IAEA
International Atomic Energy Agency

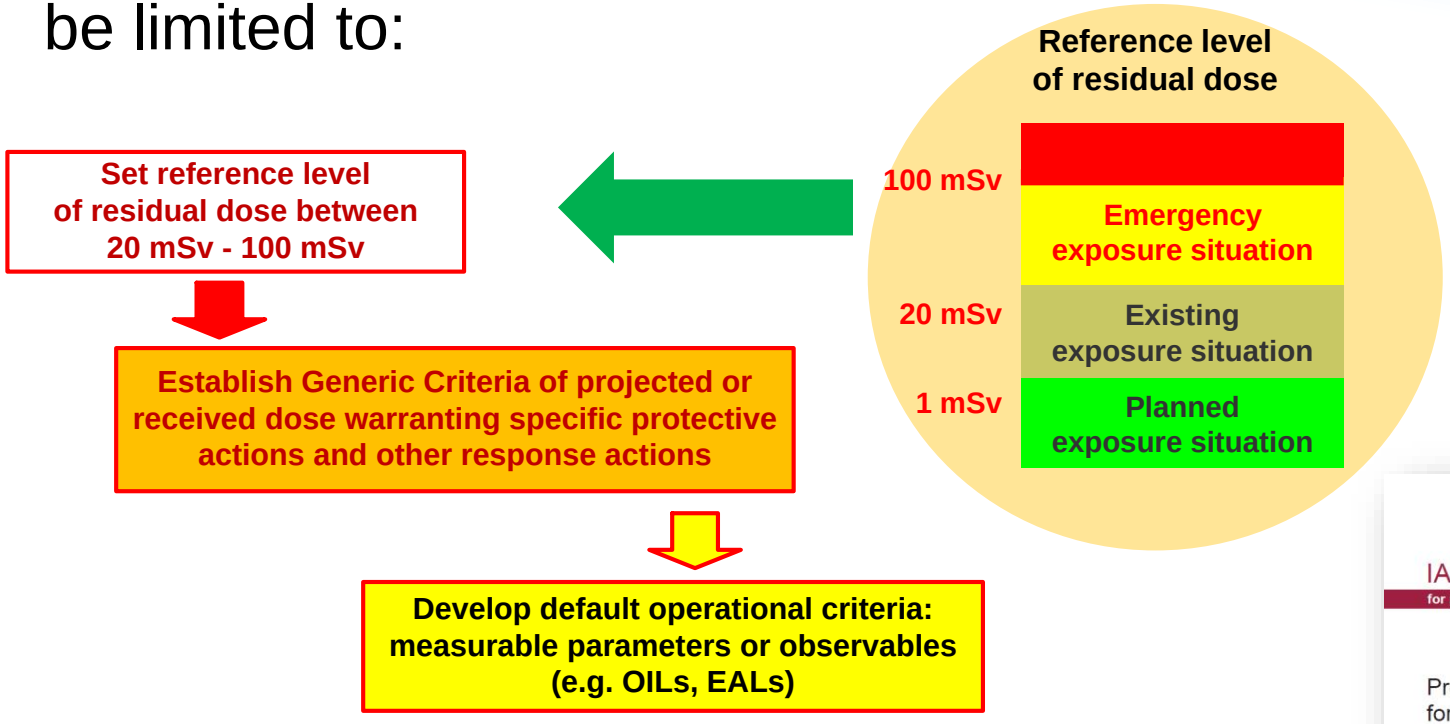
Protection Strategy for a Nuclear or Radiological Emergency

IAEA-KINS Workshop on the Emergency Preparedness and Response to Nuclear and Radiological Emergencies

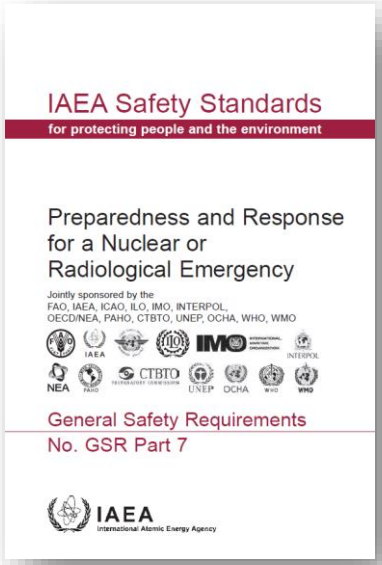
19 - 23 June 2023, Daejeon, Republic of Korea

Introduction
Req. 5 of GSR Part 7

- Development of a protection strategy to include, but not to be limited to:



- Implementation to be carried out safely and effectively in an emergency response through the execution of pre-established emergency arrangements



How did the concept evolve?

- The concept represents an evolution from the ICRP Rec. 60 and 63 and GS-R-2 approach
  - Which suggested that independent justification and optimization of individual intervention was sufficient
    - Based primarily on the doses avertable by the intervention

GS-R-2 (2002)

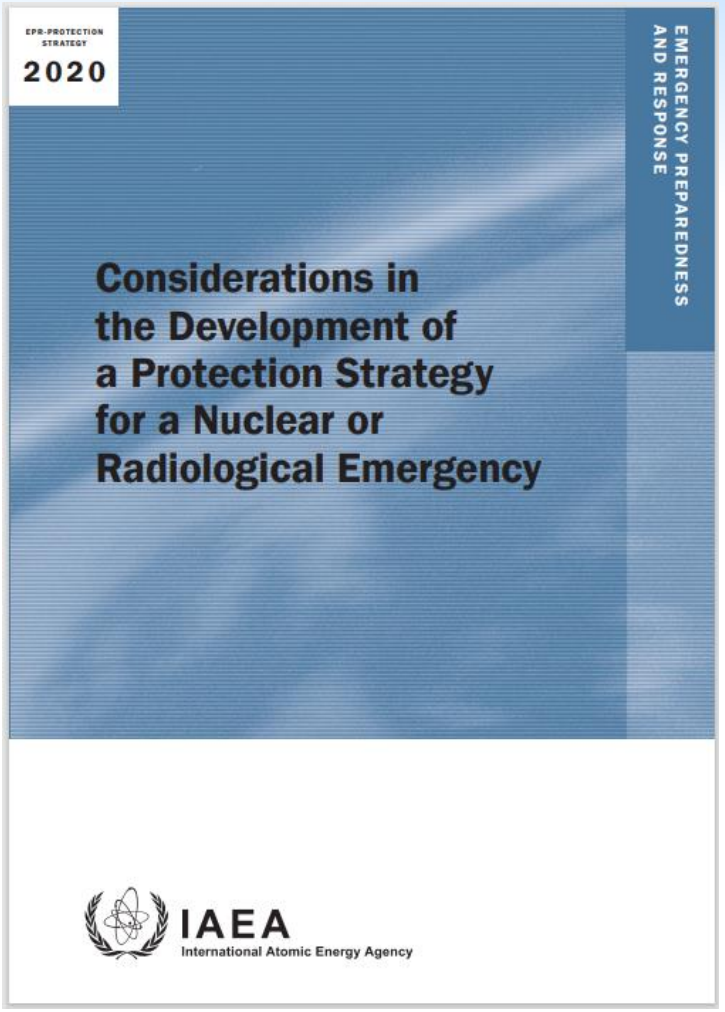
Implementation of **single protective action** (i.e. intervention) on the basis of **generic intervention level of dose *actually avertable*** by taking that intervention

GSR Part 7, GSR Part 3, GSG-2

Implementation of **protection strategy** (i.e. justified and optimized set of protective actions and other response actions) on the basis of **generic criteria (GC) for dose *projected*** and **dose *received*** with account taken of the **reference level for *residual* dose**

What the protection strategy actually is?

- Lack of clear understanding due to its implicit dual meaning:
  - **Framework** that provides the justified and optimized set of protective actions and other response actions in an emergency response
  - **Document** that outlines the goals, decision-making processes and the set of justified and optimized emergency response actions that comprise or set the framework



Concept of protection strategy

- Describes in a comprehensive manner:
  - What needs to be achieved in response to a nuclear or radiological emergency in all its phases
    - From the time the emergency is declared until the emergency is terminated
    - For large scale emergency, the protection strategy may extend in the longer term within the framework of an existing exposure situation
  - How this will be achieved
    - Through ensuring a justified and optimized set of protective actions and other response actions

Elements of protection strategy

- What does the strategy aim to achieve
- What does it apply to
- The basis upon which decisions are made including the dosimetric criteria that provide basis for justified and optimized actions
- The justified and optimized protective actions considered and means for their adjustment including lifting
- Any relevant considerations to address the prevailing conditions at the time of the emergency that may impact the selection of specific options
- Means of assessing the effectiveness of the protection strategy and for its adjustment as the emergency evolves
- Means for consultation on the adapted protection strategy in the course of the emergency response

Elements of protection strategy (cont'd)

- Protection strategy needs to address also:
  - Relation to the strategy to regain control on the site
  - How emergency workers and helpers in an emergency are protected at all times
  - Implications on the emergency management system and other strategies (e.g. related to monitoring and assessment, waste management, public communication etc.)
- Protection strategy may contain an executive summary

Implementation of the protection strategy in response

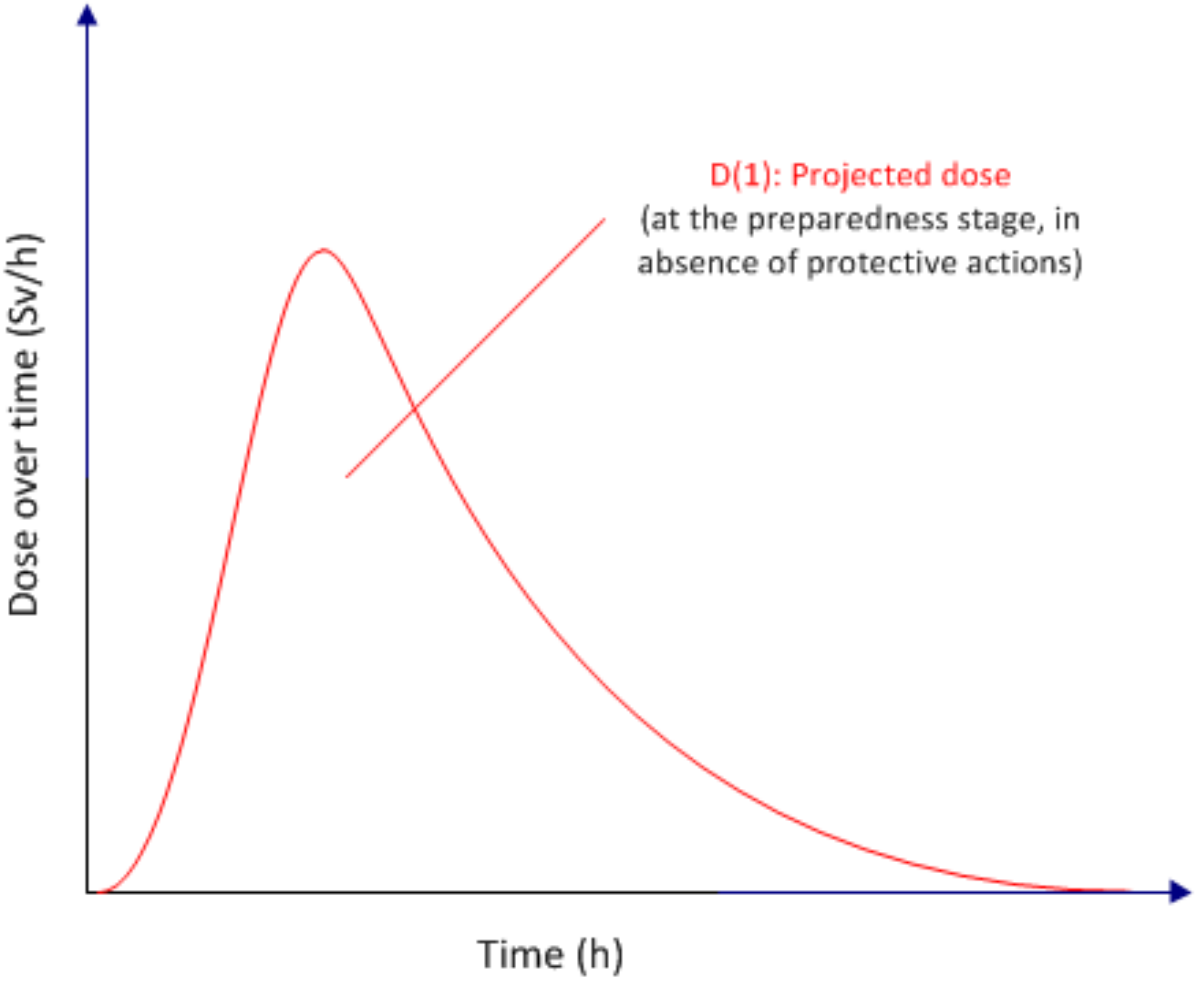
- The protection strategy (as a document) developed at the preparedness stage is not intended to change during response to an actual emergency
  - A national protection strategy
  - It is expected to be maintained as a stable basis (i.e. a framework) for implementing effective emergency response

- The protection strategy implemented in the response will be continually adapted as the emergency evolves to meet the prevailing circumstances
  - An adapted protection strategy
  - The implementation is expected to be done through execution of pre-established emergency arrangements such as plans and procedures (developed in a manner to ensure its effectiveness)

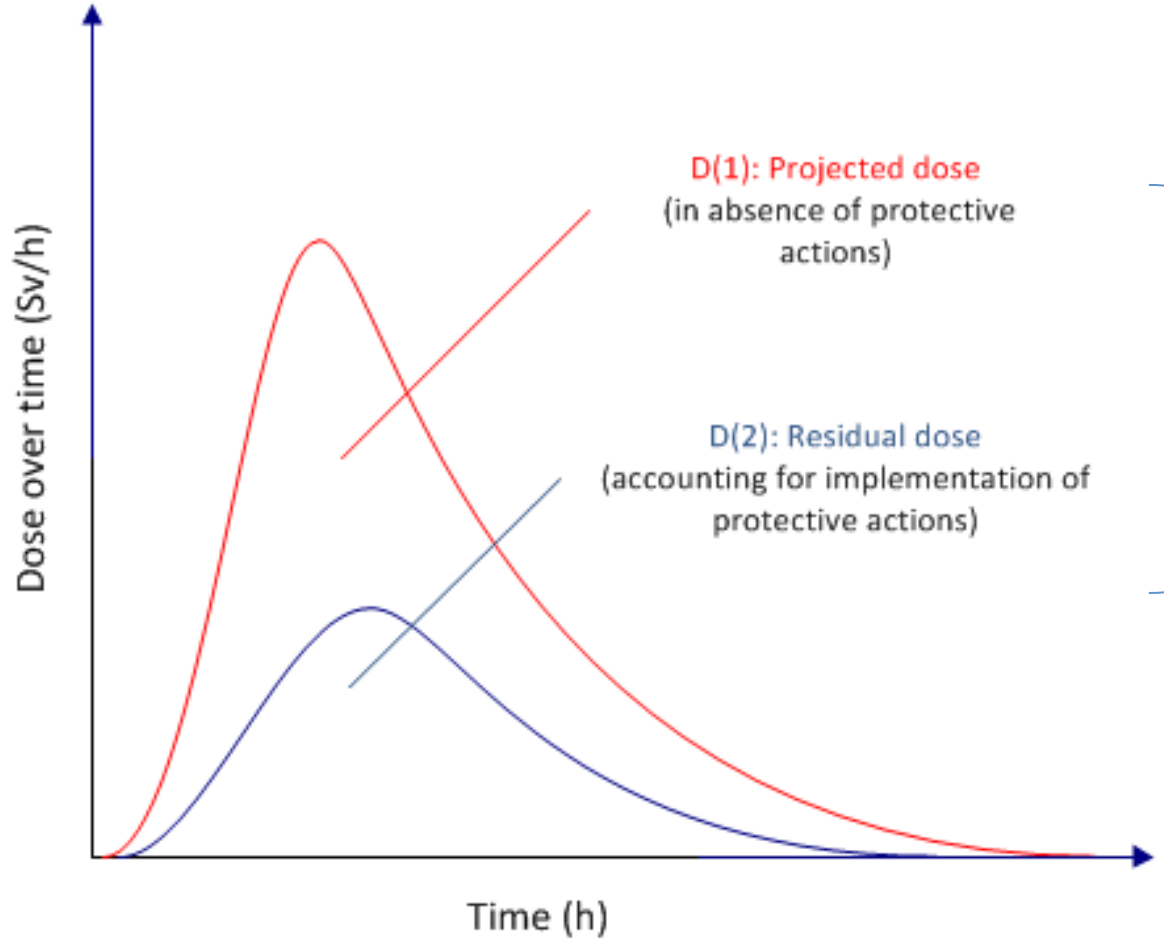
Dose Concepts

- Projected dose: The dose that would be expected to be received if planned protective actions were not taken.
- Residual dose: The dose expected to be incurred after protective actions have been terminated (or after a decision has been taken not to take protective actions).
- Received dose:: The dose that is incurred after protective actions have been fully implemented (or a decision has been taken not to implement any protective actions).

Projected dose



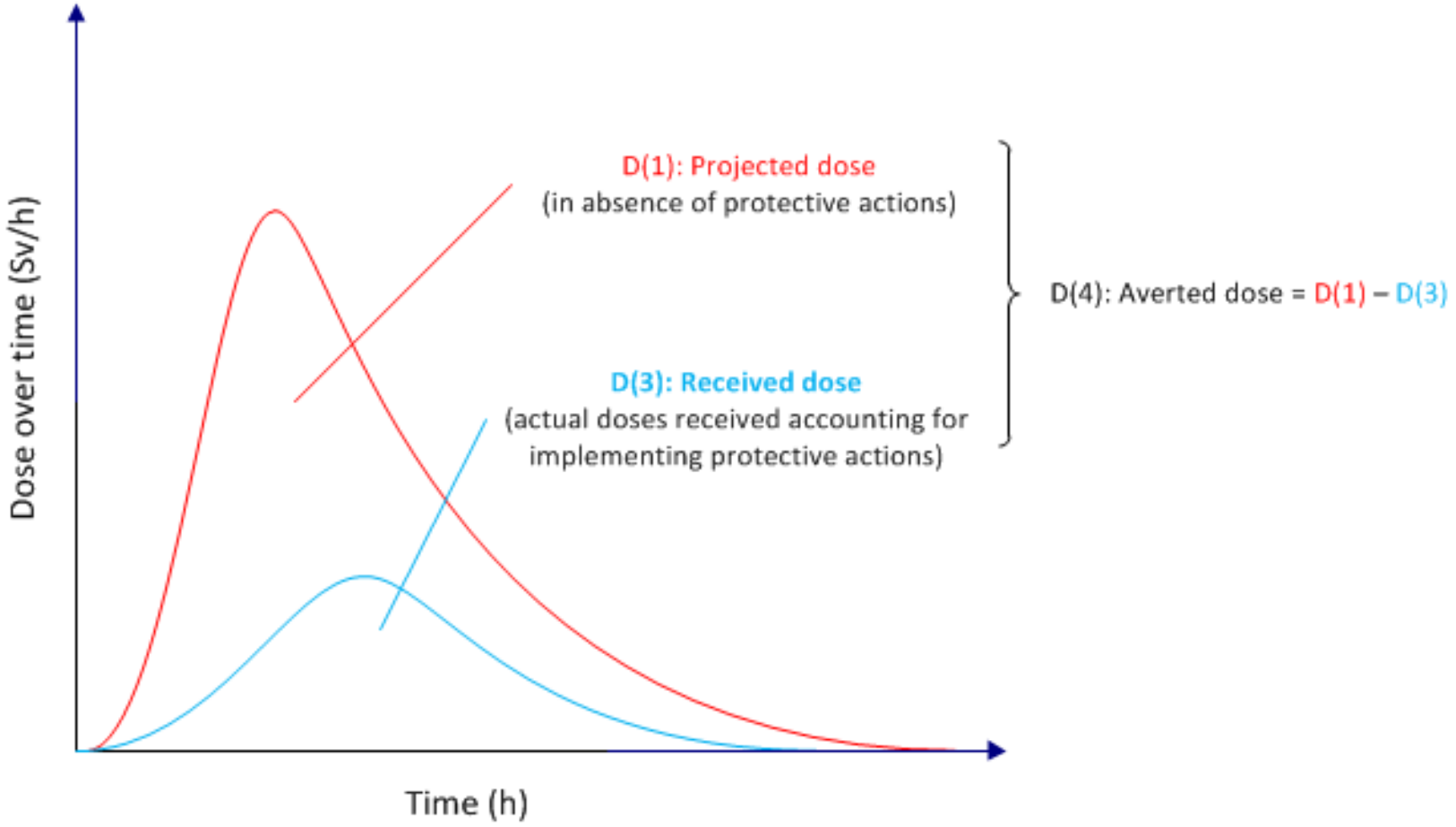
Residual dose Preparedness stage



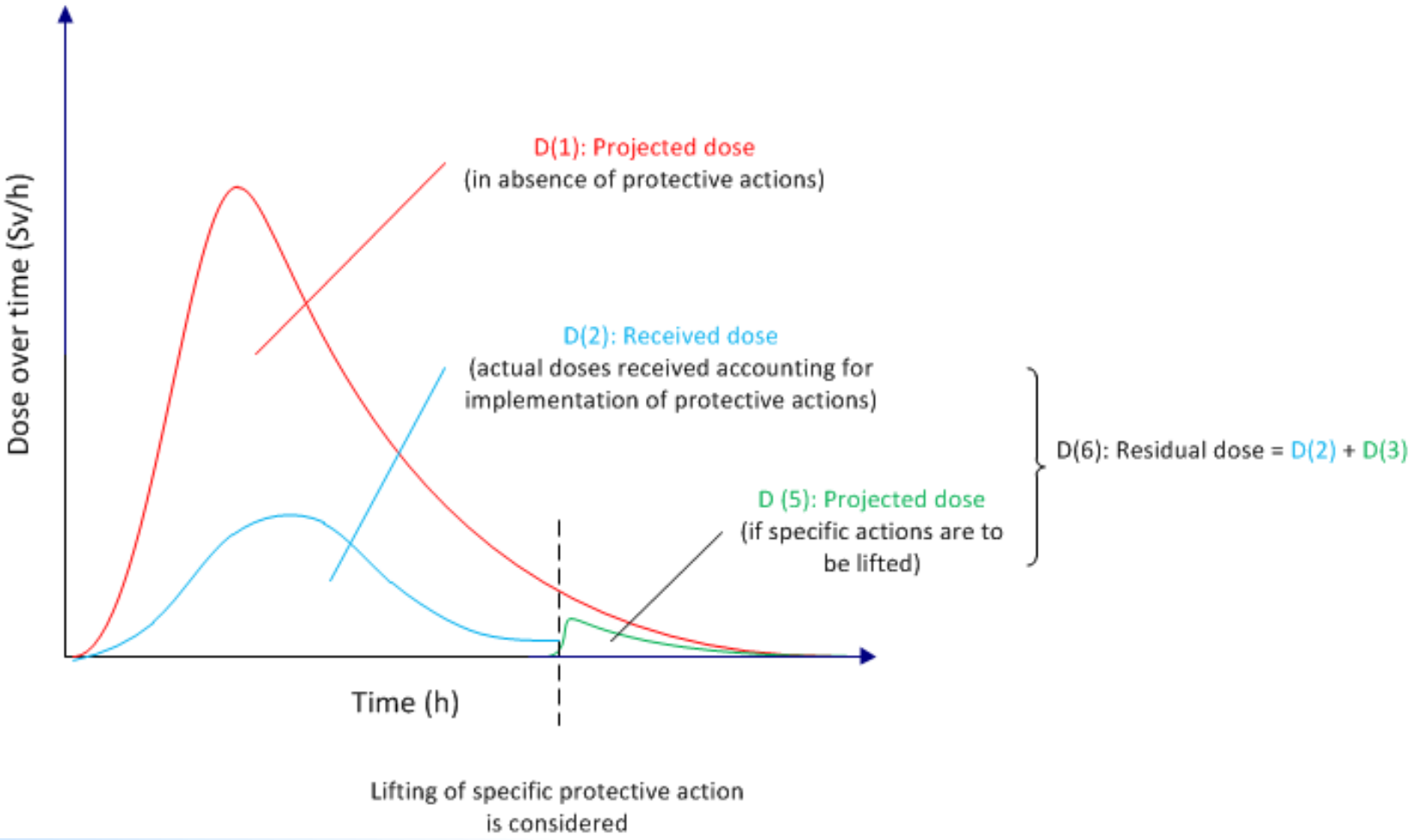
Avertable dose = D(1) - D(2)

Concept not used anymore!

Received dose During response



Residual dose During response



Protection Strategy Dosimetric Concepts

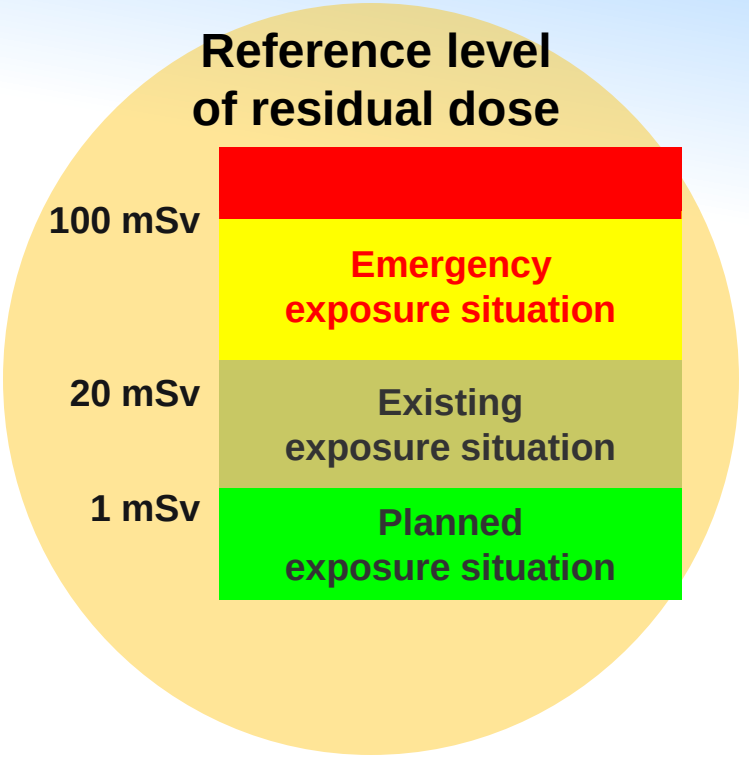
Generic criteria	Generic criteria	Reference level
Projected dose	**Received dose**	**Residual dose**
Basis to **implement response actions**	Basis to **implement medical actions**	Basis **to optimize** and **to judge effectiveness** of strategy

Protection Strategy (cont.)
Dosimetric concepts

Set reference level of residual dose between 20 mSv - 100 mSv

Establish Generic Criteria of projected or received dose warranting specific protective actions and other response actions

Develop default operational criteria: measurable parameters or observables (e.g. OILs, EALs)



Reference Level

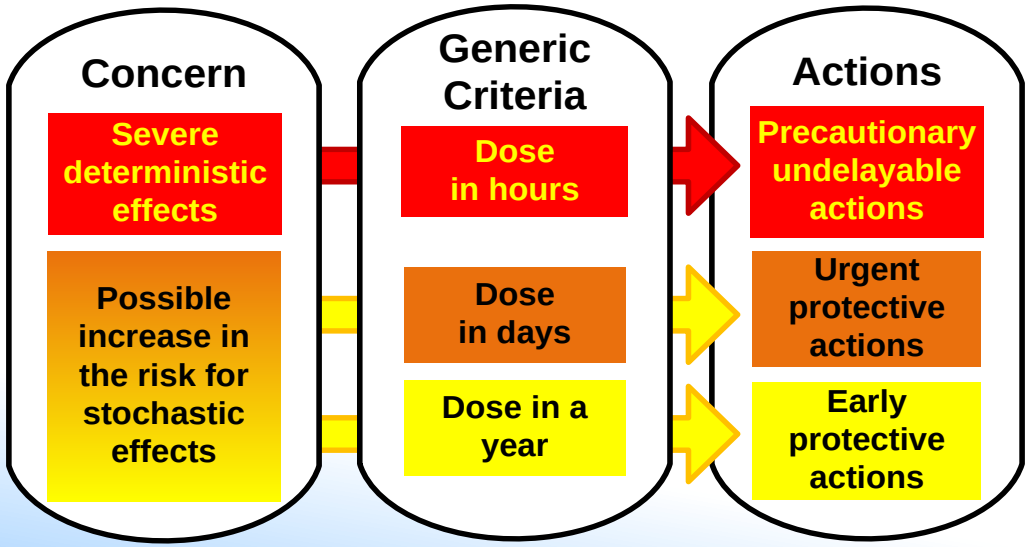
- The level of dose:
  - Above which it is not appropriate to allow exposures to occur
  - Below which optimization of protection and safety would continue to be implemented
- Role: tool for optimization of protection
- A residual effective dose in the range 20 – 100 mSv, acute or annual, via all exposure pathways

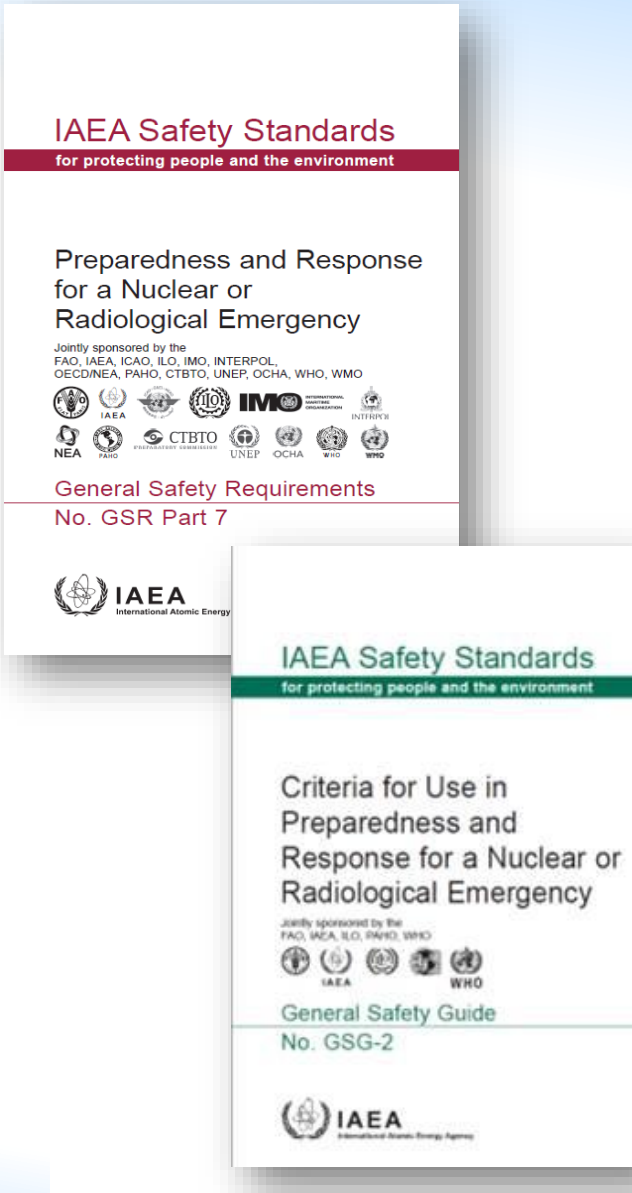
Reference level

- Choosing the value for the reference level is dependent on prevailing conditions, such as:
  - Phase of the emergency
  - Practicality of reducing or preventing exposures to occur
  - Other circumstances
- Selecting lower levels for the reference level will not necessarily provide for better protection in consideration of other factors!
- Consideration of the reference level alone may not be sufficient to provide for protection in an emergency response!

Generic criteria General

- Levels for the projected dose, or the dose that has been received, at which protective actions and other response actions are to be taken.



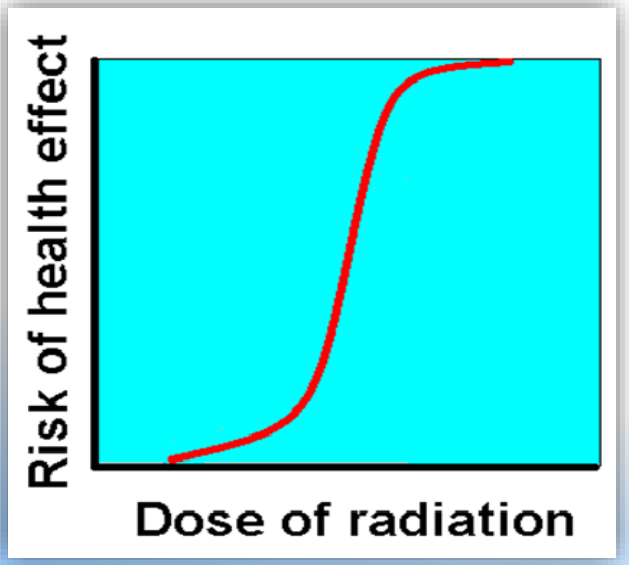


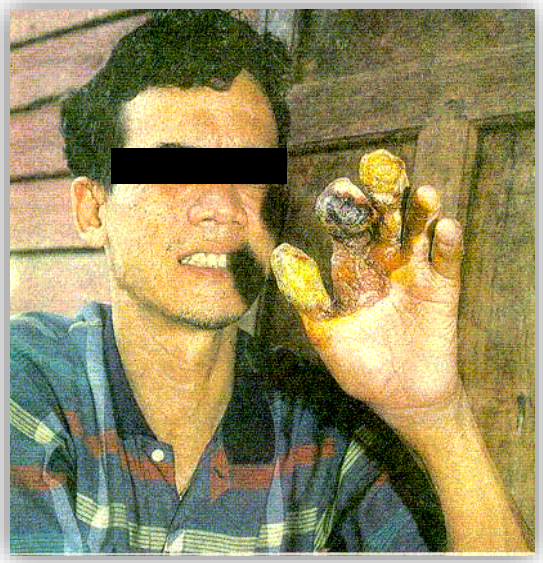
Generic criteria Dosimetric Quantities

- Quantity: ***RBE-weighted absorbed dose***, AD_T

  Purpose: To evaluate a risk of developing severe deterministic effects due to exposure of a particular organ or tissue (T)

  Unit: *gray* (*Gy*)



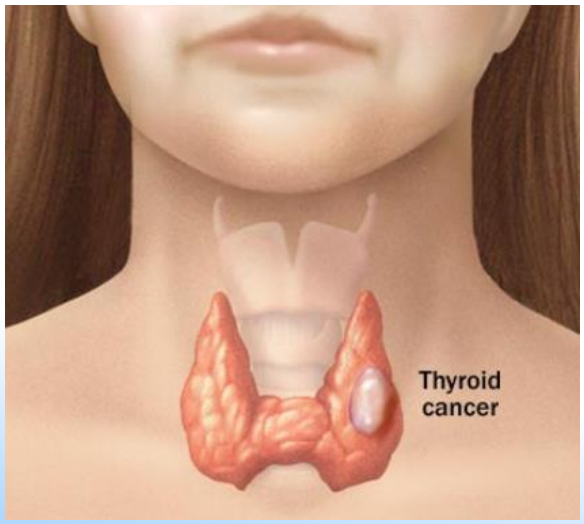


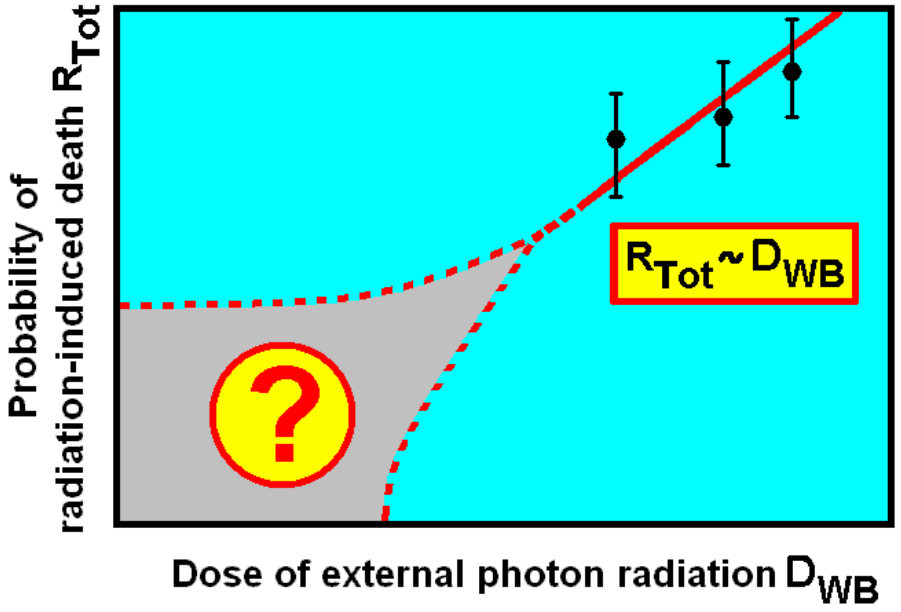
Generic criteria (cont.) Dosimetric Quantities

Quantity: ***Equivalent dose in organ or tissue***, H_T

Purpose: To evaluate risk of stochastic effects developing due to exposure of an organ or a tissue T

SI unit: *sievert* (Sv)





Generic criteria Dosimetric Quantities (cont.)

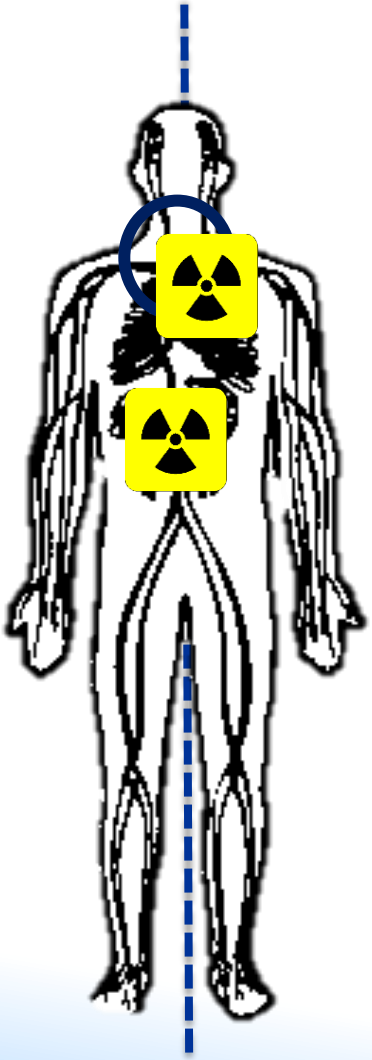
Quantity:	***Effective dose**, E
Purpose:	To evaluate the radiation detriment (radiation protection) **NOT TO ASSESS HEALTH EFFECTS!**
SI unit:	*sievert* (Sv)
	** Used in the concept of reference level*

Effective vs. Equivalent Dose

Inhalation of a certain amount of ^{131}I

E

100 mSv
***effective* dose**



H_{fetus} $H_{thyroid}$

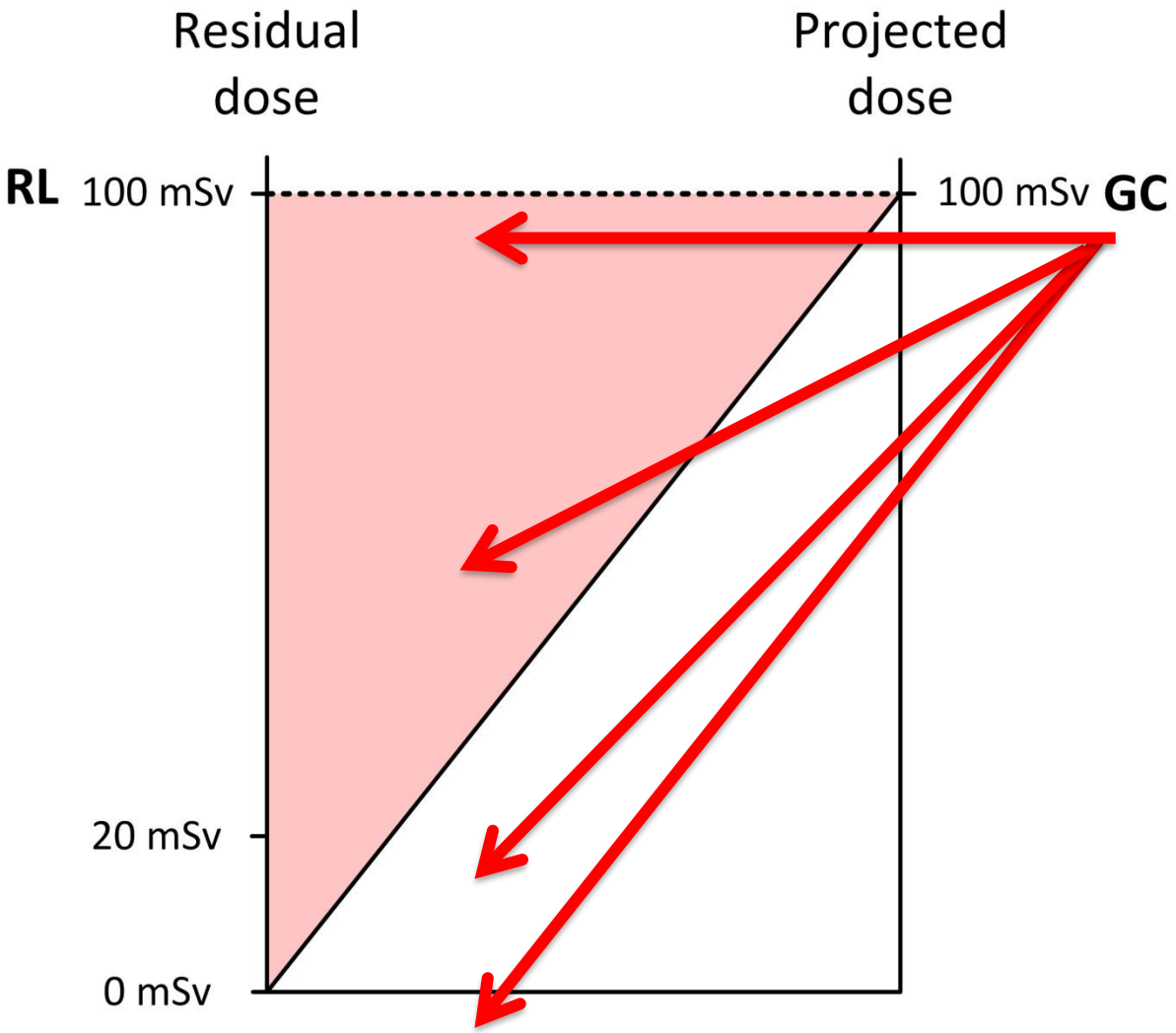
~2000 mSv
***equivalent* dose to fetus or thyroid**

Severe health effects are possible

IAEA's Generic Criteria

- Below generic criteria:
  - There will not be any severe deterministic effects or an observable increase in the incidence of cancer (even in a very large exposed group)
- Consistent with UNSCEAR 2000 and 2010:
  - Observations are frequently unable to reveal clear evidence of an increased incidence of radiation induced health effects at low doses (less than 100-200 mGy)

GC vs RL

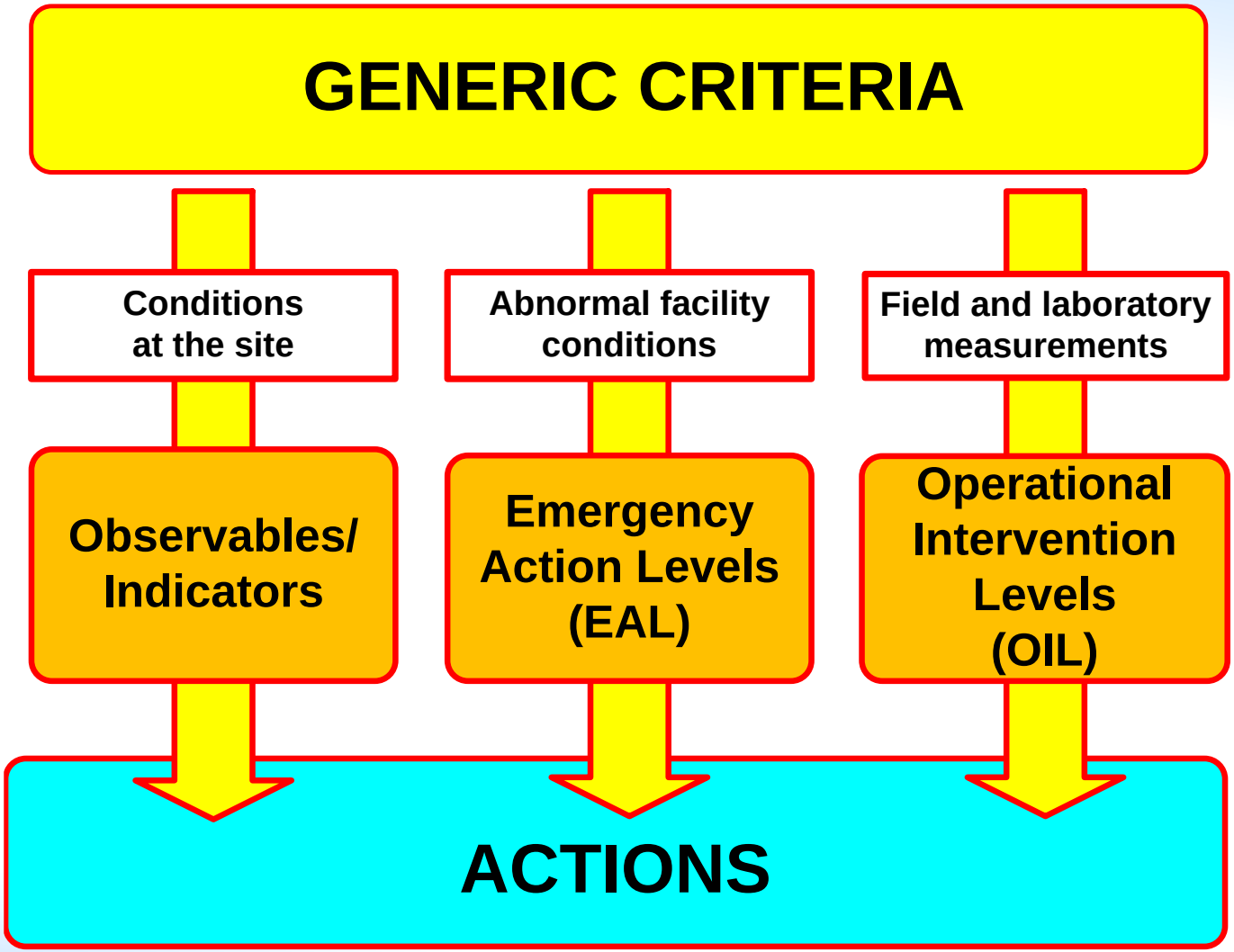

Residual dose
Projected dose
RL
100 mSv
100 mSv
GC
20 mSv
0 mSv

Operational Criteria

- Generic criteria cannot be used directly in the response
  - They are based on projected or received dose which needs to be calculated taking into account a large number of considerations and uncertainties.

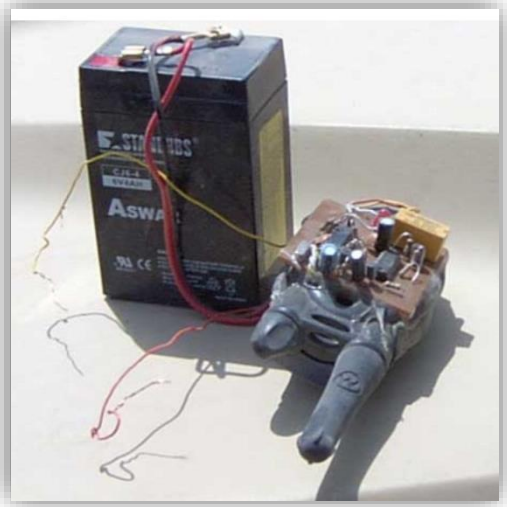
- Hence the need to develop, at the preparedness stage, criteria deriving from the generic criteria (i.e. operational criteria) that can be used directly in the response

Operational Criteria (cont.)



Observables / Indicators

- E.g. fire, earthquake, loss of control,
- unshielded source, RTG, RDD



Emergency Action Levels

- EALs are specific, predetermined and observable criteria to detect, recognize and determine the emergency class

Initiate pre-planned response

Cannot protect core!

EAL exceeded

Example for a general emergency at a NPP

Off-site decision maker implements predetermined protective actions

Declaration of General Emergency

Pressure above xx Bar

Failure to SCRAM

Temperature above xx K

Dose rate above xx µSv/h

Loss of power for xx min

Operational Interventional Levels (OILs)

Predetermined level of a measurable quantity to trigger response actions (based on GC) on the basis of monitoring and sampling:

Default OIL value exceeded

↓

Immediate action

e.g. Evacuate (establish cordon) if either of the following is exceeded:

- γ → 100 µSv/h at 1m
- α → 10 cps at 1cm
- β → 200 cps at 2 cm

Basis for Development of Protection Strategy

- Legislative basis, regulations and other relevant documents
  - Radiation protection and safety framework
  - Framework for management of any type of emergency
  - Documented materials from past experiences
  - International standards, best practices
- Inventory of facilities, activities and sources and associated hazards
  - Within the State
  - Beyond borders but which may impact the State

Basis for Development of Protection Strategy (cont.)

- Hazard assessment, i.e. consequence assessment for wide range of postulated emergencies, including:
  - Doses expected (projected, residual, received)
  - Exposure scenario, pathways, periods of exposure
  - Population and areas impacted
  - Non-radiological consequences expected
  - Dynamic and timeframe for decision making
  - Time for recovery expected
- Available resources (human, technical, financial) and infrastructure

Considerations for Development

- Coordinated by National Coordinating Mechanism
- To address the whole range of goals of emergency response and timeframes in which they are to be achieved
  - From the emergency onset by the time the emergency is declared ended
- First priority: detailed elaborated protective actions for those at risk of severe deterministic effects
- To be followed by range of actions aimed at:
  - Those at risk of stochastic effects
  - Meeting the remaining goals of emergency response

Considerations for Development (cont.)

- Influence of actions on subsequent actions
- Temporal and geographical issues
  - Need for protective actions may vary both spatially and in time
  - Important factors: demographic, economic and use of land
  - Response phases: urgent, early, transition, later
  - Need for coordination with neighbouring countries in case of transboundary emergency
- Dynamic nature of response
  - Time constraints on decision-making and implementation of actions in an effective manner
- Public self-help programmes

Considerations for Development (cont.)

- Processes to be used for adapting the strategy to the actual circumstances of the emergency
  - Large uncertainties in the prediction of the long-term development of the radiological consequences
  - The social, economic, political and other factors prevailing at the time of the emergency may not be known with sufficient accuracy
  - Adaptation as relevant information becomes available is essential to provide for the protection and safety of those affected

Justification

- "…*whether a proposed protective action or remedial action is likely, overall, to be beneficial; i.e. whether the expected benefits to individuals and to society (including the reduction in radiation detriment) from introducing or continuing the protective action or remedial action outweigh the cost of such action and any harm or damage caused by the action*."
  - Justification applies for:
    - Individual protective actions in the context of the protection strategy
    - For the protection strategy as a whole

Justification (cont.)

- **At high doses**
  - Radiological considerations prevail the non-radiological aspects in the decision-making process
  - Those situations in which the dose thresholds for severe deterministic injuries could be exceeded should always require action
  - Those situation in which the doses approach the level at which an increase in the incidence of cancers may be expected should also require action
- **At low doses**
  - Non-radiological considerations may prevail the radiological consequences
  - Careful consideration is required with account taken of different radiological and non-radiological factors when making decisions to ensure actions taken do more good than harm

Justification (cont.)

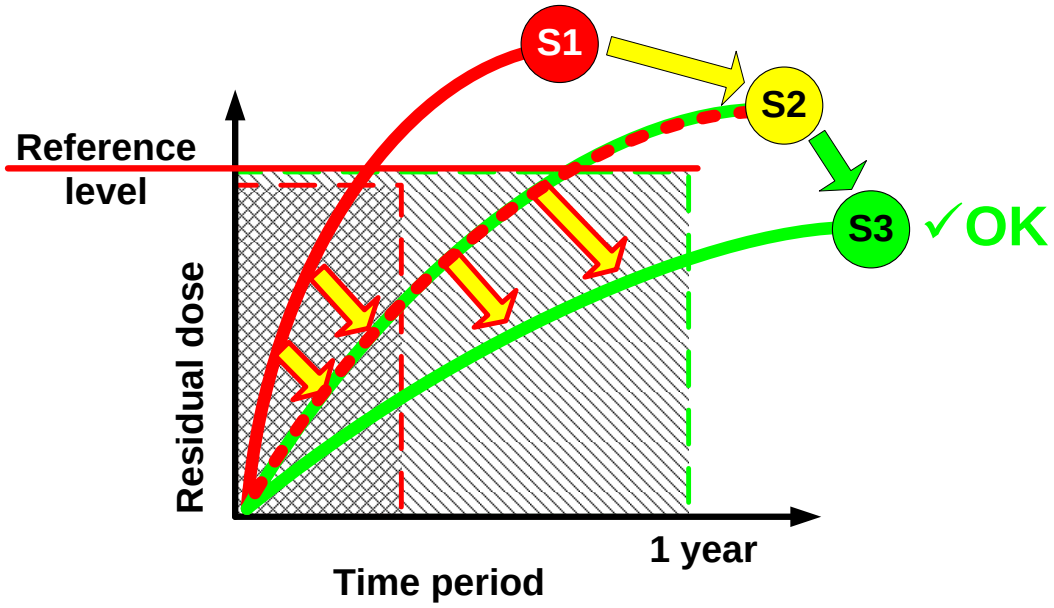
- Reasons for an option being considered unjustified may include:
  - Disruption of normal activities
  - Unreasonable economic burden
  - Greater risk by their implementation than the protect against
    - E.g. evacuation of hospitals without provision of adequate medical care to patients
  - Another protective option associated with a smaller risk which provides the same or better protection
  - Generation of large volumes of radioactive waste

Optimization

- *“Process of determining what level of protection and safety would result in the magnitude of individual doses, the number of individuals subject to exposure and the likelihood of exposure being as low as reasonably achievable, economic and social factors being taken into account.”*
- The level of protection would be the best possible under the prevailing circumstances, and will thus not necessarily be the option with the lowest dose!
- Optimization applies to protective actions and the protection strategy that have been demonstrated to be justified!

Optimization (cont.)

- **“Constraint” optimization** by using the reference level:
  - Priority is given to exposures above the reference level with the possibility for the optimization of protection to continue to be implemented below the reference level as long as this is justified, i.e. does more good than harm



Optimization (cont.)

- Reference level during an emergency response: a benchmark for a retrospective assessment of effectiveness of actions and strategy taken in an emergency response
  - To also identify a need for its adaptation to address prevailing conditions as they evolve
    - Further protective actions are determined and implemented so that they are, in priority, focussed on those groups/individuals whose residual doses are higher or exceeding the reference level and the available resources are allocated accordingly

What to Know in Order to Optimize

- Dominant exposure pathways
    - Will guide decisions on the types of protective measures allocated
    - Resources should be commensurate with the expected benefits
- Time scales over which components of the dose will be received
- Potential effectiveness of protective actions
    - Social and economic consequences in addition to dose effectiveness

What Else to Consider for Optimization

- Involves wider issues than simply the radiation health risks
  - E.g. non-radiological consequences such as psychosocial consequences and costs associated with impacts of the actions
- Potentially affected stakeholders to be engaged in development of the protection strategy
- Consider the response across all phases
    - During all time periods
    - Provide confidence that residual doses over a whole year will not exceed the reference level

Implementation of the Protection Strategy

- Actual emergency situations do not match the assumptions from planning
- The level of details of pre-planned strategy vary for the urgent phase where the time for decision making and information is limited
- As the emergency evolves, the need to assess the effectiveness of actions is essential
- Adaptation in the implementation of the protection strategy to meet the actual conditions is essential

Implementation During the Urgent Phase

- In the very beginning of the emergency:
  - Act very quickly and follow pre-planned plans and procedures
  - Use plant conditions or other measurable criteria and observables, as applicable
    - Generic and operational criteria to implement protective actions and other response actions either individually or in combination
- The protection of those at high risk should take priority over the protection of others
  - In terms of both resources and focus

Implementation During the Early Phase

- As the emergency evolves: assess the effectiveness of actions taken and identify what other actions may still be warranted
  - In light of any relevant information
  - Assess residual doses and judge the need for further actions
  - Consider effectiveness of remedial actions against effectiveness of public protective actions
- Adapt, justify and optimize the protection strategy as needed
  - Revision will be based on any significant deviations from initial assumptions
    - Extreme weather conditions
    - Unexpected geographical location
    - Unexpected circumstances such as large sporting or political events, etc.

Implementation During Transition Phase

- As the emergency progresses
  - Better understanding of the exact circumstances
  - Decisions based on actual conditions rather than pre-planned response
  - Measurable quantities and observables will trigger discussions, but decision are to be made after careful consideration of the residual doses and other factors applicable at this stage
- Adjusting/lifting protective actions
  - Essential in ensuring that they are discontinued when no more justified
  - Impact on residual dose has to be assessed
    - Lifting of a protective action should not significantly change the residual dose

Implementation During Transition Phase

- The objective of the strategy shifts to the need to timely facilitate the resumption of social and economic activities to as normal as possible and ending the emergency situation
  - Need to ensure continued efforts to reduce the risk for stochastic effects (may extend in longer term)
    - Reference level approaching the lower end of the band for emergency exposure situation will be appropriate
  - Need to resume as normal as possible life to those affected
  - Non-radiological impacts play a great role in the strategy to be implemented
  - Consultation with interested parties is essential

IAEA
International Atomic Energy Agency

Thank you!

Ms. Muzna Assi

Emergency Preparedness Officer
Incident and Emergency Centre

m.assi@iaea.org