

A Nordic approach to impact assessment of accidents with marine reactors

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NSFS 2011 conference

Reykjavík, Iceland

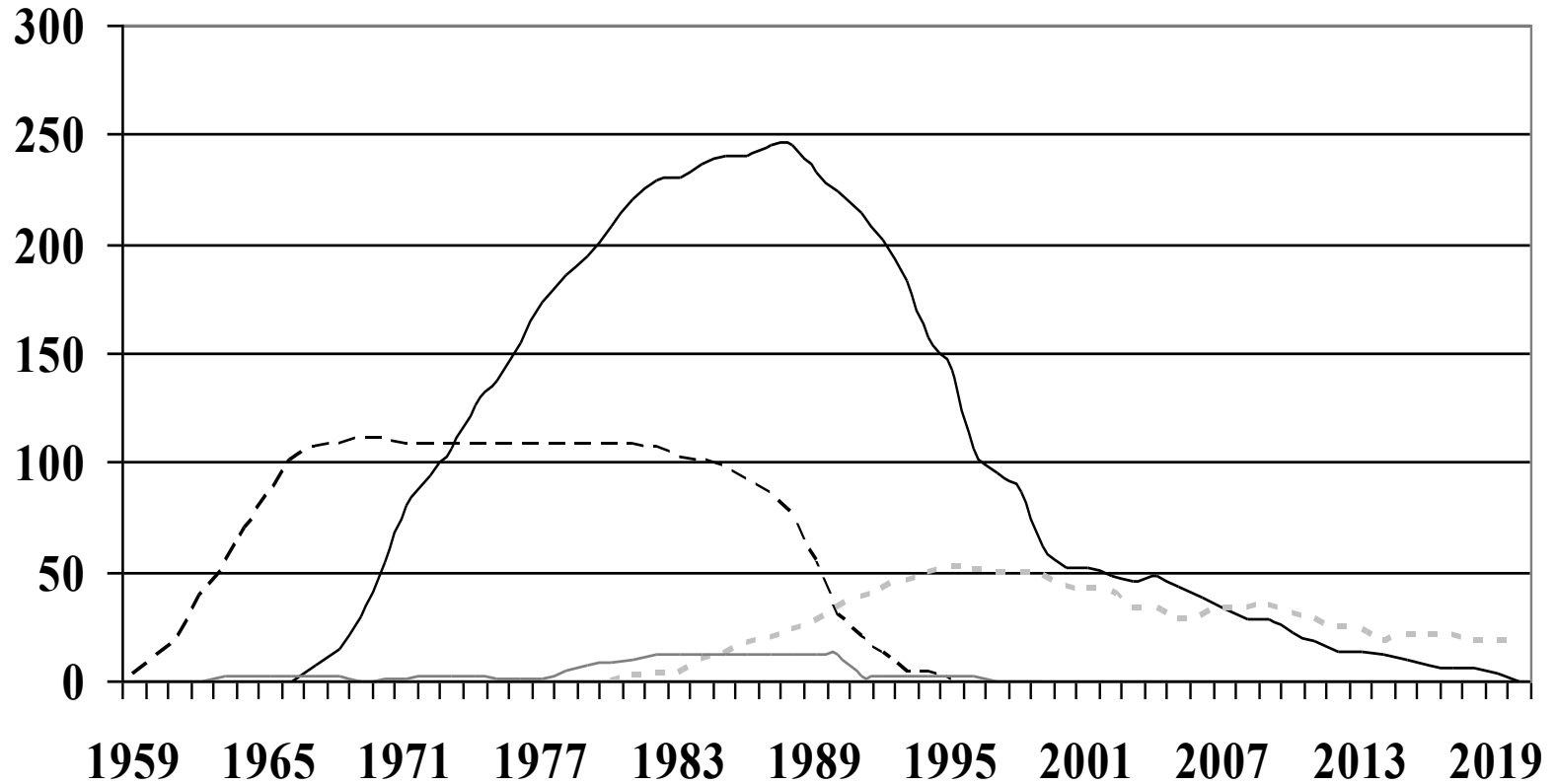
The Nordic perspective

- All Nordic countries:
 - Passage of nuclear-propelled vessels in neighbouring waters
- Norway, Finland
 - Neighbouring Russian military and civilian ports
- Norway
 - Port calls from allied vessels



	SUBMARINES NATO class (type of submarine), reactor system	MILITARY SURFACE VESSELS NATO class (type of vessel), reactor system	CIVILIAN VESSELS Class (type of vessel), reactor system
1994	Granay (SSBN), PWR (incomplete) Borei (SSBN), PWR (incomplete)		
1986	Sierra (SSN), PWR Akula (SSN), PWR Delta IV (SSBN), PWR	(Project 11437, aircraft carrier), PWR (incomplete)	Taimyr/ Sevmorput (icebreaker class), PWR
		Kapusta (service ship), PWR	Arktika (icebreaker class), PWR Rossiya (icebreaker class), PWR
1978	Victor III (SSN), PWR Mike (SSN), PWR Typhoon (SSBN), PWR		
	Oscar I, II (SSGN), PWR Delta III (SSBN), PWR Delta II (SSBN), PWR	Kirov (missile cruiser), PWR	
1970	Delta I (SSBN), PWR Victor II (SSN), PWR Alfa (SSN), LMC		<i>Lenin</i> (icebreaker), PWR*
	Charlie I, II (SSGN), PWR Victor I (SSN), PWR Yankee (SSBN), PWR		
1962	Papa (SSGN), LMC Echo II (SSGN), PWR		
	Hotel (SSBN), PWR November, (SSN), LMC Echo I (SSGN, SSN), PWR		
1954	November (SSN), PWR		<i>Lenin</i> (icebreaker), PWR

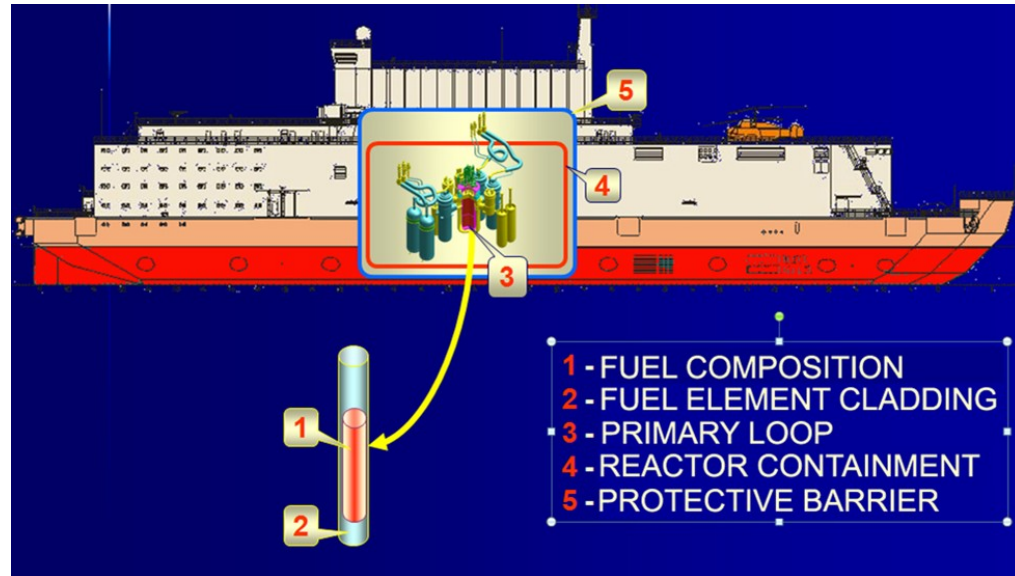
Russian submarine reactors in operation (1959 – 2020)



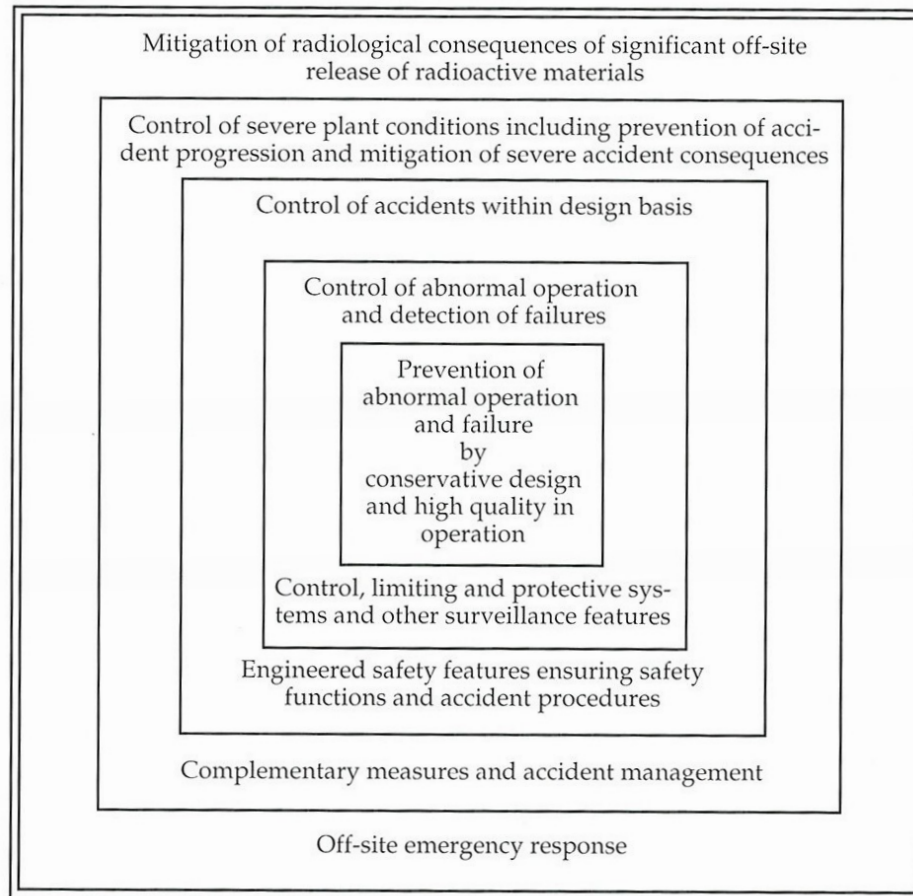
---- VM-A reactor in operation — VM-4 reactor in operation
· · · · OK-650 reactor in operation — LMC-reactors in operation

NKS MareNuc: Objectives

- To present and discuss all recent developments in relation to construction and intended use of nuclear-propelled vessels and FNPPs
- assess their possible consequences on Nordic countries, and revisit the graded approach in light of new challenges identified



The traditional approach to accident prevention and mitigation: Defense in depth concept: purposes, methods and means (INSAG)

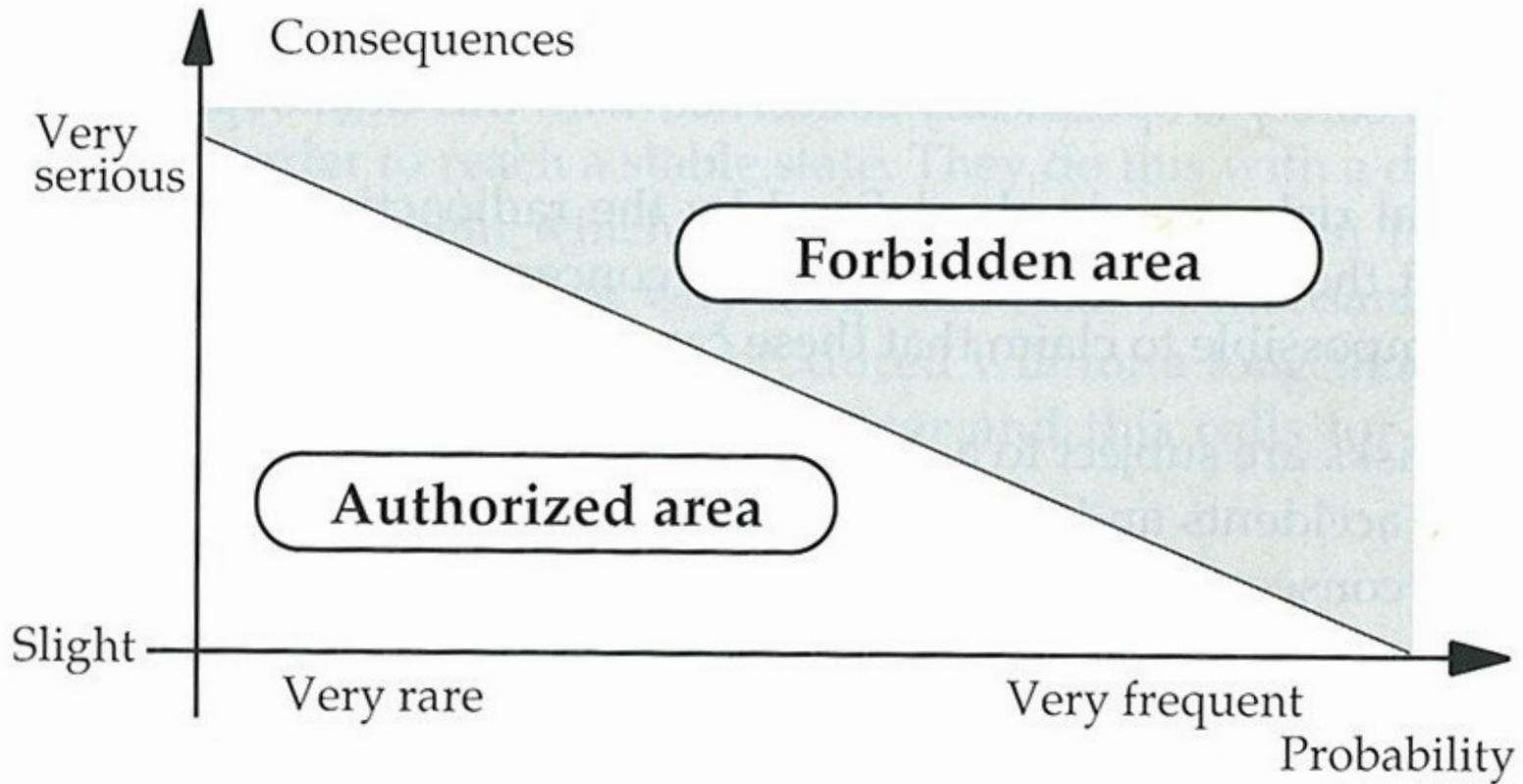


Nuclear-propelled vessels categories, design and construction data

- Summary

- Nuclear-propelled vessel design
 - Overall design - YES
- Reactor and fuel design
 - SOME
- Vessel and reactor inventory
 - SOME
- Operational experience
 - SOME
- Submarines
 - Research vessels (Russia)
 - Attack and strategic vessels (Russia, US, UK, France, China, India, ?)
- Surface vessels
 - Military vessels (Russian, US)
 - Russian icebreakers

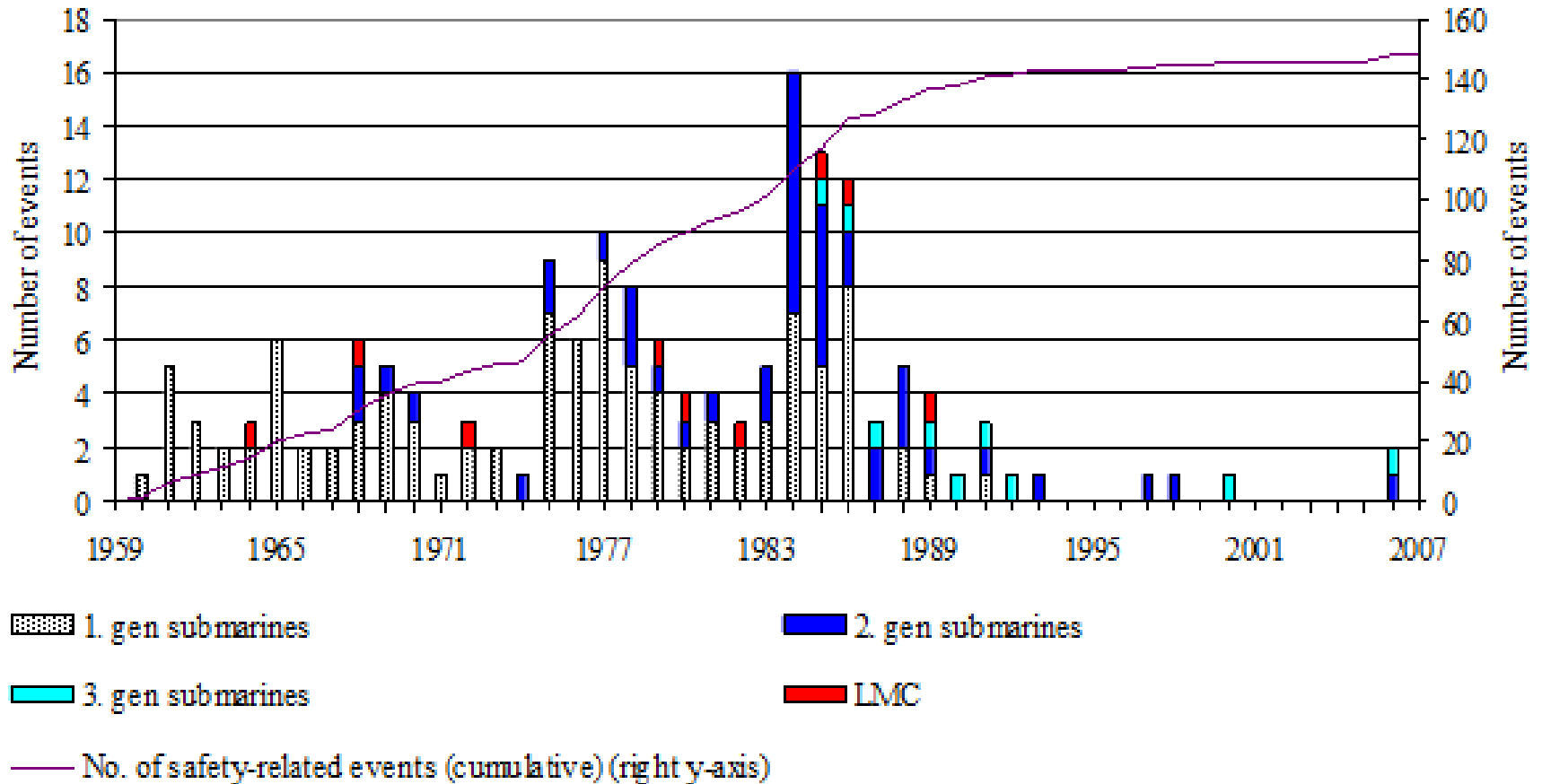
Relation between probability and consequences. Farmer graph



Distribution of a) accidents, incidents and deviations and b) various types of IE (LOCA/ transients and CCI)

	Accidents	Incidents	Deviations		LOCA	Transients	CCI
1st gen	8	90	5		11	34	58
2nd gen	5	30	9		0	12	32
3rd gen	2	6	1		0	1	8
LMC	2	7	0		4	3	2

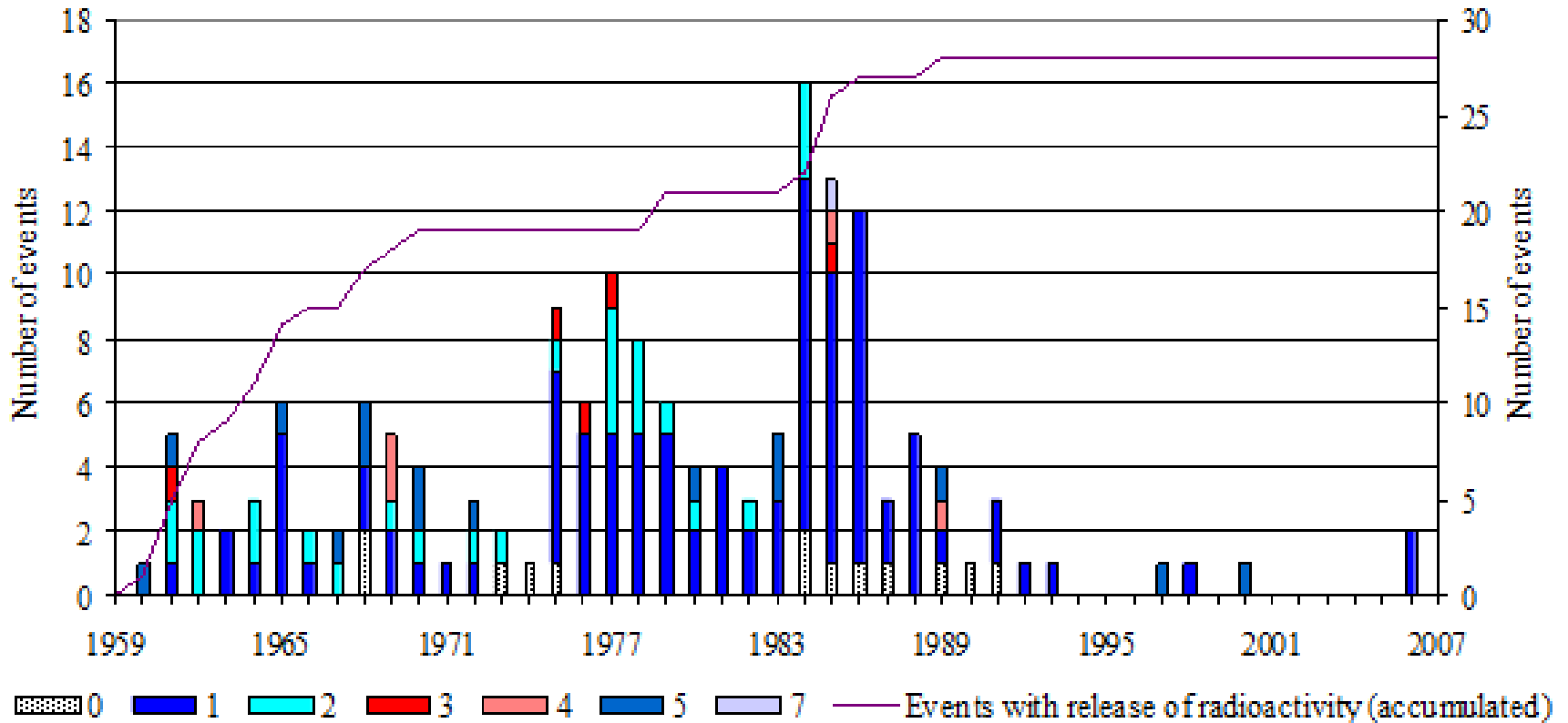
All safety-related events 1958–2007 (annual/ cumulative (right axis)) distributed by vessel category



Examples of INES ratings

- 7: major accident
 - Chahzma Bay, 1985, Chernobyl 1986, Fukushima 2011
- 6: serious accident
 - Komsomolets 1989, Kyshtym 1959
- 5: accident with wider consequences
 - Three Mile Island, 1979
- 4: accident with local consequences
 - Tokaimura 1999 (fatal criticality accident)
- 3: serious incident
 - Sellafield 2005 (release of radioactive material, contained within the installation)

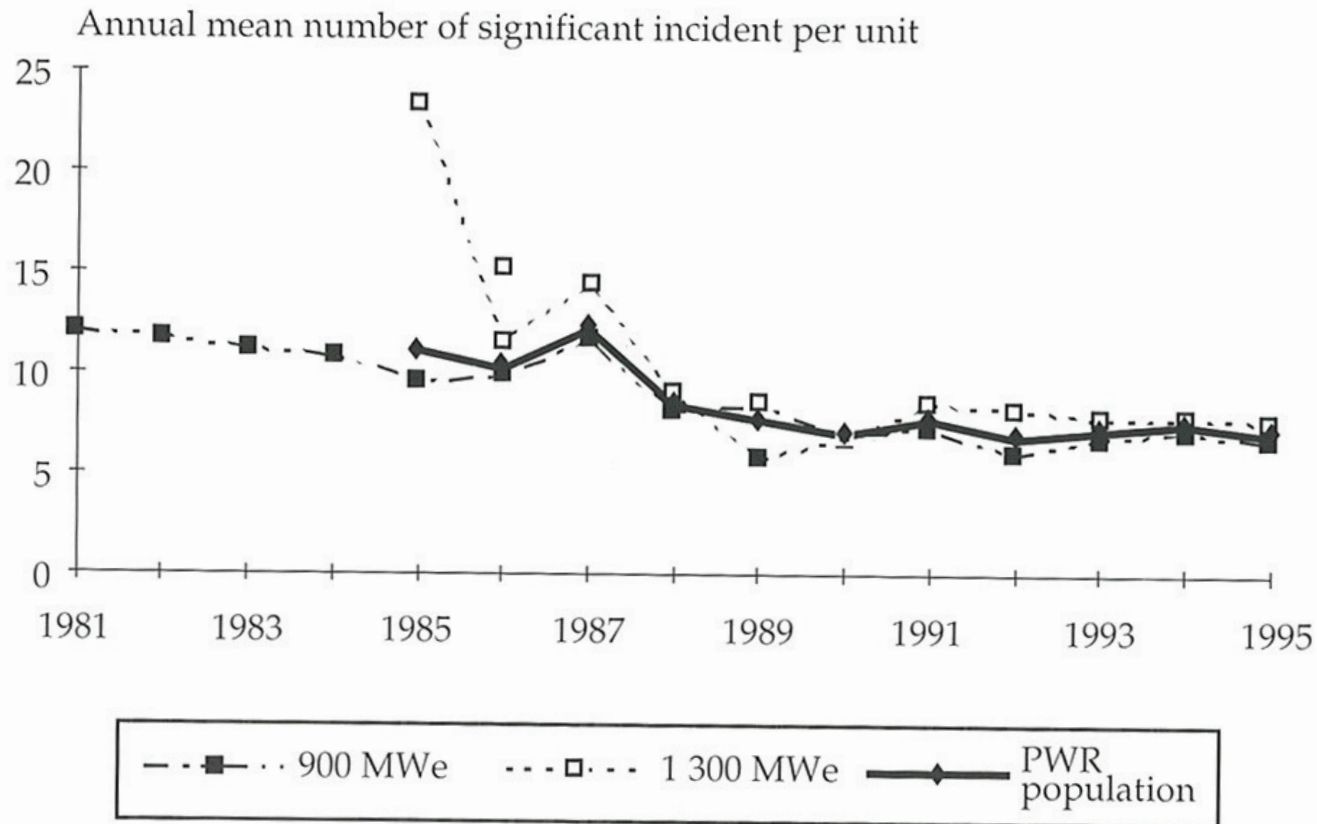
All safety-related events 1958–2007 (annual) distributed by safety significance (1–7) together (left axis) and events with release of radioactivity (cumulative) (right axis)

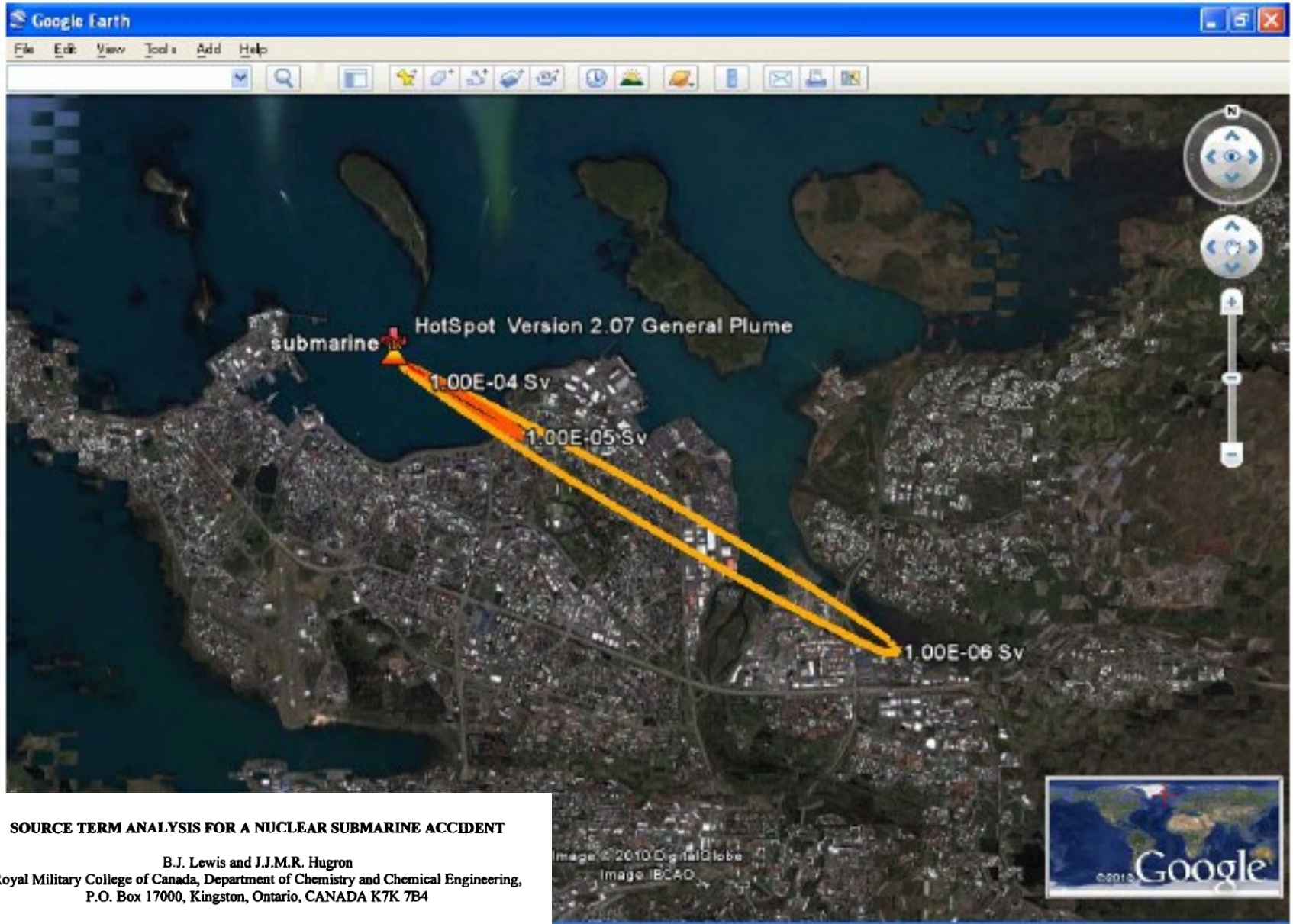


Challenges using INES for submarines

- Intended only for civilian use
- How to classify loss of complete vessel, or threat to the vessel
- Often insufficient information about submarine safety events for rating

Annual mean number of significant incidents per unit





SOURCE TERM ANALYSIS FOR A NUCLEAR SUBMARINE ACCIDENT

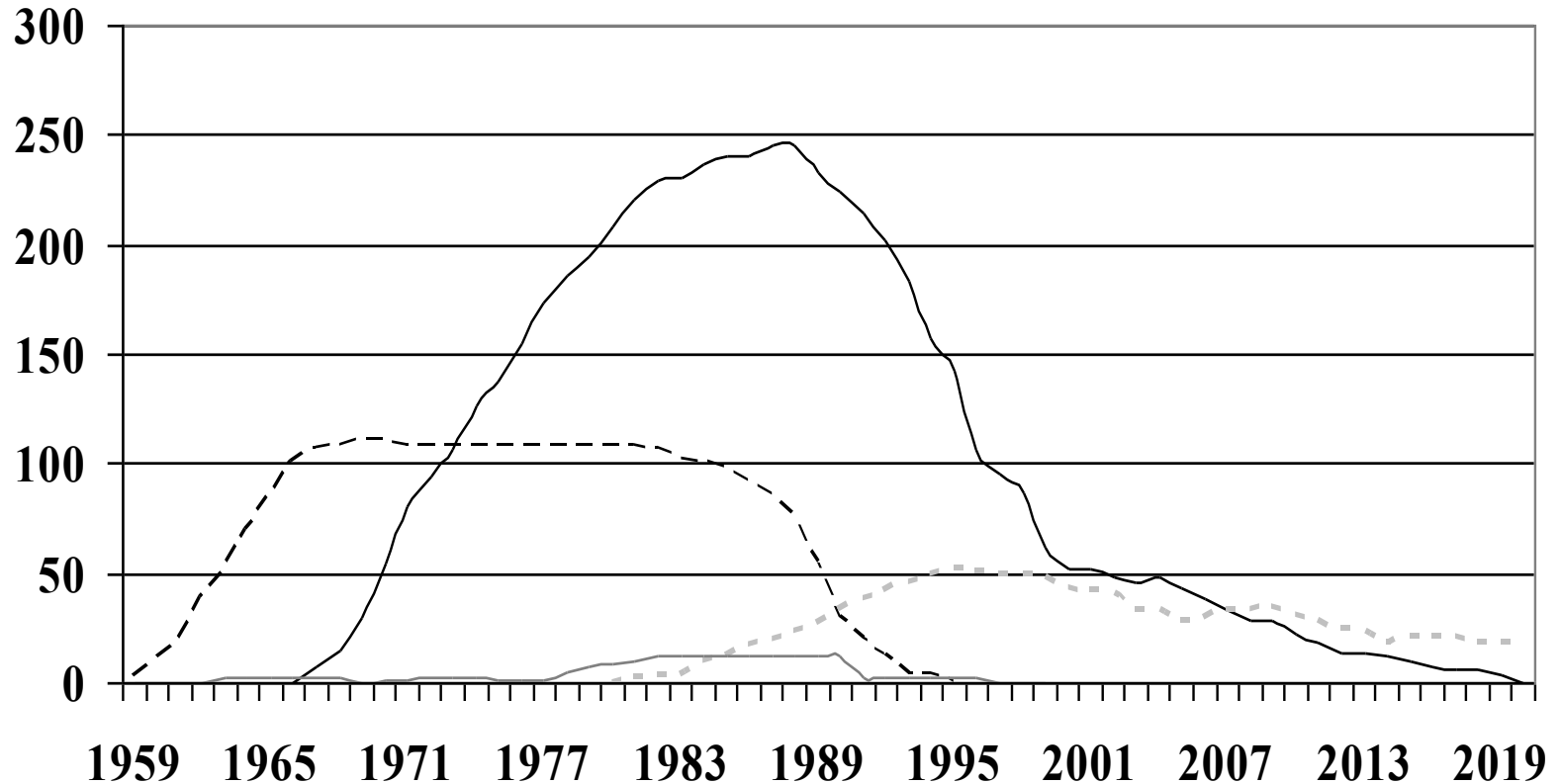
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ABSTRACT



GEISLAVARNIR RIKISINS
 ICELANDIC RADIATION SAFETY AUTHORITY

Submarine reactors in operation (1959 – 2020)



---- VM-A reactor in operation — VM-4 reactor in operation
· · · · OK-650 reactor in operation — LMC-reactors in operation ;

Other approaches:

- Reference Accident (as replacement of Beyond Design Basis Accident/ Design Basis Accident):
 - Represent an upper bound risk to the surrounding population
 - Calculated consequences are compared with national acceptability criteria
 - Basis for emergency planning measures
- Severe Accident Research

All accidents with Russian nuclear-propelled vessels

1958 –

Event no.	Year:	Vessel:	Class:	Release of radioactivity	Initiating event:	Event type:*
1	1960	K-8	November	x	2	A
2	1961	K-19	Hotel	x	1	A
15	1965	K-11	November	x	2	A
24	1967	K-3	November		3	A
25	1968	K-140	Yankee	x	2	A
29	1968	K-27	Project 645	x	1	A
37	1970	K-320	Charlie-I	x	2	A
39	1970	K-8	November		3	A
42	1972	K-19	Hotel		3	A
87	1980	K-222	Papa		2	A
98	1983	K-122/ 123?	Echo-I		3	A
100	1983	K-429	Charlie-I		3	A
124	1985	K-31	Echo-II	x	2	A
135	1986	K-219	Yankee		3	A
152	1989	K-278	Mike		3	A
161	1997	K-313	Charlie-I		3	A
163	2000	K-141	Oscar-II		3	A
Icebreaker:	1966	NS Lenin		x	1	A

International experience: Canada

- Technical Safety Review (TSR)
 - Severe Accidents with release to the environment
- Establish a reference accident
- Approach assumed by other countries:
 - Australia, New Zealand
 - Netherlands?, Germany? etc.

Objectives

- Objectives of TSR were limited to creating a good “Emergency Planning Basis”
 - Focus on a range of potential end state
- Can’t change the design or the operation of the nuclear powered vessels
 - Don’t require detailed design information

Visits by allied navies



Preliminary conclusions and future issues for MareNuc seminar August 25 – 26

- Similar challenges from all nuclear navies
 - Russian perspective “out-of-date”?

- Issues for consideration
 - Future sailing routes, new applications and construction programs
 - Russian revival
 - Floating power reactors

 - Consider a joint Nordic approach
 - Establish a reference accident for passage of nuclear propelled vessels in neighbouring waters
 - » Reference accident review
 - Severe accident analysis program
 - Emergency preparedness review