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Verification and Validation of SAMGs

SAMG-D Toolkit, Module 3, Chapter 7

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This presentation contains publicly available information related to the WOG and PWROG SAMG.

The WOG SAMG package is proprietary to the Westinghouse Owners Group.

The PWROG SAMG package is proprietary to the Pressurized Water Reactor Owners Group.

Agenda

- SAMG Verification Objectives & Criteria
- SAMG Verification Process
- SAMG Validation Objectives
- SAMG Validation Criteria
- SAMG Validation Process
- Conclusions
- References

SAMG Verification & Validation Background (1/2)

- Many acknowledged international documents provide the requirements on SAMG verification & validation:
  - IAEA Safety Guide NS-G-2.15
  - IAEA Safety Report Series No. 32
  - WENRA RHWG SRLfER 09/2014, Issue LM
- Similar requirements can be found in national legislation (decrees, guides)

SAMG Verification & Validation Background (2/2)

- International and national documents should be used as high-level reference documents when defining SAMG V&V acceptance criteria
- It is required that all developed SAMG V&V acceptance criteria can be linked to requirements specified in high-level reference documents

SAMG Verification & Validation Requirements (1/11)

- IAEA NS-G-2.15, art. 3.99:
  - All procedures and guidelines should be verified.
  - Verification should be carried out to confirm the correctness of a written procedure or guideline and to ensure that technical and human factors have been properly incorporated.
  - The review of plant specific procedures and guidelines in the development phase, in accordance with the quality assurance regulations, forms part of this verification process.

SAMG Verification & Validation Requirements (2/11)

- IAEA NS-G-2.15, art. 3.100:
  - All procedures and guidelines should be validated.
  - Validation should be carried out to confirm that the actions specified in the procedures and guidelines can be followed by trained staff to manage emergency events.

SAMG Verification & Validation Requirements (3/11)

- IAEA NS-G-2.15, art. 3.101:
  - Possible methods for validation of the SAMGs are the use of a full scope simulator (if available), an engineering simulator or other plant analyser tool, or a tabletop method.
  - The most appropriate method should be selected.
  - On-site tests should be performed to validate the use of equipment.
  - Scenarios should be developed that describe a number of fairly realistic (complex) situations that would require the application of major portions of the EOPs and the SAMGs.

SAMG Verification & Validation Requirements (4/11)

- IAEA NS-G-2.15, art. 3.101 contd':
  - The scenarios encompass the uncertainties in the magnitude and timing of phenomena (both phenomena that result from the accident progression and phenomena that result from recovery actions).
- IAEA NS-G-2.15, art. 3.102:
  - Members of staff involved in the validation of the procedures and guidelines should not be those who developed the procedures and guidelines.

SAMG Verification & Validation Requirements (5/11)

- IAEA NS-G-2.15, art. 3.103:
  - The findings and insights from the verification and validation processes should be documented and used for providing feedback to the developers of procedures and guidelines for any necessary updates before the documents are brought into force by the management of the operating organization.

SAMG Verification & Validation Requirements (6/11)

- IAEA SRS No.32, art. 4.6.1:
  - Verification is the evaluation which confirms the correctness of a written procedure or guideline and ensures that technical and human factors have been properly incorporated.
  - As such, the review of plant specific guidelines during the development phase, in accordance with QA regulations, forms part of the verification process.
  - It is advisable to perform all implementation activities, including independent review, in accordance with internationally accepted QA guidelines.

SAMG Verification & Validation Requirements (7/11)

- WENRA RHWG SRLfER 09/2014 Issue LM, art. LM4.1:
  - The set of procedures and guidelines shall be verified and validated in the form in which they will be used in the field, as far as practicable, to ensure that they are administratively and technically correct for the plant, are compatible with the environment in which they will be used and with the human resources available.

SAMG Verification & Validation Requirements (8/11)

- WENRA RHWG SRLfER 09/2014 Issue LM, art. LM4.2:
  - The approach used for plant-specific validation and verification shall be documented.
  - The effectiveness of incorporating human factors engineering principles in procedures and guidelines shall be judged when validating them.
  - The validation of EOPs shall be based on representative simulations, using a simulator, where appropriate".

SAMG Verification & Validation Requirements (9/11)

- WENRA RHWG SRLfER 09/2014 Issue LM, art. LM5.1:
  - The set of procedures and guidelines shall be kept updated to ensure that they remain fit for their purpose.

SAMG Verification & Validation Requirements (10/11)

- NRA SR, Annex No. 4 do Decree No. 430/2011, Coll. G. Operating rules, art. (11):
  - Procedures for dealing with emergency states and instructions for managing severe accidents are verified and validated in the form in which they shall be used on site, in order to ensure that they are administratively and technically correct and consistent with the environment in which they shall be used.

SAMG Verification & Validation Requirements (11/11)

- NRA SR, Annex No. 4 do Decree No. 430/2011, Coll. G. Operating rules, art. (12):
  - The verification and validation procedure for procedures for dealing with emergency states and instructions for managing severe accidents is documented.
  - Validation is performed for the given nuclear facility.
  - During validation, the effectiveness of including the human factor into procedures and instructions is assessed.
  - Validation of procedures is performed on a representative full-scale simulator.

SAMG Verification Objectives & Criteria (1/2)

- In general, SAMG verification objectives are mainly related to:
  - Check whether developed guidelines meet requirements posed on them
  - Review and correct any internal inconsistencies or errors in guidelines
  - Check whether appropriate QA regulations were followed

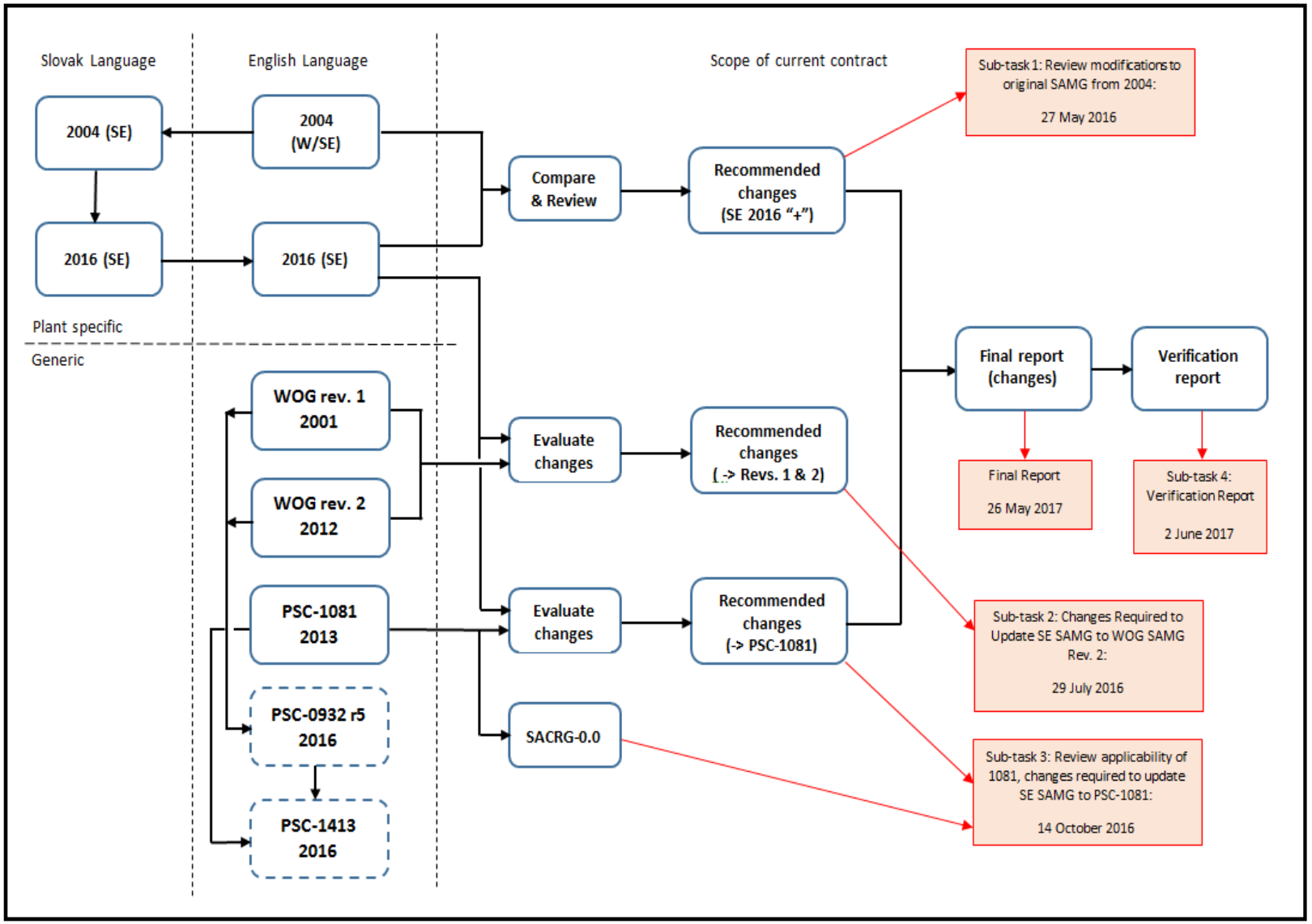
SAMG Verification Objectives & Criteria (2/2)

- SAMG verification criteria used in Bohunice NPP SAMG verification:
  - Have ALL SAMG components been verified?
  - Were the guidelines verified in the form that they will be used on site?
  - Have technical features been fully considered, especially plant design specific features?
  - Has due consideration of human factors been included?
  - Have plant specific administrative/organisational aspects been fully considered?
  - Have appropriate QA regulations been followed?
  - Have independent reviews been performed?
  - Have findings from the verification process been fed back into the guidelines?
  - Has the verification process been documented?
  - Have guidelines been updated, and is a process in place to ensure future updates are made in a timely fashion?

SAMG Verification Process

- SAMG verification process consists of a thorough review of developed SAMG package.
- All defined SAMG verification criteria have to be evaluated.
- The major task of the SAMG verification is to check whether the developed SAMG verification package meets the original requirements on the guidelines(e.g. NS-G-2.15)
- The verification process has to be systematically document.

Bohunice NPP SAMG Update & Verification Project



SAMG Verification
Bohunice NPP Lessons Learned

- SAMG verification is a major task requiring a sound QA system in place.
- Checking and corrections of internal guideline inconsistencies requires a lot of resources to be completed in timely fashion.
- It is beneficial not to start development of own SAMGs from the scratch but rather implement generic internationally recognized SAMG package
  - Straightforward development and verification process

SAMG Validation Objectives

- SAMG validation objectives and approach are designed to be in compliance with national and international requirements and guidance.
- The principal objective of a validation exercise is to check the usability of the SAMG package in as realistic environment as possible.
- Other objectives include verification of human factors approach as treated in SAMGs, collection of feedback for further ERO & SAMG optimization, etc.

Bohunice NPP SAMG Structure Overview

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Control Room

SACRG-0:
Severe Accident Control Room Guideline
Loss of DC and/or Instrumentation

SACRG-1:
Severe Accident Control Room Guideline
Initial Response

SACRG-2:
Severe Accident Control Room Guideline
TSC Functional

SACRG-3:
Severe Accident Control Room Guideline
Shutdown Modes Initial Response

SACRG-4:
Severe Accident Control Room Guideline
Shutdown Modes TSC Functional

Technical Support Center

Diagnostic Flow Chart (DFC)

Severe Challenge Status Tree (SCST)

Severe Accident Guidelines:

SAG-1: Depressurize the RCS
SAG-2: Inject into RCS
SAG-3: Inject into Containment and Cavity Flooding
SAG-4: Reduce Fission Product Releases
SAG-5: Inject into Steam Generators
SAG-6: Control Containment Conditions
SAG-7: Refill the Spent Fuel Pool

Severe Challenge Guidelines:

SCG-1: Mitigate Fission Product Releases
SCG-2: Depressurize Containment
SCG-3: Reduce Containment Hydrogen
SCG-4: Control Containment Vacuum
SCG-5: Recover Spent Fuel Pool Level

Computational Aids CA-1 to 9

CA-1: RCS Injection to Recover the Core
CA-2: Injection Rate for Long Term Decay Heat Removal
CA-4: Vent Mass Flow
CA-5: Containment Water Level and Volume
CA-6: Potential Containment Vacuum Severe Challenge
CA-7: Hydrogen Concentration in Long Term Stable Condition
CA-8: Radiation Level as a function of Time after Shutdown
CA-9: Coolant Flow needed for SFP Residual Heat Removal

SAEG-1
TSC Long Term Monitoring Activities

SAEG-2
SAMG Termination

SAMG Validation Overview (1/2)

- For accidents progressing to core damage, the MCR will be responsible for exiting the EOP and transitioning to the Bohunice NPP SAMG package. Once this transition is made, the control room utilizes the SACRG.
- The portion of the validation exercise, which concentrated solely on the control room guidelines, focused on validating the following aspects of the SAMG:
  - transition from EOP to SACRG-1,3
  - use of SACRGs
  - transition from SACRG-1 to SACRG-2, from SACRG-3 to SACRG-4, to SACRG-0 and back.

SAMG Validation Overview (2/2)

- The SAMG package is designed primarily for TSC use. The TSC utilizes the remaining portions of the SAMG, without SACRG guidelines, to evaluate accident management strategies and to decide on an optimum strategy.
- Validation aspects of the SAMG which concentrated solely on the TSC guidelines:
  - use of diagnostic tools (DFC and SCST) including the ability to diagnose plant conditions,
  - use of guidelines (SAG and SCG) to choose appropriate strategy,
  - use of computational aids (CA) to aid decision making,
  - use of the first exit guidelines (SAEG-1).

SAMG Validation Criteria (1/8)

- SAMG validation acceptance criteria are developed to meet the defined SAMG validation objectives.
- Several sets of validation acceptance criteria should be developed to fit the structure of SAMG package that is being validated.
- Validation acceptance criteria should not focus on SAMG package only, but also on the conduction of activities during the validation exercise so that the usage of SAMG package is assessed
  - Important to understand and rely on the outcomes of validation exercise

SAMG Validation Criteria (2/8)

- Based on the Bohunice NPP SAMG package structure, the following sets of validation acceptance criteria (AC) were developed:
  - EOP-SAMG Interface AC
  - Control Room Guidelines (CRG) AC
  - TSC Diagnostics (DFC and SCST) AC
  - TSC Guidelines (SAG/SCG/CA) AC
  - Exit Guidelines (SAEG) AC
  - Validation Exercise AC

SAMG Validation Criteria (3/8)

- Examples of EOP-SAMG Interface AC:
  - Is the EOP-SAMG transition clearly defined?
  - Is the EOP-SAMG transition unambiguous?
  - Is the EOP-SAMG transition easily used?

SAMG Validation Criteria (4/8)

- Examples of CRG AC:
  - Is the transition from SACRG-1 to SACRG-2 clearly defined?
  - Can the plant parameters required be obtained?
  - Are the instructions clear and easily understood?
  - Are the responsibilities between control room and TSC clearly defined?

SAMG Validation Criteria (5/8)

- Examples of TSC Diagnostics (DFC and SCST) AC:
  - Can the plant parameters required be obtained?
  - Are the priorities (SCST vs. DFC, and within each) clearly defined?
  - Can a cycle through the diagnostics be completed in a reasonable timeframe?
  - Are the DFC/SCST parameters representative of EBO specific challenges?

SAMG Validation Criteria (6/8)

- Examples of TSC Guidelines (SAG/SCG/CA) AC:
  - Can the plant parameters required be obtained?
  - Are the strategies used appropriate, applicable and usable?
  - Are the instructions clear and easily understood?
  - Are the negative impacts adequately described, and can the guidance to evaluating negative impacts be followed easily? Can decisions be reached?
  - Are the computational aids complete, appropriate, fully applicable and easy to use?
  - Is communication between TSC, ECC and control room staff adequate for guideline usage?

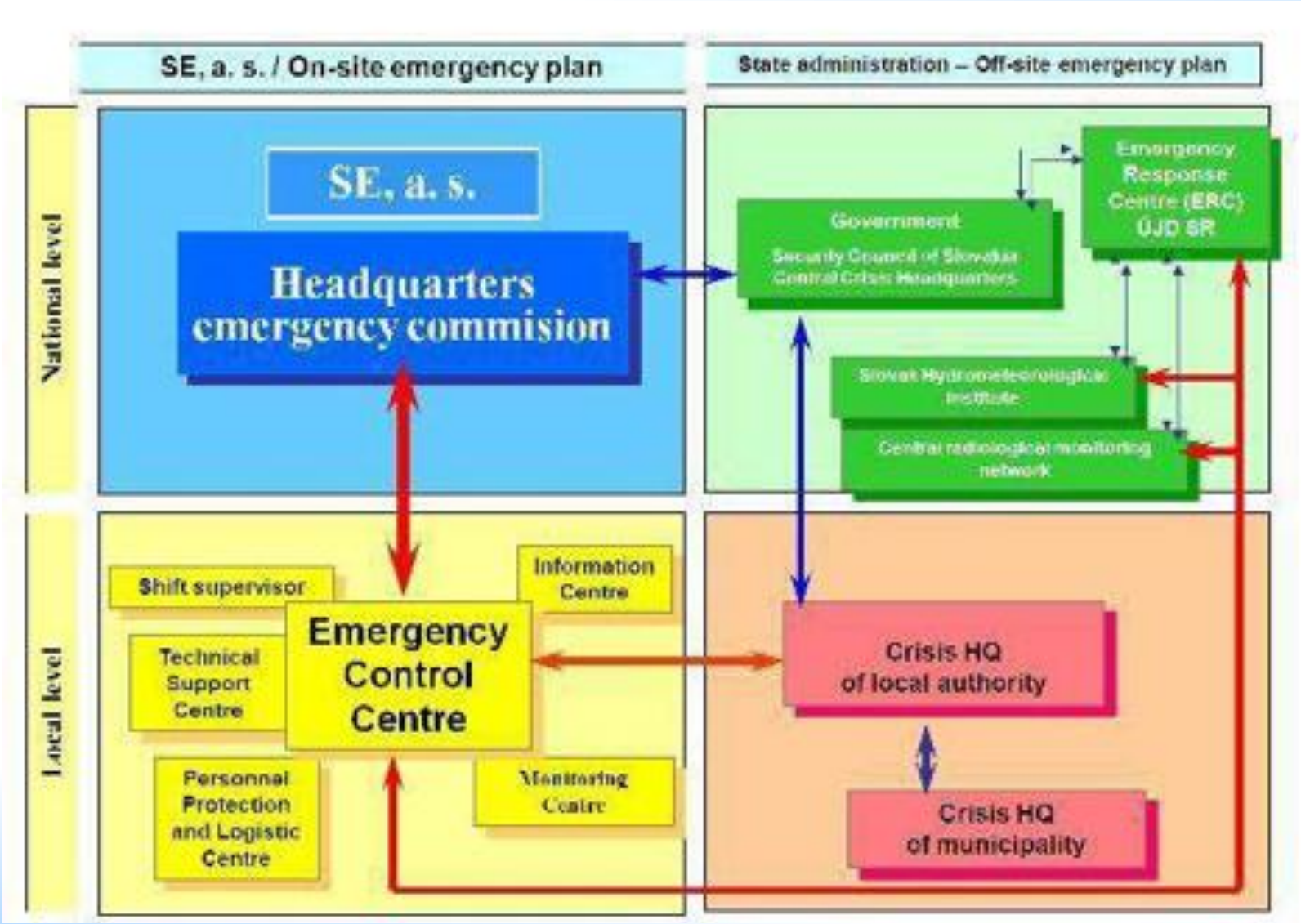
SAMG Validation Criteria (7/8)

- Examples of Exit Guidelines (SAEG) AC:
  - Is the transition from SAEG-1 to SAEG-2 clearly defined?
  - Can the plant parameters required be obtained?
  - Are the decision steps logically ordered?
  - Can the steps be completed?
  - Are the instructions clear and easily understood?
  - Are responsibilities clearly set?

SAMG Validation Criteria (8/8)

- Examples of Validation Exercise AC:
  - Were the diagnostics continuously monitored?
  - Were priorities observed (SCST vs DFC, within the diagnostics, and within the guidelines)?
  - Were negative impacts fully assessed before recommendations were made?
  - Was strategy implementation checked, and was the guidance on this clear (detailed enough)?
  - Were the SAMG evaluation duties efficiently assigned within the TSC?
  - Did the emergency organization face any problems with respect to split of responsibilities?

National Emergency Organization in Slovakia



Bohunice NPP On-Site Emergency Response Organisation

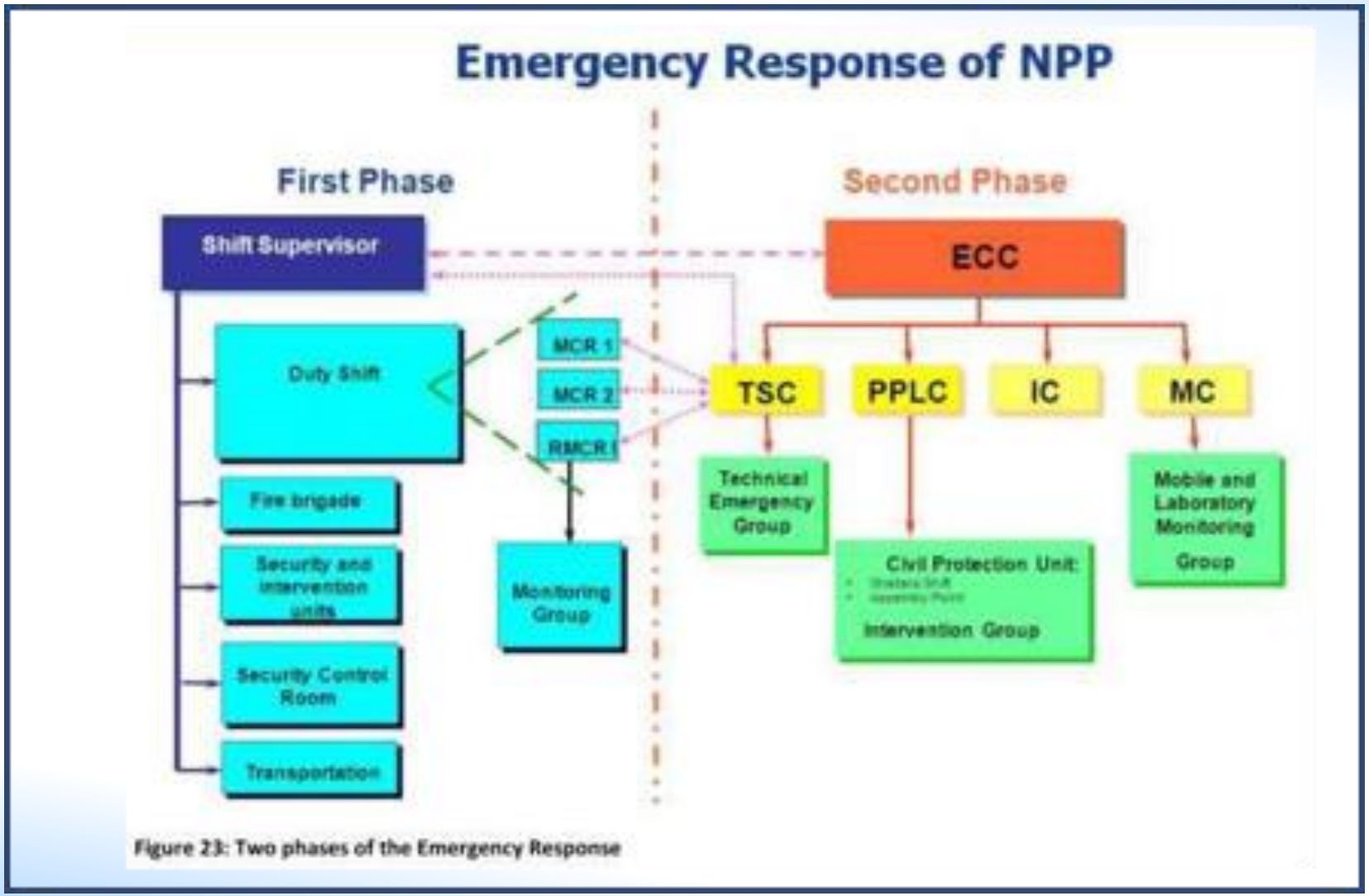


Figure 23: Two phases of the Emergency Response

SAMG Validation Participants

- "Players" are the staff actually using the SAMG – the operating team in the control room, and the TSC. These people do not know anything about the scenarios beforehand, and must be adequately trained on usage of SAMG before performing the exercise. After the exercise, they provide feedback in the form of comments on usability etc. Ideally, the players should be actual operating and TSC teams from the plant.

- "Controllers" provide the boundary conditions for the exercise (for example they act as the control room in a TSC-only exercise), and they are responsible for the realistic progression of the simulated event, and for the updating of plant data and parameters as actions are taken. The observer and controller roles should (in principle) not be mixed.

- "Observers" are dedicated to developing insights on potential improvements to usability, and other aspects of the SAMG package by observing the exercise, and then feeding back their comments, observations and insights afterwards. Observers should be persons experienced in SAMG implementation.

Bohunice NPP SAMG Validation Schedule and Participants

Day	Subject	Attendance	Location
Day 1 am	Final preparation / run-through of exercises	Controller team. Observer team. Non-player project staff. Players should not attend this session.	TSC (suggested)
Day 1 pm	Training / orientation • Validation plan/approach	Whole validation team (plus others?)	ERC training room
Day 2	TSC exercise 1 TSC exercise 2 • Briefing • Perform exercise • De-briefing session	Whole validation team – including TSC players	TSC
Day 3 am	• Preparation for simulator exercises	Controllers, simulator staff and observers only	Simulator
Day 3 pm	INT exercise 1 • Briefing • Perform exercise • De-briefing session	Whole validation team – inc operations and TSC players	Simulator, TSC
Day 4	INT exercise 3 INT exercise 2 • Briefing • Perform exercise • De-briefing session	Whole validation team – inc operations and TSC players	Simulator, TSC TSC
Day 5	TSC exercise 4 INT exercise 4 • Briefing • Perform exercise • De-briefing session	Whole validation team – inc TSC players	TSC TSC, ECC
Day 6 am	INT exercise 5 – 2 UNIT • Briefing • Perform exercise • De-briefing session	Whole validation team – inc operations, TSC and ECC players	TSC, ECC

SAMG Validation Scenarios

- A joint Westinghouse – Bohunice team prepared and finalized validation scenarios.
- Validation scenarios were developed using MAAP/VVER code (version 4.03):
  - to determine the exact starting conditions (i.e., Initial Condition) required for each scenario,
  - to determine the plant specific response to the scenarios,
  - to develop plant datasheets for players (table top).
- Validation scenarios for EOP-SAMG transition and SACRG validation were prepared on FSS.

SAMG Validation Scenarios (1/4)

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  - to determine the plant specific response to the scenarios,
  - to develop plant datasheets for players.
- Validation scenarios for EOP-SAMG transition and SACRG validation were prepared on FSS.

SAMG Validation Scenarios (2/4)

Scenario	TSC	Ops	ERC	Method	Main Guidelines Covered and Main Objectives
TSC-1 Stand-alone TSC	Y	N	N	TT	SAG-2, 3, 6 SCG-2.
TSC-2 Stand-alone TSC	Y	N	N	TT	SAG-2, 3, 5, 6, and SCG-3 Test Hydrogen SCG
TSC-4 Stand-alone TSC	Y	N	N	TT	SAGs -1, 2, 4, 5 (from SCG-1) and SCG-1 Test releases SCG
INT-1 Integrated	Y	Y	N	FSS	EOP (E-0, E-1, ES-1.2, FR-C.2, FR-C.1)-SAMG transition-SACRG-1, 2 (at power)
INT-2 Integrated	Y	Y	N	TT	EOP-SAMG transition (shutdown states) EOP-SACRG-3
INT-3 Integrated	Y	Y	N	FSS	Test SACRG-0 and transitions after power/instn. Recovered. ECA-0.0, SACRG-1, SACRG-0, SACRG-2 SACRG-0 and transition to SACRG-2 / TSC
INT-4 Integrated	Y	Y	Y	TT	Interfaces: TSC-ERC-Ops DFC, SCST SACRG2/4
INT-5 Integrated	Y	Y	Y	TT	TSC function and interfaces with ERC and ops for multi-unit accident

SAMG Validation Scenarios (3/4)

	Scenario Notes
TSC-1 Stand-alone TSC	LOCA, no SI and no active containment heat removal. Exercise begins at SAMG entry.
TSC-2 Stand-alone TSC	Blackout, no feedwater, RCS depressurization in ECA-0.0. SACRG-1 steps 3, 4, 5, 6 success (power back, depressurize RCS, flood cavity). Degraded PARs.
TSC-4 Stand-alone TSC	Hazard induced loss of all feedwater. No ECCS SI but LP injection available from SAM diesel. Unable to open any pressurizer valves No primary depressurization. Induced SGTR before TSC gets to SAG-1.
INT-1 Integrated	MLOCA + SI failure. TSC available after x hr (full implementation of SACRG-1) TSC active, transition to SACRG-2, end.
INT-2 Integrated	Vessel level at flange, CETs removed, vessel head just removed. Spurious / accidental (RHR) valve opening causes overdraining which uncovers core. No primary makeup available.
INT-3 Integrated	Loss of all ac power. Not recovered in ECA-0.0 (fire water to SG not av). Transition to SACRG-1 (pressurizer valves opened in transition). Subsequent loss of batteries/instrumentation. SACRG-0. Successful recovery of minimum instrumentation (mobile dc power unit, instrumentation, local only) and TSC activated while in SACRG-0. Transition back to SACRG-2 with TSC using SAMG. End.
INT-4 Integrated	Test ERC decision maker role (venting) Start exercise many hours into event with containment pressure increasing and nearing the SCG-2 setpoint. IVR successful but no containment heat removal available. Define active SAGs prior to reaching SCG. After successful vent, exit SCG-2, re-enter SAG-6, recover CHR. End.

SAMG Validation Scenarios (4/4)

	Scenario Notes	
INT-5 Integrated	Seismic initiator: blackout on U4, blackout plus induced MLOCA on U3. (ECA-0.0 w/o feedwater: depressurize SGs and primary to 3.5MPa using existing SG inventory…) SAM diesel in maintenance. ECA-0.0 will instruct U3: Fire truck in use to connect mobile diesel (in progress – taking time) U4: feed SGs with fire trucks but connection points inaccessible due to building damage. U3 enter SAMG from ECA-0.0 first. Mobile diesel connected U3.	
	U3, SAMG entry from ECA-0.0, TSC activated, bubble tower drained in SACRG-1, cavity flooded (valves need mobile power). Active: SAG-2: start LHSI pump (from mobile diesel) SAG-6: nothing available till SAM diesel resupplies (Containment pressurizing)	U4 still in ECA-0.0. Feeding SGs (not succeeding). SGs depleting. U4 SAMG entry from ECA-0.0 (RCS depressurized in kickout step) TSC activated SACRG-1: bubble tower not

Bohunice SAMG Validation Data Sheet

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EXERCISE — **EBO SAMG Validation** — **EXERCISE**

Scenario:		Unit:	Date:	Time:	

Primary System:			Secondary System:									Event Information:
Reactor power	% nominal	↔	SG#	1	2	3	4	5	6			
RCS temp. cold leg	°C	↔	Level (wide range)							m	↔	
RCS temp. hot leg	°C	↔	Pressure							MPa	↔	
Core exit temp. (max.)	°C	↔	Feed flow							t/hr	↔	
RCS pressure	Mpa	↔	Steam flow							t/hr	↔	
Pressurizer level	m	↔	Steamline MSIV									
Primary activity	Bq/m³		Feedline MFIV									

RCPs 1P11-16	Electrical Systems:	Containment:			Operations - procedures in use:
1YP10570,71 (SAM depress valve)	400 kV (main)	Pressure	kPa rel.	↔	
YP10530 (Psr PORV)	110 kV (aux)	Temperature	°C	↔	
YP10520 (Psr safety)	BV-BW-BX 6kV (safety)	Containment water level	m	↘	
YP10527(Psr safety)	EV-EW-EX 0.4kV (safety)	Hydrogen concentration	%	↔	Key actions already taken:
1YP10549,48 (Aux. spray)	V713 6kV (hydro)	Fuel pool level	m	↔	
1YP10529,28 (Aux. Spray)	SAM diesel generator	Drain valves of system XL			
		Input valves to ventilation system 1T11512, 22 for reactor cavity flooding			
Safeguards Systems:	**Non-safeguards Systems:**	Containment drain valves			
HHSI injection flow	t/hr ↔	CCW flow	t/hr ↔	T121 D01, D02, D03 (Containment Penetration Cooling)	
HHSI tank level	cm ↔	ESWS flow	t/hr ↔	T1,10001, D02, D03 (Containment Fan Coolers)	
LHSI injection flow	t/hr ↔			T1,11001, D02, D03 (Reactor Cavity cooler)	
Containment spray flow	t/hr ↔	TK20, 40, 60 (Charging pumps)		1A1 11 501, 3, 5, 7 (Containment vacuum breaker)	Additional information:
LHSI tank level	m ↔	Charging suction TK10,50801		T1,70, 71 (Containment Vent Paths Outlet Venting System)	
		Charging suction TB10,50802		**Radiation Monitoring:**	
0T11,2001, 0T11,1001 (ACS pumps)	(damaged discharge line)	TH 10,11,12,13 (accumulators)		Containment mSv/hr ↗	
T120, 40, 60 (HHSI pumps)		TB11, TB12 (PDPs)		Reactor hall mSv/hr ↔	
TH20, 40, 60 (LHSI pumps)		TK (booster stage RCS makeup)		Stack aerosol Bq/m³ ↔	
TQ20, 40, 60 (Containment Spray)		1TB20,40,60 (Boron conc. pumps)		Stack iodine Bq/m³ ↔	
Injection lineup		TE 10,50 (Letdown pumps)		Site boundary doserate mSv/hr ↔	
Recirculation lineup		TD21, TD22 (Auxiliary pumps)			

KEY:

Av	Currently available	↑	Increasing	ACS	Alternate cooling system	LHSI	Low head safety injection	RCS	Reactor coolant system
N/Av	Currently not available	↗	Increasing slowly	BDBA	Beyond design basis accident	MCR	Main control room	SAM	Severe accident mamanagement
OP	Open	↓	Decreasing	CCW	Component cooling water	MSIV	Main steamline isolation valve	SG	Steam generator
CL	Closed	↘	Decreasing slowly	ESWS	Essential service water system	MFIV	Main feedline isolation valve	TSC	Technical support centre
		↔	Stable	HHSI	High head safety injection	PORV	Power operated relief valve		
				LOCA	Loss of primary coolant accident	RCP	Reactor coolant pump		

EXERCISE — **EBO SAMG Validation** — **EXERCISE**

SAMG Validation Feedback

- Validation feedback should be grouped into corresponding categories:
  - Validation feedback issues potentially leading to a guideline modification. A preliminary evaluation should be presented, which will be used when the guideline change is considered for implementation.
  - Validation issues to be addressed in training.
  - Validation issues requiring no specific action (mainly related to the methodology of the exercises).

SAMG Validation
Evaluation of Acceptance Criteria

- Observers are responsible for taking notes during the validation exercise
- Notes should be taken to allow for evaluation of acceptance criteria
- All defined acceptance criteria have to be evaluated
- Conclusions should be given on the usability of SAMG in real environment

Conclusions

- SAMG V&V is an essential part of SAMG development and implementation
- SAMG verification is important tool to confirm that all requirements posed on SAMG package were met and guidelines are technically correct
- SAMG validation is essential activity to test developed and verified SAMG package in realistic environment before final implementation providing important feedback on future updates and personnel training

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Questions?