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THE AIR FORCE RESEARCH LABORATORY  
LEAD | DISCOVER | DEVELOP | DELIVER



## **FORCE HEALTH PROTECTION ELECTROMAGNETIC ENVIRONMENTAL BIOEFFECTS STANDARDIZATION REVIEW**

**DoD Electromagnetic Environmental Effects (E3) Program Review  
Gateway Club, Lackland AFB**

**03-07 April 2017**

**Mr. Roel Escobar and Dr. B. Jon Klauenberg  
Radio Frequency Bioeffects Branch  
Bioeffects Division  
Airman Systems Directorate  
711th Human Performance Wing**



# Outline



1. Why militaries need electromagnetic safety standards
2. NATO involvement in electromagnetic safety standards
3. Impact of the European Union worker safety Directive
4. Impacts of overly conservative limits: Shifting risks
5. Setting limits without data: Future risk management problem
6. New IEEE-NATO Military Standard
7. Expanding limits safely: Restricted Expert Only (REO) Zone



# Military Require Appropriate EMF Exposure Safety Standards



- Utilize a large array of electromagnetic devices
  - Many unique to the military:
  - Not evaluated by civilian standardization org
  - Some classified
- To protect personnel from EMF hazards
- Hazards are the reason for safety standards.
- Standards
  - Manage risks
  - Minimize impacts on mission
  - Facilitate multinational interoperability



# Safety Standards Enable Military EMF Emitters



- Systems enablers:
  - Communications
  - RADAR, GPS, detection and navigation
  - Electronic battlefield, aerospace tech, electric boats
  - Future technologies
- Weapons enablers
  - Non-lethal technologies, directed energy weapons
- Mission enablers
  - Least restrictive [safe](#) permissible limits
  - [Important piece of total risk assessment](#)





# **Impacts of Overly Conservative Limits: Shifting Risks**



# Risks Of Overly Restrictive Standards



- Electromagnetic spectrum supports many military mission essential systems that enable safe operations
  - Communications, navigation, detection and tracking, weapons, flight, search and rescue
- Must consider system degradation impact on mission
  - What risks will be reintroduced if emitter shutdown?
  - Effect of reducing system optimization:
    - Degraded approach radars would lead to unsafe landings
    - Degraded communications systems impact on command and control
- Must protect personnel from EM energy overexposure **AND** balance risks to protect them from alternative risks that may develop due to loss of EM-based operations





# Military Employ Rigorous Safety Programs



- Commanders need their personnel protected and healthy to maintain force capabilities.
- Military employ large sophisticated multifactor safety programs
- Include EMF-experienced medical doctors, health physicists, bioenvironmental engineers, radiation safety officers, scientists, electrical and electronics engineers, and other safety support workers, all working to ensure personnel safety
- Military/NATO led development of first EMF safety standards in 1950s and continue to be heavily involved in standardization





# NATO Involvement in Electromagnetic Safety Standards



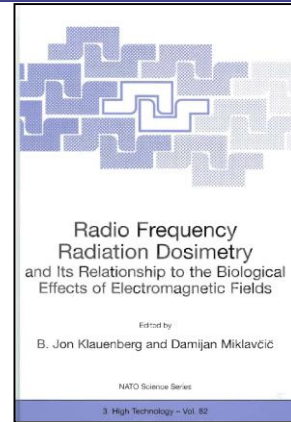
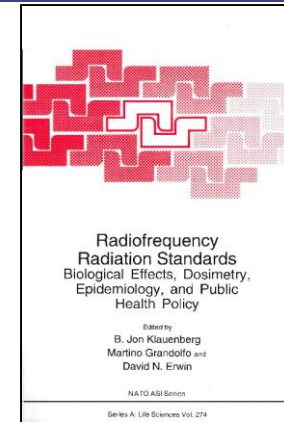
## NATO Advanced Research Workshops

- RFR Standards (Rome, 1993)
- Dosimetry and Standards (Slovenia, 1998)



## NATO Science and Technology Office

- Research Task Group (HFM/RTG-189)
- Researching operational and acquisition questions



## World Health Organization

- EMF Project International Advisory Committee



## European Commission on Worker Safety

- NATO Stakeholder to EMF advisory group: Directive 2013/35/EU



## IEEE Institute of Electrical and Electronics Engineers (IEEE)

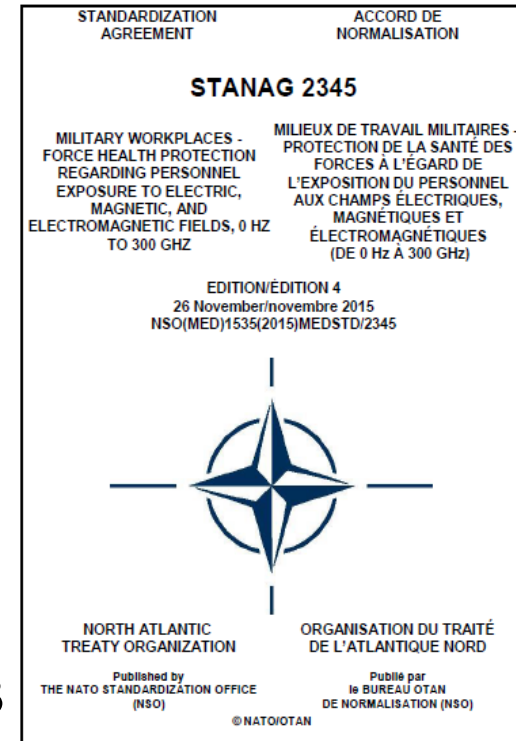
- International Committee on Electromagnetic Safety (ICES)



# NATO Electromagnetic Fields Personnel Exposure Safety Standard



- NATO Standards have led the way for 70 years
- USAF has led NATO Safety and Occupational Health standardization
- STANAG 2345 “Essential NATO STANAG”
  - USAF: Custodian 1993-present
  - High Peak Power Ultra-short Pulsed (HPPP)  
Increased from 100 kV/m to 200 kV/m: Ed 3 2003
  - Edition 4 promulgated Nov 26 2015: eliminated HPPP limits
  - Edition 4 based on civil standard IEEE C95.1-2345TM-2014





# Directive 2004/40/EC of the European Parliament



30.4.2004 EN Official Journal of the European Union L 159/

1

*(Acts whose publication is obligatory)*

## **DIRECTIVE 2004/40/EC OF THE EUROPEAN PARLIAMENT**

### **AND OF THE COUNCIL**

**of 29 April 2004**

on the minimum health and safety requirements regarding the exposure of  
workers

to the risks arising from physical agents (electromagnetic fields)

(18th individual Directive within the meaning of Article 16(1) of  
Directive 89/391/EEC)

**Proposed/ not adopted**

- Was to have become law for EU nations 28 April 2008
  - Medical concerns: Magnetic Resonance Imaging (MRI)
  - Industry concerns: Heat sealers, rail, power systems, cellular
  - **Military multinational interoperability threatened**



# Military Exemption from European Union Directive on Electromagnetic Safety



Be wise ... Standardize! **NSO**

- USAF successfully led NATO action for derogation of all military operating in EU
- Directive 2013/35/EU published 29 June 2013

## Impact/Importance:

- EU NATO nations can use NATO STANAG 2345
  - Maintains military interoperability
  - Allows use of IEEE C95.1-2345<sup>TM</sup>-2014
  - Removes impacts to operations
    - Reasonable Contact Currents limits
    - No Peak Power Ultra Short Pulsed limits

29.6.2013

EN

Official Journal of the European Union

L 179/1

I

(Legislative acts)

DIRECTIVES

DIRECTIVE 2013/35/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 26 June 2013

on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (20th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) and repealing Directive 2004/40/EC

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty on the Functioning of the European Union, and in particular Article 153(2) thereof,

Having regard to the proposal from the European Commission,

After transmission of the draft legislative act to the national parliaments,

Having regard to the opinion of the European Economic and Social Committee<sup>(1)</sup>,

After consulting the Committee of the Regions,

Acting in accordance with the ordinary legislative procedure<sup>(2)</sup>,

Whereas:

(1) Under the Treaty, the European Parliament and the Council may, by means of directives, adopt minimum requirements for the encouragement of improvements, in particular of the working environment, to guarantee a better level of protection of the health and safety of workers. Such directives are to avoid imposing administrative, financial and legal constraints in a way which would hold back the creation and development of small and medium-sized undertakings.

(2) Article 31(1) of the Charter of Fundamental Rights of the European Union provides that every worker has the right to working conditions which respect his or her health, safety and dignity.

(3) Following the entry into force of Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC<sup>(3)</sup>), serious concerns were expressed by stakeholders, in particular those from the medical community, as to the potential impact of the implementation of that Directive on the use of medical procedures based on medical imaging. Concerns were also expressed as to the impact of the Directive on certain industrial activities.

(4) The Commission examined attentively the arguments put forward by stakeholders and, after several consultations, decided to thoroughly reconsider some provisions of Directive 2004/40/EC on the basis of new scientific information produced by internationally recognized experts.

(5) Directive 2004/40/EC was amended by Directive 2008/46/EC of the European Parliament and of the Council<sup>(4)</sup>, with the effect of postponing, by four years, the deadline for the transposition of Directive 2004/40/EC, and subsequently by Directive 2012/11/EU of the European Parliament and of the Council<sup>(5)</sup>, with the effect of postponing that deadline for transposition until 31 October 2013. This was to allow the Commission to present a new proposal, and the co-legislators to adopt a new directive, based on fresher and sounder evidence.

(6) Directive 2004/40/EC should be repealed and more appropriate and proportionate measures to protect workers from the risks associated with electromagnetic fields should be introduced. That Directive did not address the long-term effects, including the possible carcinogenic effects, of exposure to time-varying

<sup>(1)</sup> OJ C 43, 15.2.2012, p. 47.

<sup>(2)</sup> Position of the European Parliament of 11 June 2013 (not yet

<sup>(3)</sup> OJ L 159, 30.4.2004, p. 1.



# EU Directive and IEEE C95.1-2005 Contact Current (CC) limits



- Directive 2013/35/EU CC limit reduced 100 mA to 40 mA
- IEEE C95.1-2005 CC limit reduced 100 mA to 50 mA
  - Unworkable limit – unnecessary restriction
- NLD Head of Delegation: Impacts to NATO 2006 RADHAZ WG
- Survey NATO nations found **operational impact on safety**
- Canadian Response: Operations impacted (non-mitigatable)
  - High Frequency communications often last 6 – 8 hrs
  - Vertical replenishment operations
  - Man-Overboard & Search-And-Rescue
  - Ship to ship supply transfers
  - Fuel transfer
  - Armaments test and transfer
- **Entire deck of ship “off limits”**
- **A new safety problem**

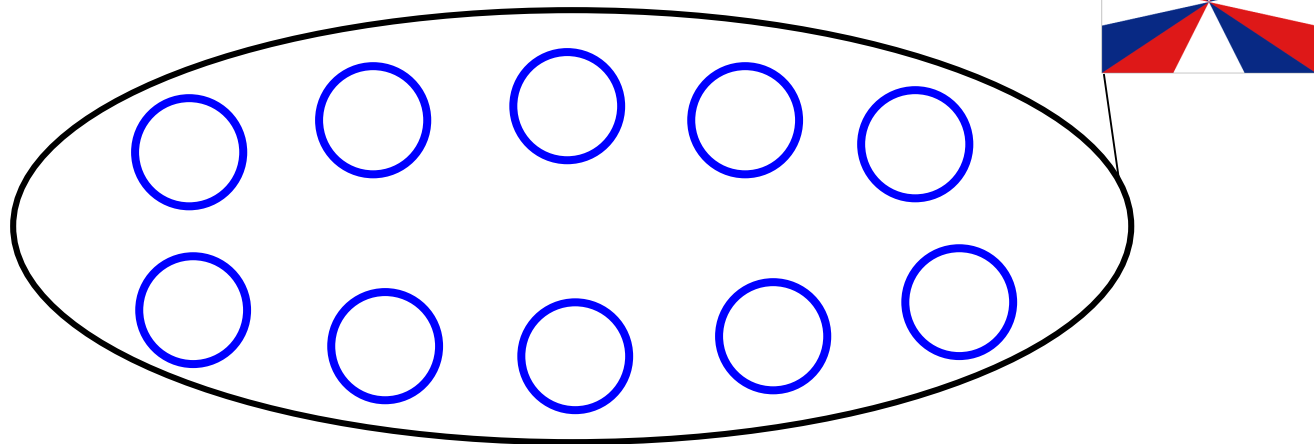




# Exclusion Zones at 100mA



**HNLMS Oblong**



**Representation of measurements on Dutch frigate**

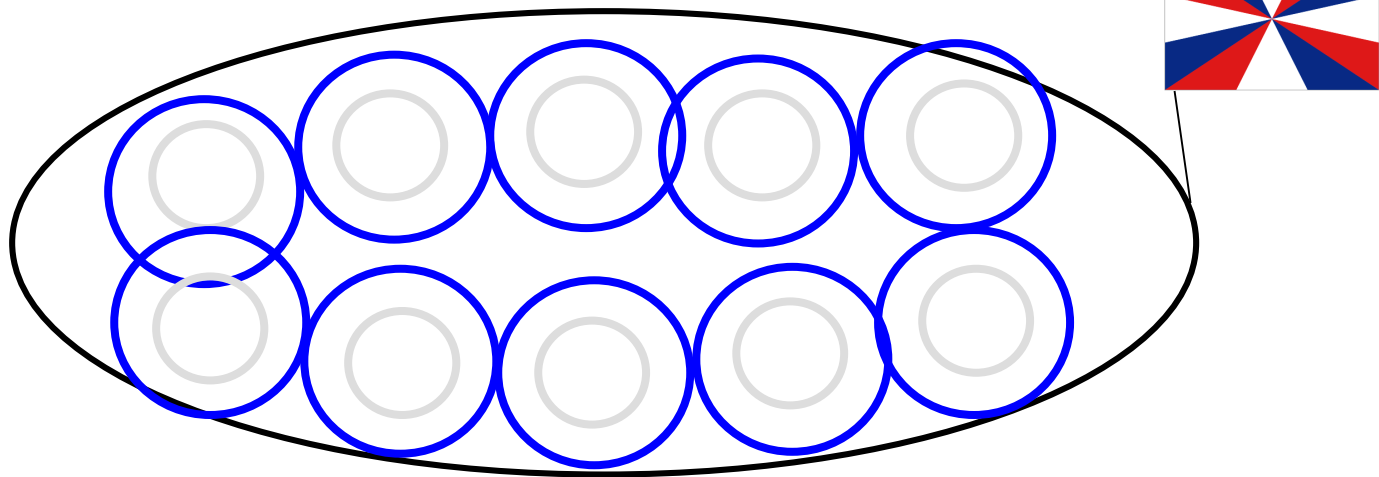




# Exclusion Zones at 40mA



## HNLMS Oblong



Representation of measurements on Dutch frigate

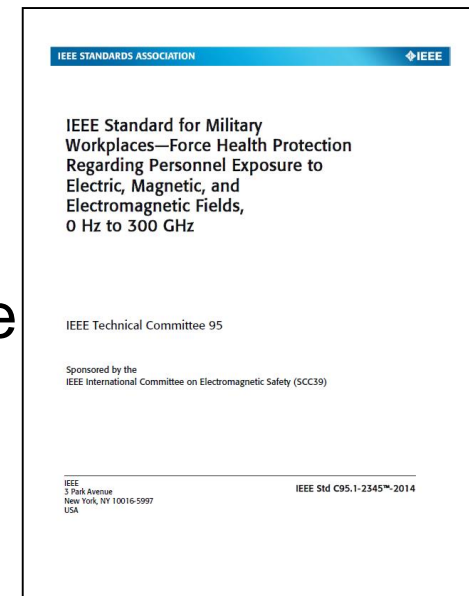
**No space on deck is open to workers! A new risk to safety**



# Science-Based Revision of Contact Current (CC) Limits



- *“IEEE Std C95.1-2345™-2014, IEEE Standard for Military Workplaces—Force Health Protection Regarding Personnel Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz”*
- Revised CC limits to workable limits
- Frequency dependent CC limits for first time
- Expanded workspace
- Removed operational impacts







# Induced and Contact Current Frequency Dependent Limits

Table 7—ERLs for induced and contact current (mA) for continuous sinusoidal waveforms—frequencies between 100 kHz and 110 MHz

	Zone 0 (unrestricted environments)			Zone 1 (restricted environments)			Zone 2 (restricted experts only—REO)
Frequency	100 kHz- 3 MHz	3 MHz- 30 MHz	30 MHz- 110 MHz	100 kHz- 3 MHz	3 MHz- 30 MHz	30 MHz- 110 MHz	100 kHz- 110 MHz
Induced, each foot	45	45	45	100	100	100	100
Contact, grasp <sup>a</sup>	—	—	—	100	$100(f/3)^{0.3}$	200	250
Contact, touch	16.7	$16.7(f/3)^{0.3}$	33.4	50	$50(f/3)^{0.3}$	100	—

NOTE 1—Tabulated values are rms values;  $f$  = frequency in MHz.

NOTE 2—Limits apply to current flowing between the body and a grounded object that may be contacted by the person.

NOTE 3—The averaging time for determination of compliance is 6 min (Zone 1 and Zone 2) and 30 min (Zone 0) for induced currents, 1 s for touch contact current (Zone 0 and Zone 1), and 6 min for grasp contact current.

NOTE 4—Calculated values for personnel in Zone 0 and Zone 1 are capped at the 30 MHz values since there is insufficient data to extrapolate above 30 MHz.

NOTE 5—Light “brush” contact may result in arcs and shock and burn even at 50 mA and should be avoided, especially with long objects such as cranes or cables.

NOTE 6—For definition of each of the zones, see 3.1.

NOTE 7—Restricted expert only access Zone 2 may be established only when mission essential and only when all personnel who are allowed access are expert on the particular system and informed that fingertip touch contact is to be avoided. Grasp is the appropriate method of contact.

NOTE 8—The ceiling values (temporal peak values as measured with accepted instruments) for induced current are 220 mA for Zone 0 (for a maximum duration of 75.3 s) and 500 mA for Zone 1 and Zone 2 (for a maximum exposure duration of 14.4 s).

<sup>a</sup> The grasping contact limit pertains to restricted environments where personnel are trained to make rapid grasping contact and to avoid touch contacts with conductive objects that present the possibility of painful contact.



# Derogation from Directive on EMF Health and Safety (2013/35/EU)



## Article 21

“(21) Given the specificities of the armed forces and in order to allow them to operate and interoperate effectively, including in joint international military exercises, Member States should be able to implement equivalent or more specific protection systems, such as internationally agreed standards, for example NATO standards, provided that adverse health effects and safety risks are prevented”.

General Provisions: Chapter III Article 8 and Article 10 Derogations

- “(b) Member States may allow for an equivalent or more specific protection system to be implemented for personnel working in operational military installations or involved in military activities, including in joint international military exercises, provided that adverse health effects and safety risks are prevented;



# **Setting Limits Without Data:**

## **The EMP Example**

### **Future Risk Management Problem**



# Early Steps Toward EMP Standard



1971 USAF set provisional EMP limit: 100 kV/m

- No adverse health effect found
- Overly precautionous
- Included in standards for 40+ years



Kirtland AFB Atlas -1 "Trestle"  
World's largest EMP simulator

B-52 Stratofortress BUFF

- No scientific rationale for setting limit
  - No effects: multiple studies: dogs, monkeys, rodents: 600 kV/m
  - No effects: humans, multiple exposures up to 80 kV/m
  - No effects between 100 kV/m and 3 MV/m (air breakdown)
- 1974: USAF Deputy Surgeon General:  
*"...it would **not** be prudent to propose standards that are not based on scientific data, particularly when all known exposure experience shows no cause-effect relationship."*



# Medical Surveillance



- 1972-1975 DoD, EG&G, and Boeing Co. and others conduct medical surveillance of EMP personnel
  - 20 pulser projects, Some over 10 years
  - ~ 600 individuals given repeated exams
  - Detailed exposure records kept
  - 1 kV/m to 50 kV/m exposures, typically 1 kV/m
  - No adverse health effects
- USAF discontinues annual EMP physicals 1975



# NATO Review High Peak Power Ultra Short Pulsed EMF Limit



- NATO Research Task Group (RTG)189  
“Bioeffects and Standardization of Exposure Limits of Military Relevant High Energetic Electromagnetic Pulses”
  - Three year effort, ten nations
  - Reviewed 50 years of published and ongoing studies
  - New USAF research was a critical decision component
  - Developed consensus agreement: basis for new standard
  - Recommended eliminating limits on high peak power electric ultra-short pulsed EMF: **DONE – IEEE C95.1-2345™-2014**
  - A few nations still uncertain that **ANY** limit should be removed





# Adopting Civil Standards Will Facilitate Harmonization



HOW STANDARDS PROLIFERATE:  
(SEE: A/C CHARGERS, CHARACTER ENCODINGS, INSTANT MESSAGING, ETC.)

SITUATION:  
THERE ARE  
14 COMPETING  
STANDARDS.

14?! RIDICULOUS!  
WE NEED TO DEVELOP  
ONE UNIVERSAL STANDARD  
THAT COVERS EVERYONE'S  
USE CASES.



SOON:

SITUATION:  
THERE ARE  
15 COMPETING  
STANDARDS.



# **New IEEE-NATO Military Standard for Personnel Exposure to Electric, Magnetic And Electromagnetic Fields: First Step to Harmonized Standards**





# Specific Agreement Between NATO and IEEE



## “New IEEE Military Workplace Standard” signed 30 July 2009

*“IEEE shall develop, maintain, revise, and update a new IEEE **military workplace standard** that will address normative military occupational/workplace-specific exposure limits to electric, magnetic and electromagnetic fields”*

Not simply adopting a non-governmental standard *in lieu* of a military drafted standard, but having civil SDO draft a military standard. **This sets a precedent.**



Agreement

between the

Institute of Electrical and Electronics Engineers, Incorporated (IEEE)

and the

NATO Standardization Agency (NSA)

for the

Development of a New IEEE Civil Standard to Replace the NATO EMF Standard, Adopted Under STANAG 2345



# First Civil Standards Organization Developed Military EMF Standard



- High Peak Power Pulsed limit gone!
  - Eliminated unnecessary limit
  - Enables weapons systems
- Relaxed exposure limit for experts
  - Supports command flexibility
  - Supports system design
  - New technologies facilitated
    - Higher limits possible
    - Alternative exposure policies

IEEE STANDARDS ASSOCIATION



IEEE Standard for Military  
Workplaces—Force Health Protection  
Regarding Personnel Exposure to  
Electric, Magnetic, and  
Electromagnetic Fields,  
0 Hz to 300 GHz

IEEE Technical Committee 95

Sponsored by the  
IEEE International Committee on Electromagnetic Safety (SCC39)

IEEE  
3 Park Avenue  
New York, NY 10016-5997  
USA

IEEE Std C95.1-2345™-2014

<http://standards.ieee.org/about/get/>



# **Expanding Limits Safely: Restricted Expert Only (REO) Zone**



Overexposure Risk

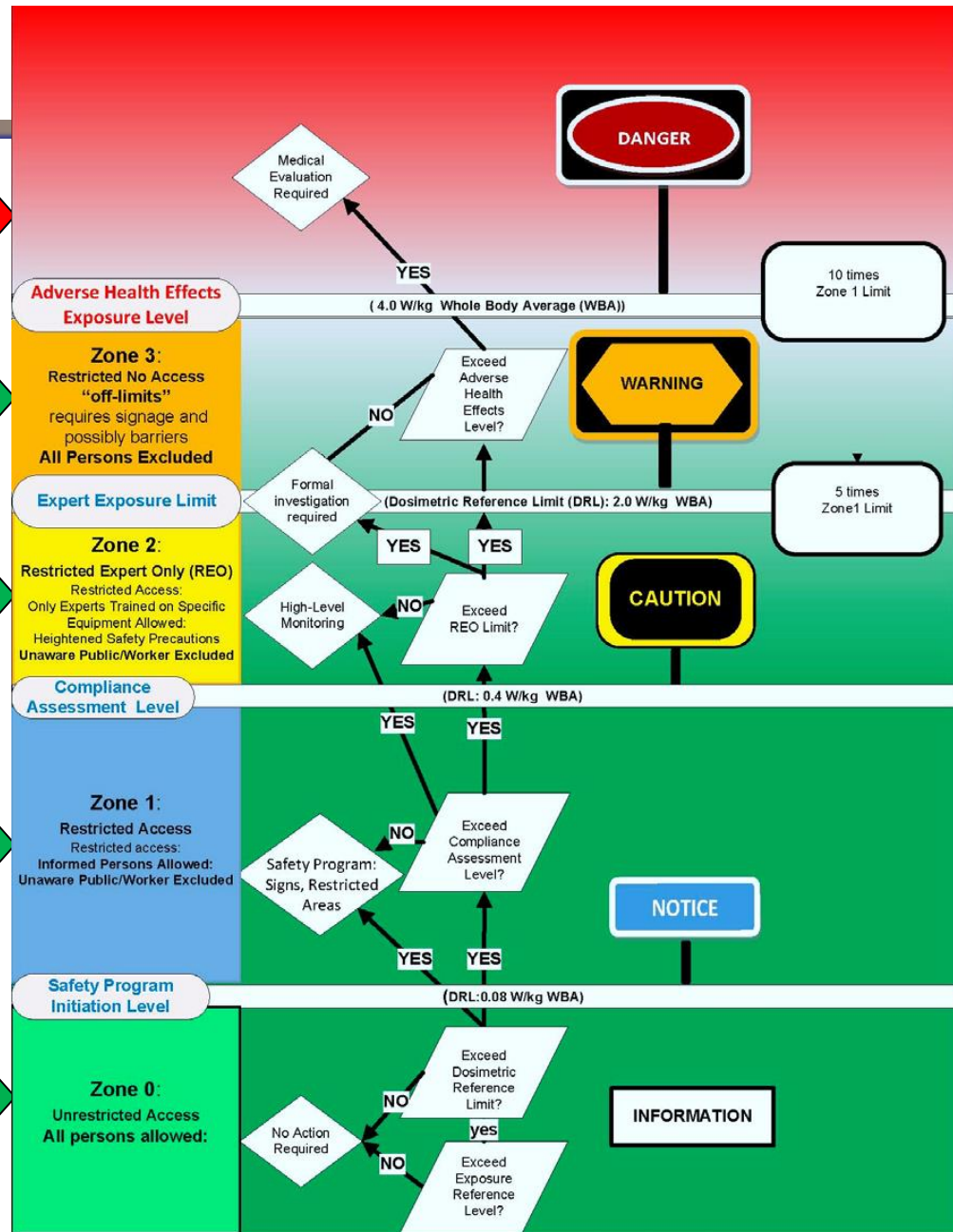
Safe: No Access Buffer

New Restricted Access Zone

Safe: Expert Only

Safe: Informed Allowed  
(Worker)

Safe: No Restrictions  
(Public)



Increasing risk of entry into over-exposure zone



# Restricted Expert Only Zone



- Provides command flexibility with safety
- Access is restricted to highly trained EMF workers to carry out necessary activities under strict and explicit guidelines
- Safety procedures are enhanced - expert is closely monitored
- **System-specific expertise required**




# STANAG 2345 EDITION 4 (26 NOV 16)



NATO  
STANDARDIZATION OFFICE

Be wise ... Standardize! NSO

STANDARDIZATION AGREEMENT	ACCORD DE NORMALISATION
<b>STANAG 2345</b>	
MILITARY WORKPLACES - FORCE HEALTH PROTECTION REGARDING PERSONNEL EXPOSURE TO ELECTRIC, MAGNETIC, AND ELECTROMAGNETIC FIELDS, 0 HZ TO 300 GHZ	MILIEUX DE TRAVAIL MILITAIRES PROTECTION DE LA SANTÉ DES FORCES À L'ÉGARD DE L'EXPOSITION DU PERSONNEL AUX CHAMPS ÉLECTRIQUES, MAGNÉTIQUES ET ÉLECTROMAGNÉTIQUES (DE 0 Hz À 300 GHz)
EDITION/ÉDITION 4 26 November/novembre 2015 NSO(MED)1535(2015)MEDSTD/2345	
	
NORTH ATLANTIC TREATY ORGANIZATION	ORGANISATION DU TRAITÉ DE L'ATLANTIQUE NORD
Published by THE NATO STANDARDIZATION OFFICE (NSO)	Publié par le BUREAU OTAN DE NORMALISATION (NSO)
© NATO/OTAN	



# DoDI 6055.11: Protecting Personnel From Electromagnetic Fields (EMF)



- Newest edition in coordination
- Adopts by reference IEEE C95.1-2345<sup>TM</sup>-2014
  - IEEE Std C95.1-2345<sup>TM</sup>-2014, IEEE Standard for Military Workplaces—Force Health Protection Regarding Personnel Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz
- Adopts by reference IEEE C95.3<sup>TM</sup>-2002 and C95.7<sup>TM</sup>-2005
  - IEEE Std C95.3<sup>TM</sup>-2002 (R2008), Recommended Practice for Measurements and Computations of Electric, Magnetic and Electromagnetic Fields With Respect to Human Exposure to Such Fields, 100 kHz-300 GHz
  - IEEE Std C95.7-2014<sup>TM</sup>, IEEE Recommended Practice for Radio Frequency Safety programs, 3 kHz to 300 GHz
- Provides procedures to request Alternative Exposure Limits
- DoD Components sponsoring free access to IEEE standards
  - Available at <http://standards.ieee.org/about/get/>



# Next NATO Actions



- NATO requirement to review every three years
  - Reaffirm, Revise if needed, or Cancel
- Estimate six months to assess need for revision:
  - January 2017 to July 2017
- Standardization Task due prior to revision:
  - Submit to Medical Board July 2017: response 3 months
- Revise C95.1-2345 standard: October 2017- January 2018
- STANAG due to Medical Board for ratification of any changes no later than February 2018
- Ratification to be completed by June 2018 with possible one time 4 month extension
- Promulgation takes another 2-3 months





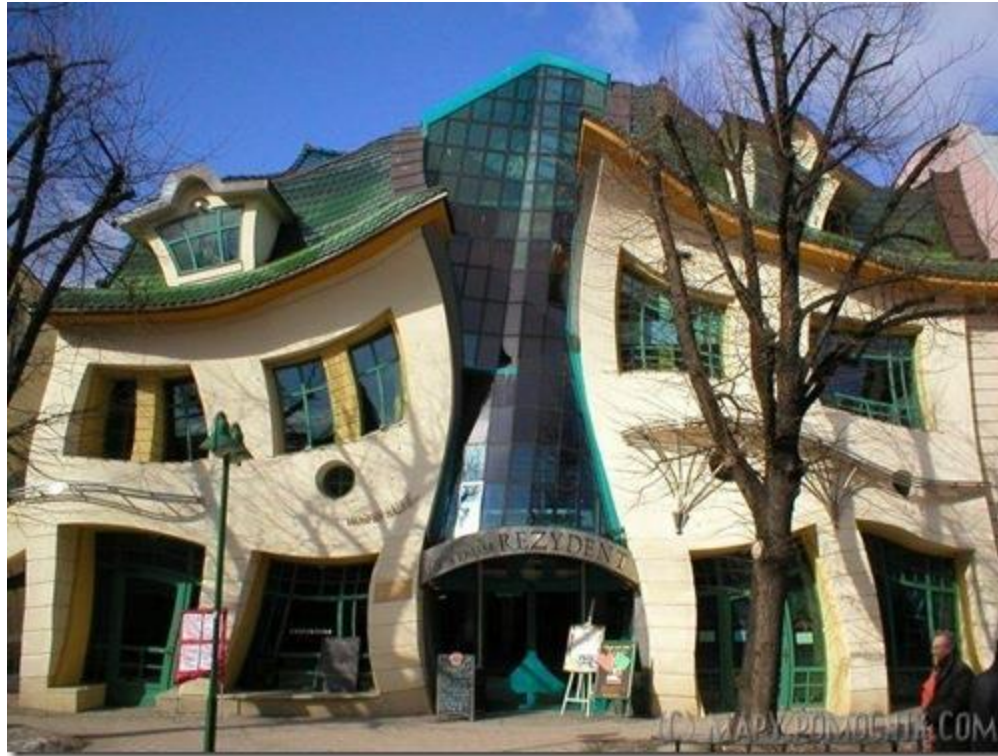
# New Opportunity to Harmonize Civilian Standards



- International Committee on Electromagnetic Safety (ICES) working with ICNIRP to bring standards closer together
- International Commission on Nonionizing Radiation Protection (ICNIRP)
  - New Chairman also member of IEEE
- First opportunity for harmonization in decades due to good personal working relationships
- Working Groups established and Workshops being organized
- Will coordinate both civilian and military standardization



# Without Standardization the Pyramids May Look Like ....



Crooked House: Sopot, Poland



# QUESTIONS?



Thank you for your attention!



?????? ? ?  
**QUESTIONS**

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