総合資源エネルギー調査会
原子力の自主的安全性向上
に関するWG　第６回会合
資料5

原子力産業界のリスク管理に期待すること

経産省WG第六回 (21November2013)
東京工業大学　尾本　彰

はじめに

福島事故の反省も踏まえ、IAEAの文書等に示されている国際的なガイドと良い慣行も勘案し、我が国原子力産業界が優れたリスク管理(LPHCリスクに焦点）を行う上で期待される事項を私見として挙げた

背景にある認識は意思決定とそれへの考え方・姿勢の影響の重要性

組織等の風土・文化に関する議論は、「福島事故はユニークな背景（国民の特性を背景にした安全文化と自然環境）によるもの」とする海外の一部風潮を肯定するものではなく、特性・バイアスを理解することで、よりよい意思決定と行動に繋げる事を目的とするもの

- ✓ 事故に関したこの分野での因果関係解明は今後の研究期待
- ✓ 国の風土と安全文化の関係の研究への関心の国際的高まり
- ✓ 日本が特徴的に劣っているとの認識に立ったものではない

①批判的な思考

- 国民の特性であろう「集団への帰属」「集団思考」で欠けがちな批判的思考、「形式に拘り目的や全体像を見失う」（参考１）を踏まえ
- 原子力のリスクに責任を有する者は、これら陥穽を避け「批判的な思考や討議」、「個々人が倫理観をもって行動」「安全第一の意思決定」が必要
- 異なった意見/批判的な意見を持った人を中に入れるだけの問題ではなく、個々人が批判的な思考を（critical thinking/reflective thinking）
- 安全文化にいう”questioning attitude”は「疑問を提示しなかった」問題も問うことが必要な場合も。NRCの定義と国内電力の定義に関連して微妙な差があるように見受けられる
- 様々な専門分野にまたがり自然現象のような不確かさの大きい課題に関する意思決定に必要な批判的な議論
  - 専門分野を超えた批判的な議論
  - 他の専門分野で「暗黙の仮定」とされている事は正しいか
  - 設計想定を超えたら、何がクリフエッジになるかどのようにクリフエッジ迄の距離を増す事ができるかの検討を通じ不測事態への備え強化

②システム的な思考

③我が国原子力界は、機器信頼性重視で良い成果を生み出す一方、システム的な思考が弱い面があるのではないか？

（福島事故に鑑みた例）

- 航空機落下時の格納容器健全性評価に注力の一方、B5bのような柔軟なシステム対応策の検討が不足
- 高い津波防波堤を検討の一方、それを超える事態に対処して安全機能を確保するシステム思考の不足
- 深層防護の層間独立性の留意不足（レベル4/5共通原因故障）

求められるものは、

✓ 設計ベースを超える事態発生に伴う残余のリスクの存在 (known unknowns and unknown unknowns)を意識し

✓ 機器の設計ベースを超える（機能しない）場合でも、システム全体で安全を確保すべくレジリエンス構築（Prepare, Respond, Recover, Prevent）

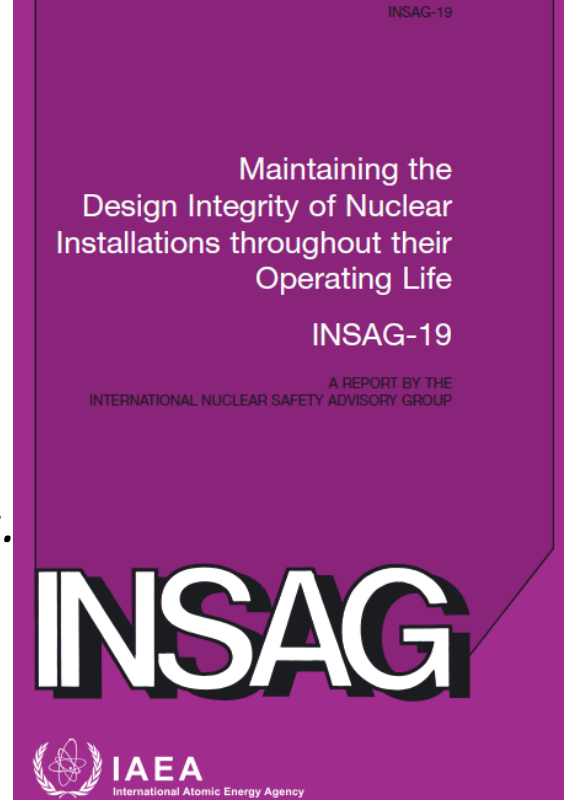
③ intelligent userになること（設置者）

- 設備（変更）と手順書（変更）の整合性確保のみならず、自社プラントの設計理解と脆弱な点の把握 (PRA/PSA情報）は安全確保の基礎
- 知識と深い洞察力を有するスタッフの厚みを有し体系的な知識管理を行うintelligent userになる事はresponsible userであるための条件
- 設計ベースに関する知識には「こう設計されている」だけでなく下記をも含む
  - ✓ 何故このような設計になっているのかの理解
  - ✓ 設計のベースを構成する安全基準、規格基準の背景にある考え
- 専門に扱う部署があれば言いという訳でもないので、Knowledge culture醸成を言う人もいる

- 国内では
  - メーカーへの強い依存の中で
  - 運転開始後のDesign Authority [DA]の役割を果たす部署は確保され、マネジメントがその重要性を認識しているか？
  - DA責任部門は、許認可ベースとシステム設計を理解し、保修部門の設備（台帳）管理に限定しない活動が行われているか？

(INSAG-19, 2003)

An operating organization must set up internally a formal process to maintain the design integrity as soon as it takes control of the plant. This may be achieved by setting up a design capability within the operating organization, or by having a formal external relationship with the original design organizations or their successors. a formally designated entity within the operating company that takes responsibility for this process.



(OSART guideline, 2005)

- *Check that there is a formally designated entity ('design authority') within the operating organization that takes responsibility for maintaining the design integrity.*
- *Check whether a plant specific PSA model has been developed and whether any PSA applications have been developed and implemented to optimize plant operation. Confirm that technical support personnel have good knowledge on the assessment techniques used for this application and understanding of any relevant PSA limitations.*

(……続き） 他にも….

- 運転期間中に競争発注で原設計者と異なる会社に電力がその都度改造を発注という条件下でも、プラント設計情報（何が初与条件か、何故このような設計なのかを含め）を長く継続的にアップデートし保持してゆくのは誰か？
- knowledge loss risk解析と方策策定
- 許認可ベースと許認可における仮定を十分理解した上での設計変更
- 設備設計変更を遅滞無く運転手順に反映
- 機器の元々の供給者が市場から消える場合への備え
- 自前の安全解析/PRA実施能力とその結果を洞察する能力

➢ intelligent userとしてどの深さまで設計関係で求められるかは議論あるところ。INSAG-19も個別委託に触れている。将来は航空のDAのあり方も参考にした議論が必要(添付２参照）

④ 設計への強い問題意識（設置者）

- 原子炉事故の背後には設計問題もあるのが一般（設置者自身の設計方針も含め）
  - ✓TMI:加圧器水位計
  - ✓チェルノブイル：
    正のボイド係数、制御棒の水排除効果による反応度印加
  - ✓福島：
    電気品室配置、使用済燃料プール位置、格納容器（冷却を優先する時の隔離解除）、事故時計装、ベントラインの号機間共用…
- しかし、原子炉事故の責任は、設計に依らず「事業者に集中」が世界共通のルール
- 設置者は設計への問題意識を設計者に提示しsafety by design強化の必要

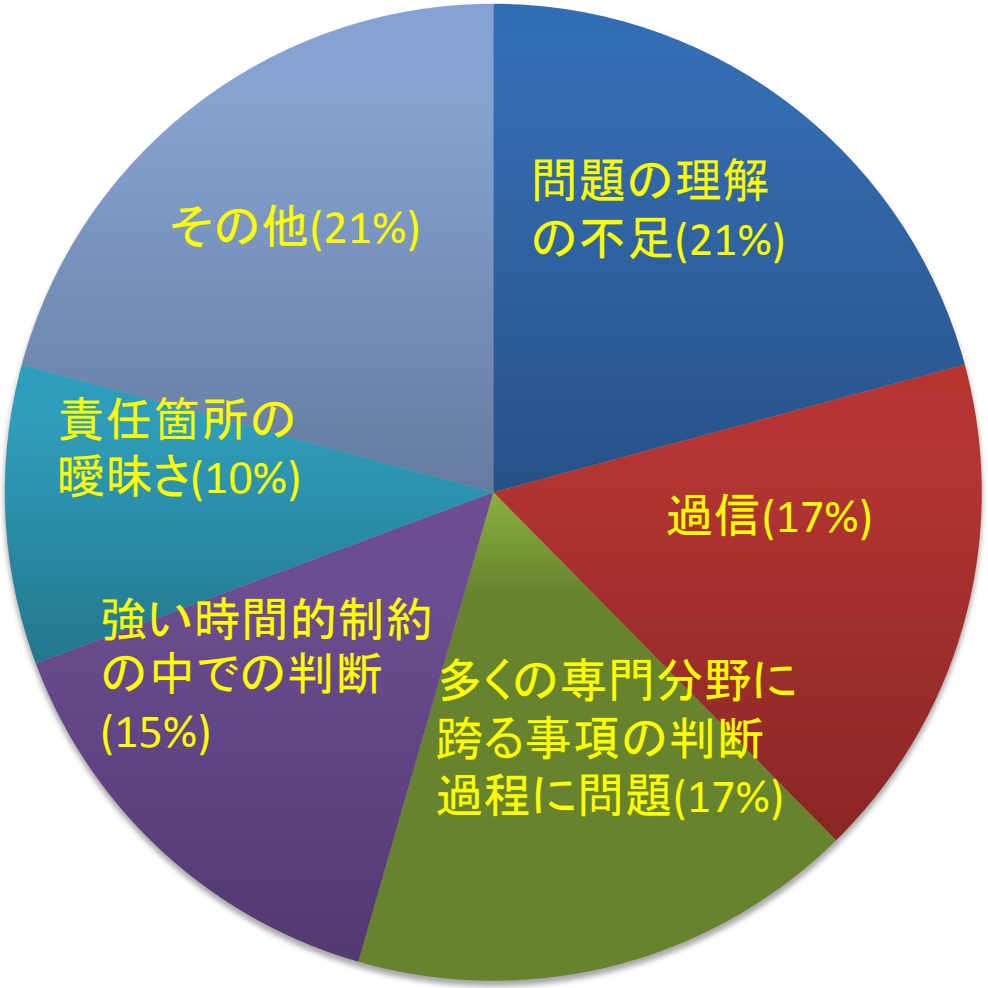
⑤海外の制度を参考に（設置者）

- 例として
  - ✓シフト技術アドバイザー(STA)
    - 米国：シフト勤務、プラントの機器システムの状態を監視し安全問題に発展しかねない懸念あれば当直長にアドバイス、異常事態発生時には独自に評価し取るべき行動を当直長にアドバイス、複数号機兼務も許容
    - 仏:シフト安全エンジニアが同様な役割
    - **①にも関連する事項**

[INPO Fukushima LL report] “This decision-making approach did not provide for independent challenge or second checks by other groups within the organization. …the site ERC did not independently review and provide feedback prior to decisions by the control room staff “

- 実際的な業務に即して日々の活動の中で優れた方式を知る必要

⑥ 技術判断の過誤の原因分析を通じ 意思決定上のバイアス、弱点の認識（原子力界全体）



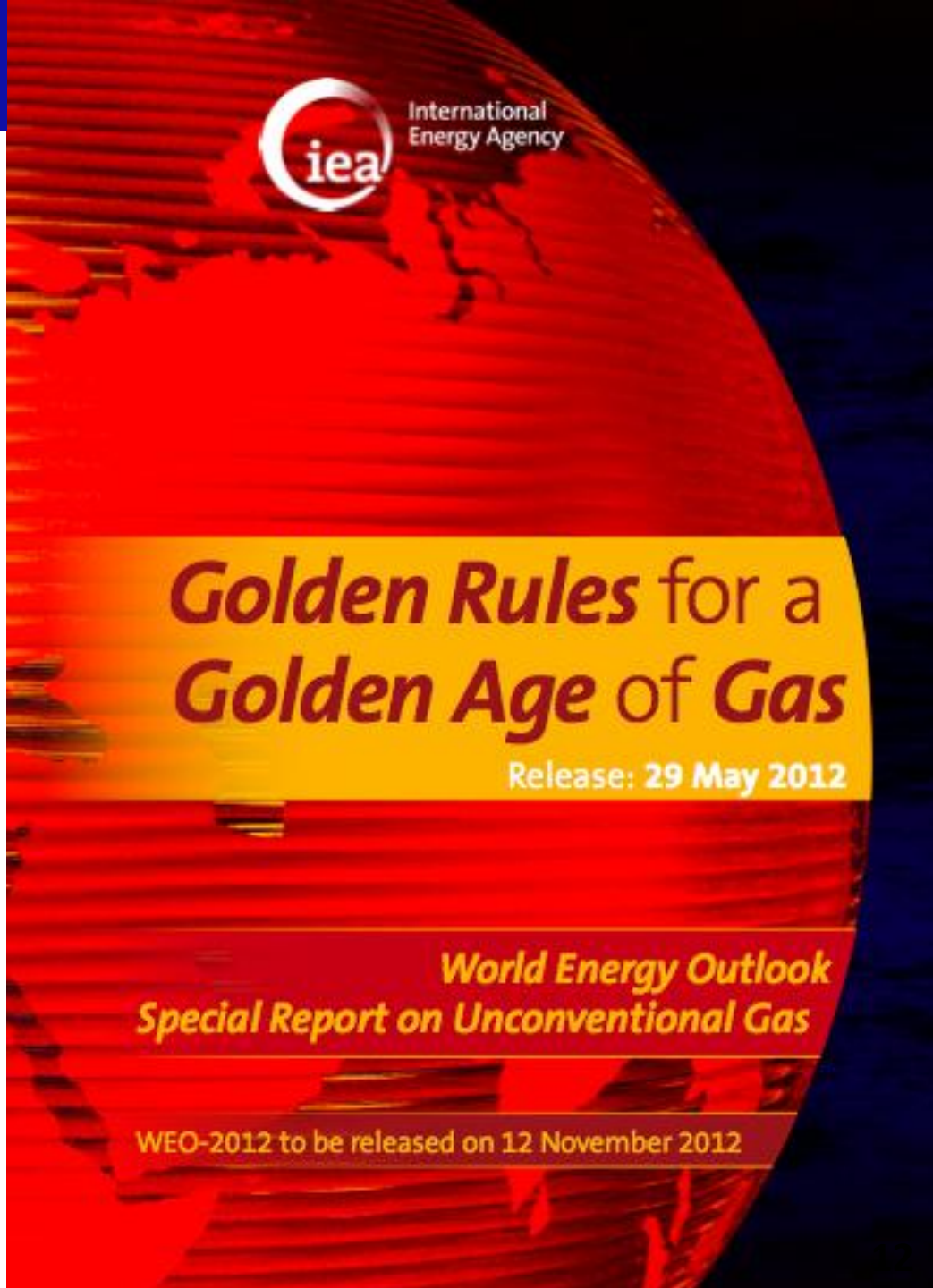
[SOURCE] Performance Improvement International, 1994)

⑦組織のリスク管理のプライオリテイとリスク管理システムの構築（設置者）

- ビジネス環境維持（コストプラス、垂直統合、立地地元関係等）重視の一方で、原子炉事故が組織の存続を左右すると考えた真剣な対応が不足していたのではないか
- CRO (Chief Risk Officer)
- 気付かない問題への対応（領域を超えた安全の専門家の意見を取り入れるなど）
- Business continuity plan (機器構造物の設計上の重要度分類目的は原子炉安全だけではないなど設計にも関与)

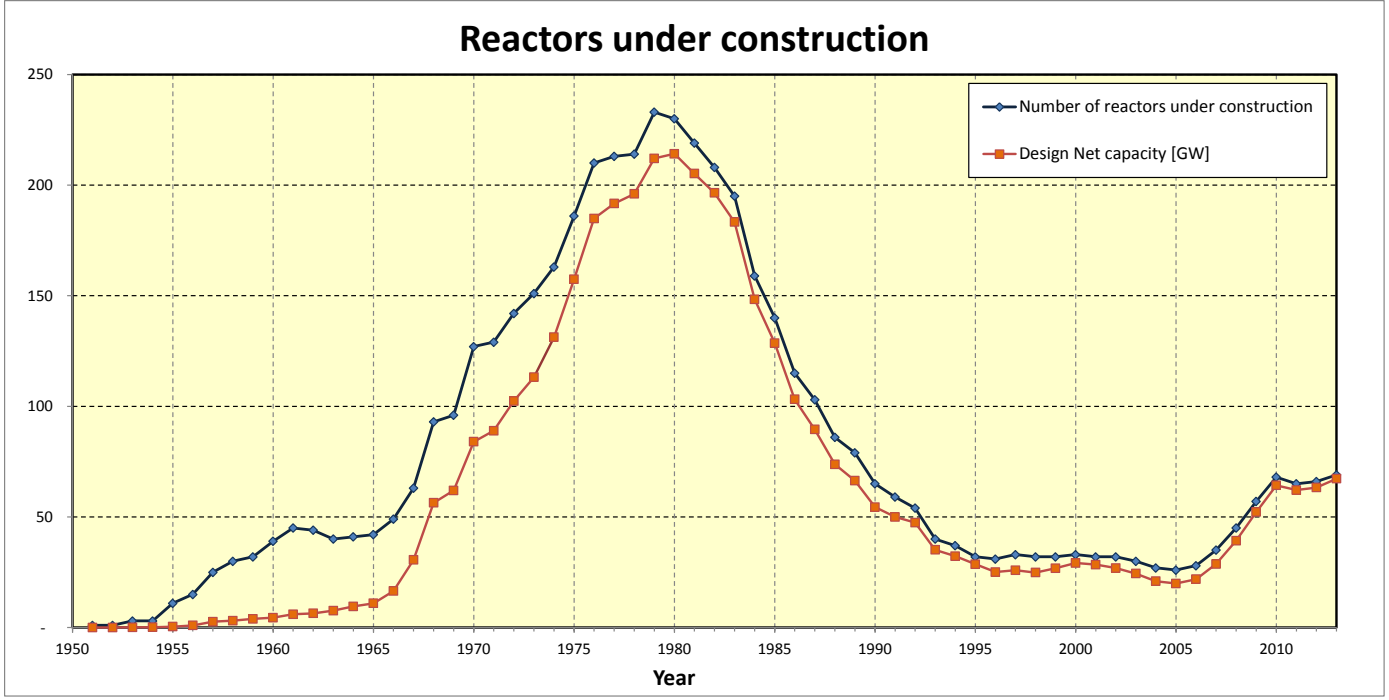
⑧　責任ある運用

“Social license
to operate”



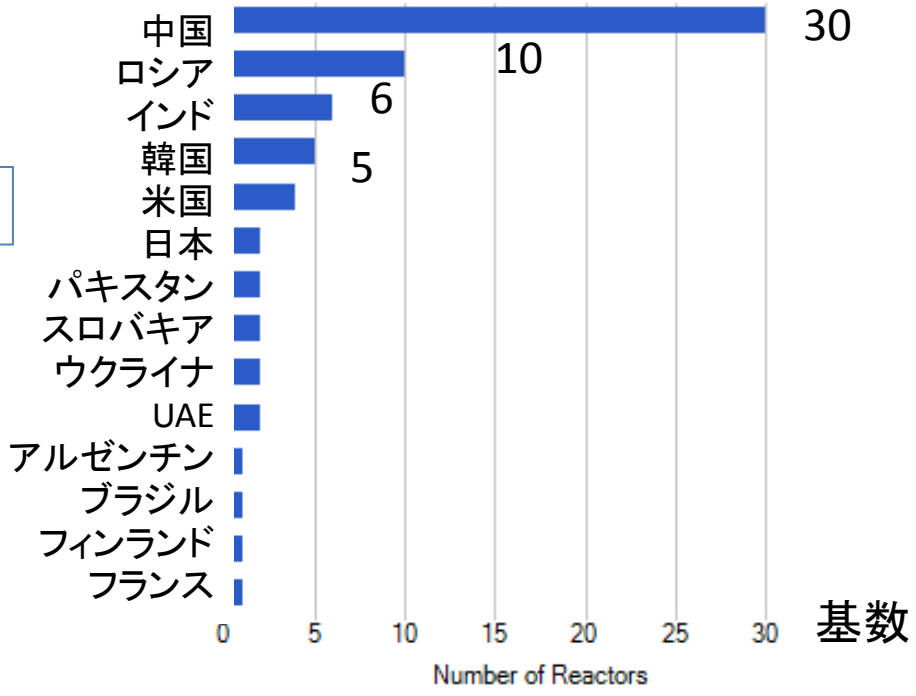
⑨将来に向け広い視野でのリスク低減活動(原子力界全体)

- IAEA安全基準の遵守とIAEA による各種安全レビュー(OSART, PSA, SAM)の活用によるベストプラクテイス習得（参考3参照）
- 福島の経験を踏まえ、原子力新設活動が活発なアジアでの安全確保に積極的な役割を果たす必要。例えば隣国中国は30基を新設中
  - ✓教訓と改善策例の知見の普遍化
  - ✓安全確保の上で必要な国際的な仕組みの提起(参考2参照）
- 「組織と安全の係わり」に関して考察を深め、諸外国が参照できる報告に:NAT(Normal Accident Theory), HRO(High Reliability Organization), STAMP(Systems-Theoretic Accident Model and Processes)等のアプローチを参照
- 航空では規制当局と被規制側である業界（エアラインとメーカー）の関係を超え世界航空安全計画（Global Aviation Safety Plan）とロードマップを作成し、安全の達成度を示す指標を用い状態改善を監視



[出典]IAEA-PRIS

現在建設中の原子炉基数：71基



[出典]IAEA-PRIS, November 2013

しかし、これらの改善や行動は産業界や個々の設置者がそれぞれ独立して実行/達成できるものでもない

- ✓社会とのコミュニケーションと社会の改善努力への「理解」（継続的改善を阻むPrisoners’ dilemma状態からの脱却）をベースに育まれるものではないか？

仏CLIは規制と地方自治体による参考例

- ✓PRA/PSA（地震の評価に用いる地震による機器構造物被害のデータベース構築なども含み）やレジリエンスに関する信頼できるシンクタンク的な存在によるサポートの必要性があるのではないか？
- ✓産業界組織：2003年の検討から１０年と福島事故を経て、在り方を再度議論する機会ではないか？
（例：米国NEIに倣えば、原子力産業会の意見の提示、研究機関との連携の在り方、電事連を含めた規制インタフェースの在り方など）

参考資料1

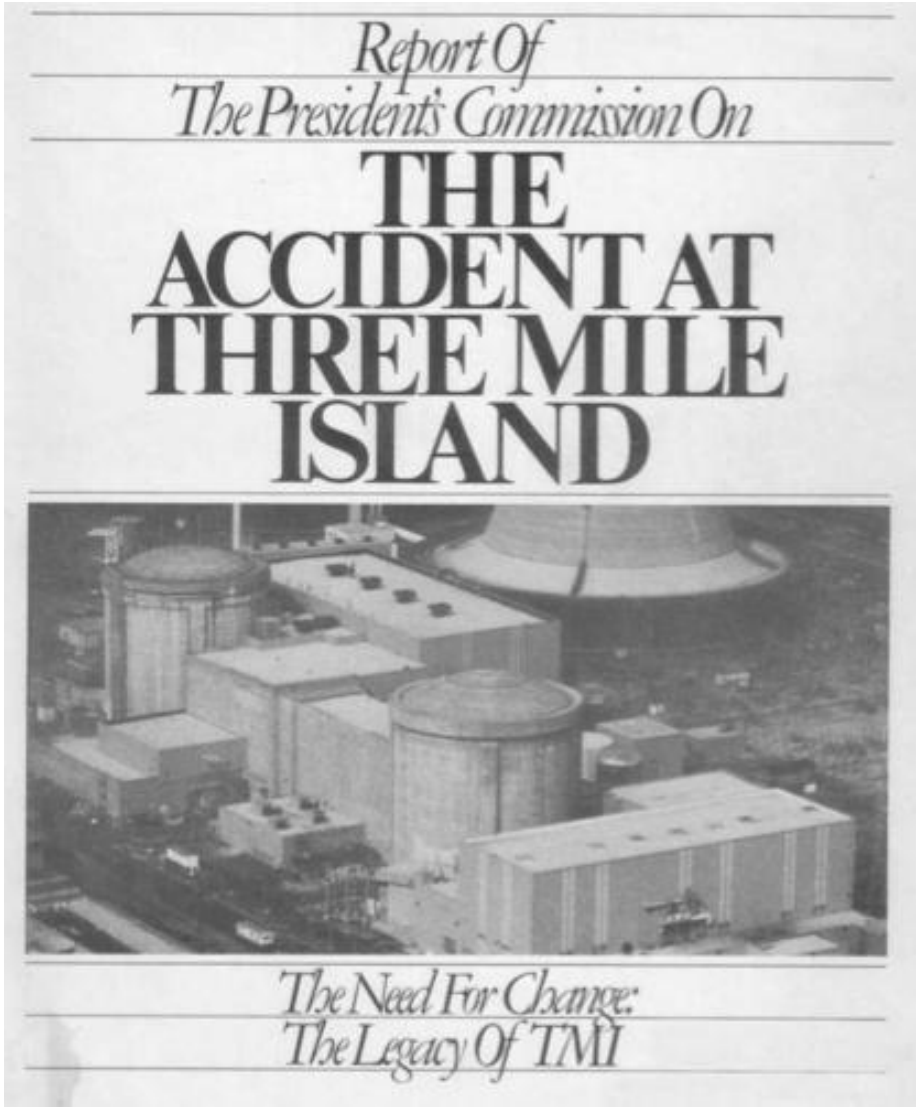
Global 2011, Nuclear Power Symposium, WNU,
IAEA 技術会合などで話した内容を纏めたもの

福島事故はユニークな背景（国民の特性を背景にした安全文化と自然環境）によるものとする海外の風潮を肯定するものでは決してなく、そのような特性を理解してよりよい意思決定と行動に繋げる事を目的とするもの

A WARNING in Sec. “overview”, Kemeny report, 1979

“We have stated that fundamental changes must occur in organizations, procedures, and, above all, in the attitudes of people.

No amount of technical "fixes” will cure this underlying problem.”



Influence of national culture?

- *In a culture where it is impolite to say "no" and where ritual must be observed before all else, I think that Western style "safety culture" will be very hard for the Japanese to accept.*

- *But there were also extraordinary – even heroic efforts made by the brilliant dedicated engineers, operators…*
I do not doubt that the Japanese Nuclear industry has the capability to transform to a nuclear operations safety culture.

Prof. D. Klein, ex Chairman of USNRC,
The Ripon Forum, Summer 2011

In the Wake of
FUKUSHIMA

DALE KLEIN

In the wake of the nuclear incident at Fukushima, Japan, the world held its breath wondering if the facilities would be capable of recovering from one of the most significant natural disasters in recorded history. While the media never failed to report on every setback, it missed the opportunity to report on what went right. This is what separates those who want to report the news from those who want to change the world.

As engineers and scientists across the globe began to review this event, some common themes and causes began to emerge. The first, and most fundamental, was the scope of the regional disaster itself and the lack of preparation by local and national authorities to cope with an event

position or understanding.

Over the years, I have made many friends within the Japanese nuclear safety community and industry. I can tell you that at an

Faced with the Fukushima disaster, and certainty of power shortages and economic hardship that will hurt the Japanese people, I believe that Japan now has the opportunity to "do it right." It took the Three Mile Island accident in the U.S. to force utilities, vendors, and regulators to do the in-depth self-criticism that eventually led them to strive for excellence. It remains to be seen if the Japanese culture can evolve to accept and embrace the concepts of self-criticism, to have a questioning attitude, to share best practices, and more importantly, fully disclose their failures when thing go wrong.

The lessons to be learned from Fukushima are many, but what may be surprising is how few may actually apply

Dr. Dale Klein

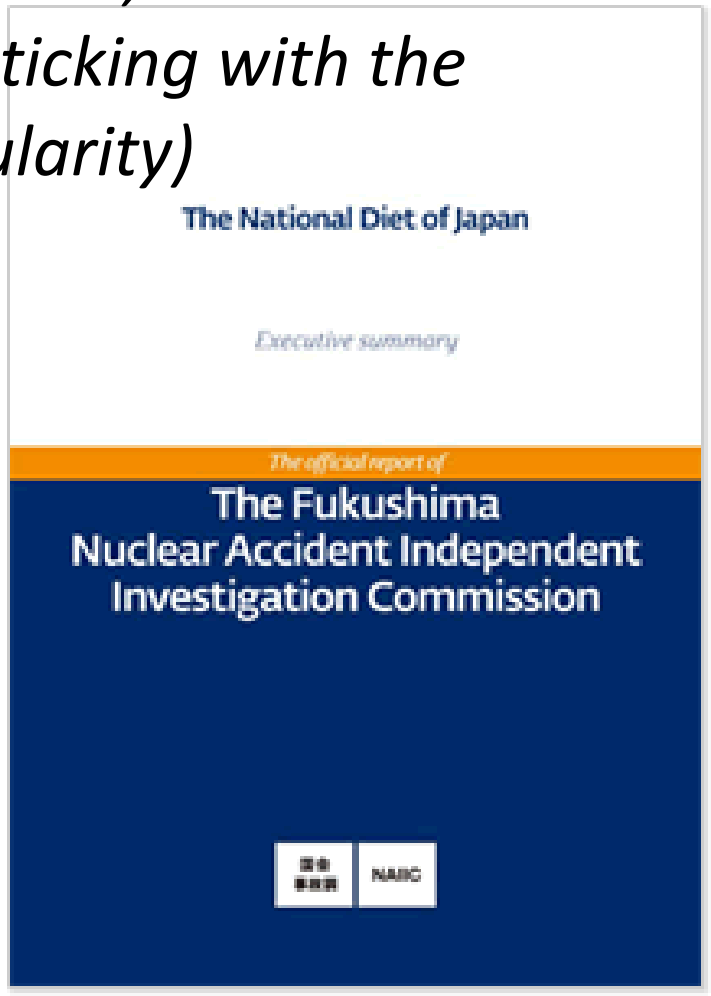
The lessons to be learned from Fukushima are many, but what may be surprising is how few may actually apply to U.S. plants.

Influence of national culture

"This was a disaster "Made in Japan.": Its fundamental causes are to be found in the ingrained conventions of Japanese culture (our reflexive obedience; our reluctance to question authority; our devotion to 'sticking with the program'; our groupism; and our insularity)

Prof. K. Kurokawa in chairman's message to the Diet's Investigation Committee's Report (2012 July)

[source] http://naiic.go.jp/wp-content/uploads/2012/07/NAIIC_report_lo_res2.pdf



However, no analysis of causal relationship in the main body of the report

✓ ***What Fukushima accident tells us about weakness in the context of Defense in Depth?***

Relevant cultural attitude issues

- ***Organizational,***
- ***Nuclear community's***
- ***National***

Level 1 Defense in Depth

Prevention of abnormal operation and failures

Technical lessons

1) When uncertainty is very high, prepare for the worst;
   -Where is cliff edge ? (when hit by high Tsunami)
   -What is possible to increase distance to cliff edge?
2) What are implicit assumptions in codes/standards/ guidelines?

Relevant cultural attitude issues

- Lack of preparedness to beyond assumed condition
- Dialogue among different disciplinary areas
- Lack of critical thinking, questioning attitude
  - questioning professional society's standards

IAEA Safety Standards

for protecting people and the environment

Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations

Jointly sponsored by the IAEA and WMO

IAEA WMO

Specific Safety Guide

No. SSG-18

ANNEX II: ASSESSMENT OF TSUNAMI HAZARD: Current practice in some states

In this annex, an outline is presented of: the methodology, namely the Tsunami Assessment Method for Nuclear Power Plants in Japan published by the Japan Society of Civil Engineers in February 2002.

Historical tsunami study

The first step is to conduct literature surveys for dominant historical tsunamis affecting the target site, and then the validity of recorded tsunami heights needs to be examined. On the basis of the results, fault models for numerical simulations for historical tsunamis can be set up.

Level 4 Defense in Depth
Control of accident beyond Design Basis

Accident Management (AM) was prepared after Chernobyl, but not assuming extensive damages by external /security events

damages to

- ✓ System, Structure, Components
- ✓ Offsite power
- ✓ Heat Sink
- ✓ Communication system
- ✓ Team

Technical lessons

- ✓AM was not robust enough, especially against external event, SBO
- ✓Independence of level 4 layer of Defense-in-Depth from the rest
- ✓Nexus between safety and security

Relevant cultural attitude issues

- ✓ Lack of critical thinking, questioning attitude
- ✓ No waiting until uncertainties of external events are reduced

Level 5 Defense in Depth
Emergency Preparedness and Response (EPR)

- **Overall offsite actions (evacuation and food control) helped reduce health risks**

- **Identified problems**
  - ✓ Offsite center's function was lost
  - ✓ Confusion in implementation of EPR
  - ✓ Delineation of responsibility including PM, communication among decision-makers

Technical lessons

Needs to revisit
- ✓Delineation of responsibility, command line, coordination
- ✓Design and function of "offsite center"
- ✓Offsite emergency plan (zoning and others)

Relevant cultural attitude issues

- ✓ Complacency: "Accident will not happen here"

What Fukushima accident tells us about weakness in Defense in Depth?

✓ ***Relevant cultural attitude issues***

- ***Organizational,***
- ***Nuclear community's***
- ***National***

Transforming Cultural Attitude in Japan?

1. **Priority of risk management**
   From Business environment (vertical integration, cost-plus tariffs, relations with local governor & mayor)
   To social responsibility to operate

2. **Complacency**
   (Change to)
   - ✓ "Accident can happen here"
   - ✓ "We must always learn from others"

3. **Preparedness to LPHC may need different approach from "continuous improvement"**

4. **Transparency and trustworthiness**
   From Prisoner's dilemma situation, preventing continuous safety improvement to "Social license to operate" by responsible use, transparency and trust

Transforming Cultural Attitude in Japan?

5. Parochialism
(Change to)
- ✓Questioning to experts in other disciplines

6. Professionalism, respect for expertise
(Was)
- ✓Lack of expertise (Regulation)
- ✓Heavy outsourcing (Utility)

(Change to)
- ✓Strengthen safety expertise levels
- ✓Capacity building of in-house resources

7. Safety culture, especially
- ✓"Questioning attitude"
- ✓Critical/reflective thinking

Nuclear community

- Technical issues leading to nuclear disaster: Mostly understood

- University of Tokyo's Nuclear GCOE project to study "Why nuclear community in Japan failed to prevent this accident"
  - ✓A series of interviews by GCOE members to 24 recognized nuclear experts (University, Regulatory body, AEC, Utility, Industry, research institute, NPO critics)

[SOURCE] A. Omoto et al, Global 2011, December 2011

Nuclear Education and Research Initiative

Why not prepared to unexpected natural hazard?

- Focus on internal events in PSA
- No question about US origin designs (in early designs)

  location of Electric Equipment Room in UG of Turbine Building by GE/EBASCO designs
- Isolation from global safety regime (complacency)
- Lack of communication & mutual understanding between natural science and engineering on uncertainty and design margin

[SOURCE] A. Omoto et al, Global 2011, December 2011

Why prevention/mitigation against beyond Design Basis was not enough

- Degraded safety culture（complacency, lack of sensitivity to information, delayed action to alert, over-confidence on Nuclear safety）
- Lack of tension between Regulators/Operators
- Too busy in caring day-by-day problems
- Society takes risk-related actions and modifications as evidence of unsafe plants (“Prisoners’ dilemma”)
- Failure of safety regulation
- “Problems was more or less recognized even before 3.11”

[SOURCE] A. Omoto et al, Global 2011, December 2011

Nuclear Education and Research Initiative

If you recognized problems, what did you do?

Took actions but not enough

- Creation of JANTI emulating INPO
- In light of 2007 KK earthquake, construct seismic isolation ERC, underground water storage tanks etc.
- "Change culture" project, Corrective Action Programme, "Safety alert" reports etc.
- Creation of CLI (Local Information Committee at KK)

If actions, why?

- Operator is a King, no criticism
- No question asked to NE programme implemented under the National Policy
- "Loose lips sink ships"
- Too busy to care

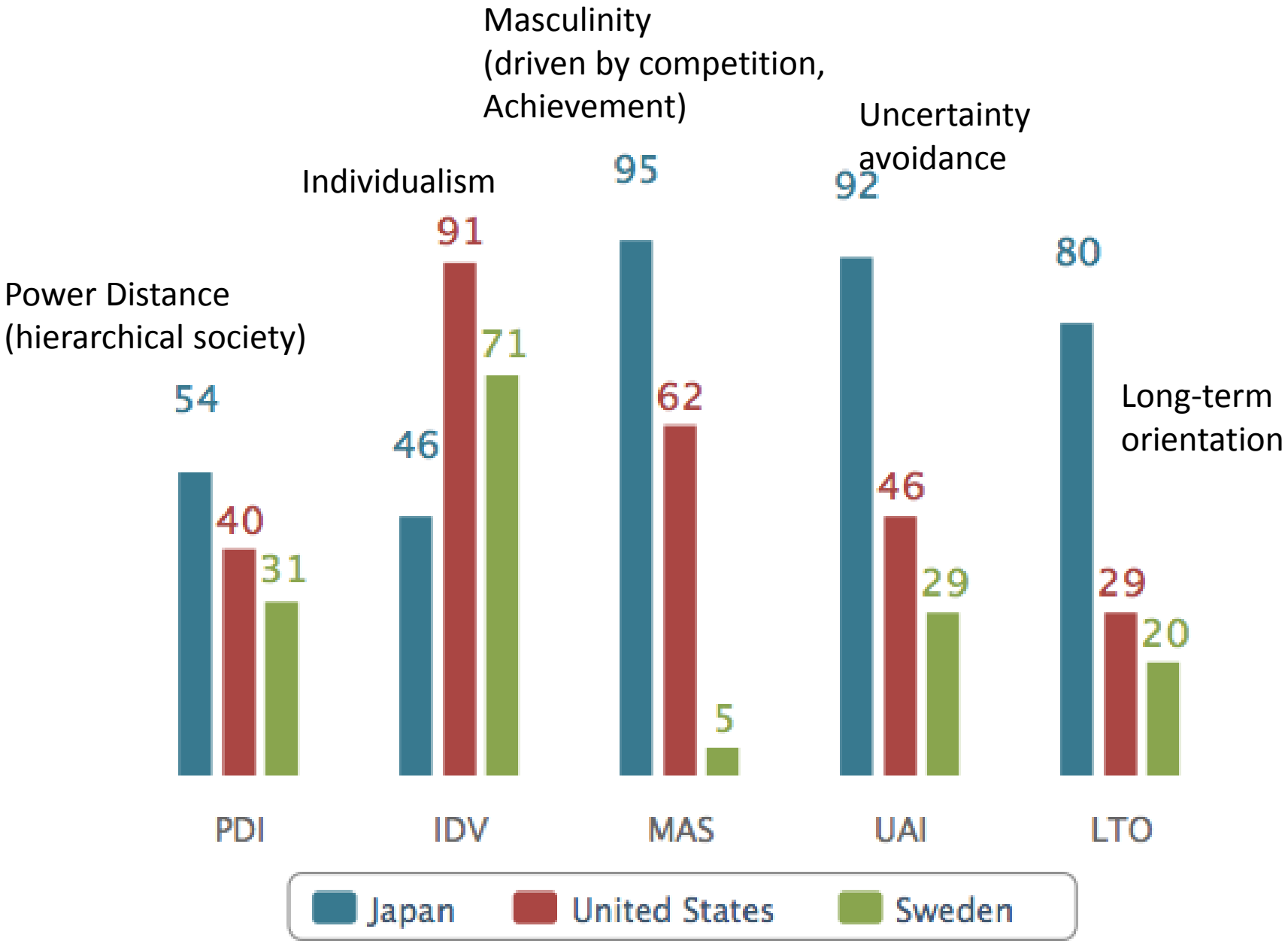
[SOURCE] A. Omoto et al, Global 2011, December 2011

CONERI
Nuclear Education and Research Initiative

Some salient features of national culture

1. Collectivism (as versus Individualism)
   - ✓ ~~"subject"~~ + "noun" + "verb" sentence
   - ✓ Think/Act as a group
   - ✓ No serious debate
   - ✓ Not speaking out:
     "Tall trees much wind"
     "Better bend than break"s

2. Less critical/reflective thinking, questioning attitude
   - ✓ Education is, more or less, for "transfer of knowledge" rather than "teaching how to think"



[SOURCE] http://geert-hofstede.com/japan.html

Some salient features of national culture

3. Lack of big-picture thinking, very often distracted by formalities and details
   - ✓ Independence is an approach to assure safety-first decision-making

Although Nisbett's "The geology of thoughts" argues Asian see object as an integral part of environment (see forest that tree)

4. Heavily in pursuit of component reliability/quality, while weak in system thinking such as;
   - ✓ Why B5b was not considered in Japan?
   - ✓ What about preparedness of the whole system to unexpected?

Look at positive side

1. Dedication

- ✓ INPO special report on the nuclear accident, Nov. 2011
  "…Some workers lost their homes and families to the earthquake and tsunami, yet continued to work. Many workers slept at the station…..usually on the floor. Because of food shortages……"
- ✓ TEPCO's investigation report Appendix touches a bit on heroic acts by operators sacrificing themselves
- ✓ Generally speaking, Utilities employee have mentality of dedication through work for the better of the society

2. Compassion

3. Politeness

4. Hard-working

参考資料2

航空分野から学ぶこと

- ✓ Does the current practices in setting user requirements, licensing, change management etc. support such growth while assuring safety? Is it an efficient system?

- ✓ Does infrastructure in new entrants warrant safe & secure operation? Anything we can do to enhance "safety by design" and "security by design" through harmonization, standardization, certification of design, peer review etc.?

- ✓ Issue of harmonization(user/regulatory requirements), standardization, design certification, international peer review

Learning from aviation

	AVIATION	NUCLEAR
Safety requirements	Chicago convention Annex	IAEA-SS
Design review	type certification(TC)* (apply in several states including origin, participation to review from countries)	reviewed for each NPP for license or approval of SD (but no global certification)
Design Authority	TC holder	manufacturer→ operator
Change management	AD* mandatory to other states	individual plant (under Owners Group coordination?)
Recom. from review	USAOP: mandatory	Up to recipient country
Safety strategy	Globally-shared (NAA-AL)safety roadmap	-

Similar arrangement as TC for airport, air traffic control etc.

(SD: Standard Design)

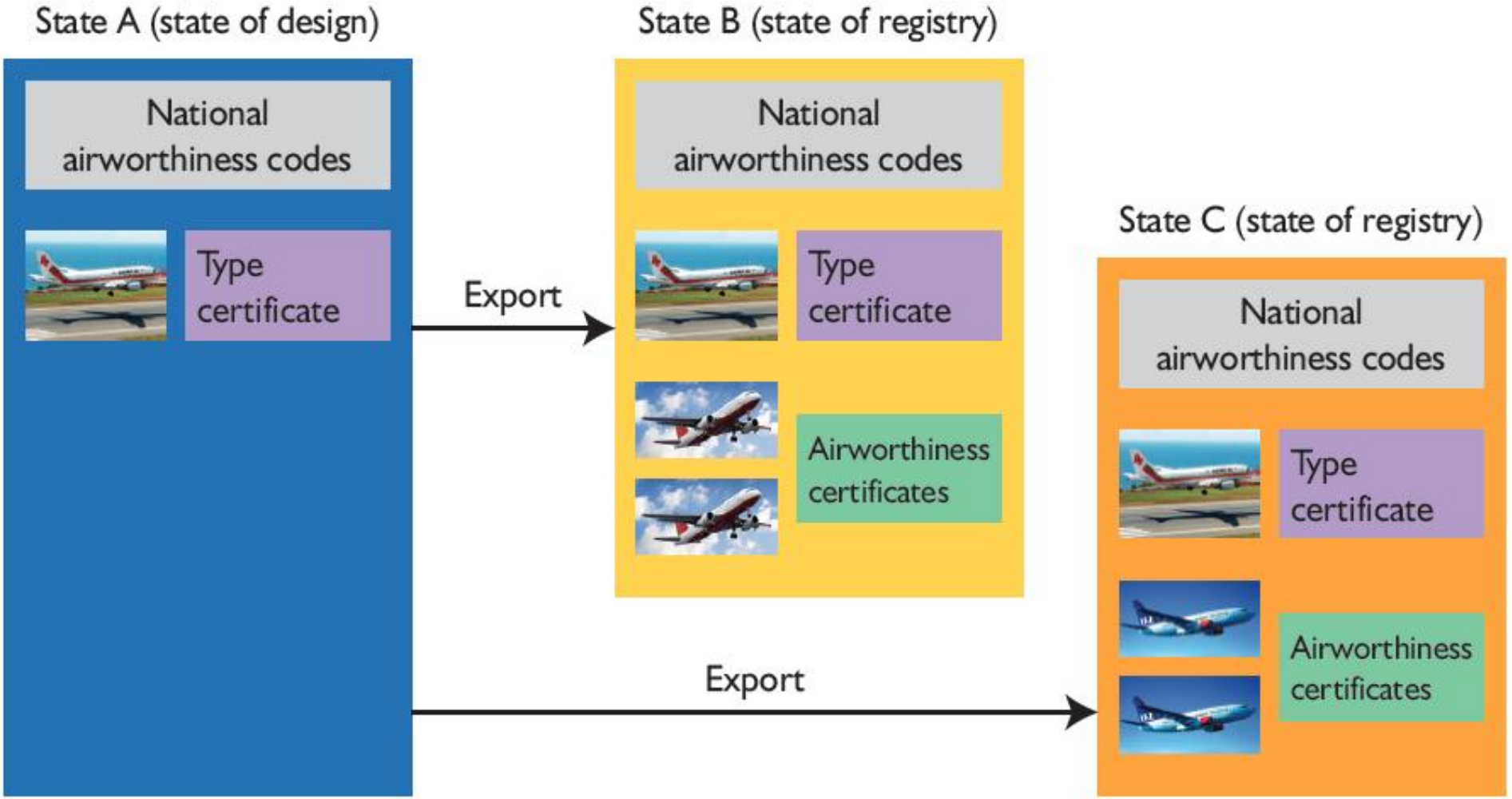
Type Certificates: On the basis of Bilateral Airworthiness Agreements, NAAs (National Aviation Authority) accept the design review work done by the NAA of the state of design and only assess compliance of the design with those of their own requirements which differ from the original ones.

AD (Airworthiness Directive): Notification based on accident etc., from the country of origin, requires mandatory implementation in other countries

USAOP (Universal Safety Oversight Audit Programme)

International system of design certificate in aviation

[SOURCE] WNA report "Aviation Licensing and lifetime Management, 2013



The airworthiness from NAA certificate attests that the aircraft is airworthy insofar as the aircraft conforms to its type design.

Things to learn from aviation

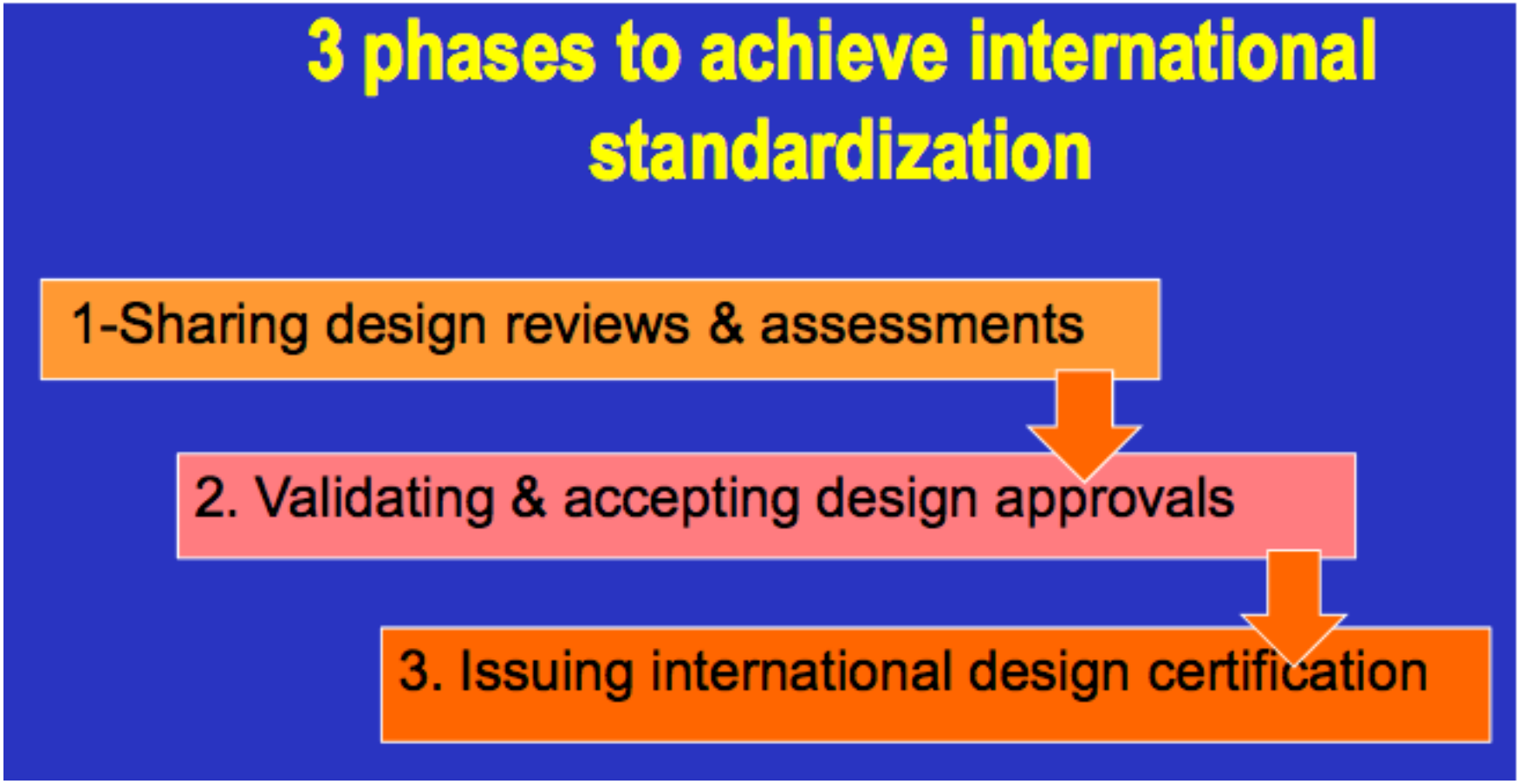
- ✓ Enabling system for aircraft to fly to a developing country
- ✓ Convention defines binding standards and certificate system, while assuring sovereign rights by NAA (NAA needs to notify ICAO what & why different) [binding standards] [harmonization] [coherent licensing system] [efficiency] [best practice to safety prevail]
- ✓ Bilateral airworthiness agreement enables accepting licensing in the country of origin [less uncertainty in licensing due to country specifics] [efficiency]
- ✓ Design authority kept by certificate holder and AD/USAOP mandatory in other states [enforcement mechanism] [consistency] [assurance of feedback from accidents & experiences][best practices to safety prevail]
- ✓ However, generic notion would be NPP is far complex than aircraft to do similar things

"This lack of an effective global system for nuclear materials security stands in stark contrast to other high-risk global enterprises.

For example, in aviation, countries set standards for airline safety and security through the International Civil Aviation Organization, which then audits state implementation of the standards and shares security concerns with member states. If your practices don't meet these standards, your plane isn't going to land in the United States, the E.U., China, Russia, Japan, India, Brazil, or most other places around the world."

(Senator S. Nunn, ANS, 2013Nov)

International standardization/certification as envisioned by CORDEL (WNA)



[SOURCE] Magnus Mori, E.ON, EUR course 2010

参考資料3

IAEA によるPSAやシビアアクシデント対策などのレビューサービス

Application of Safety Assessment Methods and Tools

IPSART → International PSA Review Team

GRSR → Generic Reactor Safety Review

RAMP → Review of Accident Management Programme

SAR → Review of Safety Analysis Reports:

Accident Analysis
Chapter 4 (Fuel behavior)
Chapter 15 (Accidents Analysis) and
Chapter 19 (PSA and Severe Accidents)

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IPSART

International Probabilistic Assessment Review Team

Mission Objectives

- To assess the adequacy of the treatment of analysis methods and data used in the PSA
- To assess whether specific conclusions and applications of the PSA are adequately supported by the underlying technical basis
- To assess the validity and applicability of the PSA models as a tool for risk management or specific applications

As many MSs have nearly completed their PSA programmes, and the emphasis of current and future missions is placed on applications, mostly by Licensees but also by RBs.

So far, we have addressed these needs with expert missions or workshops, e.g. on Risk Monitor implementation and use.

Hence, there is a need to make the service modular and application oriented, and to integrate it in other services,
e.g. OSART

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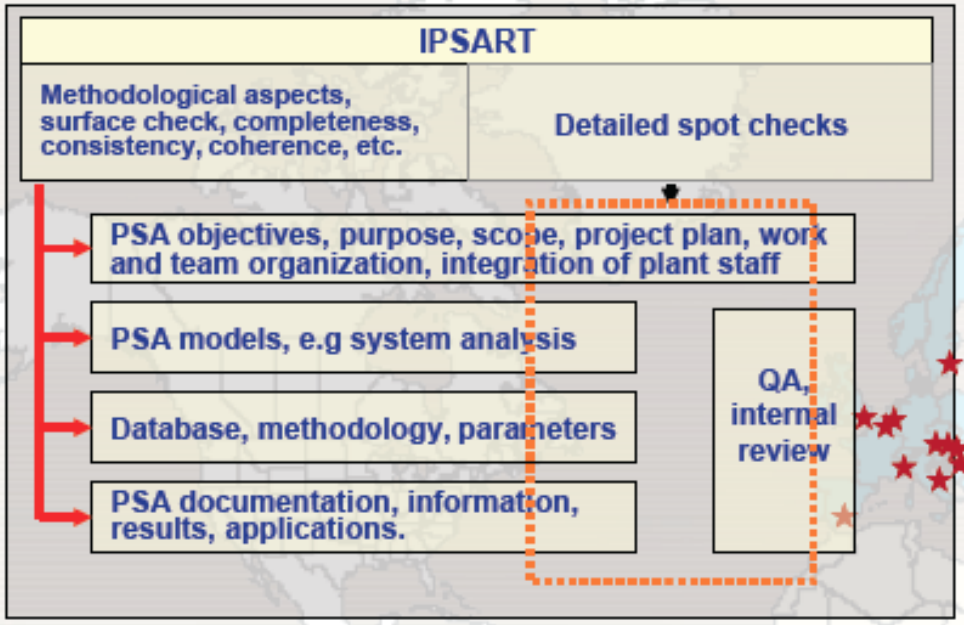
Summary of IPSART missions



- Whole coverage review: The general and methodological aspects of all PSA areas within the scope of the mission are reviewed.
- Detailed limited review: Spot checks of the individual areas to verify application of processes and methods. Choice based on the relevance of particular aspects, expertise of the reviewers and the experience from previous missions. Identification of: isolated, endemic and general findings. Tendency to generalize the findings

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RAMP

Review of Accident Management Programmes

Objectives:

- ✓ to explain to licensee personnel principles and possible approaches in effective implementation of AMP
- ✓ to perform an objective assessment of the status in various phases of AMP implementation
- ✓ To provide licensee with suggestions and assistance for improvements of AMP

Review Area of RAMP

Review of accident analysis for accident management

- *to check completeness and quality of accident*
- *analysis covering BDBA and severe accidents*

Review of AMP (RAMP)

- *to check quality, consistency and completeness of AMP*

ACCIDENT MANAGEMENT MEASURES AGAINST TERRORIST ATTACKS OR ATTACKS OF A MALEVOLENT NATURE

An effort to enhance the protection of NPPs against acts of malevolent nature through consistent use of PSA and accident management strategy

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