



# **Design Evaluation by FTA Method of Failing of SCRAM Activation System following Coolant Level decrease in a MTR-Pool Type Reactor**

**Presented at IAEA TM on "EFFECTIVE COMBINATION OF DETERMINISTIC AND  
PROBABILISTIC SAFETY ANALYSIS IN PLANT SAFETY MANAGEMENT"**

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Presentation

System

FTA

Probabilities

Results

Conclusions

## Overview

- Presentation**
- System**
- FTA**
- Probabilities – Data Base**
- Results & Sensitivity analyses**
- Conclusions**



## **System Technical Details**



Presentation

System

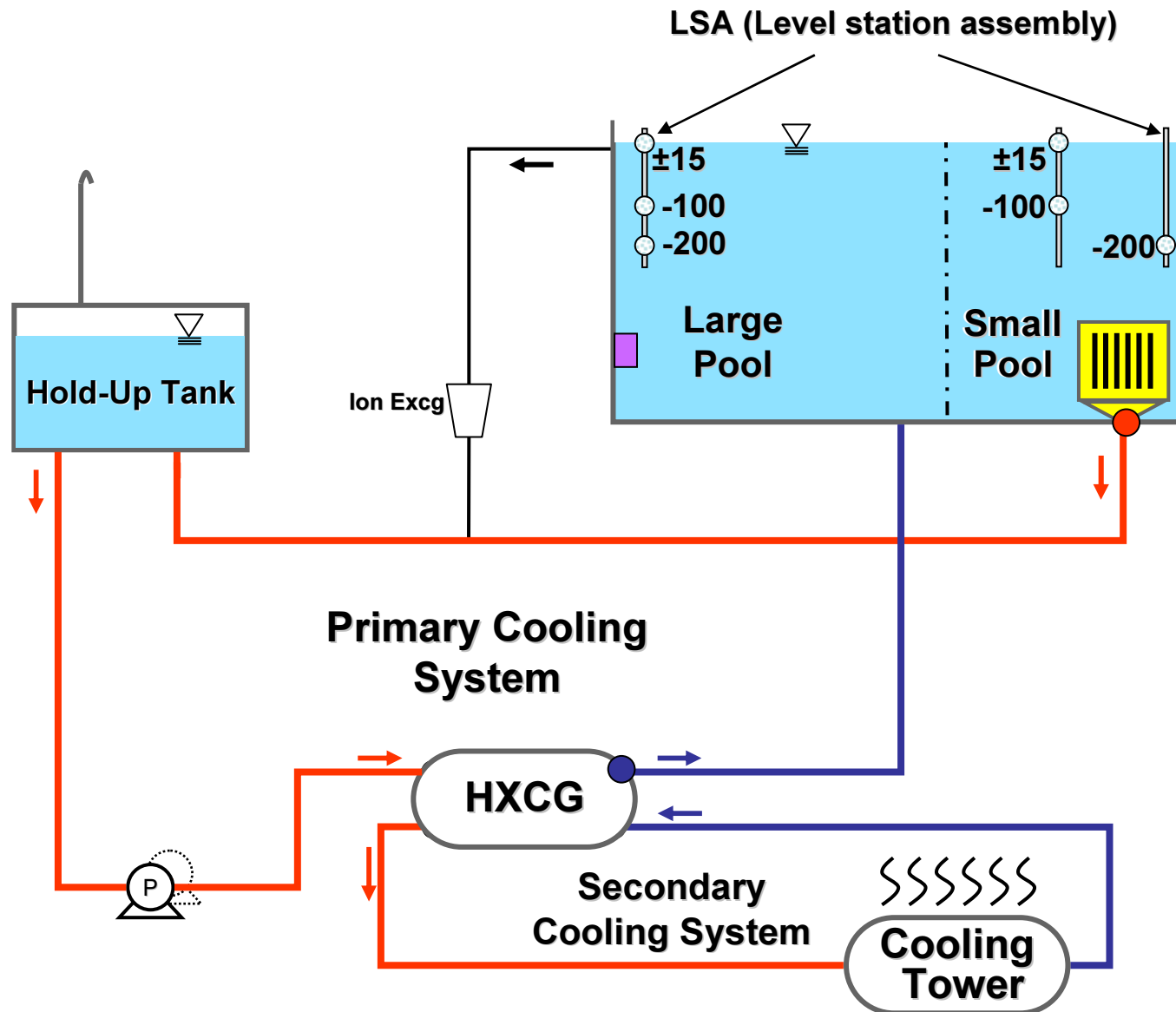
FTA

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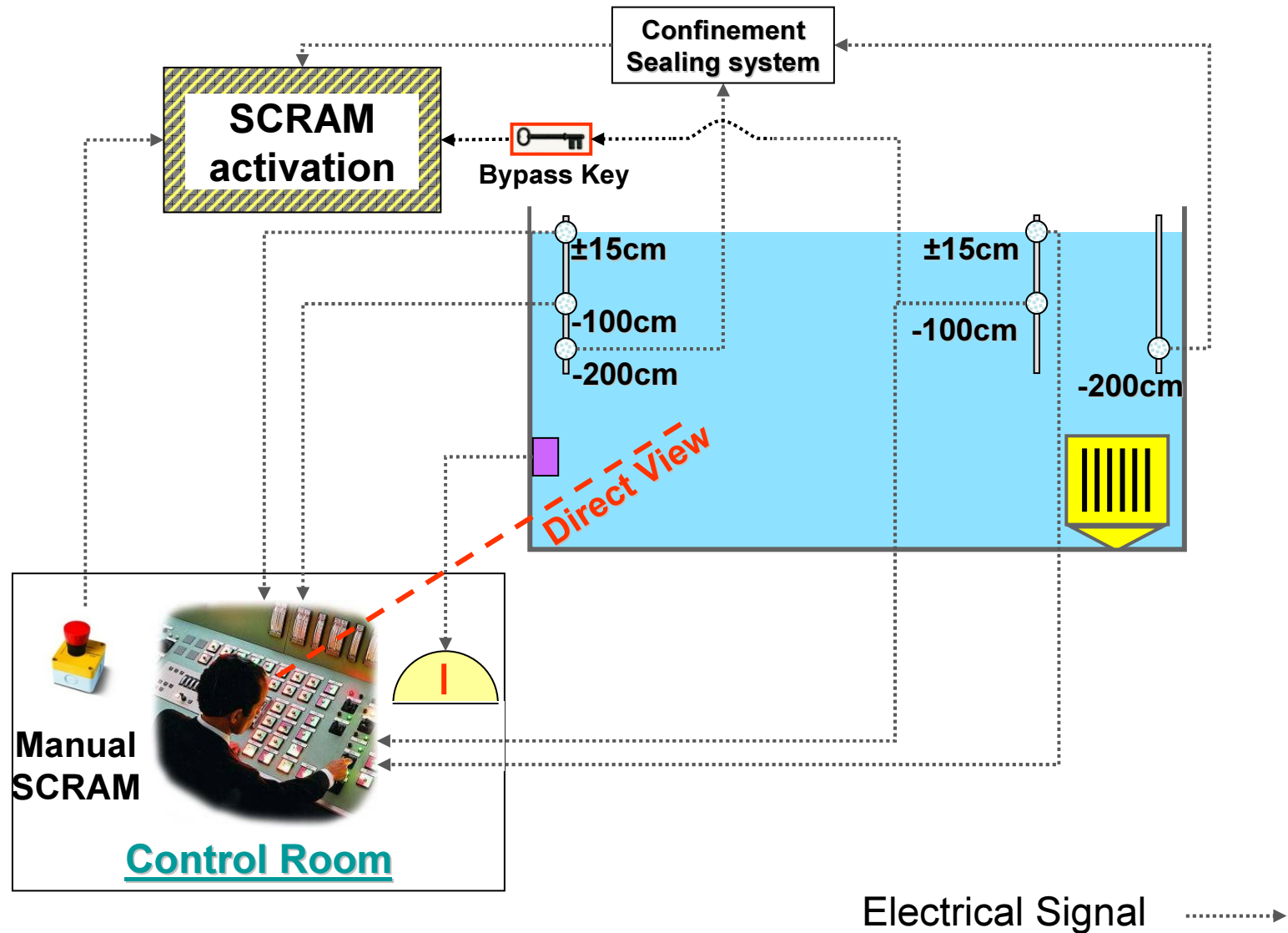
Conclusions

# MTR Pool Type Reactor – Cooling System



- Presentation
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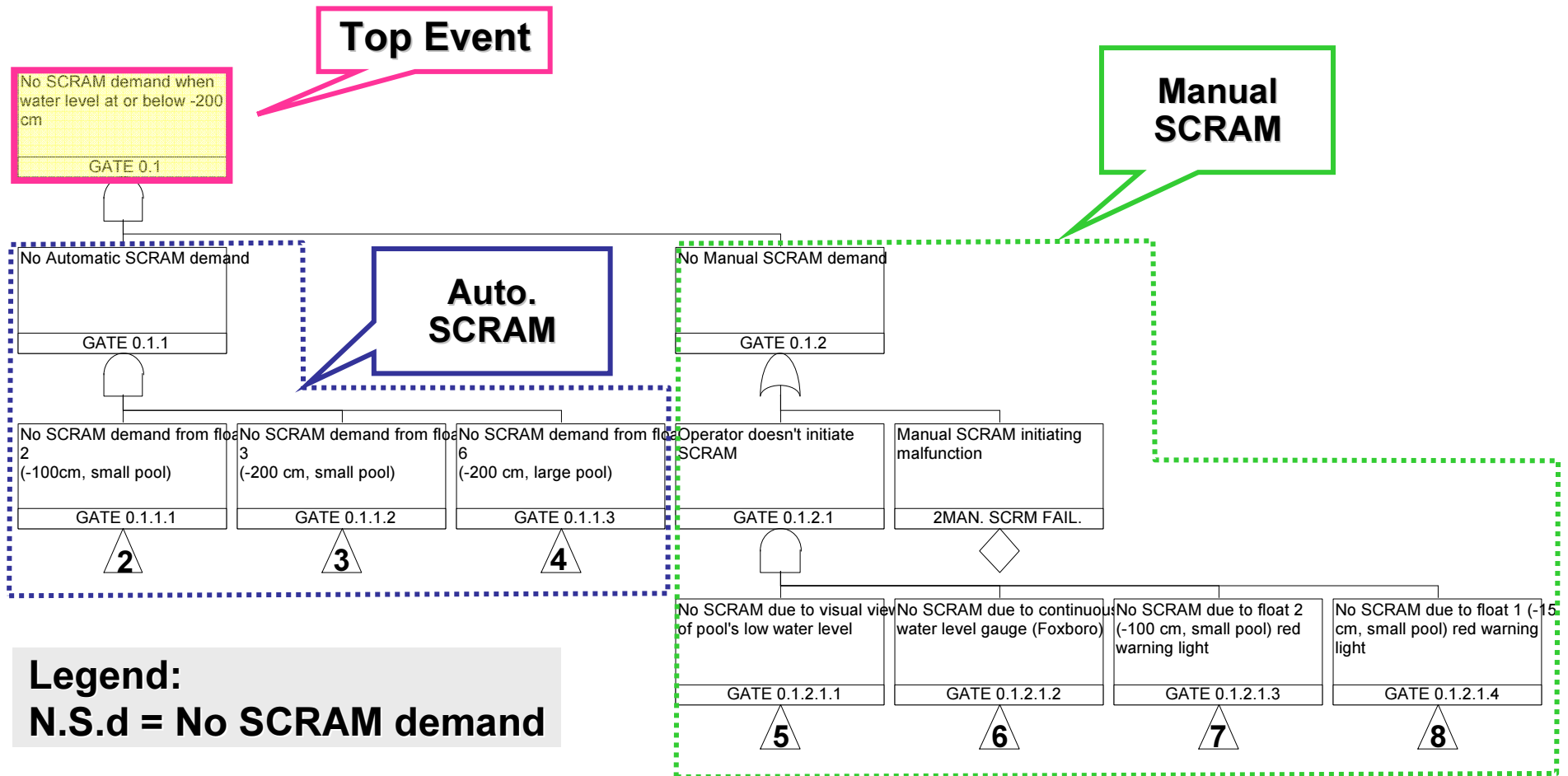
# LMAS (Level Measuring Alert System)





## **Fault Tree Analysis (FTA)**

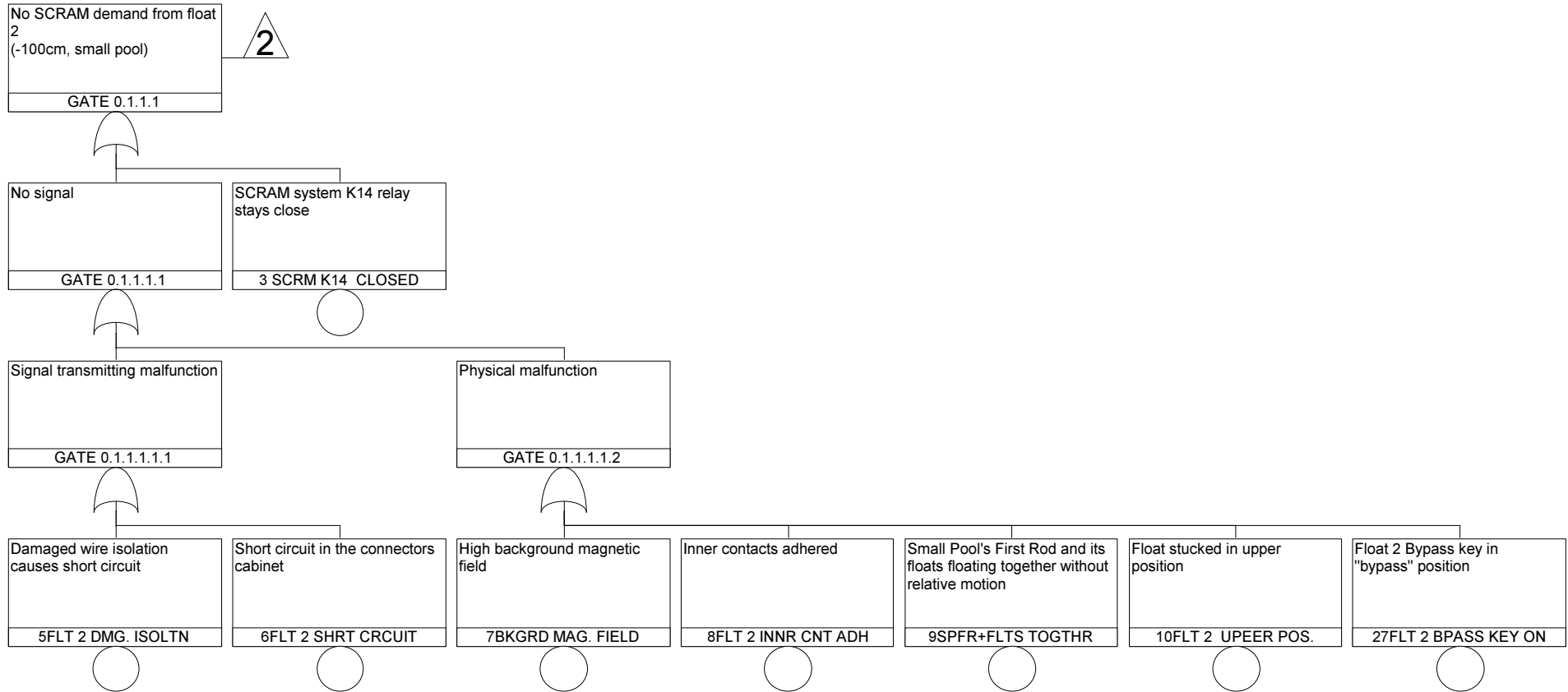
# Tree Top Structure



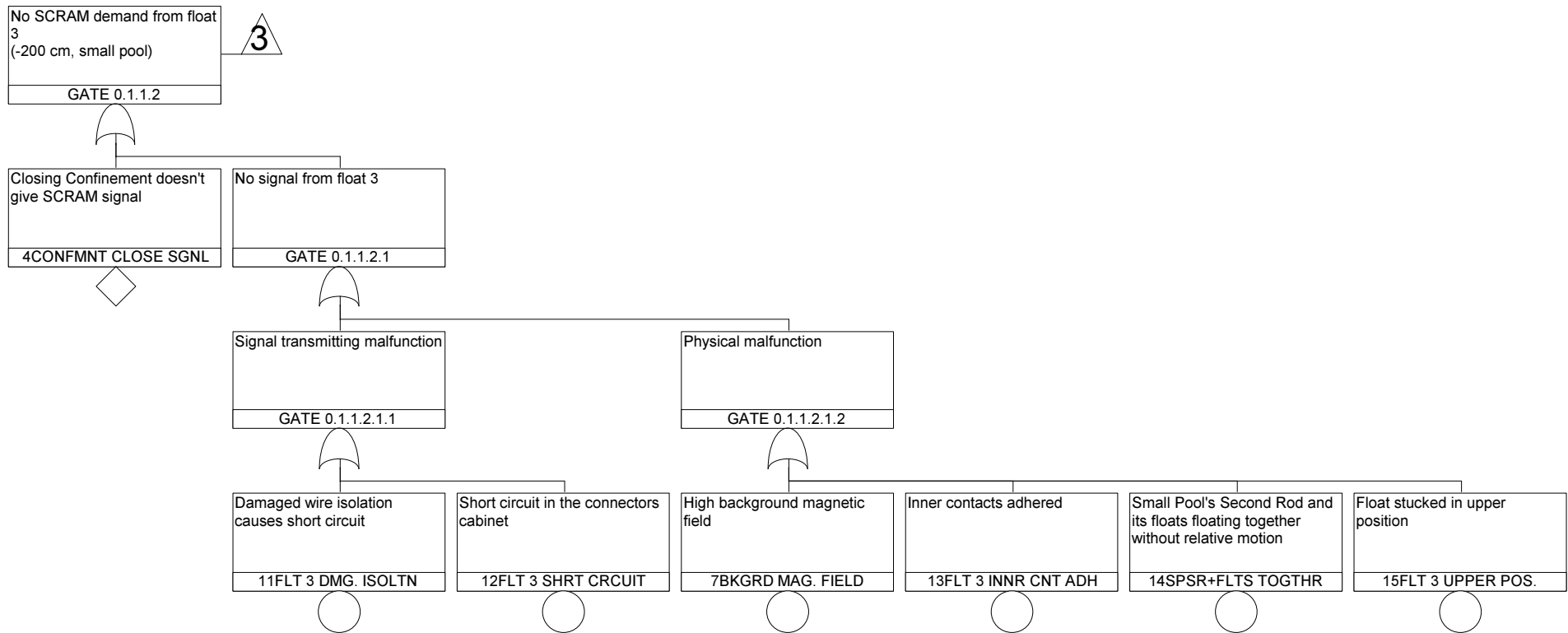
- N.S.d from -100 cm (s.p)
- N.S.d from -200 cm (s.p)
- N.S.d from -200 cm (l.p)

- N.S.d – Direct View
- N.S.d – Continuous level meas.
- N.S.d – Light bulb -100 cm (s.p)
- N.S.d – Light bulb -15 cm (s.p)

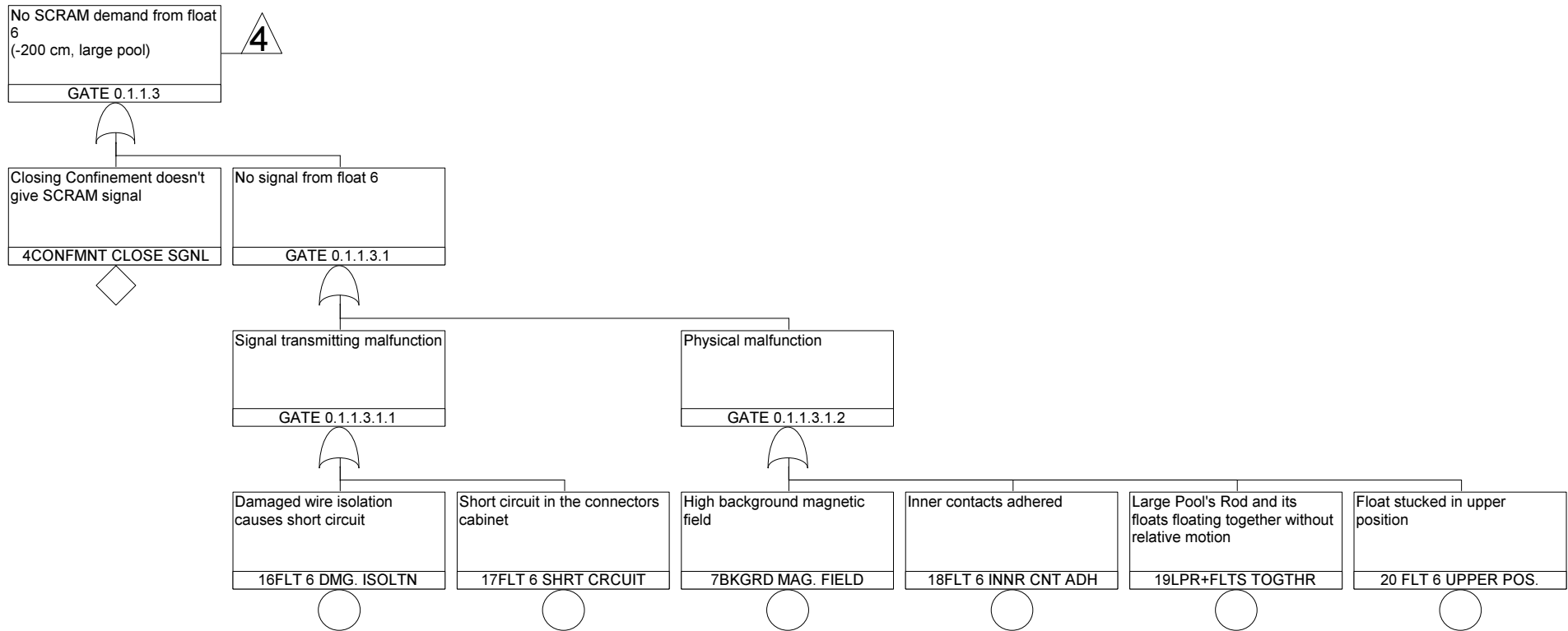
# N.S.d from -100 cm (s.p)



# N.S.d from -200 cm (s.p)

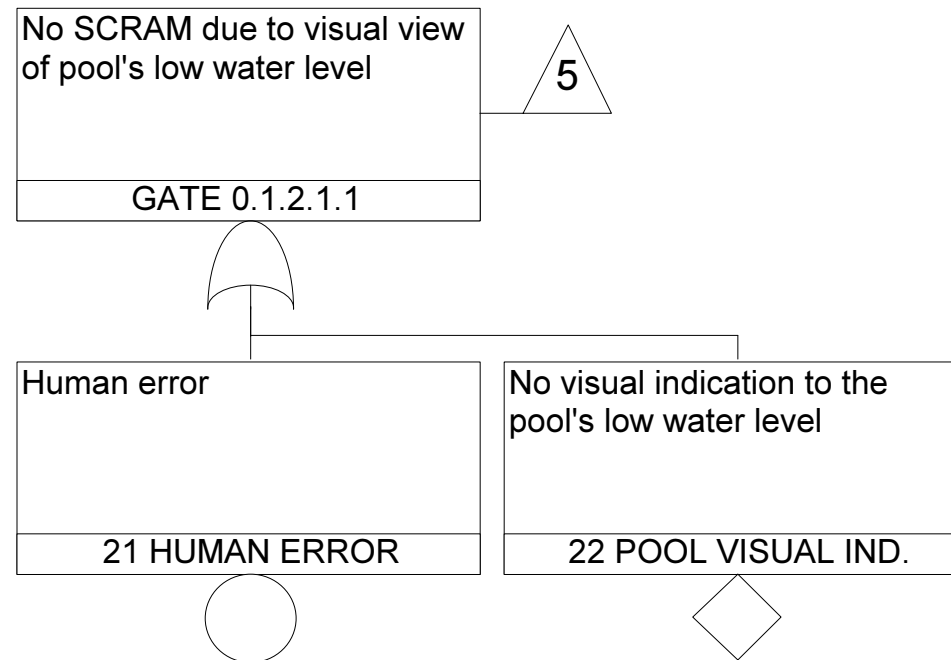


# N.S.d from -200 cm (l.p)

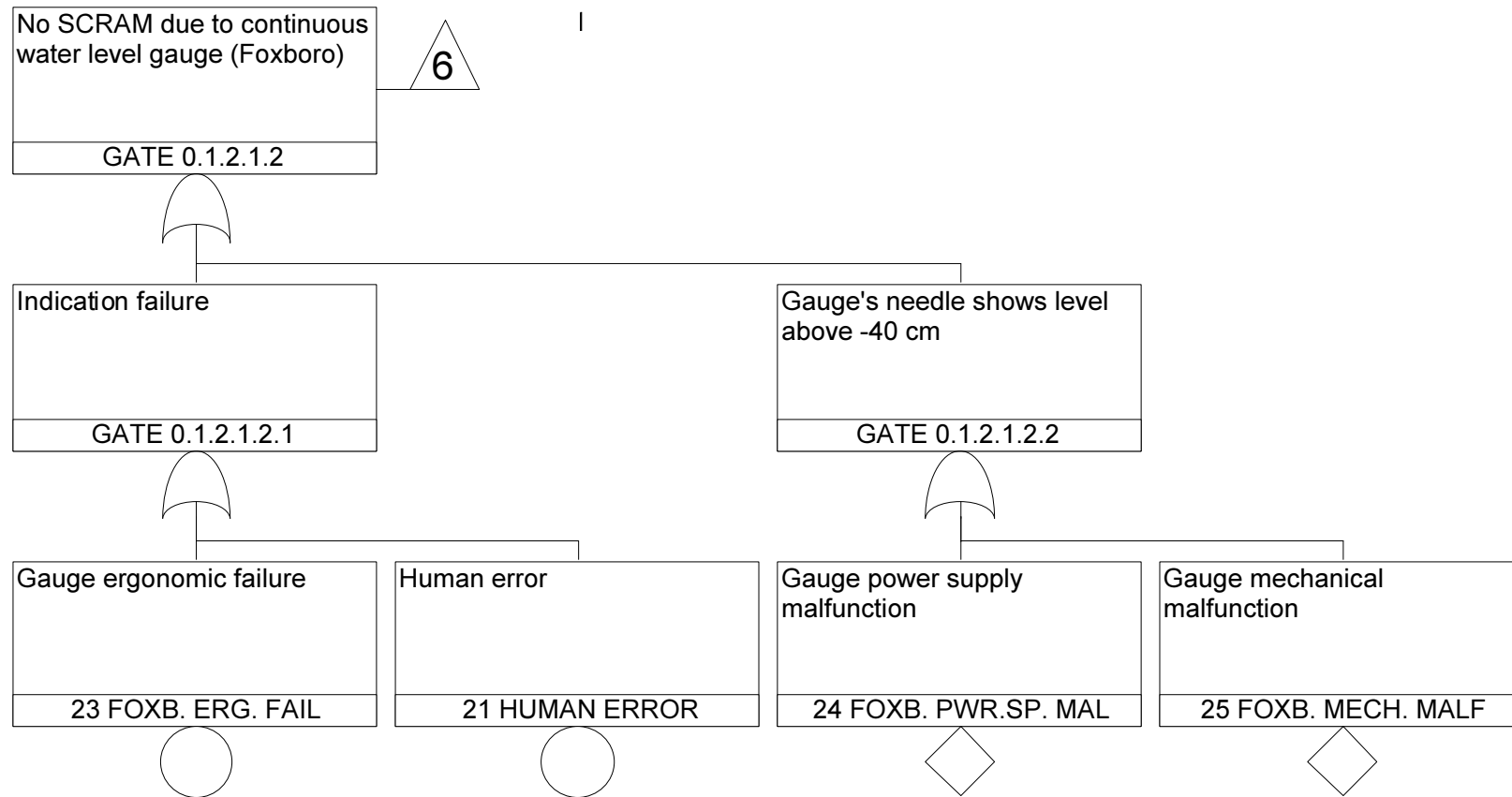




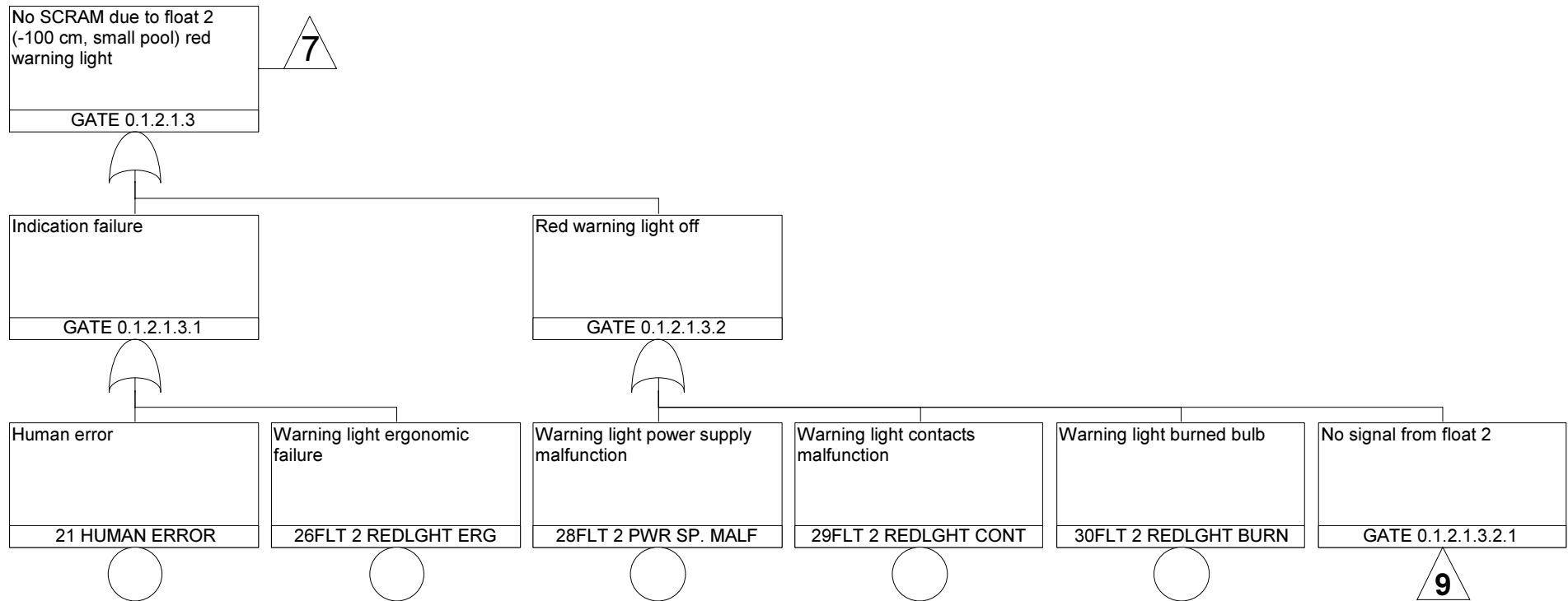
## N.S.d – Direct View



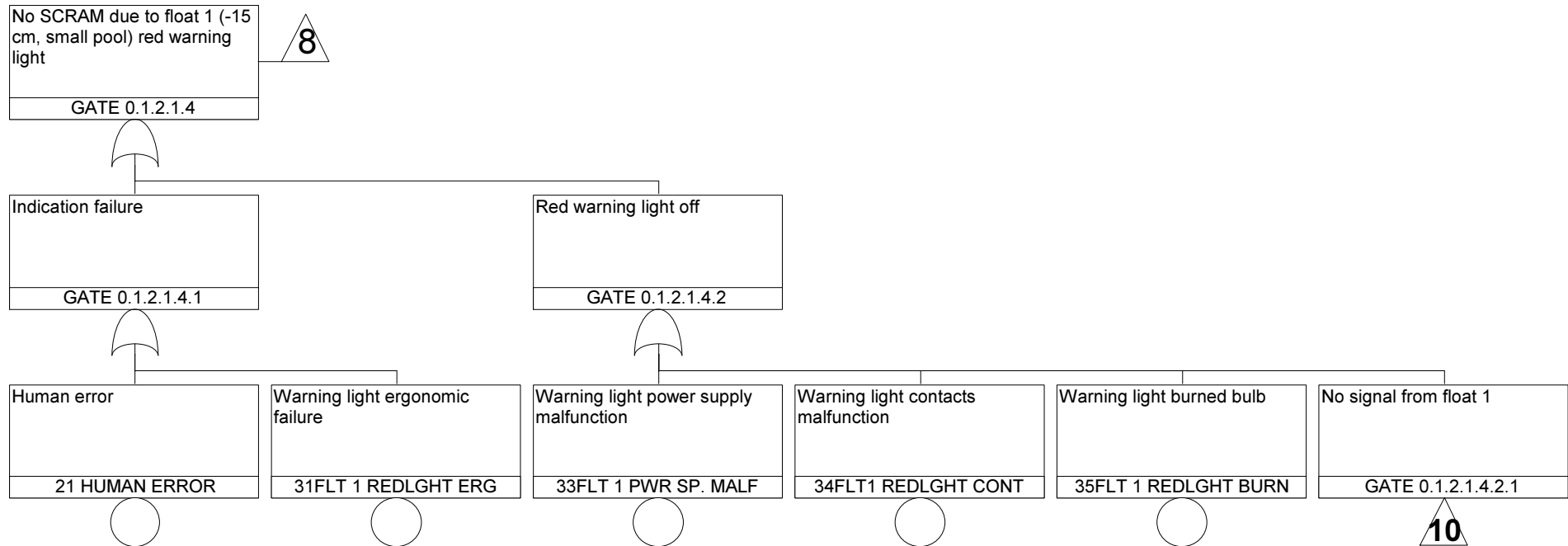
## N.S.d – Continuous level meas.



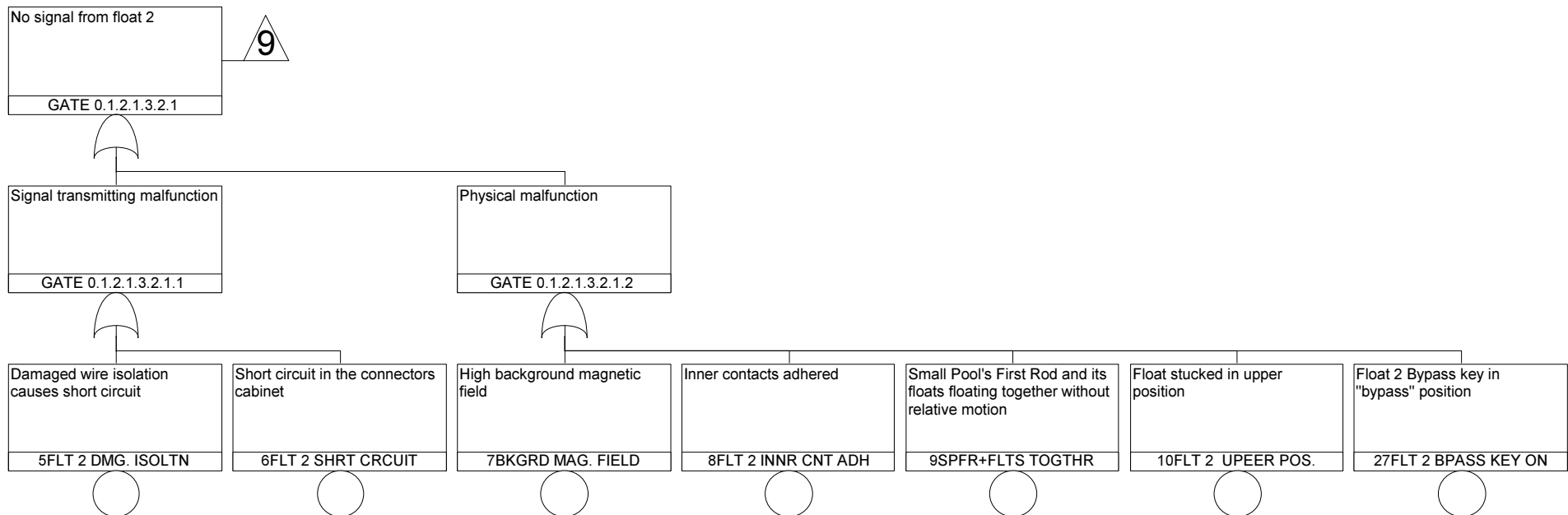
# N.S.d – Light bulb -100 cm (s.p)



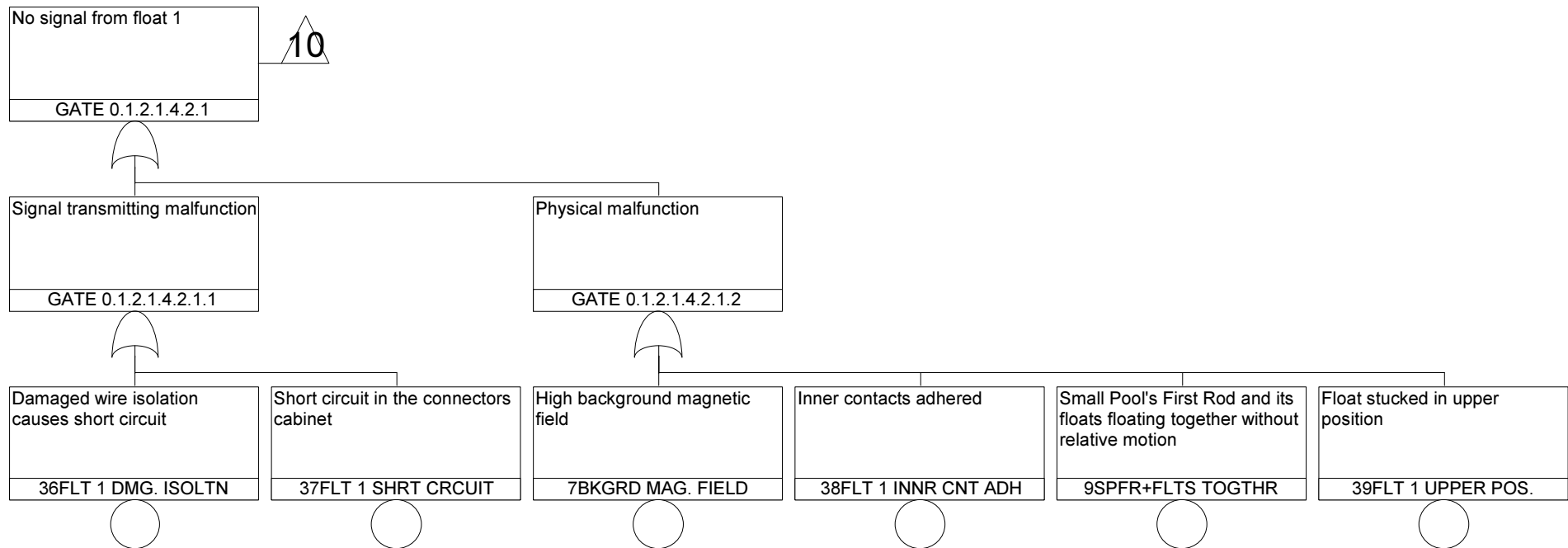
## N.S.d – Light bulb -15 cm (s.p)



## Same as Tree No. 2 [N.S.d from -100 cm (s.p)]



# No Signal from -15 cm float (s.p)



## Probabilities Data Base



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## Basic Assumptions

- Operator – well trained**
- 1 operating yr. = 100 days (8 hrs.)**
- Probabilities references**
  - **Manufacture**
  - **Other system analyses**
  - **Operating data base**
  - **Open literature**



## Basic Events - Faults probability of occurrence [1/day]

Human / Ergonomic							
					<b>Key in Bypass state</b>		
					<b>Ergonomic failure of cont. gauge</b>		
				<b>Ergonomic failure of light bulb</b>	<b>Human Error</b>		<b>No direct view</b>
<b>1x10<sup>-6</sup></b>	<b>3.5x10<sup>-5</sup></b>	<b>7.2x10<sup>-5</sup></b>	<b>9.8x10<sup>-5</sup></b>	<b>1x10<sup>-4</sup></b>	<b>1x10<sup>-3</sup></b>	<b>5x10<sup>-3</sup></b>	<b>1x10<sup>-2</sup></b>
<i><b>N.S.d from confinement system</b></i>	<b>Power Failure to cont. gauge</b>	<b>Short circuit in connectors cabinet</b>	<b>Power Failure to light bulb</b>	<b>Electro magnetic interference (EMI)</b>	<b>SCRAM relay failure</b>	<i><b>Manual SCRAM failure</b></i>	
	<b>Mech. fault of cont. gauge</b>	<b>Float inner contacts adhere</b>		<b>Tube + floats buoyant</b>	<b>Short circuit in trans. cable</b>		
		<b>Light bulb contacts failure</b>		<b>Float stuck</b>	<b>Burned alert light bulb</b>		

**Technical**



## **Results & Sensitivity analyses**



## a. Nominal Probability Values

### Minimal Cutsets

Top event probability  $Q = 6.011E-07$

No.	Prob.	%	Event		
1	5.000E-07	83.18	2MAN. SCRM FAIL.	7BKGRD MAG. FIELD	
2	1.000E-07	16.64	21 HUMAN ERROR	7BKGRD MAG. FIELD	
3	1.000E-09	0.17	22 POOL VISUAL IND.	23 FOXB. ERG. FAIL	7BKGRD MAG. FIELD
4	3.560E-11	0.01	22 POOL VISUAL IND.	24 FOXB. PWR.SP. MAL	7BKGRD MAG. FIELD
5	3.560E-11	0.01	22 POOL VISUAL IND.	25 FOXB. MECH. MALF	7BKGRD MAG. FIELD



# Sensitivity analyses [1/day]

Human / Ergonomic							
					Key in Bypass state		
					Ergonomic failure of cont. gauge		
				Ergonomic failure of light bulb	<b>Human Error</b>		No direct view
<b>1x10<sup>-6</sup></b>	<b>3.5x10<sup>-5</sup></b>	<b>7.2x10<sup>-5</sup></b>	<b>9.8x10<sup>-5</sup></b>	<b>1x10<sup>-4</sup></b>	<b>1x10<sup>-3</sup></b>	<b>5x10<sup>-3</sup></b>	<b>1x10<sup>-2</sup></b>
<i>N.S.d from confinement system</i>	Power Failure to cont. gauge	Short circuit in connectors cabinet	Power Failure to light bulb	<b>Electro magnetic interference (EMI)</b>	SCRAM relay failure	<i>Manual SCRAM failure</i>	
	Mech. fault of cont. gauge	Float inner contacts adhere		Tube + floats buoyant	Short circuit in trans. cable		
		Light bulb contacts failure		Float stuck	Burned alert light bulb		

Technical



## b. Human Error (X10) failure probability

### Minimal Cutsets

Top event probability  $Q = 1.501E-06$

No.	Prob.	%	Event		
1	1.000E-06	66.61	21 HUMAN ERROR	7BKGRD MAG. FIELD	
2	5.000E-07	33.31	2MAN. SCRM FAIL.	7BKGRD MAG. FIELD	
3	1.000E-09	0.07	22 POOL VISUAL IND.	23 FOXB. ERG. FAIL	7BKGRD MAG. FIELD
4	3.560E-11	0.00	22 POOL VISUAL IND.	25 FOXB. MECH. MALF	7BKGRD MAG. FIELD
5	3.560E-11	0.00	22 POOL VISUAL IND.	24 FOXB. PWR.SP. MAL	7BKGRD MAG. FIELD



## c. EMI (X 1/10) failure probability

### Minimal Cutsets

Top event probability  $Q = 6.016E-08$

No.	Prob.	%	Event
1	5.000E-08	83.11	2MAN. SCRM FAIL. 7BKGRD MAG. FIELD
2	1.000E-08	16.62	21 HUMAN ERROR 7BKGRD MAG. FIELD
3	1.000E-10	0.17	22 POOL VISUAL IND. 23 FOXB. ERG. FAIL 7BKGRD MAG. FIELD
4	5.000E-12	0.01	11FLT 3 DMG. ISOLTN 16FLT 6 DMG. ISOLTN 2MAN. SCRM FAIL. 5FLT 2 DMG. ISOLTN
5	5.000E-12	0.01	11FLT 3 DMG. ISOLTN 16FLT 6 DMG. ISOLTN 27FLT 2 BPASS KEY ON 2MAN. SCRM FAIL.
6	5.000E-12	0.01	11FLT 3 DMG. ISOLTN 16FLT 6 DMG. ISOLTN 2MAN. SCRM FAIL. 3 SCRM K14 CLOSED



## d. EMI (X 1/1000) failure probability

### Minimal Cutsets

Top event probability Q = 6.573E-10

No.	Prob.	%	Event
1	5.000E-10	76.06	2MAN. SCRM FAIL. 7BKGRD MAG. FIELD
2	1.000E-10	15.21	21 HUMAN ERROR 7BKGRD MAG. FIELD
3	5.000E-12	0.76	11FLT 3 DMG. ISOLTN 16FLT 6 DMG. ISOLTN 2MAN. SCRM FAIL.
4	5.000E-12	0.76	11FLT 3 DMG. ISOLTN 16FLT 6 DMG. ISOLTN 2MAN. SCRM FAIL.
5	5.000E-12	0.76	11FLT 3 DMG. ISOLTN 16FLT 6 DMG. ISOLTN 27FLT 2 BPASS KEY ON
6	5.000E-12	0.76	2MAN. SCRM FAIL. 3 SCRM K14 CLOSED 4CONFMNT CLOSE SGNL 5FLT 2 DMG. ISOLTN
7	5.000E-12	0.76	27FLT 2 BPASS KEY ON 2MAN. SCRM FAIL. 4CONFMNT CLOSE SGNL 3 SCRM K14 CLOSED
8	5.000E-12	0.76	2MAN. SCRM FAIL. 4CONFMNT CLOSE SGNL 5FLT 2 DMG. ISOLTN 2MAN. SCRM FAIL.

## Conclusions



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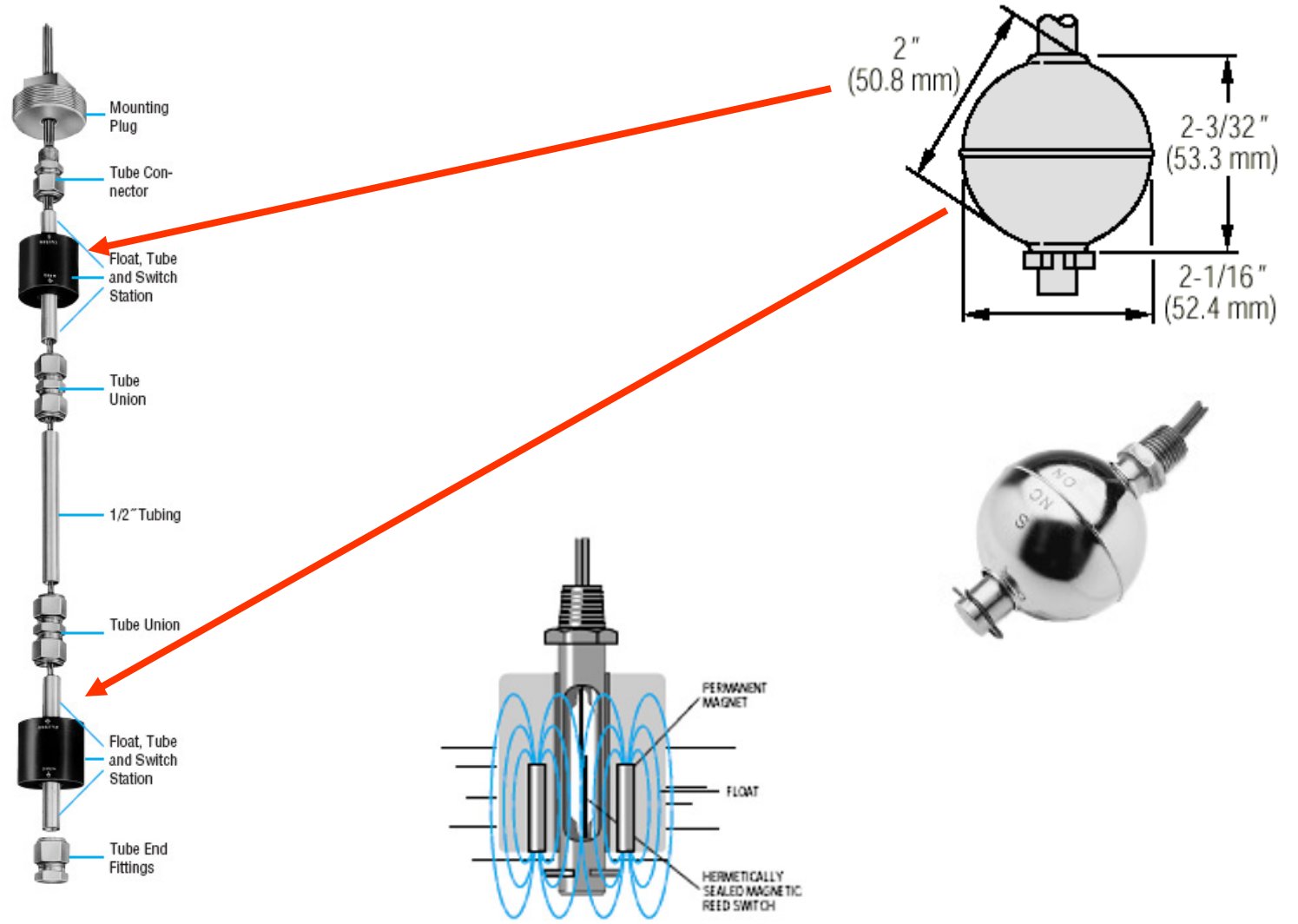
## Conclusions

- $1 \times 10^{-6}$  [1/day] תכן המערכת עומד בדרישה: הסתברות קטנה מ-  
 $6.01 \times 10^{-7}$  [1/day] הסתברות התרחשות אירוע העל שהתקבלה:
- לא נמצא אופן כשל בודד
- צירופי אירועי בסיס הדומיננטיים (צח"מים)
  - "טעות אנוש" בו זמנית עם "שדה מגנטי משבש"
  - "כשל בייזום השתקה ידנית" בו זמנית עם "שדה מגנטי משבש"
- המערכת רגישה יותר לטעות אנוש מאשר לשדה מגנטי משבש
- חשיבות הבדיקות התקופתיות (שמירת ערכי ההסתברות)

# Drawer



# Level Station Assembly (LSA)





# "Control Room" deployment

