Methodology and tools for demonstration of Safety

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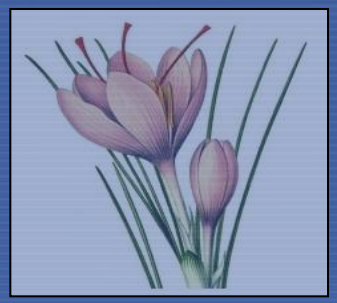
THE SADRWMS METHODOLOGY



The SAFRAN Tool

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Guidelines for safety assessment applied to predisposal waste management – *the SADRWMS methodology*

Last update: May 2011

The SADRWMS methodology

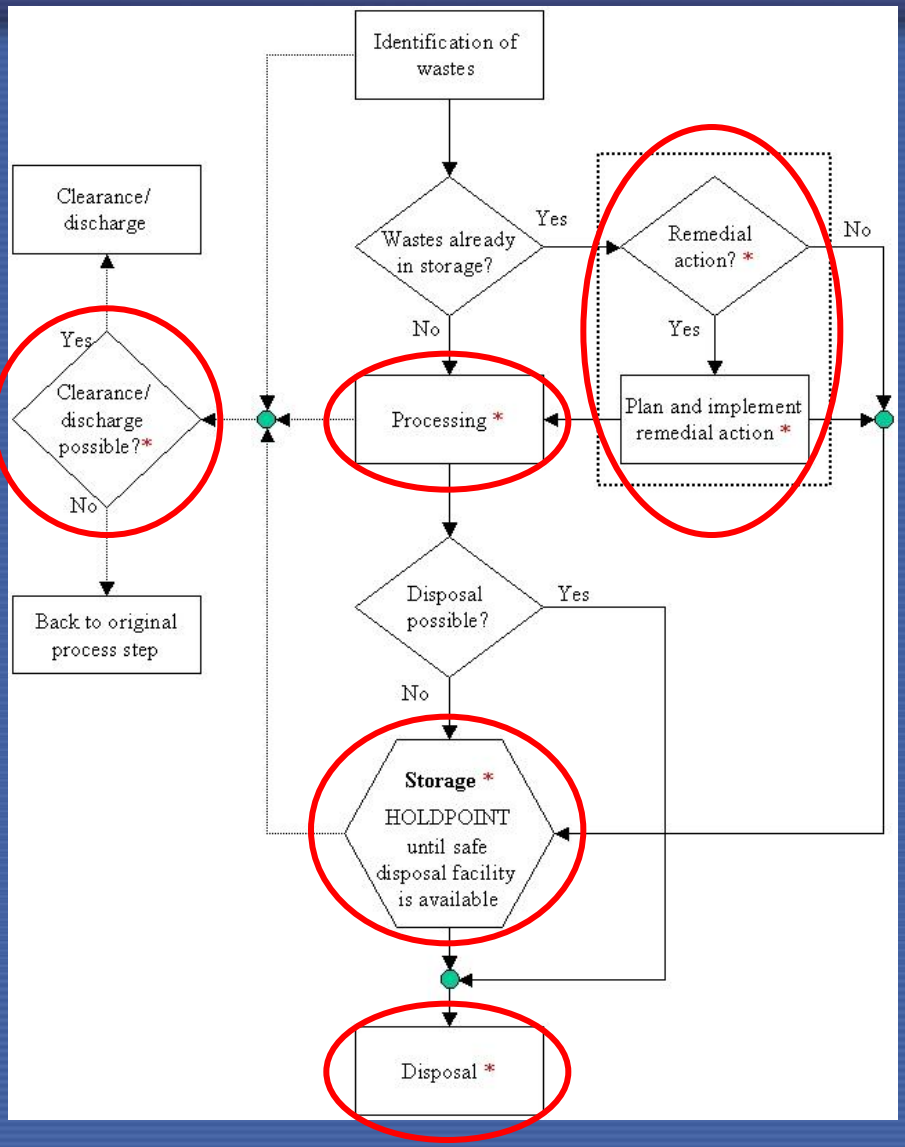
- Provides detailed advice for each step of the Safety Assessment
- Describes the different types of assessments that might be required
- Provides methods for Hazard identification and screening
- Provides methods for performing qualitative and quantitative assessments for different scenarios

Content of the methodology report

1. Introduction
2. The Waste Identification and Pre-disposal Waste Management Process
3. Key Components of the Safety Assessment
4. Assessment Context of the Pre-disposal Waste Management Processes
5. Implementation of the Safety Assessment Methodology in the SAFRAN tool
6. Hazards Screening and Dose Assessments for Normal Operation Scenarios
7. Hazards Screening and Dose Assessments for Accident Scenarios
8. References

ANNEXES – Description of models

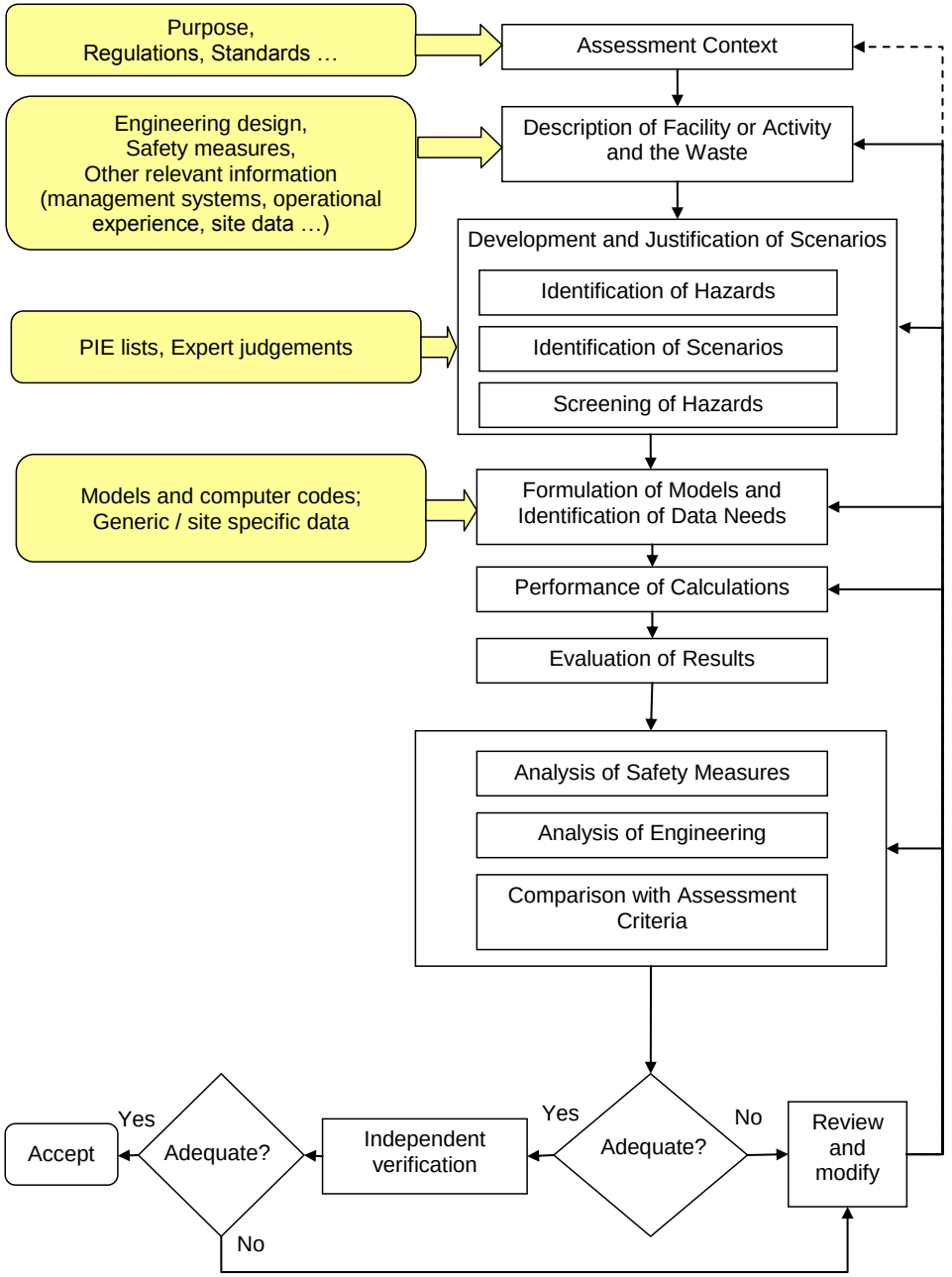
Waste identification and predisposal WM process (section 2)



SADRWMS methodology

Provides detailed guidelines for safety assessment.

Based on the IAEA safety guide DS284: The Safety Case and Safety Assessment for Predisposal Management of Radioactive Waste ,

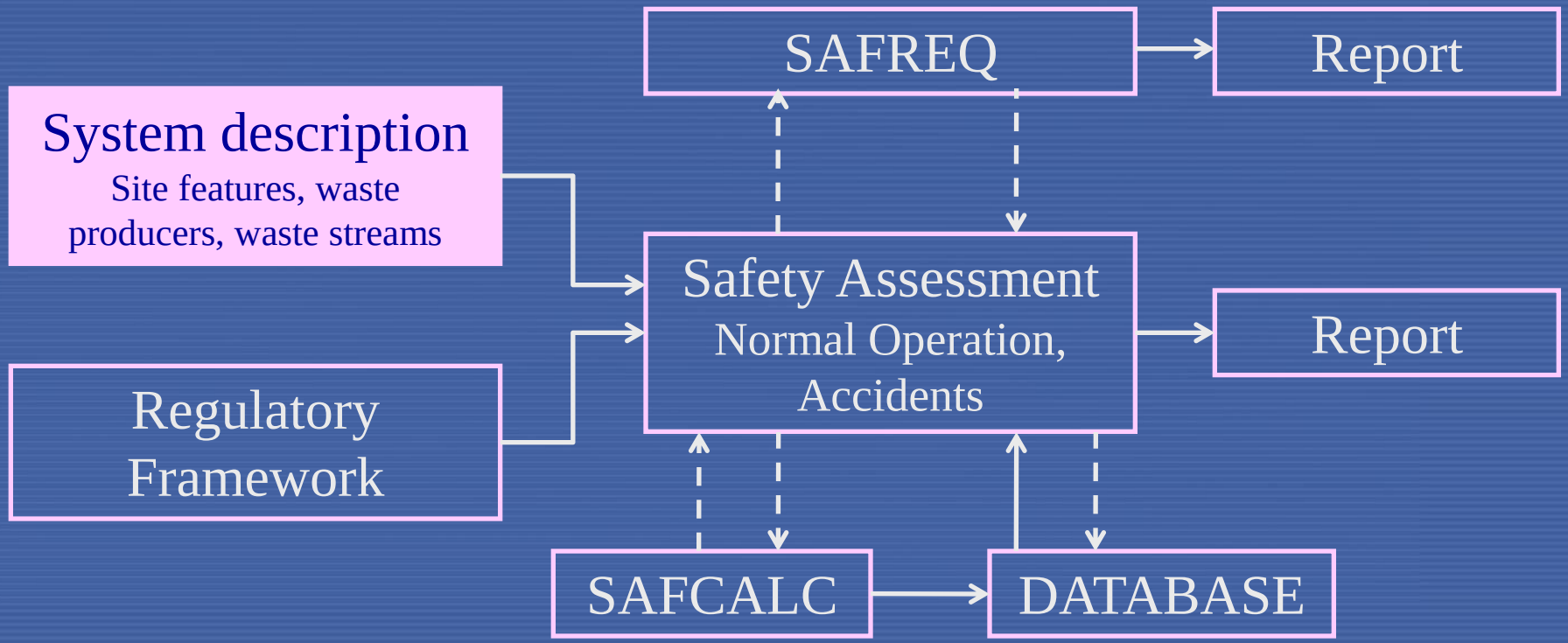


Purpose of the SAFRAN tool

Implements methodologies developed within the SADRWMS project. It provides aid in:

- Describing predisposal radioactive waste management activities in a systematic way,
- Conducting the safety assessment with clear documentation of the methodology, assumptions, input data and models,
- Establishing a traceable and transparent record of the safety basis for decisions on proposed waste management solutions,
- Demonstrating clear consideration of and compliance with national and international safety standards and recommendations.

SAFRAN components



System Description

For each configuration

- Site
  - Facilities
    - Rooms
      - » Areas (Storage or Processing)
        - Physical elements
        - Safety elements
  - Waste Management Activities
    - Processes
    - Check for clearance
  - Waste Producers
    - Primary Waste Components
      - » Waste Streams

Types of safety elements

- Site selection
- Safety functions
- Limits and conditions
- Mantainance requirements
- Operational procedures
- Emergency procedures
- Management systems

Can be linked to physical elements and assessments

Waste management activities

- Description
- Output(s) from activities
- Reduction factors
- One and only one WMA can be assigned to an area

Reduction factors

- Define how the activity changes the waste properties: Volume, mass and activity

Sorting of waste

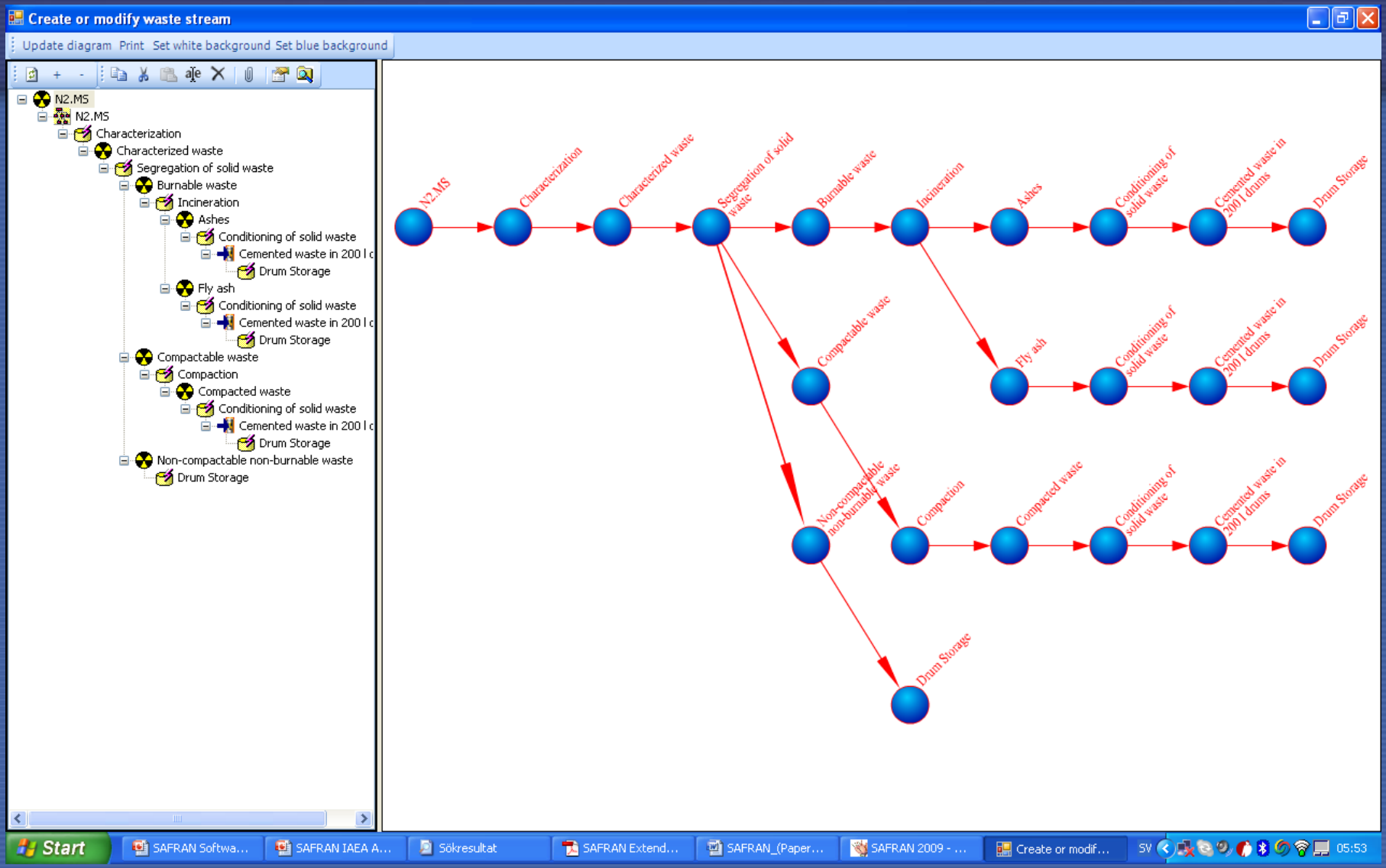
Output	Volume	Massa	Activity
Combustible	5 %	5 %	5 %
Non combustible	95 %	95 %	95 %

Check for clearance

- Possible to make comparisons of activity concentrations in the waste components against IAEA´s and user defined clearance criteria
- Clearance criteria are defined for unconditional clearance of solid materials and expressed in Bq/g

Waste Streams

- Waste streams represent the fate of waste components through different steps of processing, storing and clearing of wastes
- Consider changes of waste properties in these steps.



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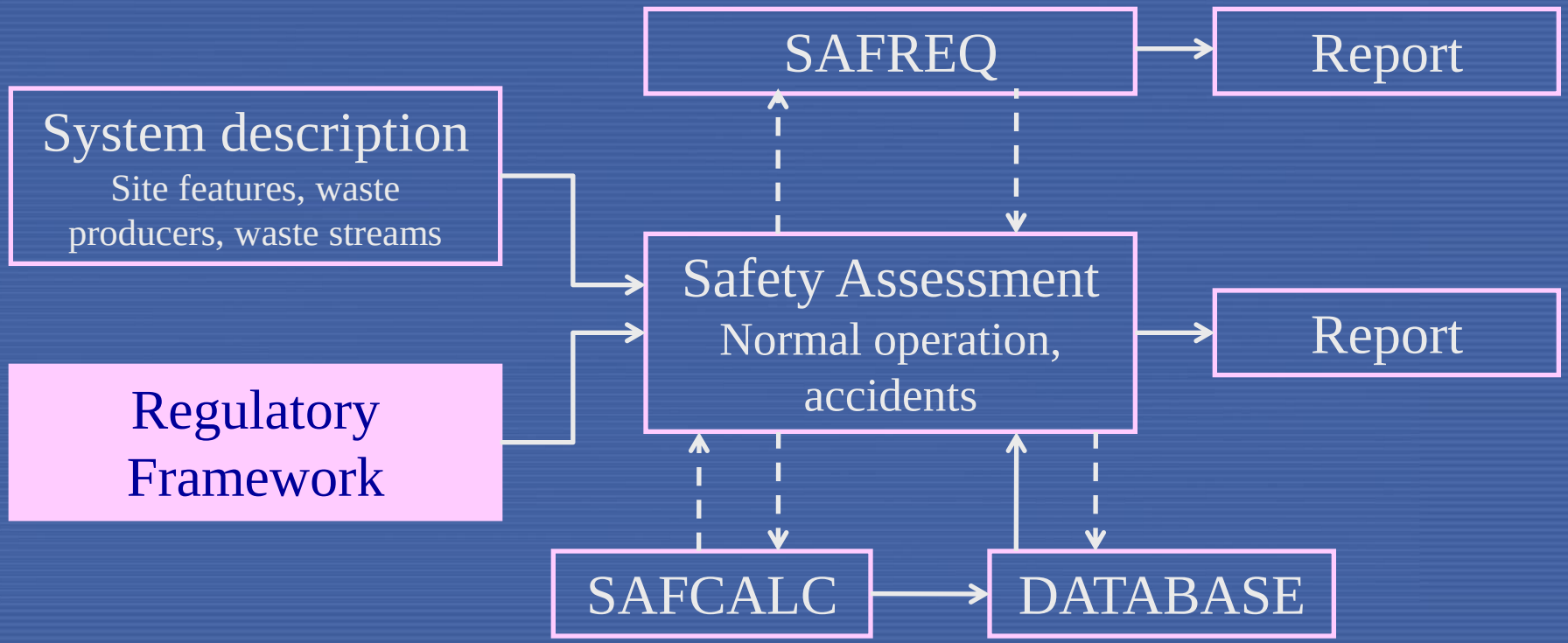
SAFRAN components

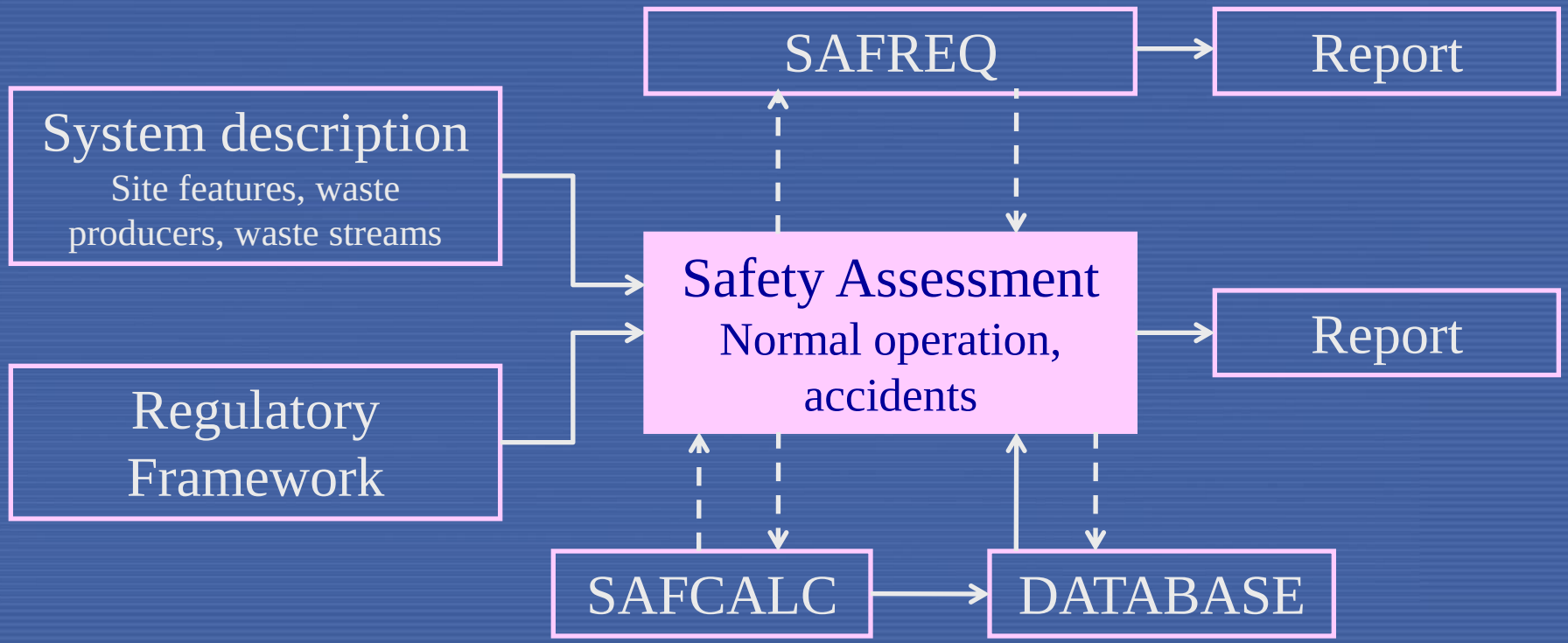


Regulatory Framework

- Regulatory requirements
- Criteria Doses in during normal operation (Sv/y) and accidents (Sv).

  Workers and members of the public
- Several regulatory frameworks can be added to a project, for example IAEA and national, and all can be used in the SA

SAFRAN components



Assessment context

- Link to one or more Regulatory Frameworks
- Purpose – select from a list or add own
- Scope – Define which facilites, rooms and areas will be included in the SA and at what level the assessment is carried out
- Approach
  - PIEs will be defined or only PIE types will be used.
  - Include or not a step for Screening of Hazards.
  - Compliance with Safety Requirements will be assessed or not?

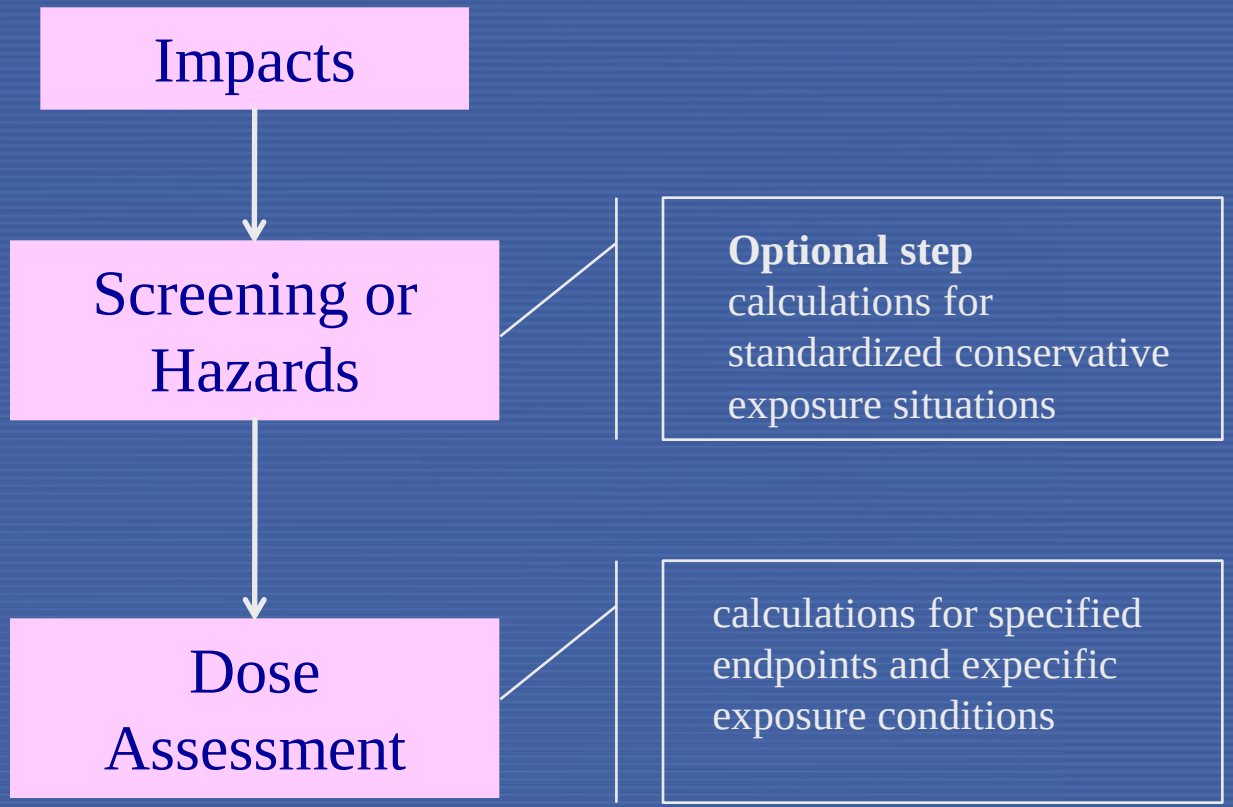
Assessment context of the predisposal WM processes (section 4)

Assessment of waste retrieval	SA-RETRIEVE
Purpose of assessment	1. Assessment of the safety of retrieval operations, allowing for their detailed planning. 2. Establishment of a. limits (qualitative or quantitative restrictions to any part of the activity, which are applied to ensure compliance with safety principles and requirements); b. controls (processes, procedures or other instruments that are put in place to ensure compliance with safety principles and requirements); and c. conditions (prerequisites, requirements for functions, facilities or organizations that must exist to ensure safety) for the retrieval operations.
Assessment end points	1. Assessment of the retrieval operations, possible end points include: a. Radionuclide releases caused by the retrieval and upgrading operations; b. Radionuclide concentrations in environmental materials; c. Doses and risks to workers during waste retrieval and upgrading of the facility; d. Doses to public (potential exposure group member); e. Doses to non-human biota.
Assessment philosophy	1. Use of cautious assumptions, but in view of the intervention situation these should be as realistic as possible (see Table 1). 2. Use of actual data to the extent possible and warranted; i.e. the use of generic data is restricted to cases in which site-specific data are not available (see Table 1).
Assessment timeframes	1. Duration of retrieval activities.
Remarks	1. The assessment of the fate of retrieved wastes is not part of this safety assessment. This will be covered by other relevant safety assessments addressing the management steps for these wastes such as clearance, discharge, processing, storage, transport and disposal.

Assessment types

- For normal operation and accidents.
- Doses to workers and members of the public.
- Radiological impacts indoors and outdoors.

Graded approach to the assessments



Normal operation scenarios

- Impacts are classified by their location and type:
  - Inside the facility (workers exposure)
    - Direct external exposure and exposure via inhalation,
    - Other;
  - Outside the facility (public exposure):
    - Releases to air,
    - Liquid discharges,
    - Other.

Screening of hazards and Hazard Quotient

- Screening of hazards – implementation of the graded approach;
- For screening of hazards SAFRAN uses the concept of hazard quotient (HQ)

$$HQ = \frac{Impact}{Screening\ Impact}$$

Impact Category	HQ values
(1)	(2)
Very High	> 100
High	10-100
Medium	1-10
Low	0.1-1
Very Low	< 0.1

HQ: External irradiation and inhalation

$$HQ = \frac{DoseRate_{total}}{ScreeningDoseRate}$$

$$ScreeningDoseRate = \frac{ScreeningDoseWorker}{ExposureTime}$$

- SAFRAN default values:
  - Screening dose to worker is 0.1 mSv/y,
  - Annual worker exposure time is 2000 h/y (i.e. working time is 8 h per day, 5 days per week and 50 weeks per year).

- User may set its own value for screening dose rate basing on actual conditions to be assessed.

HQ: Releases to atmosphere

$$HQ = \frac{Release\ Rate}{Screening\ Release\ Rate}$$

$$ScreeningReleaseRate = \frac{ScreeningDosePublic}{DoseCalculationFactor_{release}}$$

- SAFRAN default values:
  - Screening dose to member of the public is 0.01 mSv/y,
  - Release to dose calculation factors (mSv/Bq) are based on the IAEA Safety Report Series No. 19 defined Generic Environmental Model;
- User may set its own value for screening release rate basing on actual conditions to be assessed.

Dose assessments

- If scenario is not screened out basing on HQ
  - dose rate (inside facility)
  - release / discharge (outside facility)

  then dose calculation is performed;

- Calculation continues with already identified impacting parameters (dose rate, release / discharge rate).

Dose assessments (cont.)

- External irradiation and inhalation:
  - User defines actual exposure time:

$$Dose = DoseRate_{total} \times time_{exposure}$$

$$DoseRate_{total} = \sum_{i} DoseRate^{i}_{ext} + \sum_{i} DoseRate^{i}_{inh}$$

- Releases to atmosphere / Liquid discharges
  - SAFRAN includes database of release to dose conversion factors:

$$Dose = ReleaseRate \times DCF$$

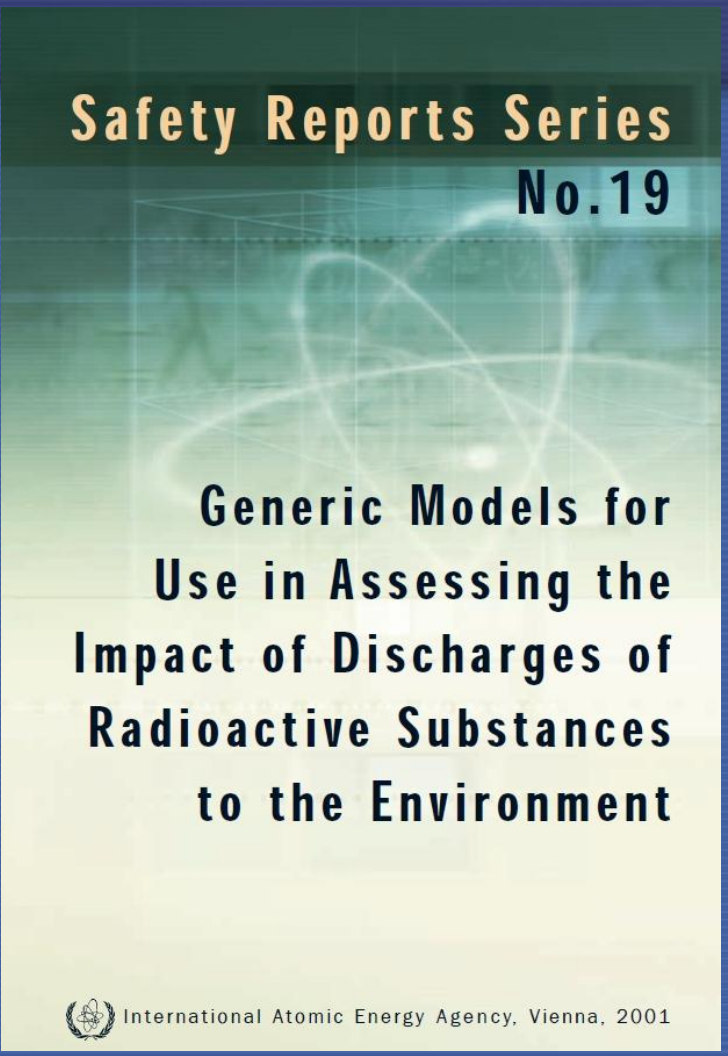


TABLE I–III. DOSE CALCULATION FACTORS FOR DISCHARGES TO THE ATMOSPHERE BASED ON THE GENERIC ENVIRONMENTAL MODEL (Sv/a per Bq/s)[a]

Nuclide	Generic dose factor (Sv/a per Bq/s)	Contribution (%)				
		Crops	Milk	Meat	External	Inhalation
Ac-228	4.7×10^{-7}	0	0	0	5	95
Ag-110m	6.3×10^{-5}	2	0	0	98	0
Am-241*	7.9×10^{-4}	8	0	0	2	90
As-76	6.9×10^{-8}	0	0	0	81	19
At-211*						
Au-198						
Bi-206						
Bi-210*						
Bi-212*						
Br-82						
Cd-109						
Ce-141						
Ce-144						
Cm-242*						
Cm-244*						
Co-58						
Co-60						
Cr-51						
Cs-134*						
Cs-135*						
Cs-136						
Cs-137*						

TABLE I–IV. DOSE CALCULATION FACTORS FOR DISCHARGES INTO A SEWER BASED ON THE GENERIC ENVIRONMENTAL MODEL (Sv/a per Bq/a)[a]

Nuclide	Total dose (Sv/a per Bq/a)	Contribution (%)	
		External	Inhalation
Ac-228	8.8×10^{-13}	100	0
Ag-110m	2.4×10^{-12}	100	0
Am-241	2.6×10^{-14}	96	4
As-76	4.9×10^{-13}	100	0
At-211			
Au-198			
Bi-206			
Bi-210			
Bi-212			
Br-82			
Cd-109			
Ce-141			
Ce-144			
Cm-242			
Cm-244			
Co-58			
Co-60			
Cr-51			
Cs-134			

TABLE I–V. DOSE CALCULATION FACTORS FOR DISCHARGES INTO SURFACE WATER BASED ON THE GENERIC ENVIRONMENTAL MODEL (Sv/a per Bq/s)[a]

Nuclide	Generic dose factor Sv/a per Bq/s	Contribution (%)		
		Drinking water	Fish	External
Ac-228[b]	2.3×10^{-8}	48	42	10
Ag-110m*[b]	2.2×10^{-7}	38	29	33
Am-241*	4.9×10^{-6}	12	6	82
As-76[b]	1.4×10^{-6}	3	97	0
At-211[b]	5.9×10^{-7}	54	46	0
Au-198[b]	9.0×10^{-8}	33	67	0
Bi-206[b]	6.7×10^{-8}	62	36	2
Bi-210[b]	6.4×10^{-8}	63	37	0
Bi-212[b]	9.8×10^{-9}	63	37	0
Br-82[b]	2.6×10^{-7}	4	96	0
Cd-109[b]	5.4×10^{-7}	7	85	8
Ce-141	8.1×10^{-8}	26	45	29
Ce-144	7.3×10^{-7}	22	38	40
Cm-242	8.6×10^{-7}	37	63	0
Cm-244	3.3×10^{-6}	37	63	0
Co-58	7.2×10^{-7}	3	44	53
Co-60*	5.4×10^{-6}	1	9	90
Cr-51	2.0×10^{-8}	5	54	41
Cs-134*	9.2×10^{-5}	0	99	1
Cs-135*	9.6×10^{-6}	0	100	0
Cs-136	2.3×10^{-5}	0	100	0
Cs-137*	6.3×10^{-5}	0	99	0

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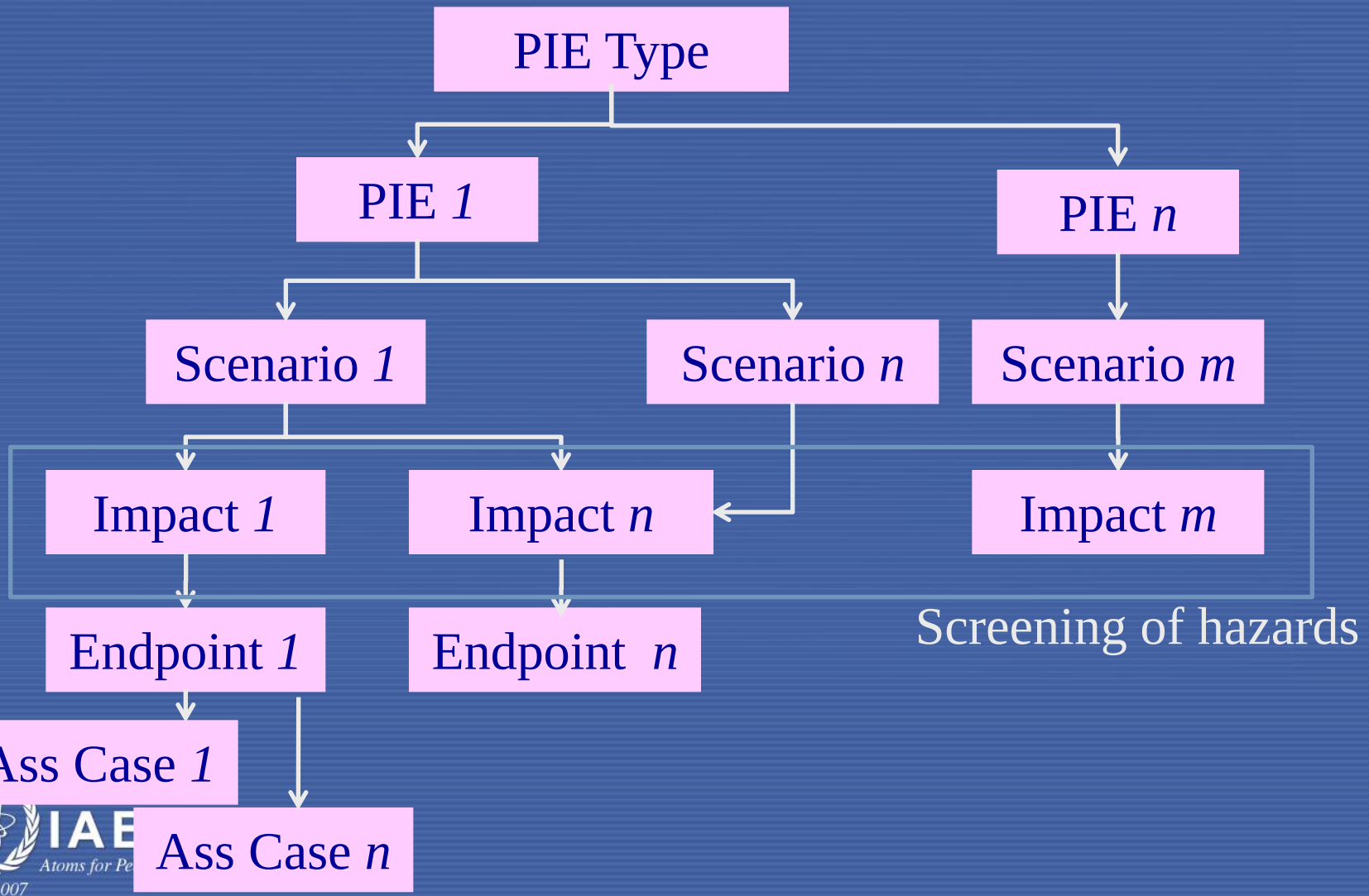
Dose assessments (cont.)

- Releases to atmosphere / Liquid discharges
  - SAFRAN includes database of release to dose conversion factors;
  - SAFRAN includes SAFCALC tool where IAEA Safety Reports Series No. 19 models are implemented and can be used with user defined parameters;
  - User values of DCF.

Assessments for accidents



Accident scenarios

- Impacts are classified by their location and type:
  - Inside the facility (workers exposure)
    - Direct external exposure,
    - Releases to air;
      - *type of material and stress conditions*
    - Other;
  - Outside the facility (public exposure):
    - Releases to air,
      - *type of material and stress conditions*
    - Other.

HQ: External exposure

$$DoseRate = \sum_k \sum_i N_k \times PAI_k^i \times SGRDC^i$$

- *N* – number of affected waste components per particular waste stream;
- *PAI* – Potentially affected inventory of waste component (Bq),
- *SGRDC* – Specific gamma ray dose constant (Sv/h per Bq at distance of 1 m). Values of SGRDC are included in the SAFRAN database.

$$HQ = \frac{Dose\ Rate}{Screening\ Dose\ Rate}$$

- SAFRAN default value for the Screening Dose Rate is 0.1 mSv per exposure time of 1 h.

Potentially Affected Inventory (PAI)

Also known as Material At Risk

Is the radionuclide inventory or amount, in Bq, that can be affected during an accident.

Examples

- The PAI for an accident consisting of dropping a waste package equals the total activity in the package.
- The PAI for an accident during a processing activity equals the activity involved in one instance of the activity

HQ: Release inside

$$ReleaseInside_k^i = N_k \times PAI_k^i \times ARF_k^i$$

- ARF – airborne release fraction. SAFRAN includes database for AFR;

$$HQ = \sum_k \sum_i \frac{ReleaseInside_k^i}{ScreeningReleaseInside^i}$$

- Screening release inside is pre-calculated with SAFCALC tool for 0.1 mSv dose:
  - Accident occurs in a relatively small room of 50 m^3 volume,
  - There is no air extraction from the room,
  - All accident released activity is respirable and worker does not wear any protective equipment.

Airborne Release Fractions

- Airborne Release Fraction (ARF) is the fraction of the Potential Affected Inventory that is released to air during the accident.
- The RF depends on the Waste Form, the Radionuclide and the Type of Effect of the accident.
- Values of ARF are given in the SAFRAN Database.
- It is assumed that ARF correspond to respirable fractions.

HQ: Release outside

$$ReleaseOutside^{i} = \sum_{k} ReleaseInside_{k}^{i} \times (1 - FiltrationEfficiency)$$

$$HQ = \sum_{i} \frac{ReleaseOutside^{i}}{ScreeningReleaseOutside^{i}}$$

- Screening release outside is pre-calculated with SAFCALC tool for 0.1 mSv dose:
  - Release occurs from the building at the effective height of 10 m,
  - Critical group members live at a distance of 30 m from the source in the downwind direction.

Comparison of hazards

- Each hazard is characterized
  - Impact (HQ)
  - Probability of scenario

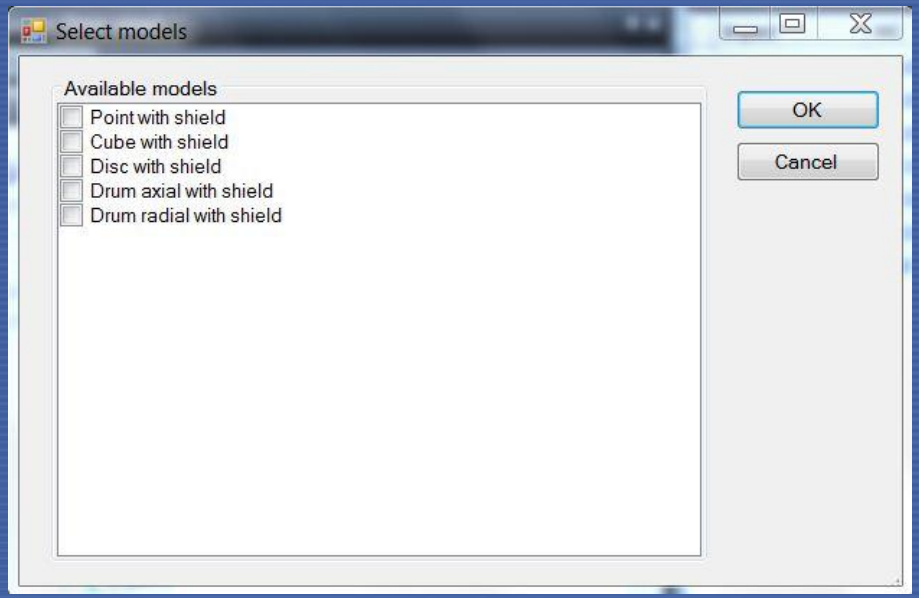
Qualitative Category	Probability during life time	Annual probability 1/y
(1)	(2)	(3)
Very High	> 95 %	> 3,0E-02
High	75-95 %	1,4E-02 - 3,0E-02
Medium	5-75 %	5,0E-04 - 1,4E-02
Low	0,1-5 %	1,0E-05 - 5,0E-04
Very Low	< 0,1 %	< 1,0E-05

Example of Probability-Consequence plots

HQ/Prob	Very Low	Low	Medium	High	Very High
<0.1				SC3	
0.1- 1					SC4
1-10			SC2		
10-100					
>100	SC1				

Dose assessment: direct external exposure

- SAFRAN tool:
  - Simple geometries:
    - Point source,
    - Cube,
    - Disc,
    - Cylinder;
  - Without of with shielding
    - Water,
    - Concrete,
    - Lead.



Dose assessment: release inside

$$Dose = \sum_i Dose^i_{inh} + Dose^i_{extCloud}$$

$$= \sum_i Release^i \times DispFactor \times (InhRate \times ProtFactor \times DCC^i_{inh} + DCC^i_{extCloud})$$

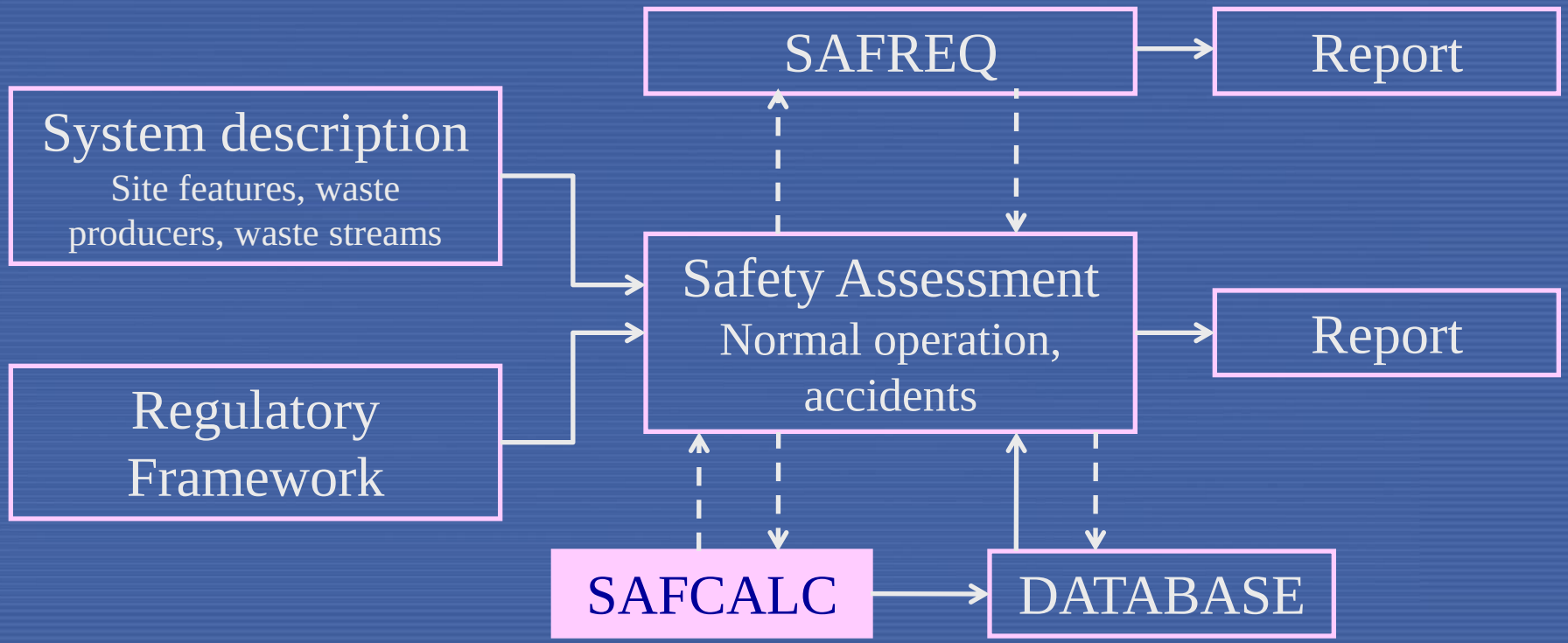
- Use SAFRAN database with pre-calculated DispFactor values
  - Room volume (50, 200, 600, 1200, 3000 m^3)
  - Exposure distance (1, 2, 3, 5, 7, 9, 12 m)
  - Exposure time (1, 5, 10, 30, 60 min)
- Use SAFCALC models

Dose assessment: release outside

$$Dose = \sum_i Release^i \times DCF^i_{airAcc}$$

- Use SAFRAN database with pre-calculated DCF values:
  - For Generic environment model ;
- Use SAFCALC models.

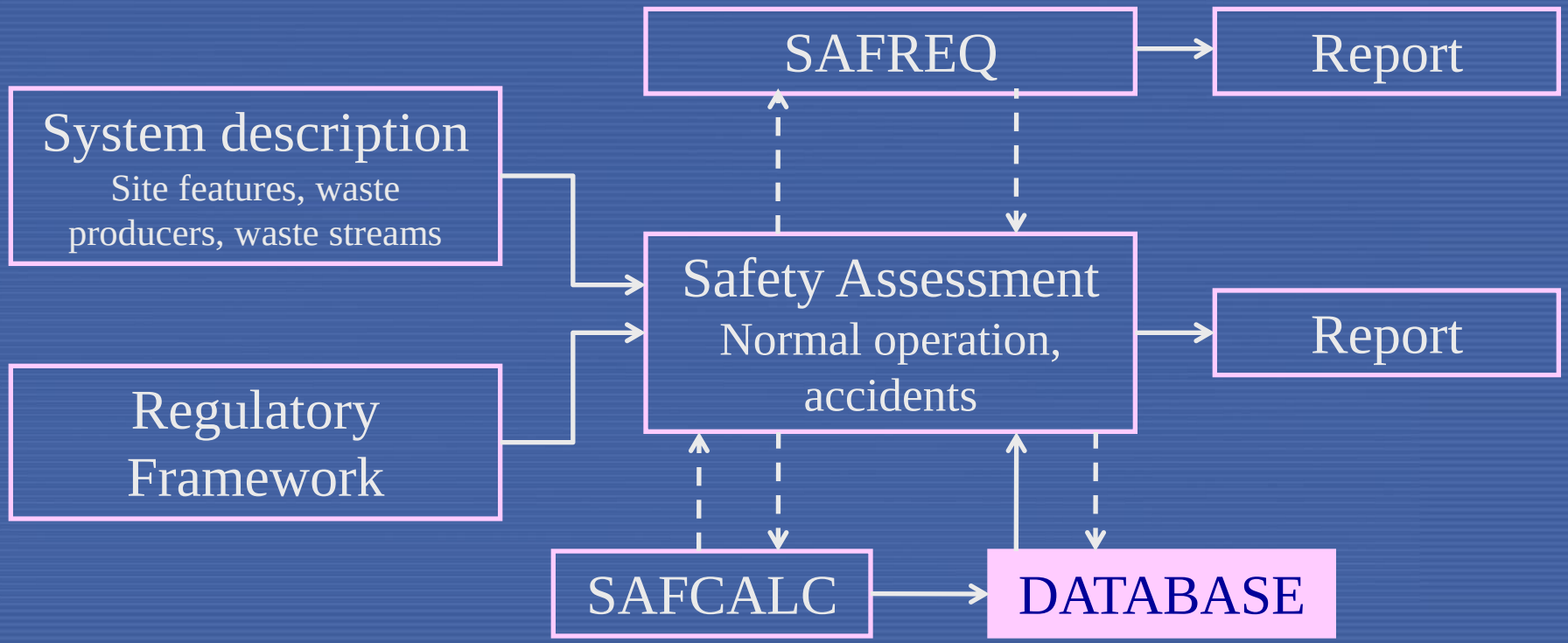
SAFRAN components



Models available in SAFCALC

- IAEA SR-19 models: screening models for routine releases to the atmosphere, lakes, rivers, estuarines and coastal areas.
- Model for accidental releases to the atmosphere.
- Model for accidental releases inside a room.
- Simple dosimetry models: point source, disc, cylinder, cube (with and without shielding)

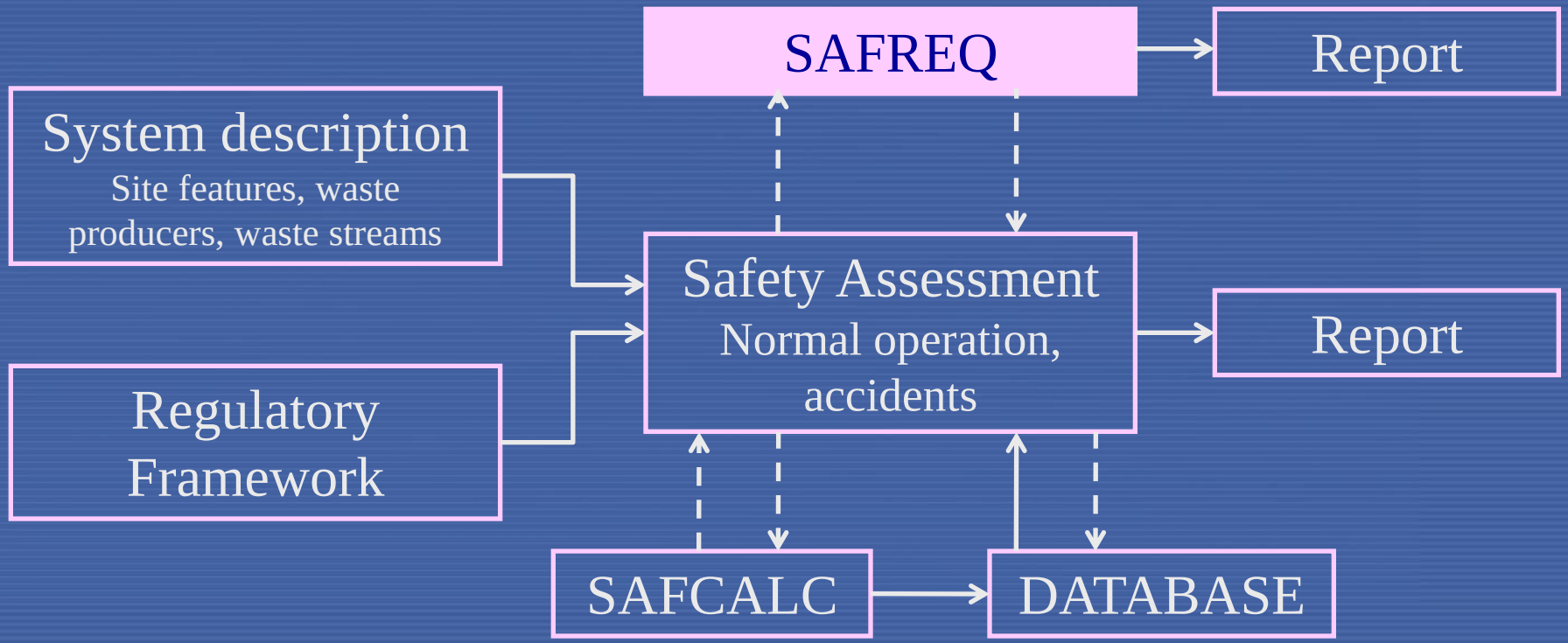
SAFRAN components



Database

- Radionuclide half lives.
- Clearance levels.
- Gamma constants – dose rates at 1 m from a point source.
- Screening dose rates for Normal and accidental situations.
- Screening release rates for Normal operation.
- Screening releases for accidental situations.
- Release Fractions.
- Dispersion factors.
- Dose Conversion Factors for Normal and accidental situations.

SAFRAN components



SAFREQ

- Tool for auditing of compliance with IAEA safety requirements.
- Two versions: stand alone and incorporated the in the SA module
- Questionnarie for each requirement
- Capability to regenate a report

SAFRAN website

- www.safran.facilia.se
- Free download of the software and documentation
- Online User Guide
- Tutorials
- SAFRAN projects – TNIT test case
- Discussion Forum