ALL	MH_SDC_1	MH_SDC_3	
COR1H_ISU_	COR1_ISU_I	COR2_EPS	COR3H_ISU_IE	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	EP_SDC_1	EP_SDC_3	EP_SDS-ALL	HE_SDC_U1	HE_SDC_U3	
COR1_OPS	COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EM	EPS_COM	EPS_U1	EP_SDS	HE_SDC_U1	IE_EMU_1	M1\EP_SDS	M1\HE_OPS	M1\HE_SDS	M1\OPS	SDC_COM
COR2L_ISU_	COR2_EPS	COR2_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U2	EP_SDS-ALL	HE_SDC_U1	HE_SDC_U2	IE_ISU_2_1	SDC_COM			
COR1_OPS	COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EM	EPS_COM	EPS_U1	HE_SDC_U1	IC_SDC_1	IE_EMU_1	M1\HE_OPS	M1\HE_SDS	M1\MH_SDS	M1\OPS	MH_SDS
COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OT	EPS_COM	EPS_U1	EP_SDS	HE_SDC_U1	IC_SDS_1	IE_EMU_1	M1\EP_SDS	M1\HE_EPS	M1\HE_SDS	SDC_COM	
COR2L_ISU_	COR2_EPS	COR2_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U2	HE_SDC_U1	HE_SDC_U2	IC_SDS_2	IE_ISU_2_1	MH_SDC-ALL			
COR2_EPS	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	EP_SDC-ALL	HE_SDC_U1	HE_SDC_U3	IC_SDS_3	IE_ISU_3_1				
COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OT	EPS_COM	EPS_U1	HE_SDC_U1	IC_SDC_1	IC_SDS_1	IE_EMU_1	M1\HE_EPS	M1\HE_SDS	M1\MH_SDS	MH_SDS	
COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OT	EPS_COM	EPS_U1	HE_SDC_U1	IC_SDS	IE_EMU_1	M1\HE_EPS	M1\HE_SDS	M1\IC_SDS	MH_SDS_1	SDC_COM	
COR1_OPS	COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EM	EPS_COM	EPS_U1	EP_SDC_1	EP_SDS	HE_SDC_U1	IE_EMU_1	M1\EP_SDS	M1\HE_OPS	M1\HE_SDS	M1\OPS
COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OT	EPS_COM	EPS_U1	HE_SDC_U1	IE_EMU_1	M1\HE_EPS	M1\HE_SDS	M1\MH_SDS	MH_SDC-ALL	MH_SDS	MH_SDS_1	
COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OT	EPS_COM	EPS_U1	HE_SDC_U1	IE_EMU_1	M1\HE_EPS	M1\HE_SDS	M1\MH_SDS	MH_SDC_1	MH_SDS	MH_SDS-ALL	
COR2_EPS	COR3_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U3	HE_SDC_U1	HE_SDC_U3	IC_SDC-ALL	IE_ISU_3_1	MH_SDS_3				
COR2L_ISU_	COR2_EPS	COR2_SDS	COR4_SDC	EPS_COM	EPS_U1	EPS_U2	EP_SDC-ALL	EP_SDS_2	HE_SDC_U1	HE_SDC_U2	IE_ISU_2_1			
COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OT	EPS_COM	EPS_U1	EP_SDS	EP_SDS_1	HE_SDC_U1	IC_SDC_1	IE_EMU_1	M1\EP_SDS	M1\HE_EPS	M1\HE_SDS	
COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OT	EPS_COM	EPS_U1	EP_SDC_1	EP_SDS	HE_SDC_U1	IC_SDS_1	IE_EMU_1	M1\EP_SDS	M1\HE_EPS	M1\HE_SDS	
COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OT	EPS_COM	EPS_U1	EP_SDS_1	HE_SDC_U1	IC_SDS	IE_EMU_1	M1\HE_EPS	M1\HE_SDS	M1\IC_SDS	MH_SDC_1	
COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OT	EPS_COM	EPS_U1	EP_SDC_1	HE_SDC_U1	IC_SDS	IE_EMU_1	M1\HE_EPS	M1\HE_SDS	M1\IC_SDS	MH_SDS_1	

IE CODE	IE	Corr fact	Details correction factor				
IE1	IE_ISU_3_1	CI4	COR2_EPS	COR3_OPS	COR3_SDS	COR4_SDC	
IE2	IE_ISU_3_1	CI4	COR2_EPS	COR3_OPS	COR3_SDS	COR4_SDC	
IE3	IE_ISU_2_1	CI3x	COR2_EPS	COR2_OPS	COR2_SDS	COR4_SDC	COR2L_ISU_IE
IE4	IE_ISU_1_1	CI3x	COR1_OPS	COR1_SDS	COR2_EPS	COR4_SDC	COR1L_ISU_IE
IE5	IE_ISU_1_1	CI3x	COR1_OPS	COR1_SDS	COR2_EPS	COR4_SDC	COR1L_ISU_IE
IE6	IE_ISU_1_1	CI3x	COR1_OPS	COR1_SDS	COR2_EPS	COR4_SDC	COR1L_ISU_IE
IE7	IE_EMU_1	CM2	COR1_OPS	COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OTHER_H
IE8	IE_EMU_1	CM2	COR1_OPS	COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OTHER_H
IE9	IE_EMU_1	CM2	COR1_OPS	COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OTHER_H
IE10	IE_EMU_1	CM2	COR1_OPS	COR1_SDS	COR2_EPS	COR4_SDC	CORR_IE_EMU_OTHER_H

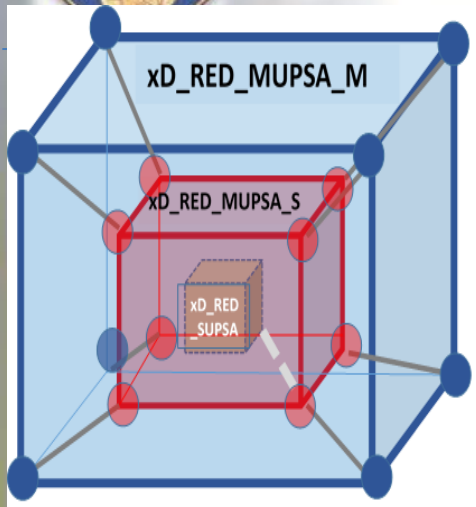
$$
\begin{bmatrix} S1^{(1)} \\ S2^{(1)} \\ \dots \\ Sn\text{-}2^{(1)} \\ Sn\text{-}1^{(1)} \\ Sn^{(1)} \end{bmatrix}
=
\begin{bmatrix} c1 \\ c2 \\ \dots \\ cn\text{-}2 \\ cn\text{-}1 \\ cn \end{bmatrix}
*
\begin{bmatrix} IE1 \\ IE2 \\ \dots \\ IEn\text{-}2 \\ IEn\text{-}1 \\ IEn \end{bmatrix}
*
\begin{bmatrix}
S1^{*(1)} & EPS\_COM * EPS\_U1 * SDC\_COM * HE\_SDC\_U1 \\
S2^{*(1)} & EPS\_COM * EPS\_U1 * EPS\_U3 * (IC\_SDC\_1 * HE\_SDC\_U1) * (MH\_SDC\_3 * HE\_SDC\_U3) * MH\_SDS\_3 \\
\dots & \dots \\
Sn\text{-}2^{*(1)} & EPS\_COM * EPS\_U1 * EPS\_U2 * SDC\_COM * EP\_SDS\text{-}ALL * HE\_SDC\_U1 * HE\_SDC\_U2 \\
Sn\text{-}1^{*(1)} & EPS\_COM * EPS\_U1 * (IC\_SDC\_1 * HE\_SDC\_U1) * MH\_SDS * (M1\backslash MH\_SDS * M1\backslash HE\_SDS) * (M1\backslash OPS * M1\backslash HE\_OPS) \\
Sn^{*(1)} & EPS\_COM * EPS\_U1 * EPS\_U3 * EP\_SDS\_3 * HE\_SDC\_U1 * HE\_SDC\_U3 * IC\_SDC\_1 * IC\_SDC\_3 * MH\_SDS * M1\backslash HE\_EPS * M1\backslash HE\_SDS * M1\backslash MH\_SDS
\end{bmatrix}
$$

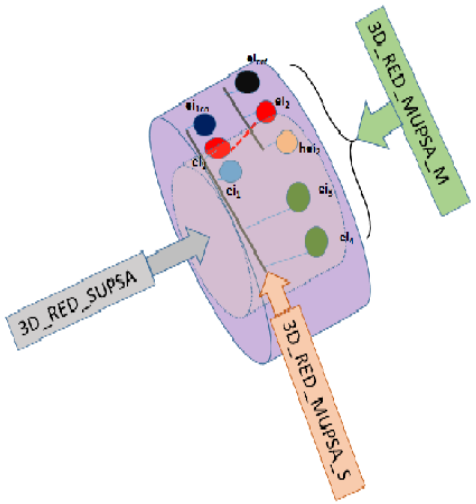
$$\begin{bmatrix} IE_1 \\ IE_2 \\ IE_3 \\ \dots \\ IE_{n-2} \\ IE_{n-1} \\ IE_n \end{bmatrix} * \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ \dots \\ c_{n-2} \\ c_{n-1} \\ c_n \end{bmatrix} * \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ a_{21} & \cdots & a_{2n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} =$$

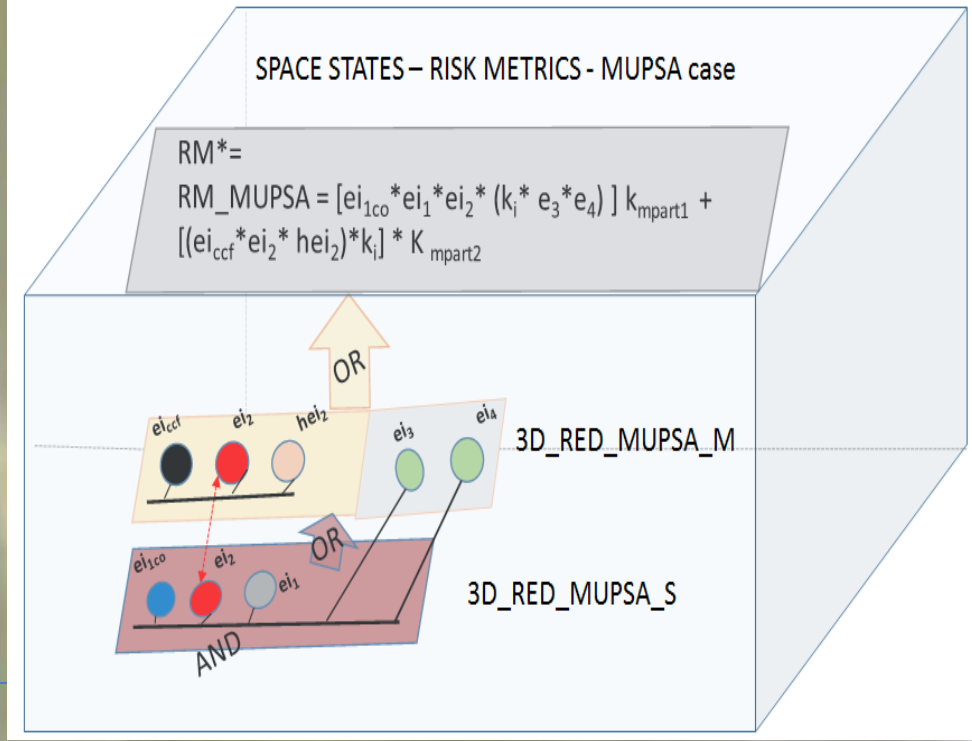
$$= \begin{bmatrix} S_1^1 \\ S_2^1 \\ S_3^1 \\ \dots \\ S_{n-2}^1 \\ S_{n-1}^1 \\ S_n^1 \end{bmatrix} \xrightarrow{NON\ S_k^l} \begin{bmatrix} SeSq_{1=}^1 1 - S_1^1 \\ SeSq_{2=}^1 1 - S_2^1 \\ SeSq_{3=}^1 1 - S_3^1 \\ \dots \\ SeSq_{n-2=}^1 1 - S_{n-2}^1 \\ SeSq_{n-1=}^1 1 - S_{n-1}^1 \\ SeSq_{n=}^1 1 - S_n^1 \end{bmatrix}$$

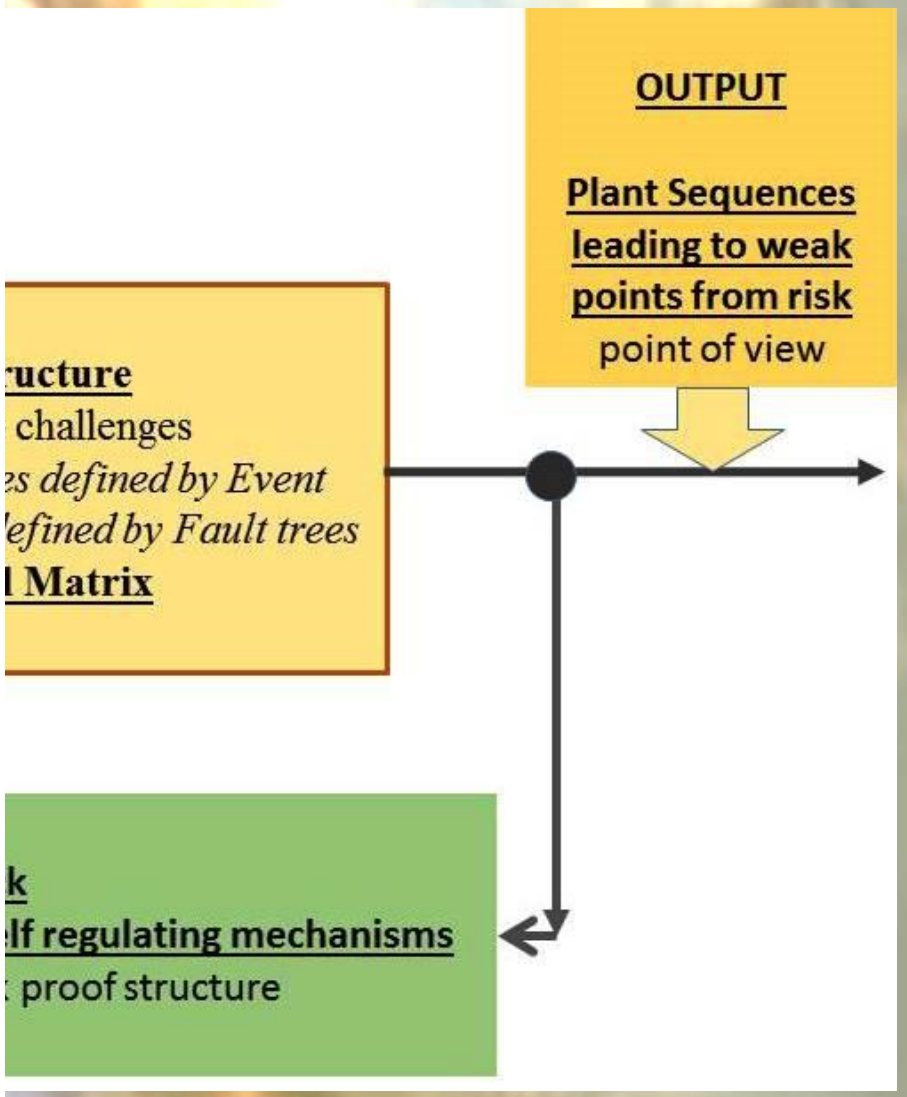
Where the vector of the IE $|IE\ i|$ is combined with the vector of correlating factors $|C\ i|$ and the matrix $|a\ ij|$, which is describing the feedback of the structure, after the plant risk resistant structured was challenged by the IE and it reacted to it. The plant reaction leads to a state described by a series of sequences $|si|$. The negated sequences are used for the calculation of the risk metrics, as per formula

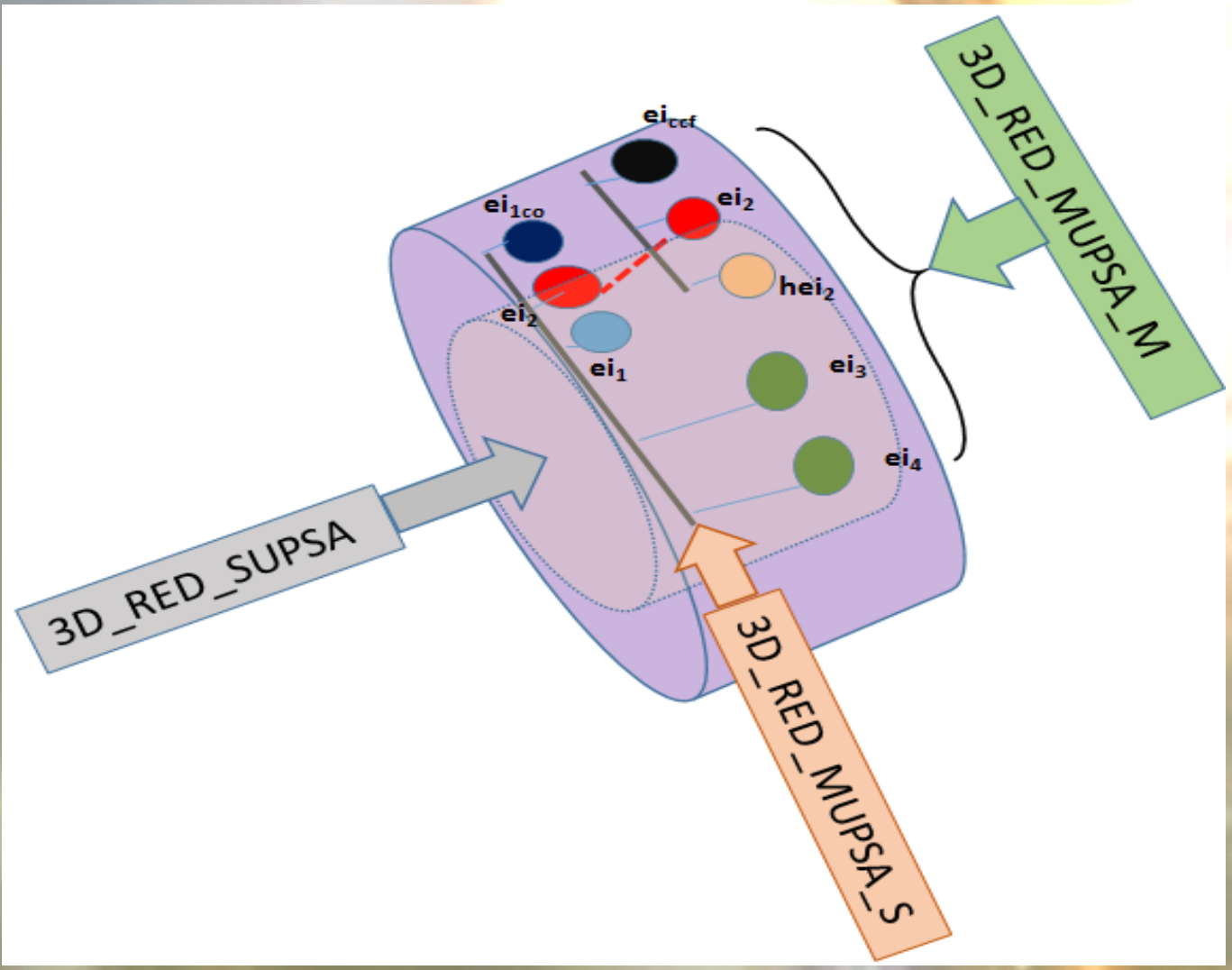
$$RM1 = 1 - \sum\left(1 - (1 - si) \dots (1 - sn)\right)$$


xD_RED_MUPSA_M
xD_RED_MUPSA_S
xD_RED
_SUPSA


3D_RED_MUPSA_M
3D_RED_SUPSA
3D_RED_MUPSA_S


SPACE STATES – RISK METRICS - MUPSA case
RM*=
RM_MUPSA = [ei1co*ei1*ei2* (ki* e3*e4)] kmpart1 +
[(eiccf*ei2* hei2)*ki] * K mpart2
OR
eiccf
ei2
hei2
ei3
ei4
3D_RED_MUPSA_M
OR
ei1co
ei2
ei1
3D_RED_MUPSA_S
AND


OUTPUT
Plant Sequences leading to weak points from risk point of view
ructure
challenges
es defined by Event
efined by Fault trees
l Matrix
k
lf regulating mechanisms
proof structure

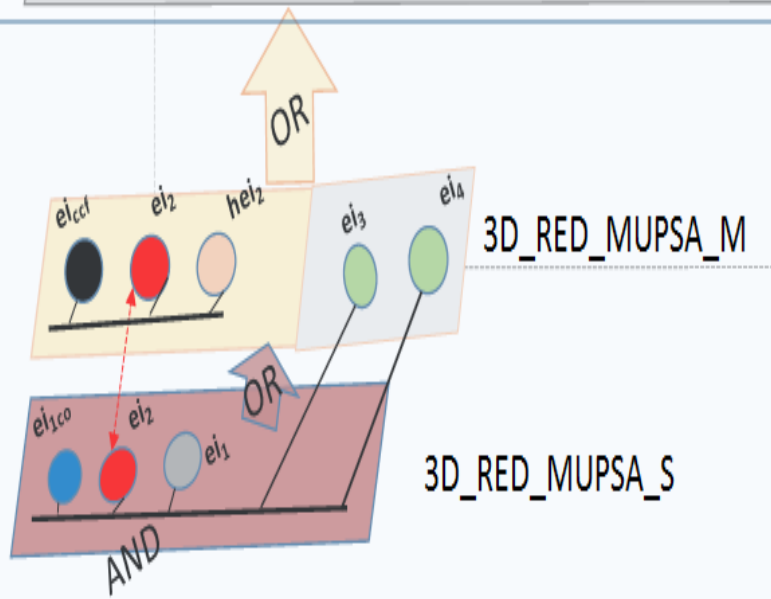


The results that consider both Tables 1 and 2 and the fact that the MUPSA and SUPSA models represent a cybernetic type of plant reaction to risk challenges may be represented as a 3 dimensional (3D) of a model for MUPSA, SUPSA and the connecting parts between them. This concept illustrates in our view the best the type of risk analyses and may be used better for post processing and interpretation of results.

SPACE STATES – RISK METRICS - MUPSA case

RM*=

$$RM\_MUPSA = [ei_{1co} * ei_1 * ei_2 * (k_i * e_3 * e_4)]\, k_{mpart1} + [(ei_{ccf} * ei_2 * hei_2) * k_i] * K_{mpart2}$$



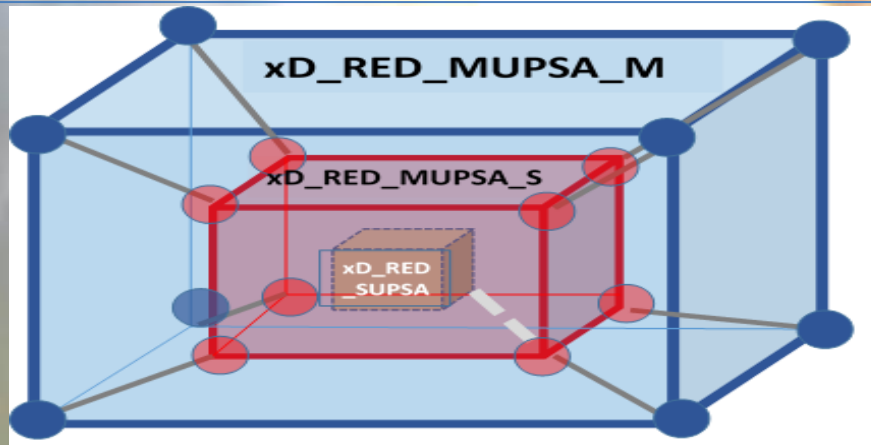
$$RM_* \equiv \alpha * x^k + \beta * x^{k-1} + \gamma$$
$$\equiv (a_{2i} * k_{em_{ccf}} * k_{em}^{type1}) * x^k +$$
$$+ (a_{3i} * k_i * k_{em}^{type2}) * x^{k-1} + (a_{2i} + a_{3i})$$

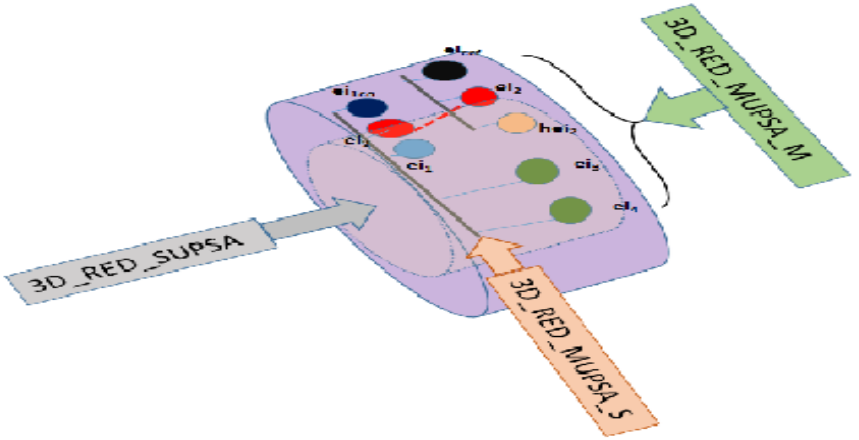
Where the notations are:

- $f_d(x) = k_d * x$
- $(ei_{1co} * ei_1 * ei_2) * (ei_3 * ei_4 * f_i(x))$
  $= [(ei_{1co} * ei_1 * ei_2) * (ei_3 * ei_4)] * k_i * x) =$
  $\equiv a_{1i} * k_i * x$

The following are failing elements of the model:

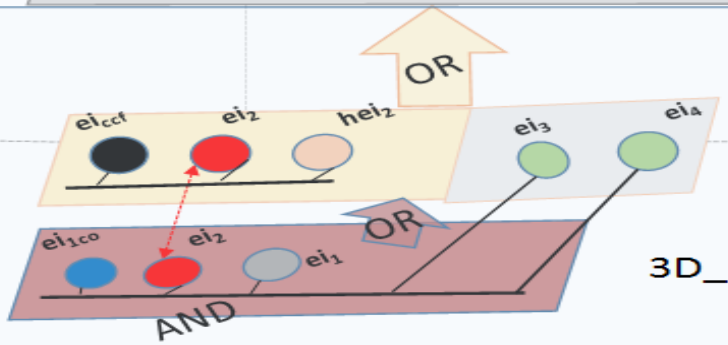
- $ei_{1co} * ei_{2co} * ei_1 * he_{i2} \equiv a_{2i}$
- $ei_{1co} * ei_{ccf} * ei_2 * he_{i2} \equiv a_{3i}$
- $em_{ccf}(x) = k_{em\_ccf} * x$
- $em_1(x) = k_{em1} * x$



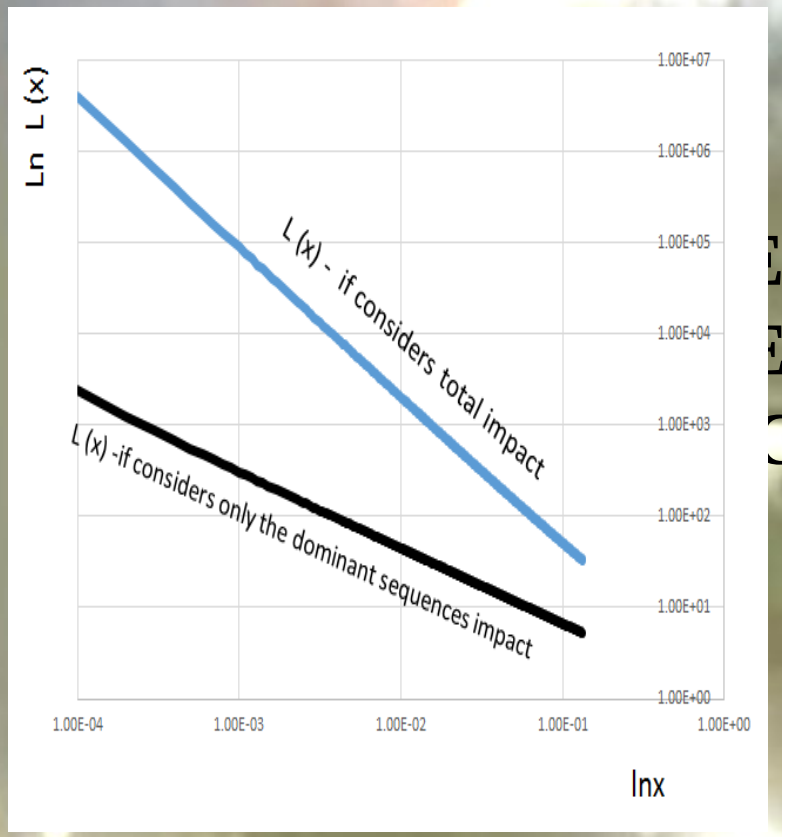


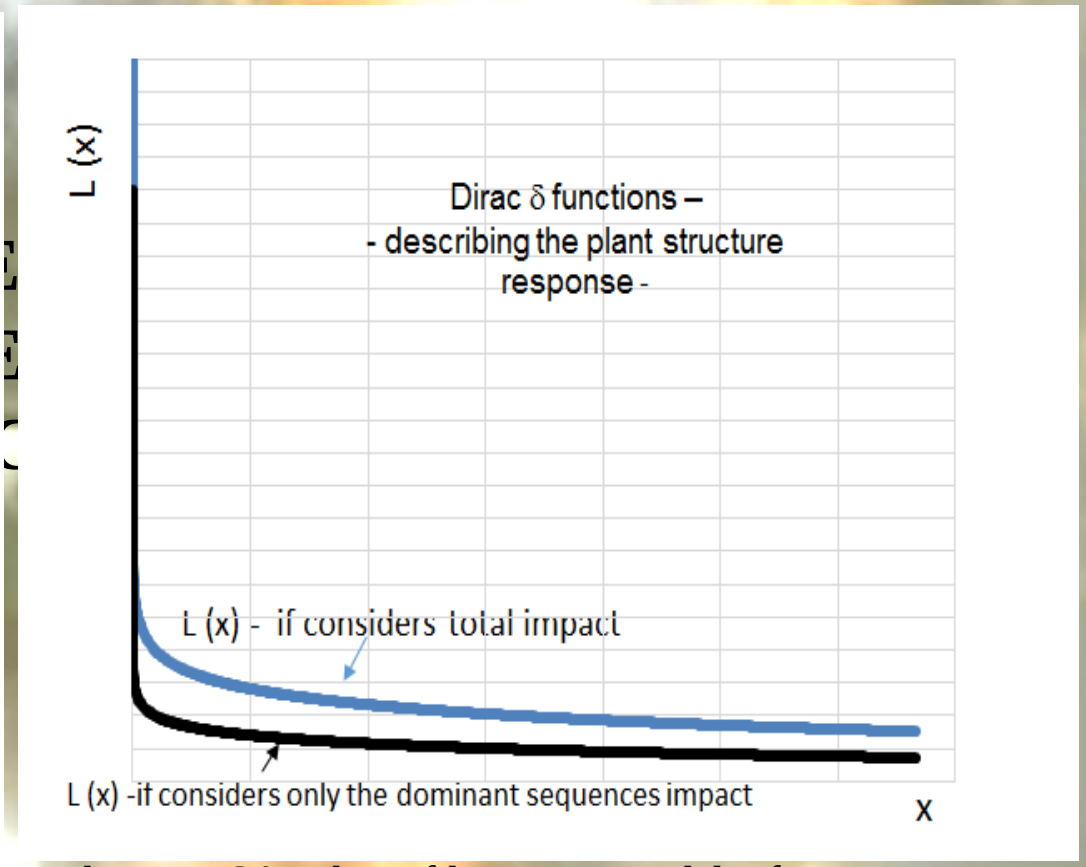
SPACE STATES – RISK METRICS - MUPSA case

RM*=
RM_MUPSA = $[ei_{1co}*ei_1*ei_2*(k_i*e_3*e_4)]\ k_{mpart1}$ +
$[(ei_{ccf}*ei_2*hei_2)*k_i]*K_{mpart2}$

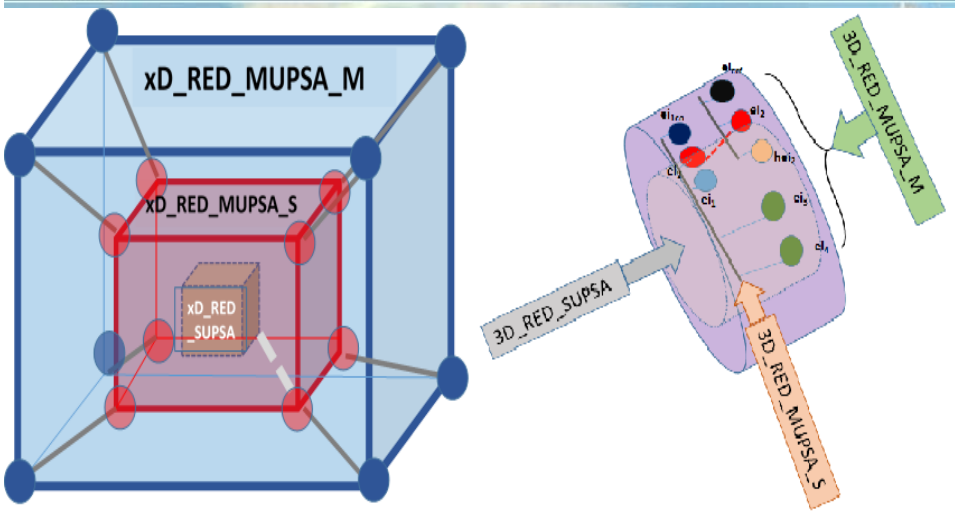


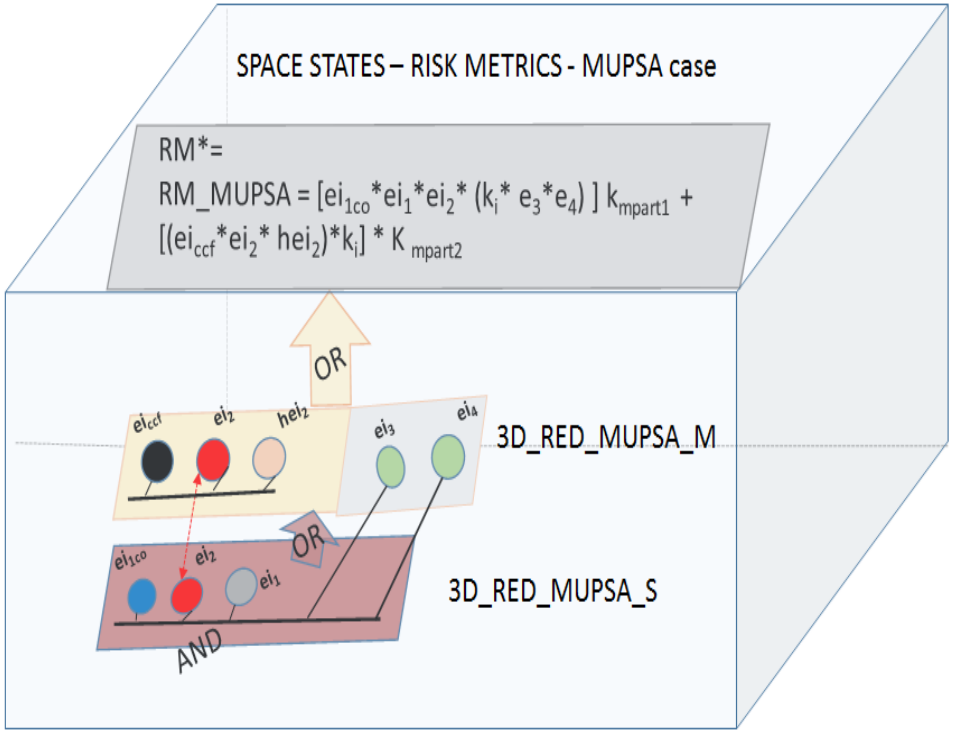
These conclusions help in defining the target of the **last step modeling using the dominant worst cases.**



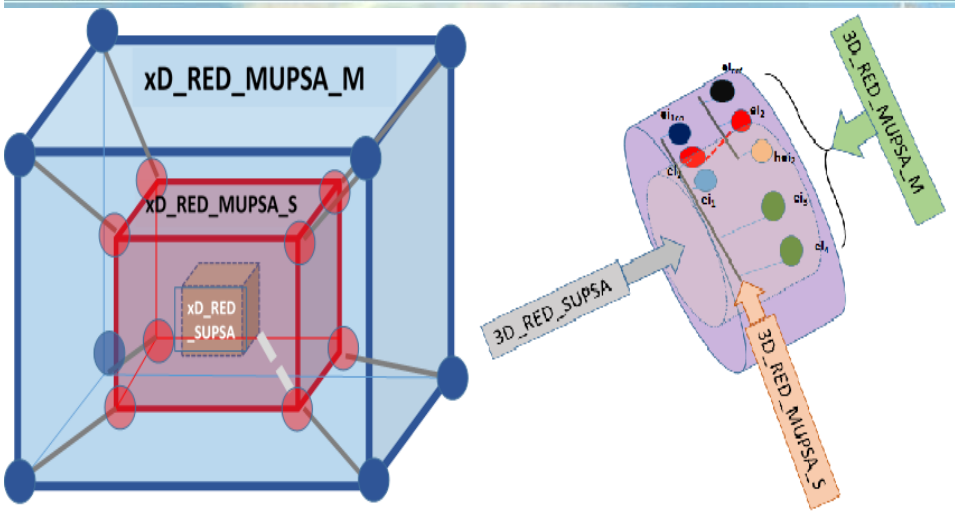


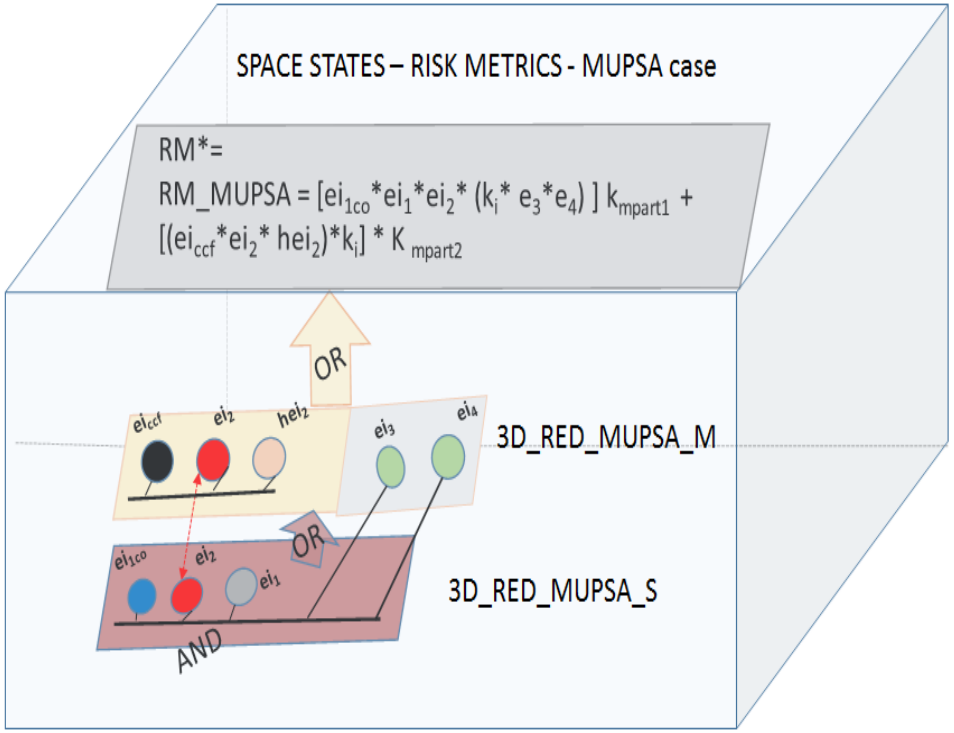
The physical meaning of the results describing the MUPSA risk profile as a Direc delta function is confirmed by real major accidents in which there are dominant well defined contributors specific to MUPSA by comparison to SUPSA. Those dominant features are also confirmed not only by complementary tools, but also by real cases of the major nuclear accidents





- A specific aspect under review as part of post Fukushima reviews, the **evaluation of multiunit site risks** are a very actual topic under intensive international debate.
- From Probabilistic Safety Analysis (PSA) point of view this evaluations lead to the need to **review some of the fundamentals of the methodology.**
- **The single unit PSA (SUPSA) and the Multiunit PSA (MUPSA) combined methodologies are currently under review** and methodological development of new approaches.
- **Important outcomes** of this process are that:
  - the **Reliability Equivalent Diagrams (RED) representing the risk models for the MUPSA projects depend much more than in the case of SUPSA on various parameters** and
  - they are build starting with and based on SUPSA models, in integrated risk





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CAZ A4 STUDIURHUTENIU

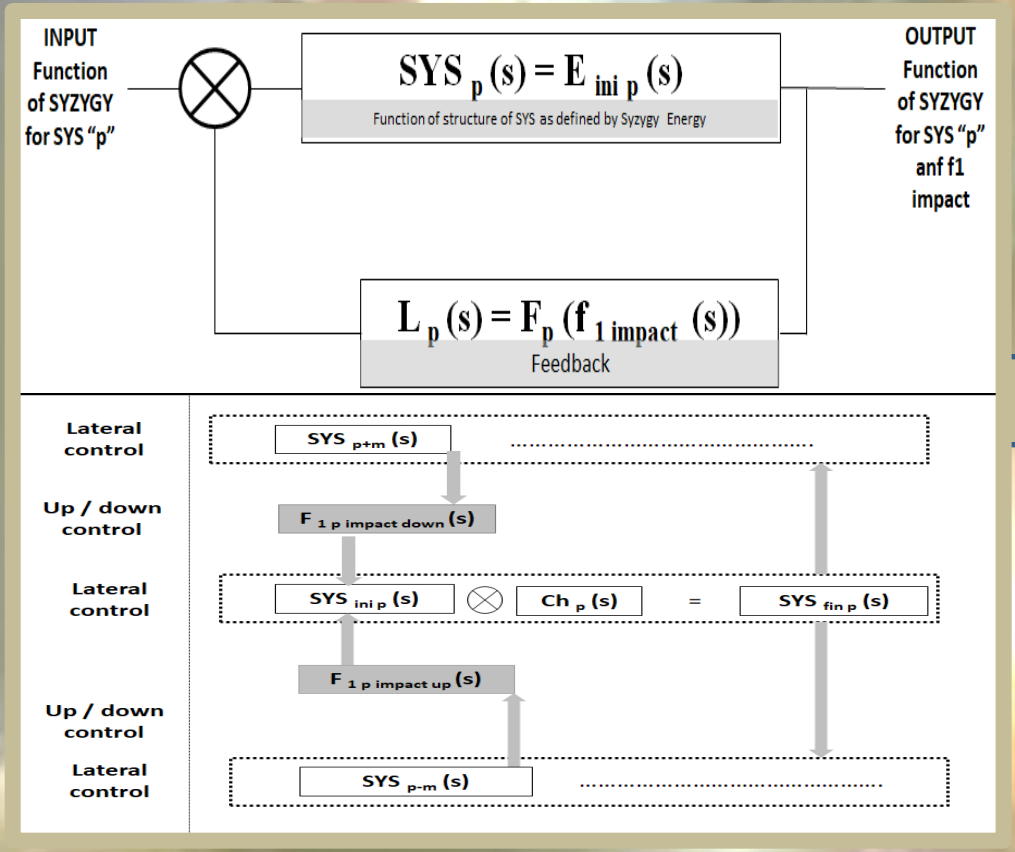
- **MODEL CLASIC si CAS**
- **METODE 1-3**

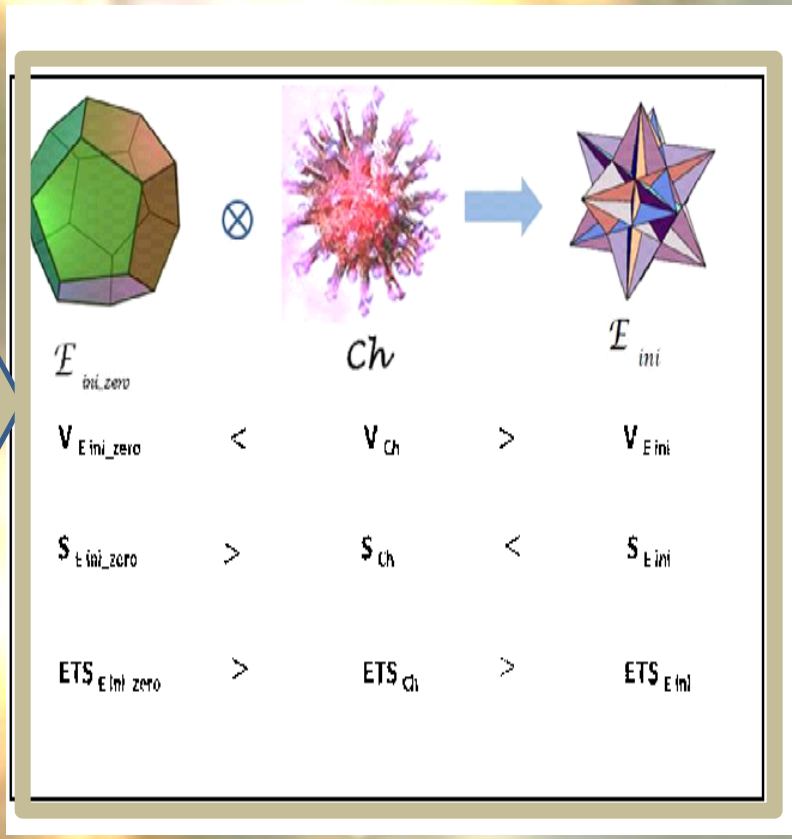
Secvente de impact / Metode de decizie	Principiul abordarii precaute Precautionary principle PREC PREC	Principiul deliberarii Deliberative Principle DELIB	Principiul deciziei pe baza informatiilor de risc Risk Informed Decision Making RIDM
Ridicat	**Se poate astepta cea mai conservativa decizie facuta cu prioritate maxima, atunci** cand **Interfata internationala slaba**, chiar si singura, si **cu atat mai mult daca are loc atunci cand si coomunicarea este slaba**, iar **incertitudinea** asupra situatiei pe teren **este mare**	**Se poate astepta ca o dezbatere cu partile implicate sa aiba loc cu prioritate maxima,** daca **Interfata internationala este ridicata**, chiar si singura, si cu atat mai mult daca are loc atunci cand si **comunicarea este buna, chiar si daca incertitudinea asupra situatiei pe teren este mare**	**Se poate astepta o decizie bazata pe evaluarea riscului sa fie luata cu prioritate maxima, cu sprijinul grupului GLERUNR**, in conditiile unei interfete **internationale bune**, a existentei unor rezultate de analiza confirmate de criteriul de succes pe centrele luate in consideratie, chiar si **in conditiile unor incertitudini asupra situatiei pe teren**
Mediu	**Se poate astepta cea mai conservativa decizie facuta cu prioritate medie, atunci** cand **Interfata internationala slaba**, in timp ce **monitorarea** cu criteriul sau de succes pentru centrele / laboratoarele autorizate **si coordonarea/verificarea monitorarii sunt slabe**	**Se poate astepta ca o dezbatere cu partile implicate sa aiba loc cu prioritate medie, cu suport din partea grupului de analize GLERUNR si cu o** comunicarea buna, chiar si daca interfata internationala nu este foarte buna, iar **rezultatele analizelor conform criteriilor de succes** al centrelor/laboratoarelor si **incertitudinea** asupra situatiei pe teren **sunt de nivel mediu**	
Scazut	**Se poate astepta cea mai conservativa decizie facuta cu prioritate scazuta, atunci** cand **Interfata internationala este puternica**, chiar daca a esuat comunicarea, in timp ce **monitorarea** cu criteriul sau de succes pentru centrele / laboratoarele autorizate si coordonarea/verificarea monitorarii sunt **slabe**	**Se poate astepta ca o dezbatere cu partile implicate sa aiba loc cu prioritate scazuta, cu suport din partea grupului de analize GLERUNR, in conditiile in care nu se activeaza SNSMU,** interfata internationala nu este foarte buna, iar **rezultatele analizelor conform criteriilor de succes** al centrelor/laboratoarelor si **incertitudinea** asupra situatiei pe teren **sunt de nivel mediu**	
Foarte Scazut		**Se poate astepta ca o dezbatere cu partile implicate sa aiba loc cu prioritate foarte mica, in conditiile in care interfata internationala si comunicarea sunt foarte bune, iar monitorarea conform criteriilor de** succes al centrelor/laboratoarelor si coordonarea acesteia sunt la nivel scazut	

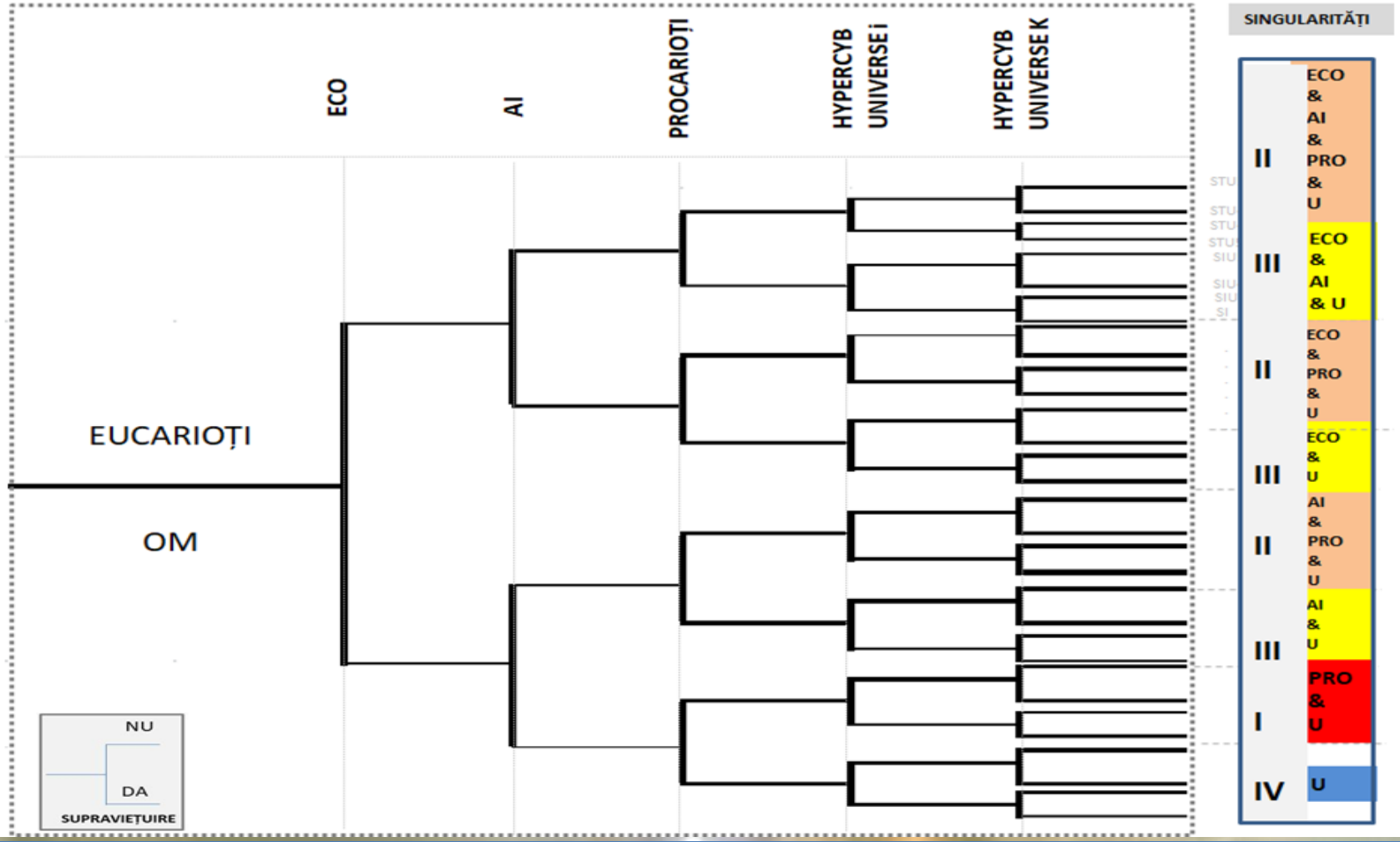
Componente/ Impact asupra metodelor de decizie (N= fara impact; H=ridicat; M=mediu; MH= Mediu catre ridicat; L=scazut; VL=Foarte scazut; A,B,C = Categorii conform secvente)	Principiul abordarii precaute Precautionary principle PREC	Principiul deliberarii Deliberative Principle	Principiul deciziei pe baza informatiilor de risc Risk Informed Decision Making	Aggregate conclusion
	PREC	DELIB	RIDM	AGGREG
Comunicare	H	H	N	MH
Interfata internationala	H	H	H	H
Monitorare (cu criteriu de succes 3 din 4 centre / laboratoare)	L	L	N	L
Coordonare monitorare	L	VL	N	L
Rezultate (criteriu de succes 3 din 4 centre/laboratoare)	N	M	M	M
Analiza / Suport grup analize (GLERUNR)	N	MH	MH	MH
Combinatii secvente dominante	A	B	C	ABC

CAZ B - Transformarile unor sisteme de energie cu componente biologice la provocări externe (cazul COVID)

- **MODEL CATS**
- **METODA 4**


INPUT
Function
of SYZYGY
for SYS "p"
SYS p (s) = E ini p (s)
Function of structure of SYS as defined by Syzygy Energy
OUTPUT
Function
of SYZYGY
for SYS "p"
anf f1
impact
L p (s) = F p (f 1 impact (s))
Feedback
Lateral control
SYS p+m (s)
Up / down control
F 1 p impact down (s)
Lateral control
SYS ini p (s)
Ch p (s)
=
SYS fin p (s)
F 1 p impact up (s)
Up / down control
Lateral control
SYS p-m (s)


E ini_zero
Ch
E ini
V E ini_zero
<
V Ch
>
V E ini
S E ini_zero
>
S Ch
<
S E ini
ETS E ini zero
>
ETS Ch
>
ETS E ini


ECO
AI
PROCARIOȚI
HYPERCYB UNIVERSE i
HYPERCYB UNIVERSE K
EUCARIOȚI
OM
NU
DA
SUPRAVIEȚUIRE
SINGULARITĂȚI
II
ECO & AI & PRO & U
III
ECO & AI & U
II
ECO & PRO & U
III
ECO & U
II
AI & PRO & U
III
AI & U
I
PRO & U
IV
U

Singularități UPSCAT posibile evoluții

Problema este că gestionarea provocărilor poate duce la singularitate reală, fără adaptare și deci la dispariția UPSCAT. Cu cât evoluăm mai mult, cu atât ne va fi mai greu să nu ne autodistrugem, dacă nu ne modificăm fundamental.

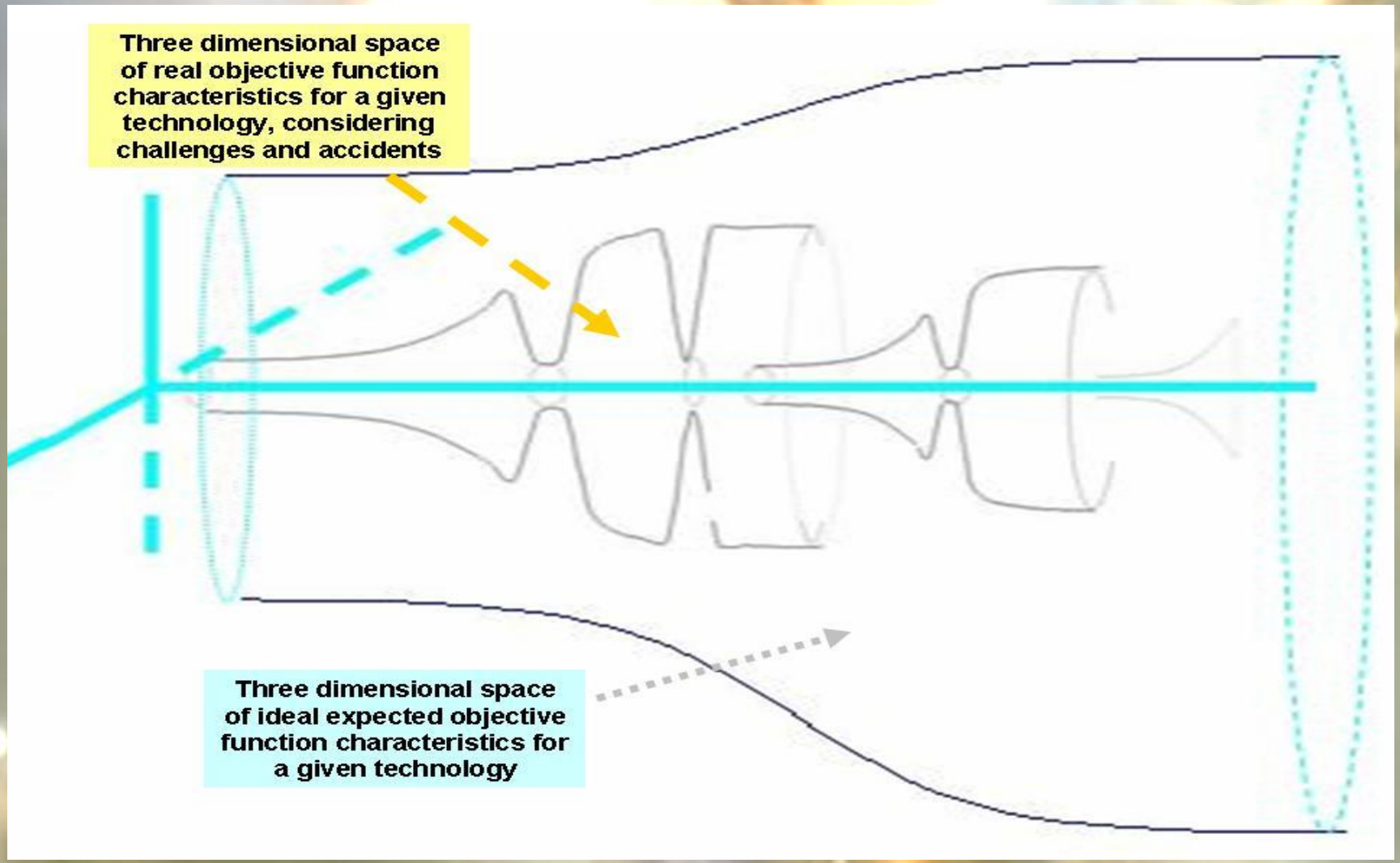
UPSCAT (OM) are patru categorii de posibile singularități Combinate cu impact de pe alte tărâmuri (galactic, cosmic, multiunivers)

I Biologice
II Biologice și (Ecologice și/sau din cauze AI)
III Ecologice și/sau AI

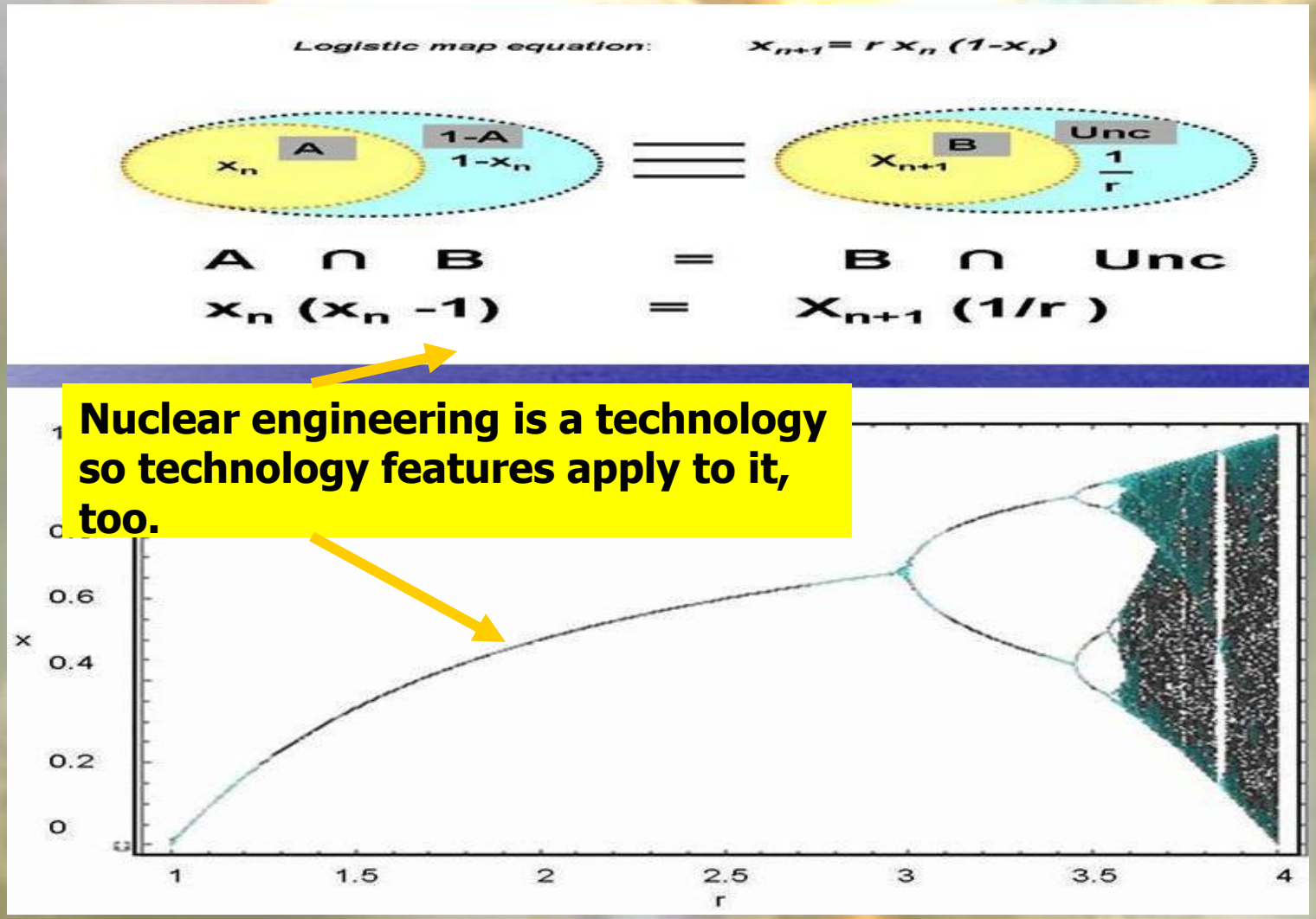
Impact exclusiv de pe alte tărâmuri (galactic, cosmic, multiunivers)

CAZ C Riscurile inovării în sistemele energetice, cu exemple din domeniul nuclear

- **MODEL CATS si TRADITIONAL**
- **METODE 1-4**


Three dimensional space of real objective function characteristics for a given technology, considering challenges and accidents
Three dimensional space of ideal expected objective function characteristics for a given technology

Tehnologiile si viitorul lor



Evolution of the Performance and Risk functions for a technology during its lifetime

Use of topological spaces for the evaluation cases with more than three criteria

Acceptable space of solutions $= M^{tot} =$ *Volume Poliedra*

$M^s = M^{s1}$

$(i \to s \to c \to p) \cup M^{s2}$
$(i \to t \to p)$

$x \to y =$ x is a function of y

$M^w = [M^{w1}(i \to p) \cup M^{w2}(i \to p)] \cup [M^{w3}(i \to c \to p) \cup M^{w3}(i \to c \to p)]$

$M^{tot} = M^s \cup M^w$

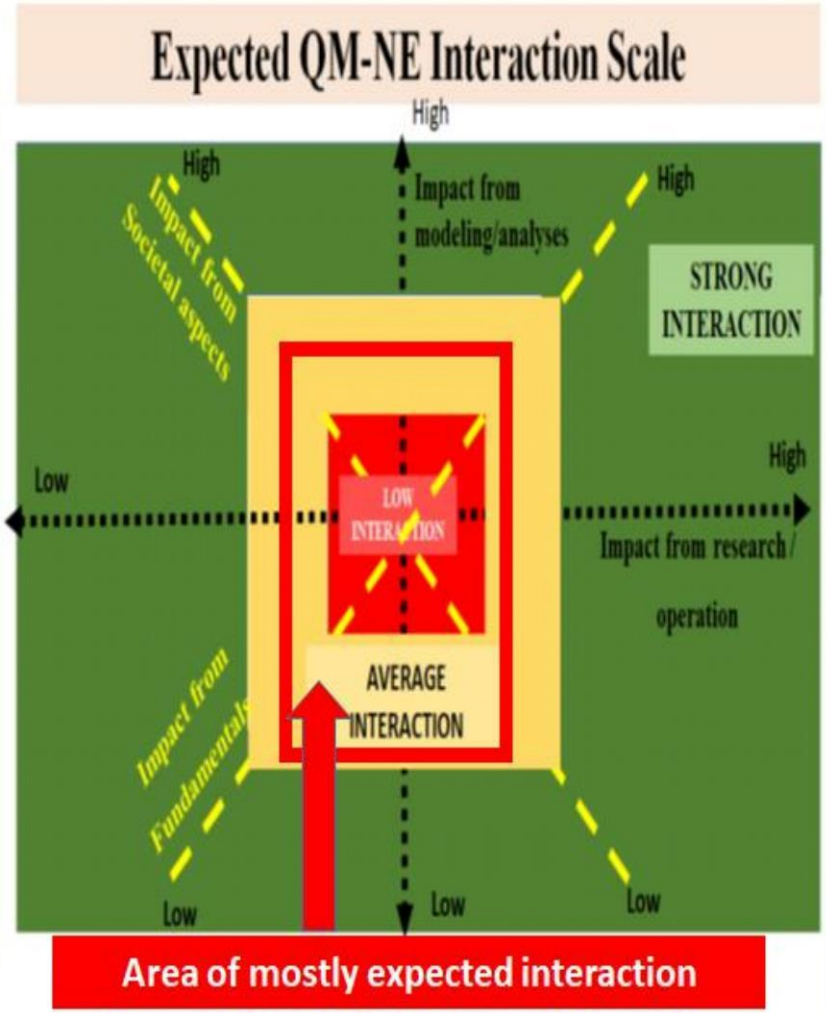
Interaction QM-NE is governed by

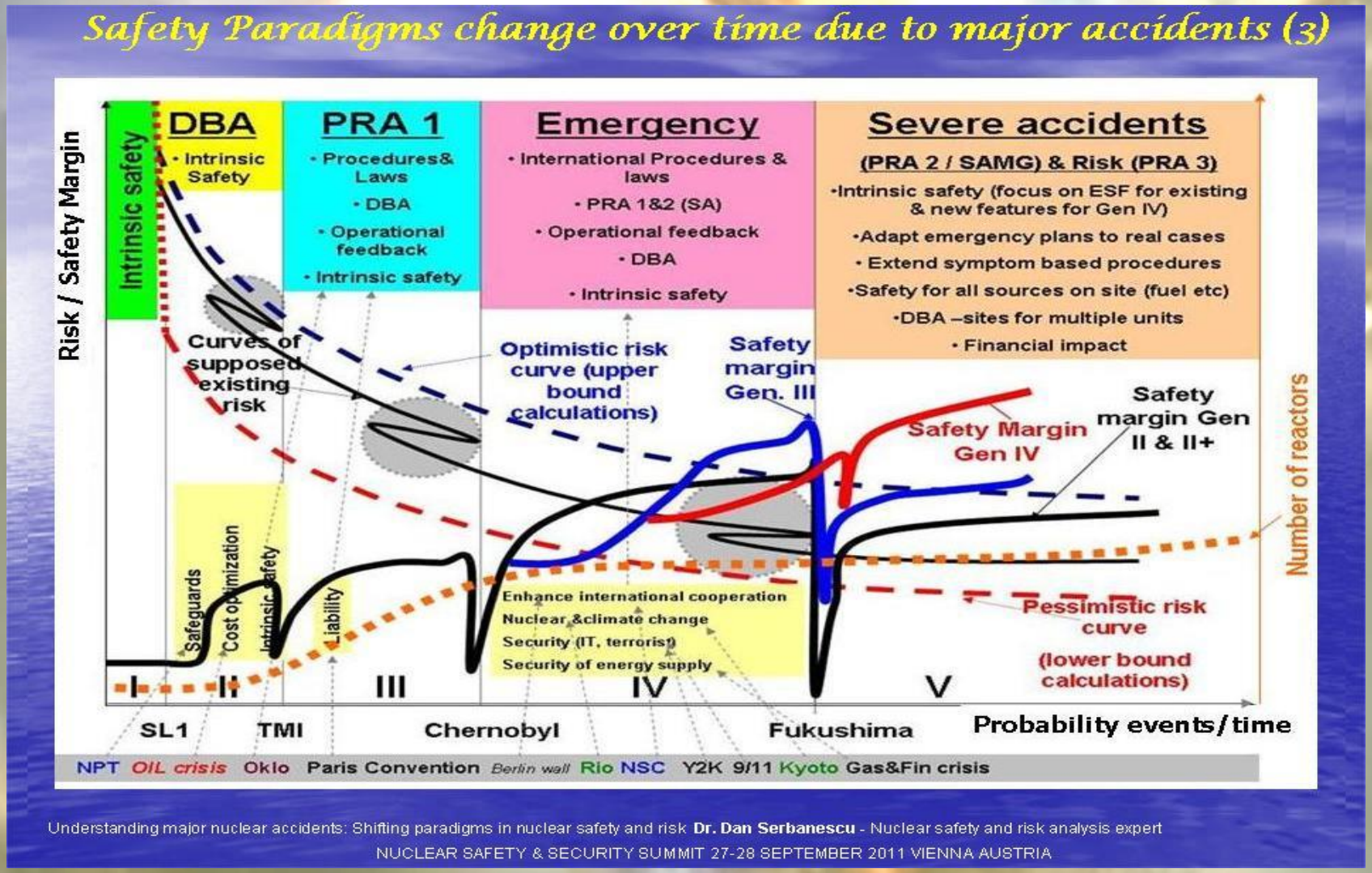
MAINLY

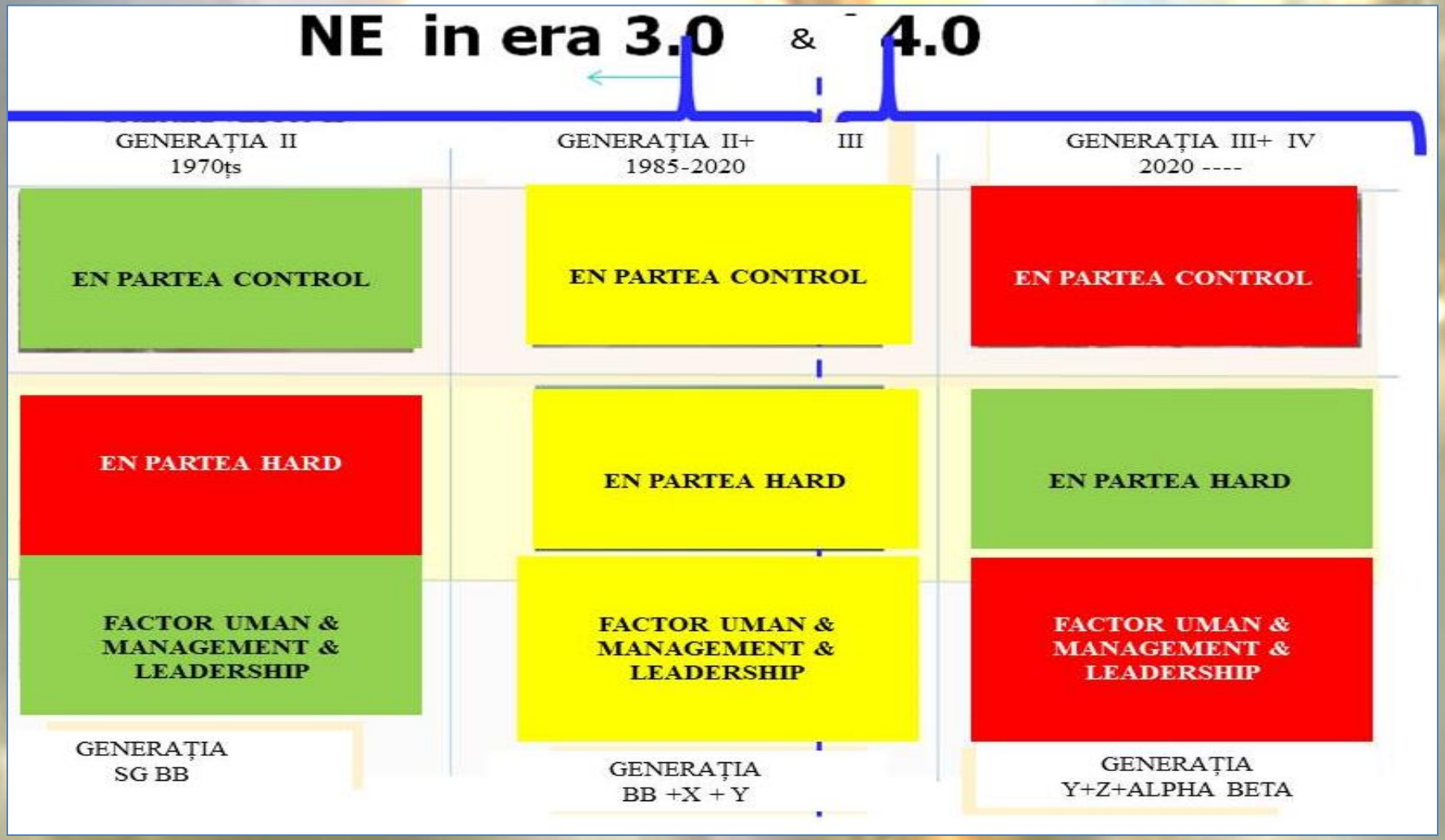
- **Clear and timely in the lifecycles of the both technologies of**
  - *Supply chain for smooth implementation of QM applications in NE*
  - *Correlation with other technologies (material fabrication, maintenance etc)*
  - *Identification of the areas of applications of QM in desktop design /safety activities and in NE lifecycle phases correlated with the QM research and implementation*
- **By increasing the independence on political factors**
  - *better structure at societal level,*
  - *more resources and*
  - *administrative independence to the review organizations*

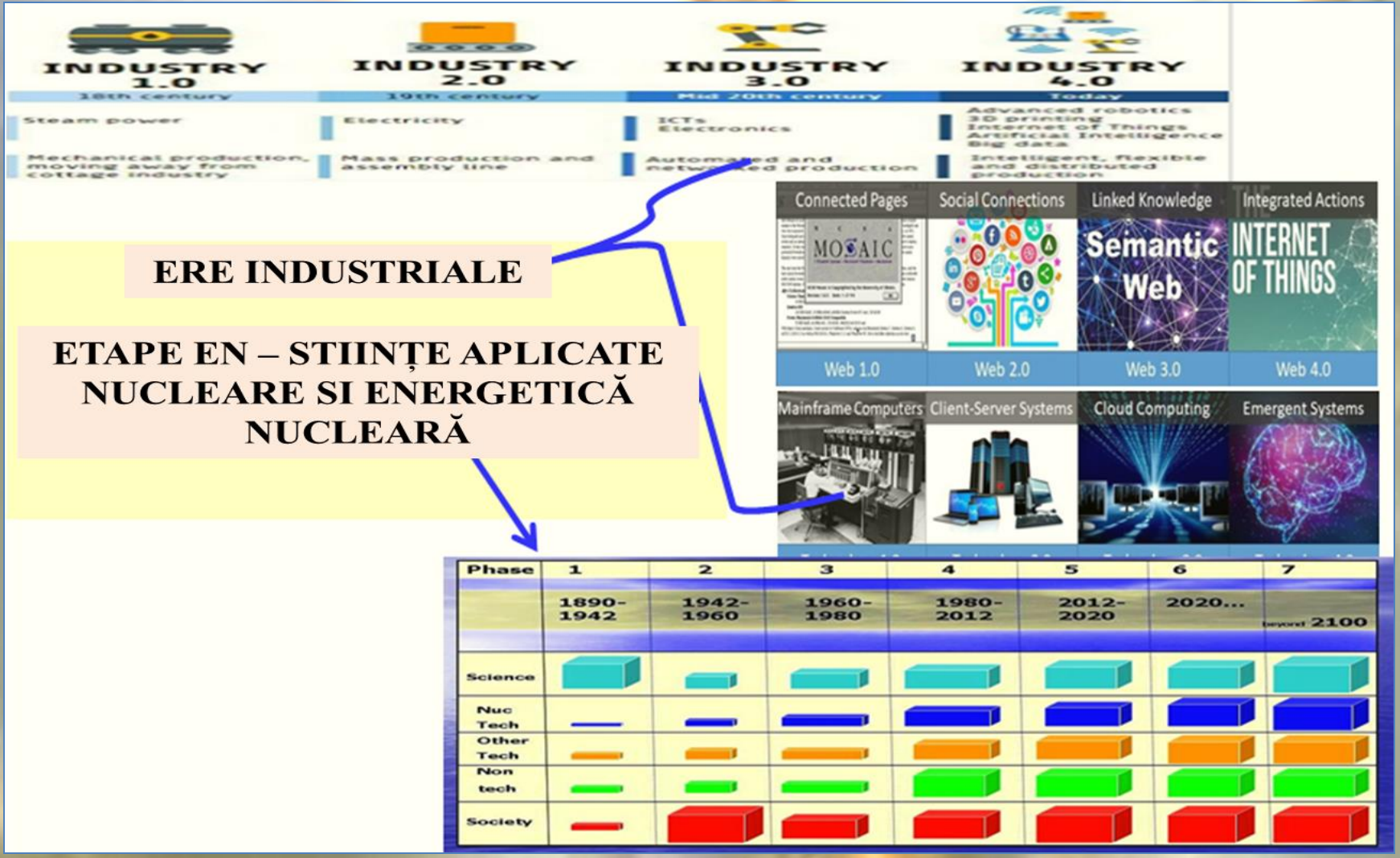
SECONDLY

- **By interference of the societal factors in the evaluation process**
- **Improving interface and orientation to applications of the researches and possible fundamental new scientific connections**




Safety Paradigms change over time due to major accidents (3)
Risk / Safety Margin
Intrinsic safety
DBA
• Intrinsic Safety
PRA 1
• Procedures& Laws
• DBA
• Operational feedback
• Intrinsic safety
Emergency
• International Procedures & laws
• PRA 1&2 (SA)
• Operational feedback
• DBA
• Intrinsic safety
Severe accidents
(PRA 2 / SAMG) & Risk (PRA 3)
•Intrinsic safety (focus on ESF for existing & new features for Gen IV)
•Adapt emergency plans to real cases
• Extend symptom based procedures
•Safety for all sources on site (fuel etc)
•DBA –sites for multiple units
• Financial impact
Curves of supposed existing risk
Optimistic risk curve (upper bound calculations)
Safety margin Gen. III
Safety Margin Gen IV
Safety margin Gen II & II+
Number of reactors
Safeguards
Cost optimization
Intrinsic safety
Liability
Enhance international cooperation
Nuclear &climate change
Security (IT, terrorist)
Security of energy supply
Pessimistic risk curve
(lower bound calculations)
I
II
III
IV
V
SL1
TMI
Chernobyl
Fukushima
Probability events/time
NPT OIL crisis Oklo Paris Convention Berlin wall Rio NSC Y2K 9/11 Kyoto Gas&Fin crisis
Understanding major nuclear accidents: Shifting paradigms in nuclear safety and risk Dr. Dan Serbanescu - Nuclear safety and risk analysis expert
NUCLEAR SAFETY & SECURITY SUMMIT 27-28 SEPTEMBER 2011 VIENNA AUSTRIA


NE in era 3.0 & 4.0
GENERAȚIA II
1970ts
GENERAȚIA II+ III
1985-2020
GENERAȚIA III+ IV
2020 ----
EN PARTEA CONTROL
EN PARTEA CONTROL
EN PARTEA CONTROL
EN PARTEA HARD
EN PARTEA HARD
EN PARTEA HARD
FACTOR UMAN & MANAGEMENT & LEADERSHIP
FACTOR UMAN & MANAGEMENT & LEADERSHIP
FACTOR UMAN & MANAGEMENT & LEADERSHIP
GENERAȚIA SG BB
GENERAȚIA BB +X + Y
GENERAȚIA Y+Z+ALPHA BETA

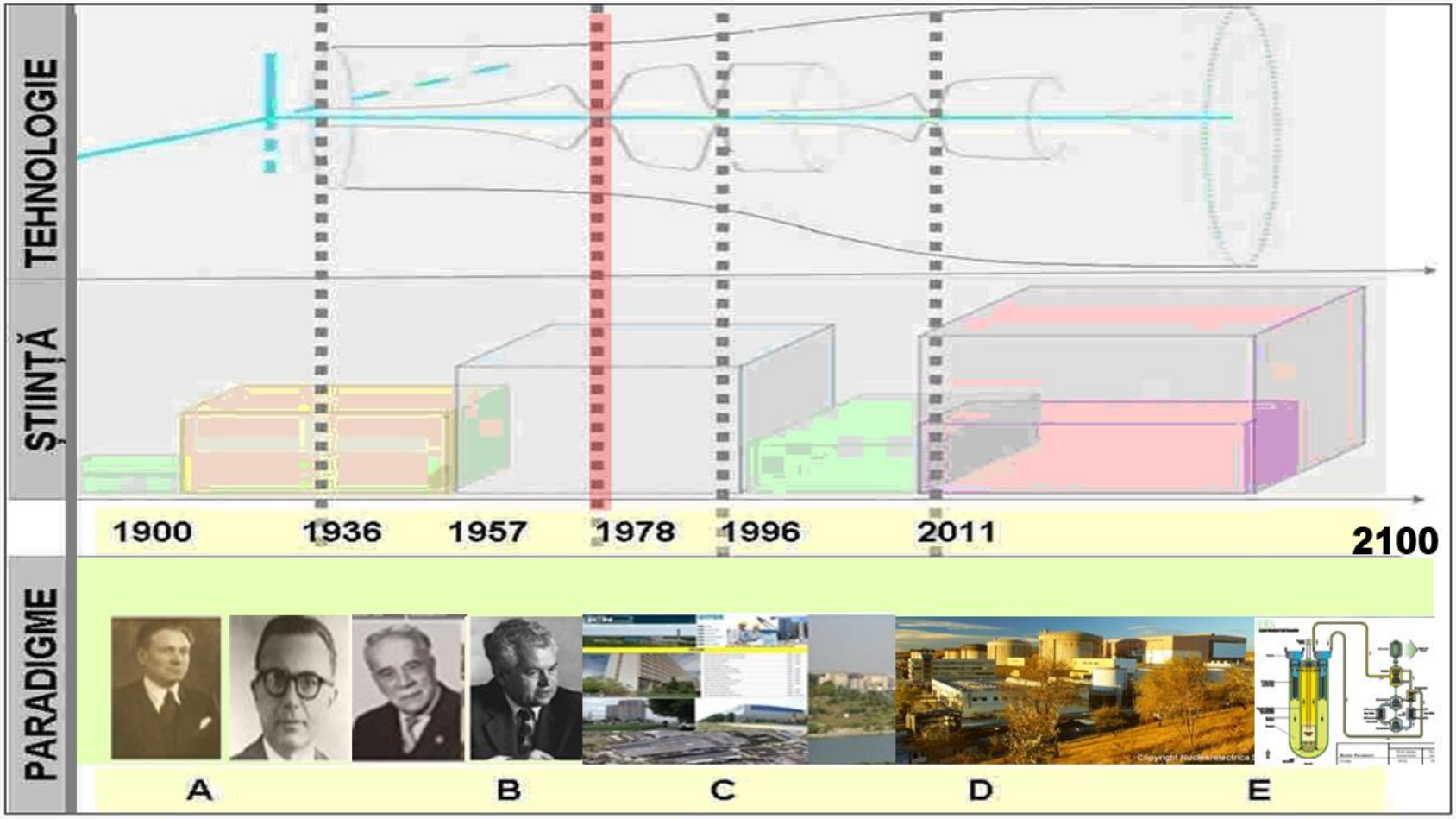

INDUSTRY 1.0
18th century
Steam power
Mechanical production, moving away from cottage industry
INDUSTRY 2.0
19th century
Electricity
Mass production and assembly line
INDUSTRY 3.0
Mid 20th century
ICTs
Electronics
Automated and networked production
INDUSTRY 4.0
Today
Advanced robotics
3D printing
Internet of Things
Artificial Intelligence
Big data
Intelligent, flexible and distributed production
ERE INDUSTRIALE
ETAPE EN – STIINȚE APLICATE NUCLEARE SI ENERGETICĂ NUCLEARĂ
Connected Pages
Social Connections
Linked Knowledge
Integrated Actions
MOSAIC
Semantic Web
INTERNET OF THINGS
Web 1.0
Web 2.0
Web 3.0
Web 4.0
Mainframe Computers
Client-Server Systems
Cloud Computing
Emergent Systems
Phase
1
2
3
4
5
6
7
1890-1942
1942-1960
1960-1980
1980-2012
2012-2020
2020...
beyond 2100
Science
Nuc Tech
Other Tech
Non tech
Society

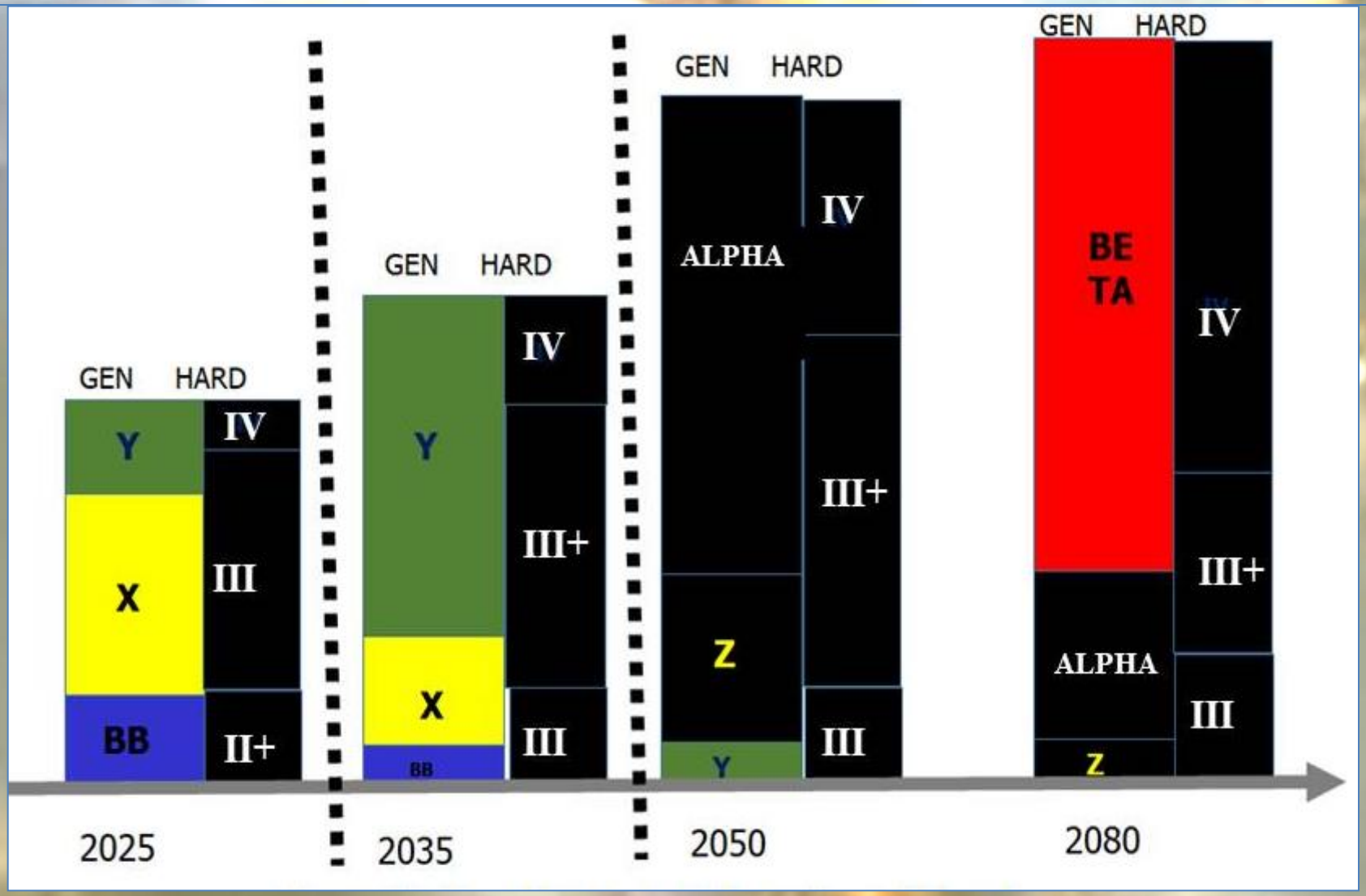
EN in erele 3.0 si 4.0

	GNENERATION II 1970's	GNENERATION II+ to II+ 1985-2020s	GNENERATION IV 1950's on
NUCLEAR PLANT CONTROL ROOM			
NUCLEAR PLANT			
HUMAN FACTORS	GNENERATION SG+ BB	GNENERATION BB+X+Y	GNENERATION Y+Z+ALPHA

Locul fizicii si energeticii nucleare in Romania intr-un secol si jumatate (2)

Un secol și jumătate de fizică teoretică (A-E) și patru decenii de energetică nucleară (C-E)




GEN
HARD
Y
X
BB
IV
III
II+
2025
GEN
HARD
Y
X
BB
IV
III+
III
2035
GEN
HARD
ALPHA
Z
Y
IV
III+
III
2050
GEN
HARD
BE
TA
ALPHA
Z
IV
III+
III
2080

D.IN LOC DE CONCLUZII

In this KP for the ES cases there is a set of assumptions generated by the paradigms, creating paradoxes, as for instance :

Paradigm 1-ES as a CS: A modeling system has to be built in order to represent **Risk Analyses for ES (RES) as a complex system, too.** RES is converging to a stable unique real state. However the KP results, including those RES are limited by our present knowledge, as described by the real Earth level mentioned above.

Paradigm 2: ES model involves knowledge of the risks associated to a certain source of energy. However, usually we actually are not aware of the real risks and we know very little about the interconnections of lifecycle dangers for interfering processes (energy level, emergence correlated with civilization one or with geological one etc.)

Paradigm 3: Details of ES and their lessons learnt. We design ES (MMES) for which Nature already indicated the optimal solutions. However, due to our reduced technical and scientific level at a certain moment we cannot understand the lessons from the beginning, but step by step.

Paradigms(cont'd)

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Paradigm 4: Understanding the ES risks (RES) and defining them is a difficult task as we design first of a kind MMES and as we are not aware of all the aspects of the lifecycle. The MMES are challenged inevitably by serious events, which apparently test the design continuously.

Paradigm 5: ES risk analyses results are seen as inputs to decision making risk calculation results are used for decisions. However we are facing decisions under high uncertainties and the use of lateral thinking is decisive.

Paradigm 6: In the ES risk analyses results there are limits and biases specific to the level of knowledge of that issue, but also there are "hidden" biases due to the level of KP in the whole civilization at that moment. Inter and trans disciplinarity is not just a desired option, but a mandatory one to minimize such biases.

Paradigm 7: RES results evaluation for further iterations in the.KP is an iterative process and the Principle 3 mentioned above applies. The result could be a better understanding by the use of diverse tools, as for instance the information one can get by "backward engineering" from natural examples.

ANNEX 1

PRINCIPALELE PROVOCARI ALE FIZICII SI ENERGETICII NUCLEARE ACTUALE

MONDIALE SI NATIONALE

1. **Rezilienta/ Robustetea sistemelor energetice nationale si utilizarile locale ale diverselor forme de energie**
2. **Sistemele energetice necesita sa fie gandite fractalic, autoreglabile/apoietice pe tot ciclul de viata si cuprinzand materiile prime-exploatare- dezafectare etc, impreuna cu consumatorii**
3. **Oikonomia ar trebui sa fie un principiu fractalic si autoreglabil**
4. **Ciclul de viata sa cuprinda cercetarea, testarea si functionarea ceea ce in energetica neceesita timpi indelungati**
5. **Adaptarea la utilizari diverse, dinamice ale energiei sub diverse forme, in diverse locatii, solutii de stocare**

6. **Prezenta indepartare de modelele din natura/cosmos – de ex Oklo sau fuziunea nucleara si necunoscutul descoperirilor/dezamagirilor ar trebui considerate**
7. **Dilemele si problemele surselor de energie, de exemplu cele ale reactorilor de fisiune -** *Sursele de energie vazute ca parte a unui ciclu si nu doar sursa. Energetica nucleara de fisiune necesita de exemplu raspuns la cum arata ciclul de combustibil si integrarea acestei surse in diverse locatii*
8. **Presiunea gasirii de solutii pentru supravietuire- la scara de comunitati, dar si planetara - pericolul atingerii momentului singularitatii omenirii ca sistem de energie biologica constienta planetara (biologic, IA, socio-politic, cosmic)**

9. **Raspunsuri la accidentele majore si o orientare mai buna in definirea paradigmelor in domeniu**
10. **Promovarea de tehnologii noi aliniate la rezultate recente din fizica teoretica si aplicata:**
    i. **Utilizarea de noi tehnologii – nanotehnologii, Proiectare/operare cu utilizarea spatiului virtual, considerarea evolutiei generatiilor umane, robotizare/IA inclusiv calculatoare cuantice etc.**
    ii. **Rezultate noi in cercetarea de materiale si filiere cunoscute, dar prentru care tehnologiile nu permiteau pana acum utilizarea lor comerciala**
    iii. **Noi rezultate din abordari / recalculari / remodelari din fizica teorica asupra fenomenelor de baza ale fisiunii (sectiuni eficace, zona activa recalculate etc)**
11. **Implementarea lectiilor marilor accidente**

12. Raspunsuri la probelemele specifice nationale

i. **de stabilitate, rezilienta SEN generate de masurile de atingere a tintelor de protectie climatica, ce necesita oprirea a cca 2000 MW de centrale termice pe carbune**
ii. **Asigurare a functionarii in regim de reglaj de frecventa in SEN**
iii. **Proiectarea functionarii SMR pe platforme energetice complexe, inclusiv cu regenerabile, pentru a intruni avantajele diverselor surse.**
iv. **Utilizarea la maxim de resurse – inclusiv umane si instalatii disponibilizate prin oprirea centralelor pe carbune**
v. **Sprijinirea industriei si cercetarii nationale nucleare**
vi. **Integrarea in procesul de reinnoire tehnologica in domeniu - Industry 4.0**

ANNEX 2

INVATAMINTELE DEZVOLTARII STIINTIFICE SI TEHNOLOGICE NUCLEARE

SMR pot indeplini functii complementare

- **Centralelor de mare putere in furnizarea de energie in regim de reglaj de frecventa in SEN**
  - **Pentru asigurarea de energie termica**
  - **Pentru alte aplicatii (de exemplu fabricarea de hidrogen)**
- **Pentru functionarea in tandem pe platforme energetice cu surse regenerabile si sisteme de stocare a energiei**
- **Pot asigura (in variantele cu alti agenti de racire decat apa, ca centrale de generatie IV, cicluri de combustibil mai bine integrate, si micsorarea foarte semnificativa a deseurilor inalt radioactive**

ROMANIA

Intarirea sectorului nuclear si cresterea contributiei sale

i. **Consolidarea functionarii pe termen lung a centralelor in functione care functioneaza in regim de baza de sarcina in SEN**
   a. **Retehnologizarea U1**
   b. **Punerea in functiune de noi centrale de mare putere (U3/4)**

ii. **Considerarea energetiicii nucleare pentru a participa la reglarea in SEN prin utilizarea de centrale de puteri mai mici ce asigura acest lucru sub forma reactorilor de fisiune , de tip SMR, etapizat**
   a. **SMR cu apa**
   b. **SMR de generatie IV**

SMR pot da solutii la actualele probleme energetice in general si ale celei nucleare mai ales cele nationale in particular, si anume:

1. **Asigura introducerea gradata de innoiri in domeniul nuclear. Plecand de la elemente de proiect si fabricatie/exploatare recunoscute si verificate, SMR cu apa introduc elemente suplimentare de protectie pasiva la accidente foarte severe si asigura o siguranta crescuta centralelor. Rezista mult mai bine, practic nu sunt afectate de accidente foarte severe si de hazarduri externe (cutremure, caderi de avioane etc)**
2. **Prin aspectul modular si constructia fiecarui modul pot asigura o participare flexibile la furnizarea de energeie electrica in SEN si de asemenea asigura aplicatii de mar interes ca furnizarea de energie termica, fabricatia hidrogenului**
3. **Asigura un volum mult redus de deseuri radioactive, mai ales cele inalt radioactive**
4. **Sunt mult mai usor de construit, fazele importante avand loc in uzinele de fabricatie, au posibilitatea standardizarii si utilizeaza tehnologii deja omologate.**
5. **Planul de urgenta este mult mai simplu si centrala are un nivel de risk foarte redus**
6. **Are o durata si un cost de instalare si PIF mult reduse fata de cele de putere mare.**
7. **Pot utiliza amplasamente dezafectate de obiective industriale si/sau centrale termice dezafectate.**
8. **Pot face parte din platforme flexibile de energie cu surse regenerabile.**