Falcon Analytics

Electrical and Electronics Systems in Nuclear Environment

Dr. Yehoshua Socol

Electricity 2010

Electricity 2010 International Convention & Trade Show

The Annual Convention of the Society of Electrical and Electronics Engineers in Israel

Eilat, Israel, November 17-20, 2010

When Hitler first bombed London the **panic** the bombs caused did far **more damage than the bombs** themselves. After the citizens of London lost their exaggerated fears of the bombings, life went on much as normal. And so it would be with a nuclear terrorist attack …

Cresson H. Kearny
Civil Defense Consultant (Ret.)
to the US Government
Feb 1999

The Message

- There is what to do
- There is MUCH what to do
  - Damage reduction to 1/10 or less
- It is better doable at the development stage

Contents

- Introduction: nuclear weapons
- Nuclear environment
- EMP protection – system approach
- EMP – technical
- Summary

Nuclear Warheads

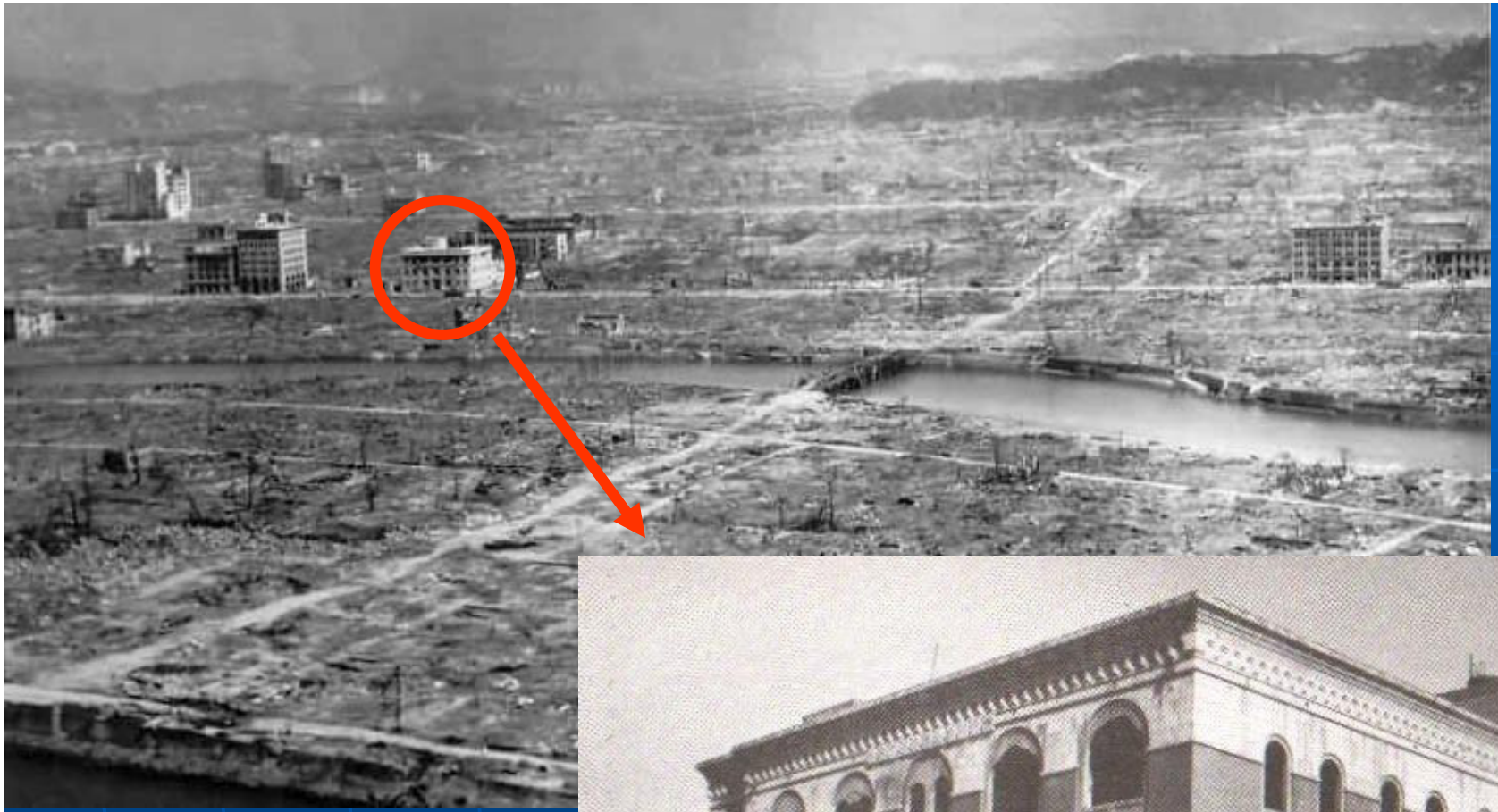
"Atomic"	1-20 Kton
Hiroshima	~16 Kton
Nagasaki	~21 Kton
Severe damage range	1-1.5 km

"Hydrogen"	100-1000 Kton

much more complicated

Severe damage range	3-5 km

Hiroshima today

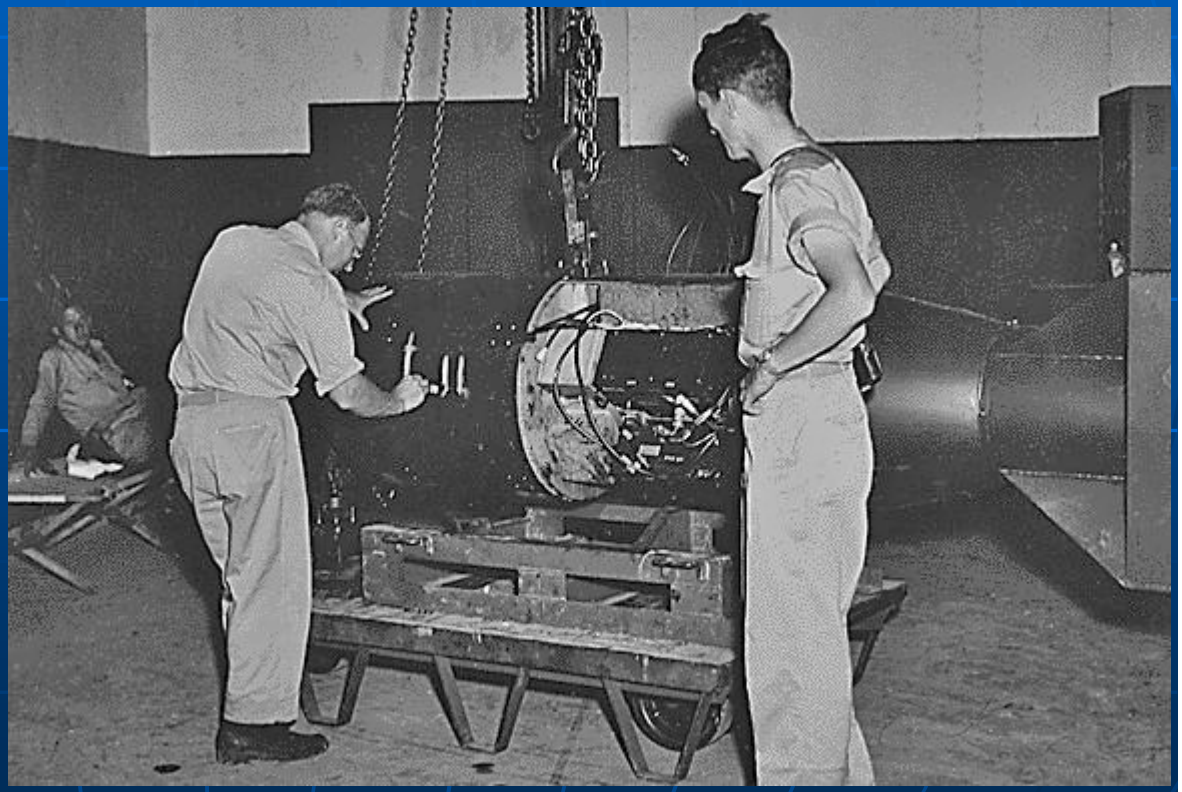


200 m

from ground zero (!)

“Little Boy” (Hiroshima)

Length	3 m
Diameter	71 cm
Weight	4000 kg

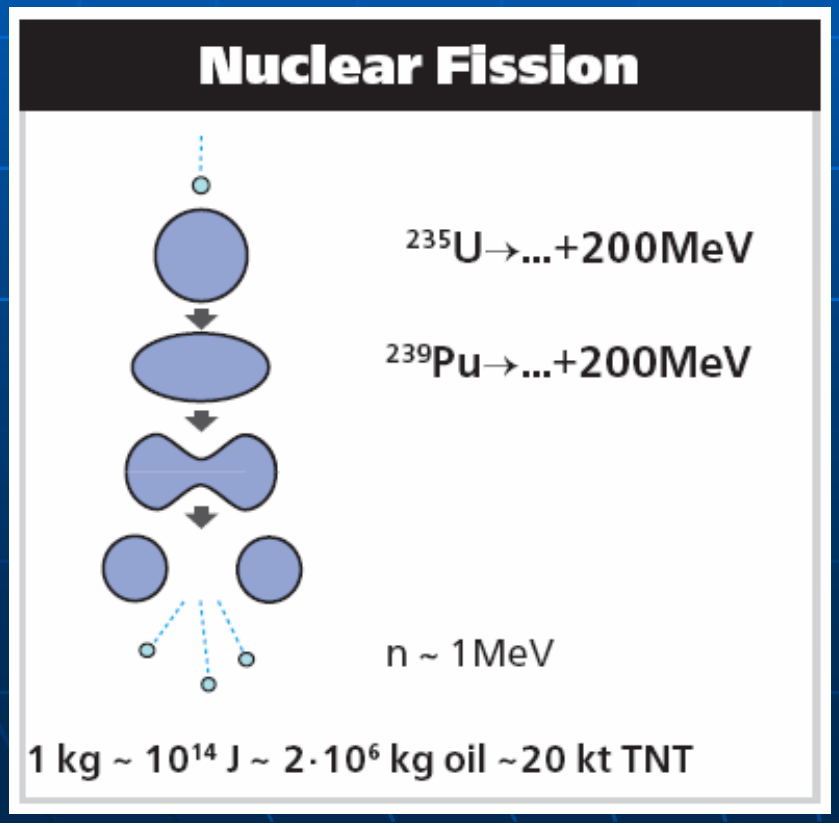


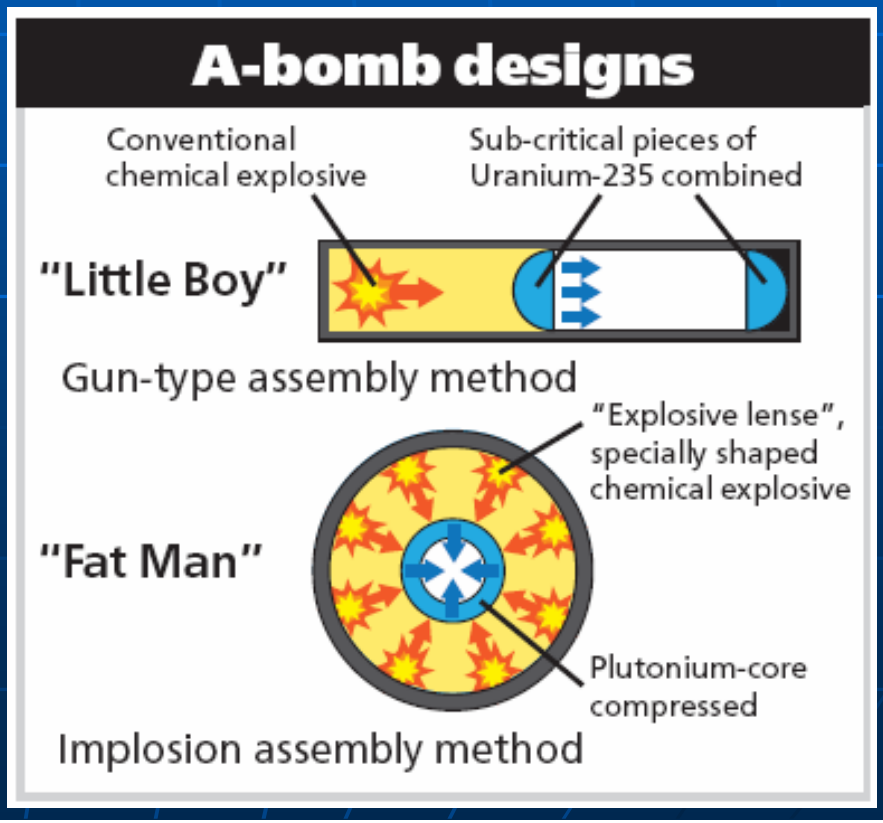
Nuclear Warheads

"Atomic" (fission) 1-20 Kton

Hiroshima ~16 Kton

Severe damage range 1-1.5 km





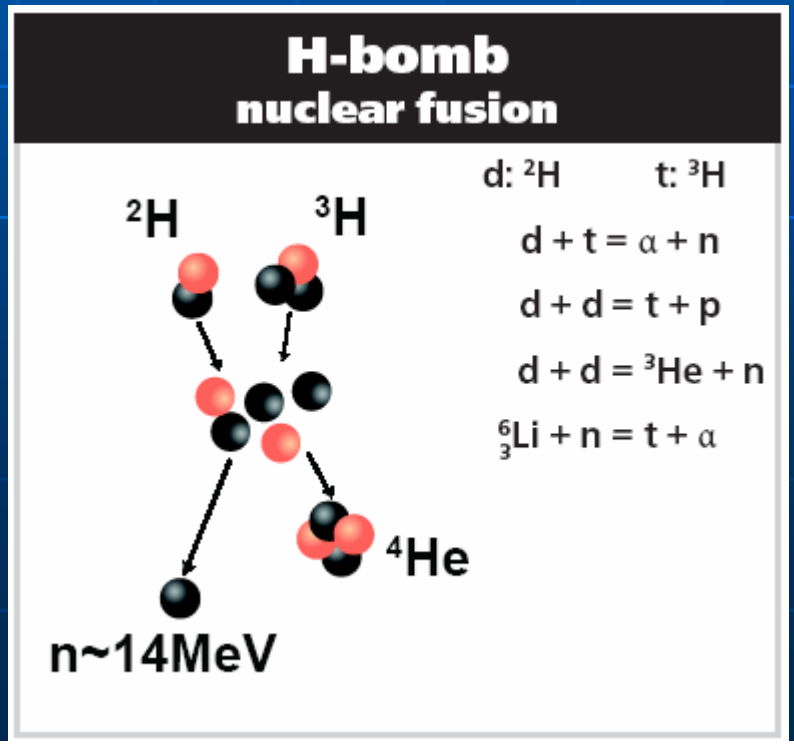
Nuclear Warheads

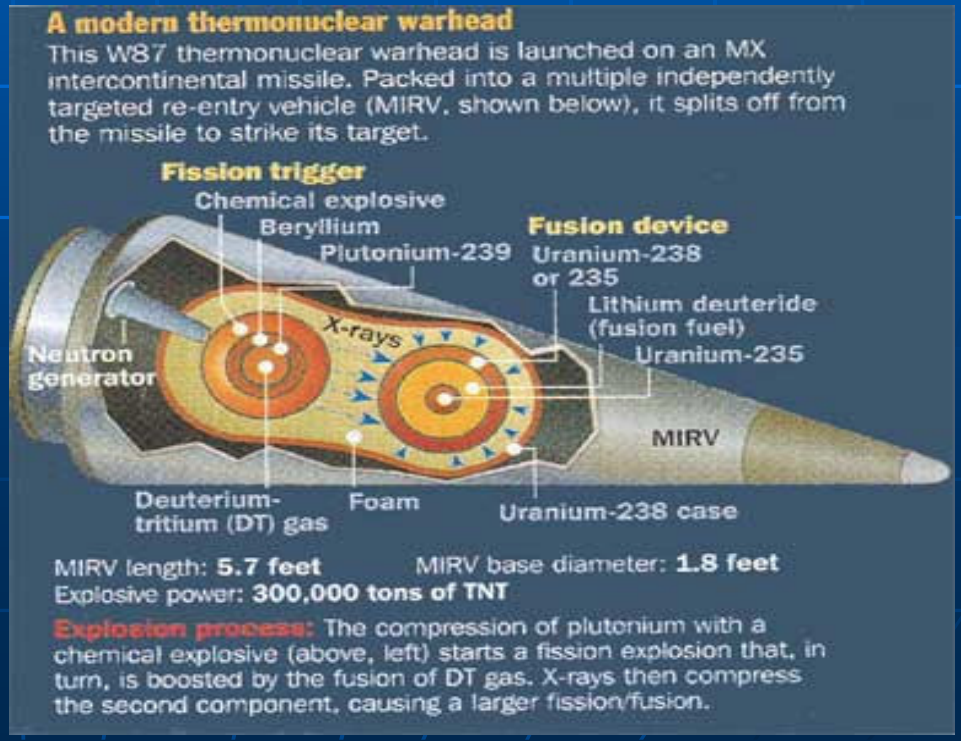
"Hydrogen" (thermo-nuclear, fusion)

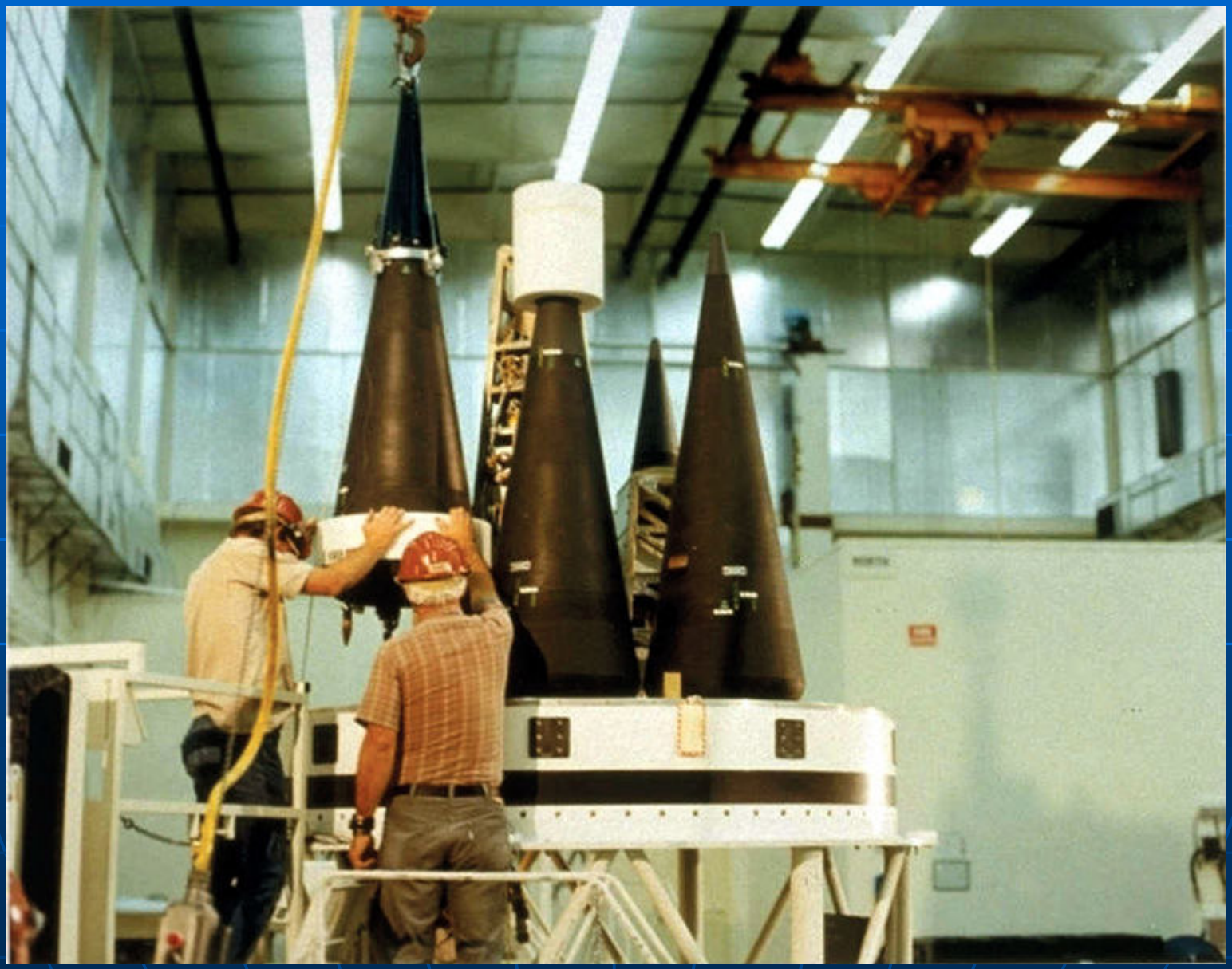
100-1000 Kton

much more complicated

Severe damage range 3-5 km







Hydrogen warheads **200-475(?) KT** “Peacekeeper” ICBM US 1983

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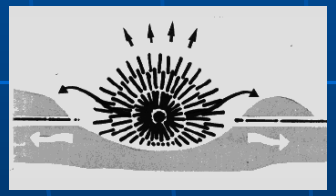
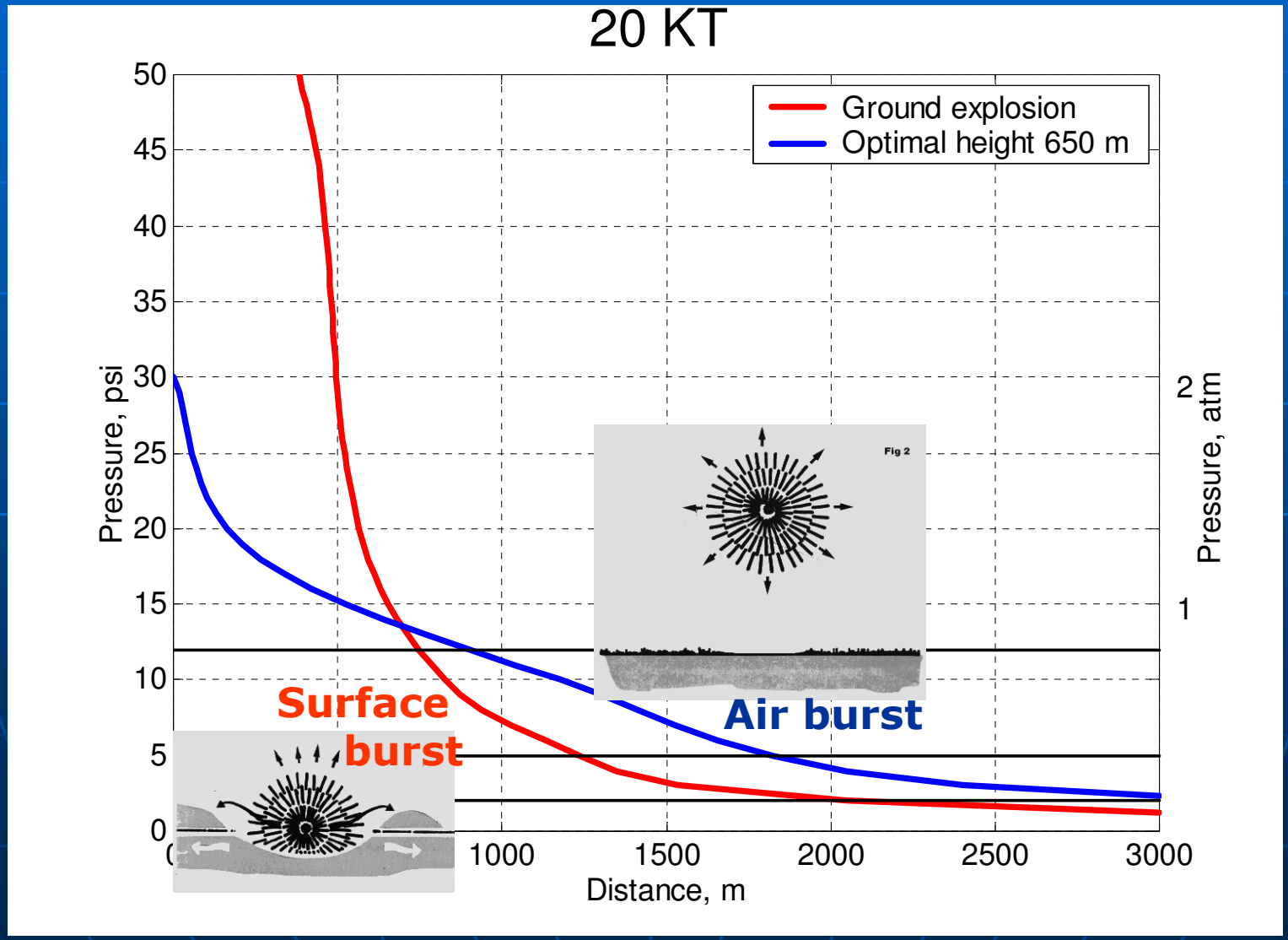
Nuclear Attack Effects

- Prompt destruction of life and property
  - Blast, thermal radiation, prompt nuclear radiation
- Delayed effect on personnel
  - Nuclear fallout – radioactive contamination
- Prompt effect on devices & installations
  - Electromagnetic pulse (EMP)

Explosion types – altitude

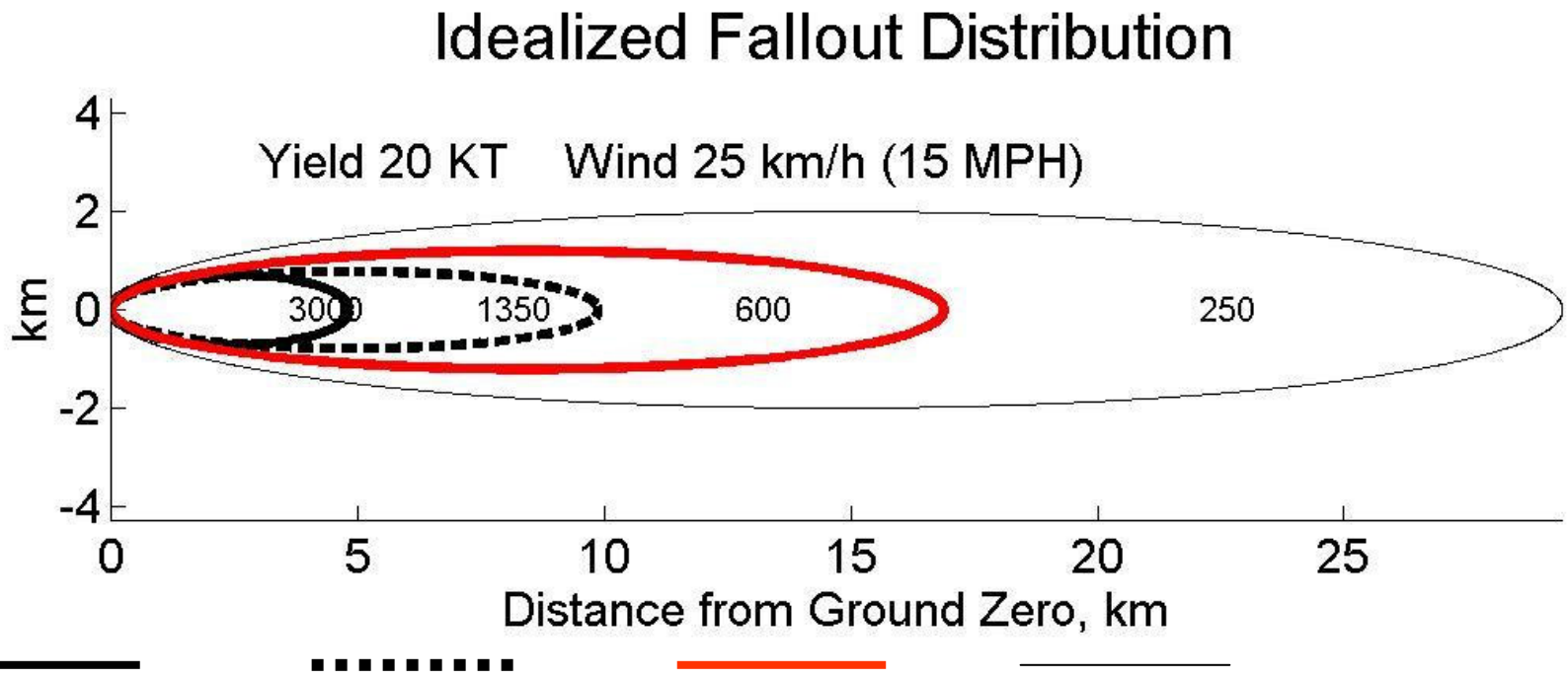
		+	–
Air burst		Maximal extent of destruction (x2)	1. No fallout 2. Less damage to reinforced structures
Surface burst		1. Fallout 2. Total destruction near ground zero	Lesser extent of destruction (1/2)
High-altitude burst	> 30 km	Wide-area EMP	No physical damage

Blast – overpressure



Fallout – mortality

2 days of exposure



100%			10-100%	Open/tent
100%	50-100%	0-50%	Slight illness	1-storey
25-50%	0-50%	Slight illness	NO illness	4-5 storey
NO illness				Shelter PF=40

Radiophobia vs. emerging scientific evidence

Japan A-bombing 1945 – 2008

- cancers < 1% of direct deaths
  - 450 deaths 1946-1990
- no evidence of effects in offspring

RERF, 2008

Chernobyl accident 1986 – 2005

- very limited increase in cancers – 15 lethal cases 1986-2002
- no radiation-related increase in congenital malformations

IAEA, 2005

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EMP catastrophe?

"……. Few, if any people would die right away. But the loss of power would have a cascading effect on all aspects of U.S. society. Communication would be largely impossible. Lack of refrigeration would leave food rotting in warehouses, exacerbated by a lack of transportation as those vehicles still working simply ran out of gas (which is pumped with electricity). The inability to sanitize and distribute water would quickly threaten public health, not to mention the safety of anyone in the path of the inevitable fires, which would rage unchecked. And as we have seen in areas of natural and other disasters, such circumstances often result in a fairly rapid breakdown of social order. "

Senator Jon Kyl, Chairman;
US Senate Subcommittee on Terrorism, Technology & Homeland Security.
Washington Post April 15 **2009**

"… DNA (Defense Nuclear Agency) has not endorsed, nor does it now endorse, the view of EMP-induced catastrophe… The fact that some electronics systems are vulnerable to EMP should not lead one to infer that all *systems are vulnerable or that widespread catastrophe will necessary result from EMP exposure."*

Dr. Gordon K. Soper
Scientific Assisstant to the Deputy Director, DNA
National Defense, Nov **1985**

EMP catastrophe?

"... We simply do not know with high confidence what its effect on the United States power system will be."

Dr. Edward F. Vance
SRI International, Menlo Park, CA
February 9 **1987**

"... The real problem is that no one really knows what the effect of the high-altitude EMP would be on the power grid."

Dr. Carl E. Baum
Air Force Weapons Lab, NTaab, Kirtland AFB, NM
February 17 **1987**

"... whatever the target system, no indispensable industry was permanently put out of commission by a single attack. Persistent re-attack was necessary."

US Strategic Bombing Survey (European war)
Washington DC September 15 **1945**

What is anticipated

- Multiple upsets and failures
- Extensive secondary damage
  - Accidents as a result of controls' failure
- Unanticipated
  - However, to consider anticipated helps also to counter unanticipated!

Reducing Vulnerability

Keep it Simple!

"We have produced designs so complicated that we cannot possibly anticipate all the possible interactions of the inevitable failures; we add safety devices that are deceived or avoided or defeated by hidden paths in the systems." Charles Perrow, *Normal Accidents*

Reducing Vulnerability

Make it effective, not perfect

Efficacy vs. Excellence

- Do not over-regulate
- Follow 80-20 principle
  - 80% performance for 20% resources

Reducing Vulnerability

Make it Redundant

Immunity vs. Efficiency

"...more precise the coordination affecting the efficiency, more perfect interaction between different parts of the system – more the danger that upset of one part will cause the collapse of the whole system."

Prof. Martin Van Creveld
"The Transformation of War "

Reducing Vulnerability

Think System!

"Communicating across disciplines requires domain experts to learn one another's language to pose significant questions and usefully interpret answers," National Academy of Sciences, *Making the Nation Safer; The Role of Science and Technology in Countering Terrorism*

EM Protection

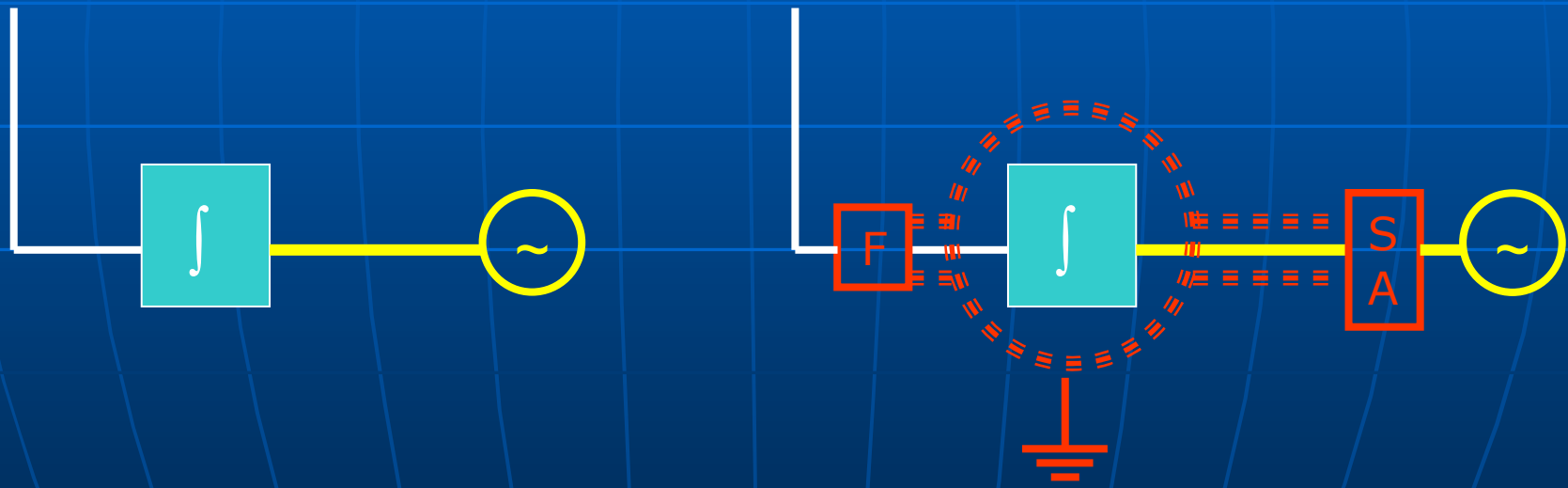
Screening

Bonding

Grounding

Filters

Surge Arresters



EM Protection

Screening
Bonding
Grounding

Filters
Surge Arresters

Hardening costs: 1%-3%
at the development stage

- ”New units can be EMP-hardened for a very small fraction of the cost of the non-hardened item, e.g., 1% to 3% of cost, if hardening is done at the time the unit is designed and manufactured. In contrast, retrofitting existing functional components is potentially an order of magnitude more expensive.“

The US Congress ***EMP Commission***
Executive Report, 2004

Shared Benefits

Most of the ... actions ... militate against more than an EMP attack. The protection and/or rapid restoration of critical infrastructures in the civilian sector from an EMP attack also will be effective against other types of infrastructure disruptions, such as attacks aimed at directly damaging or destroying key components of the electrical system, and natural or accidental large-scale disruptions ... Some of these steps also **enhance reliability and quality** of critical infrastructures...

The EMP Commission
Executive Report, 2004

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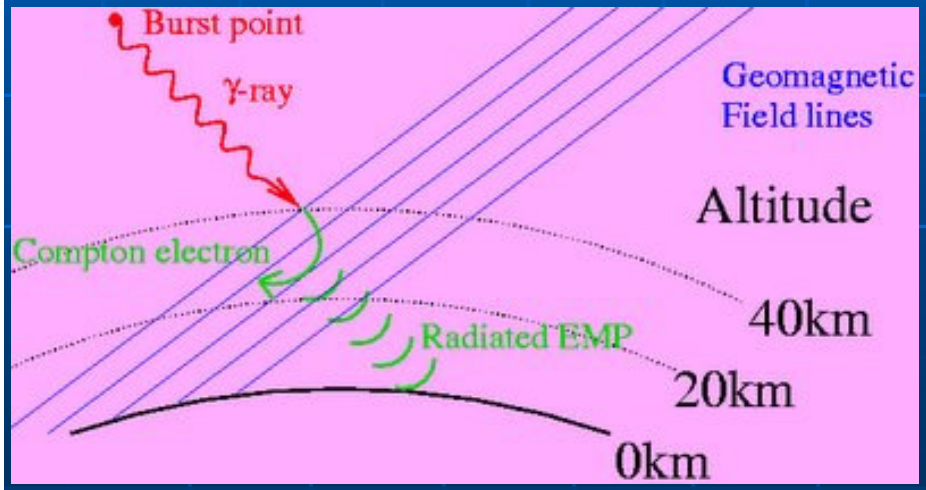
HEMP – High-altitude EMP

Nuclear explosion effects

- Shock wave
- Light emission
- Penetrating radiation
- Radioactive contamination (Fallout)

- **EMP – Electro-Magnetic Pulse**



Scenario

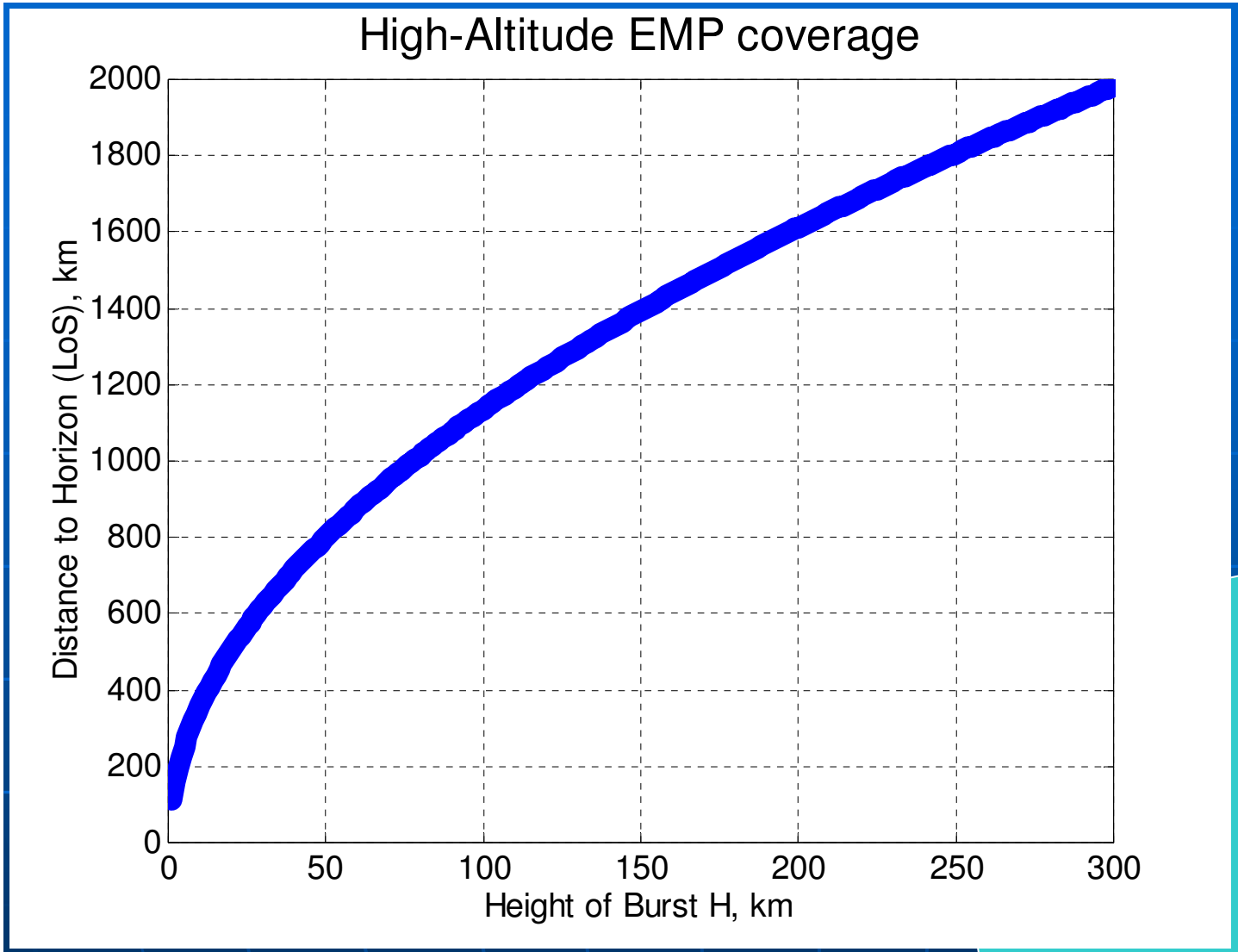
- simultaneously over the entire continental US
- no immediate casualties

Electronic systems' shutdown

Electric grid disruption

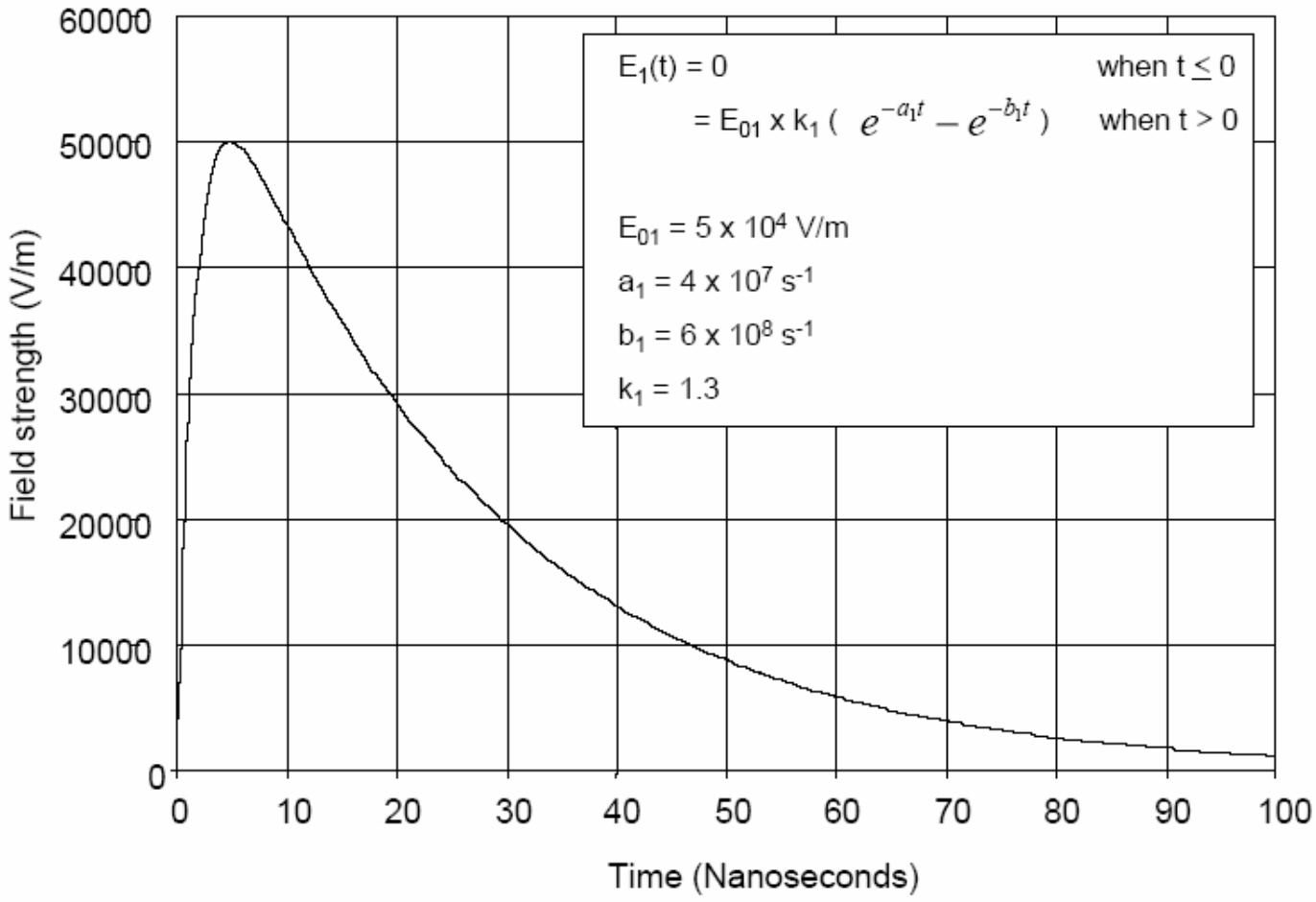
Pilot strike ?!

EMP

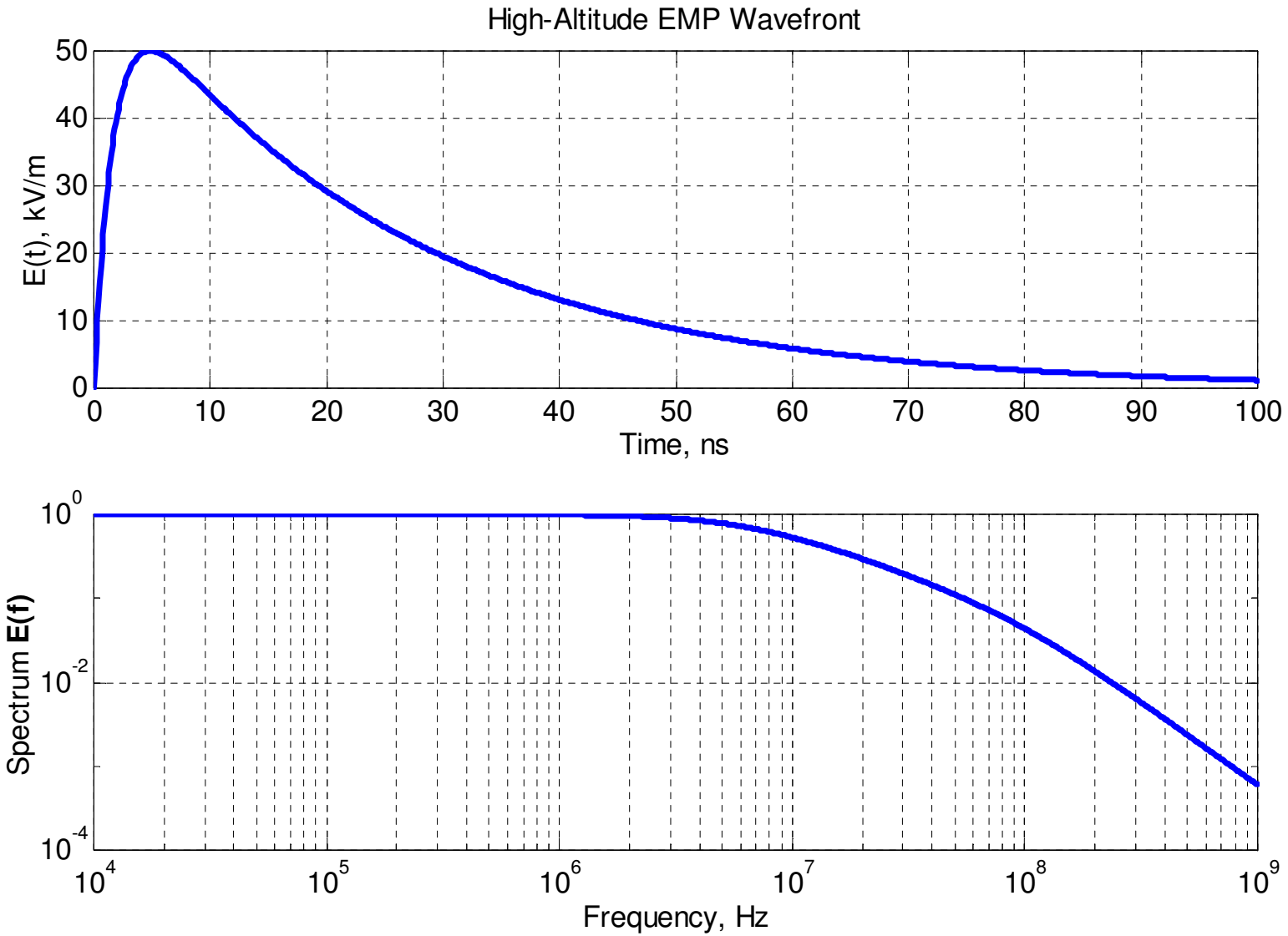


High-altitude EMP: above 30 km

EMP wavefront
MIL STD 461E / RS105



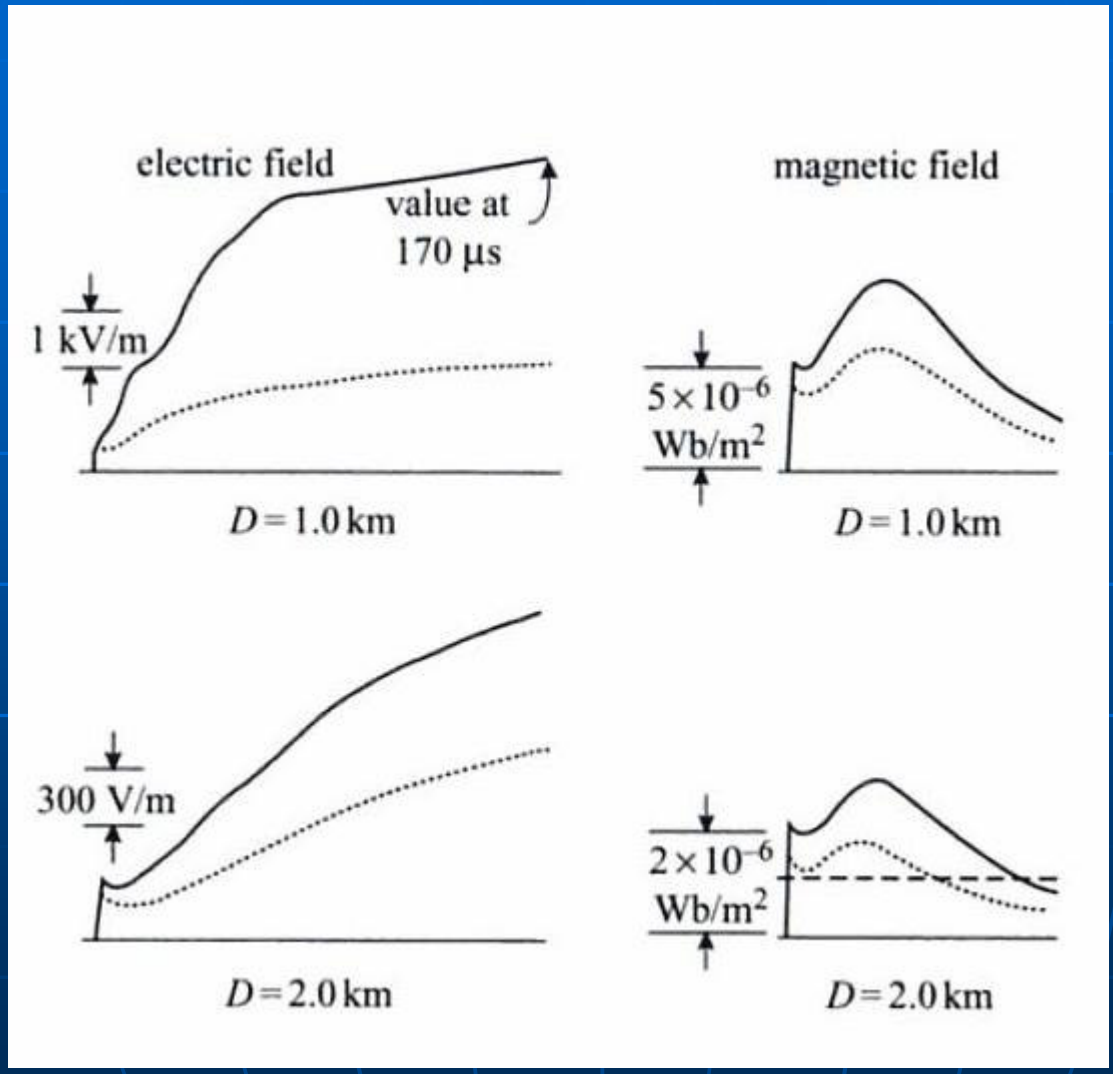
EMP wavefront



EMP wave

E V/m	H A/m	H Oersted/ Gauss	Energy flux S W/cm^2
25,000	70	0.8	160
50,000	135	1.6	650

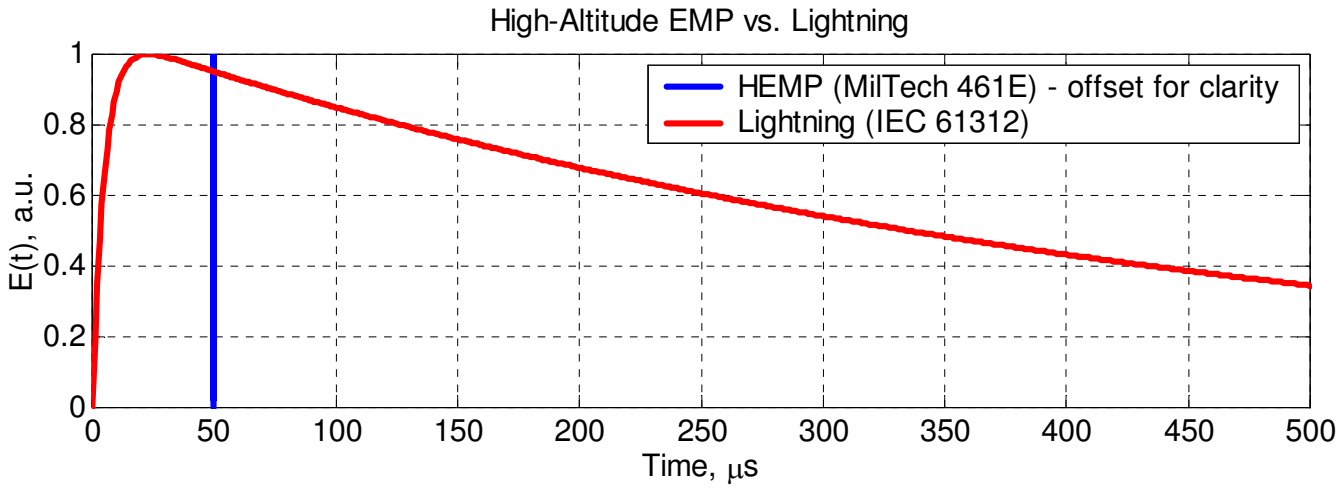
Lightning

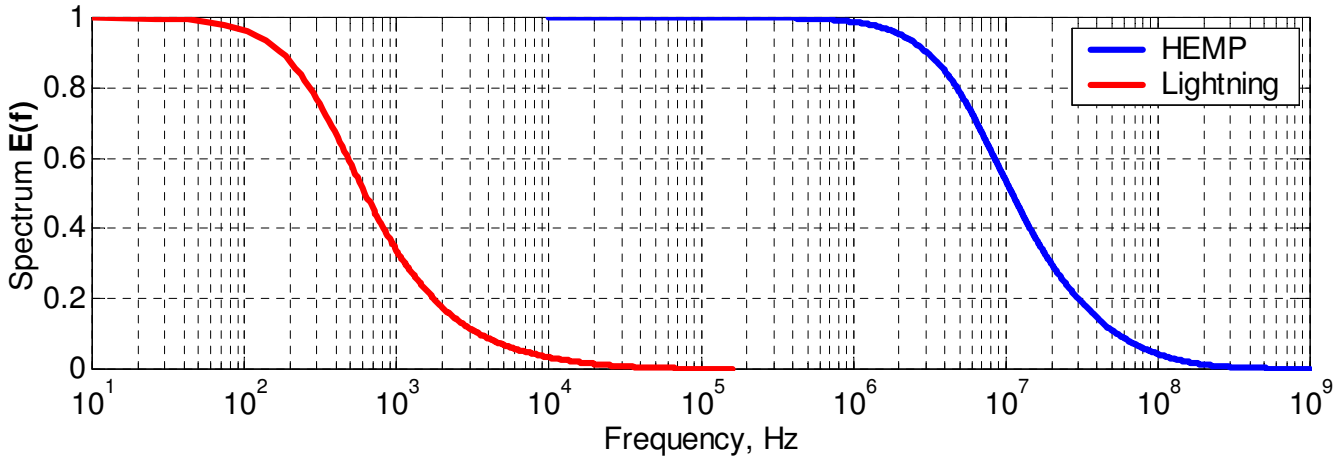


V. Cooray (Ed.)
The lightning flash. IET, 2004

Lightning: E ~ 5,000 V/m at 1000 m
May reach E ~ 500,000 V/m at 10 m, but low frequencies !

EMP vs. Lightning



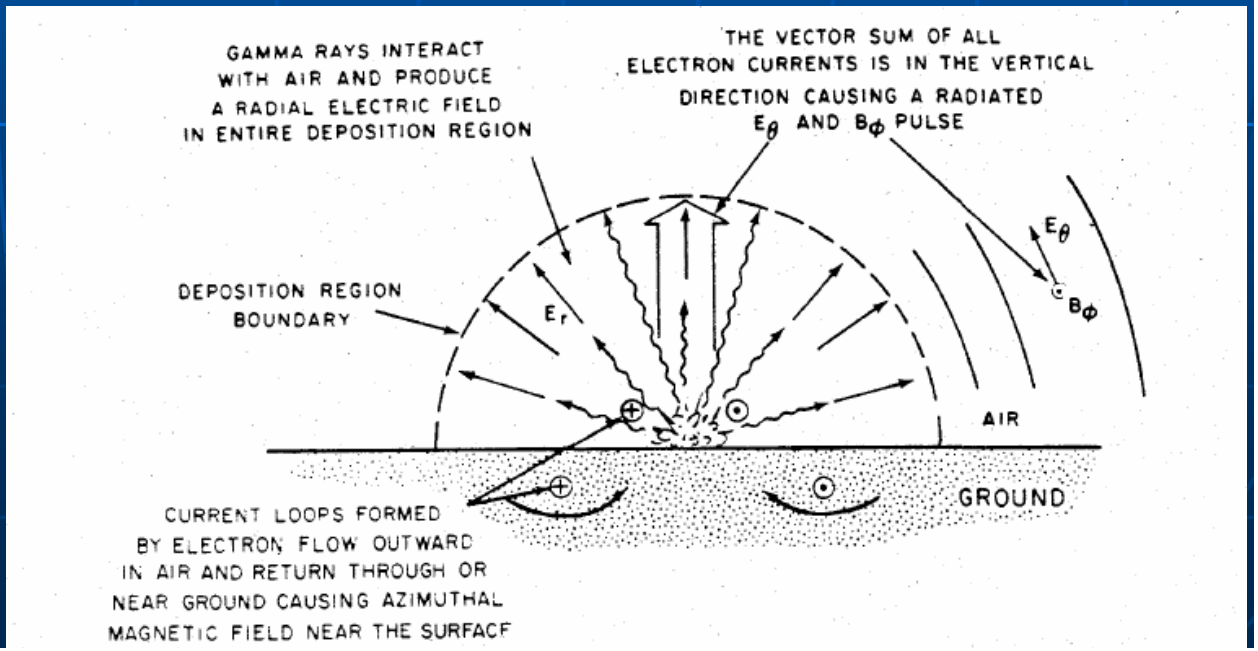


Lightning: E ~ 5,000 V/m at 1000 m
May reach E ~ 500,000 V/m at 10 m, but low frequencies !

Surface-Burst EMP

Possible also in case of nuclear terror

- Deposition region: R_0 ~ 3-5 km
- E ~ 100 kV/m – t ~ ns
- E ~ 10 kV/m – t ~ μs



Summary

- High cost-efficiency of hardening at the **development stage**
- System approach, simplicity, redundancy
- Time to act!

Appendices

Fallout

(2 days – 1 year) = ½ (0 – 2 days)

Lethal Dose:

LD_{50}	=	350 R
Slight or no radiation sickness		100-200 R
No illness	<	100 R
Acceptable dose (present peace-time standard for life-threatening emergency)		50 R

Cancer: +4% for 50 R
ICRP, 1990

Natural: 40%

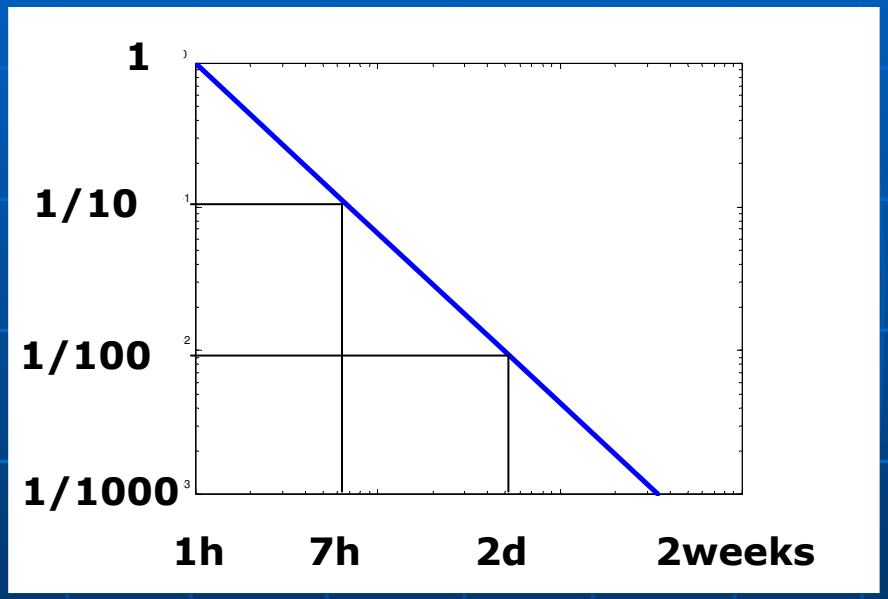
Radiation Level Decay

1 h	100 R/h
7 h	10 R/h
2 days	1 R/h
2 weeks	0.1 R/h

Natural background: 0.4 R/year

Lung X-ray: 0.03 R

Fallout radiation decay



UNITED STATES STRATEGIC BOMBING SURVEY
Summary Report (Pacific War) 1946

... It would be rash … to predict an increase in the effectiveness of defensive control sufficient to insure that not a single enemy plane or … missile will be able to penetrate.

… Civilian injuries and fatalities can be reduced, by presently known techniques, to ***one-twentieth or less*** of the casualties which would be suffered were these techniques not employed. This does not involve moving everything underground, but does involve a progressive evacuation, dispersal, warning, air-raid shelter, and post-raid emergency assistance program, the foundations for which can only be laid in peacetime. The analysis of the effects of the atomic bombs at Hiroshima and Nagasaki indicates that the above statement is ***just as true and much more terrifyingly significant in an age of atomic bombs*** than it was in an age of conventional weapons. Similarly, economic vulnerability can be enormously decreased by a well worked out program of stockpiles, dispersal and special construction of particularly significant segments of industry. Such a program in the economic field can also be worked out satisfactorily only in peacetime.