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# **Infrasound and Low Frequency Noise: A Public Health Nightmare**

**Mariana Alves-Pereira, Bruce Rapley,  
Huub Bakker, Rachel Summer**

*Glasgow, Scotland, Sept 22, 2017*

**ATKINSON & RAPLEY**  

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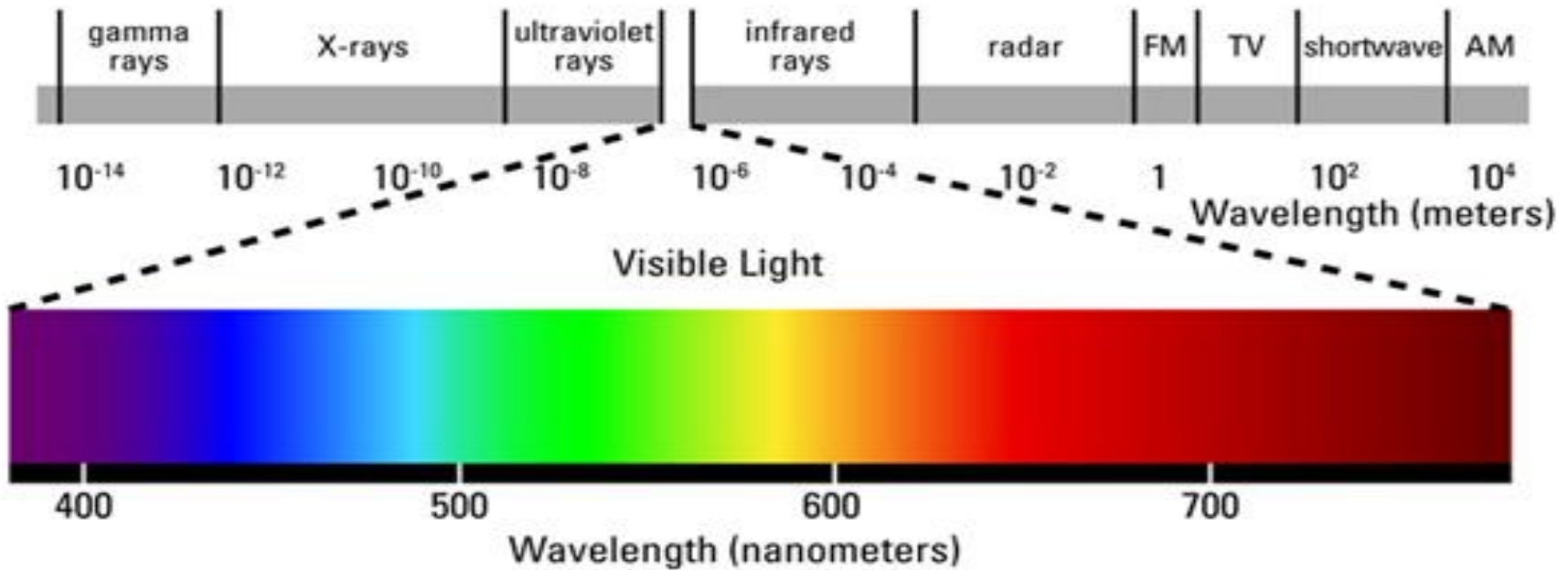
**C O N S U L T I N G**

# Disclaimer

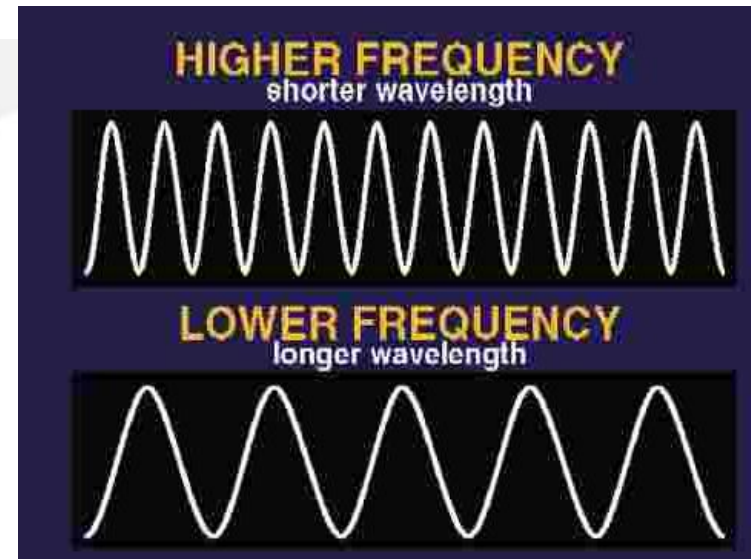
**We:**

- *Do not harbour anti-technology sentiments;*
- *Consider industrial activities to be important to modern technological societies;*
- *Have scrutinized data under one, and only one, agenda - pure scientific inquiry;*
- *Are not producing a report arguing against industrial complexes.*

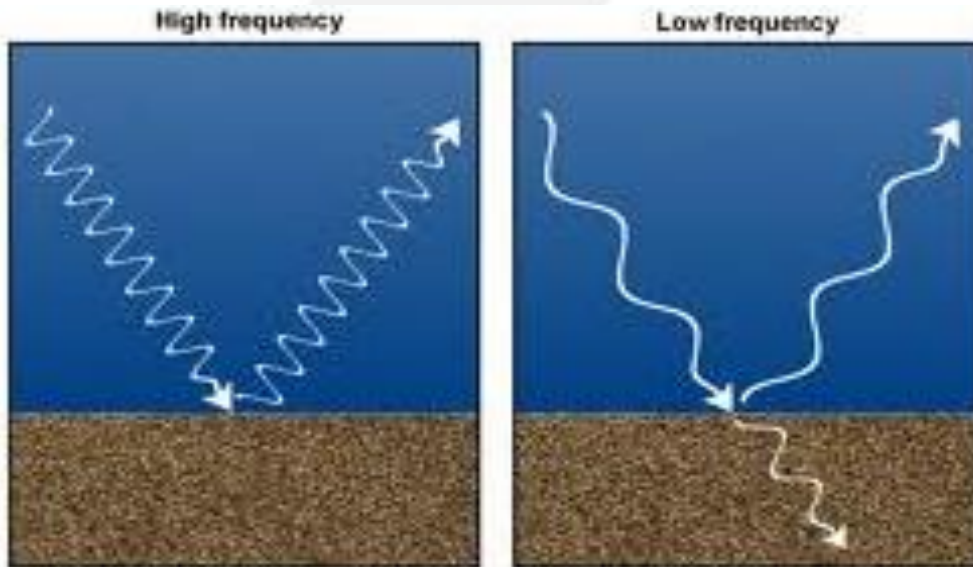
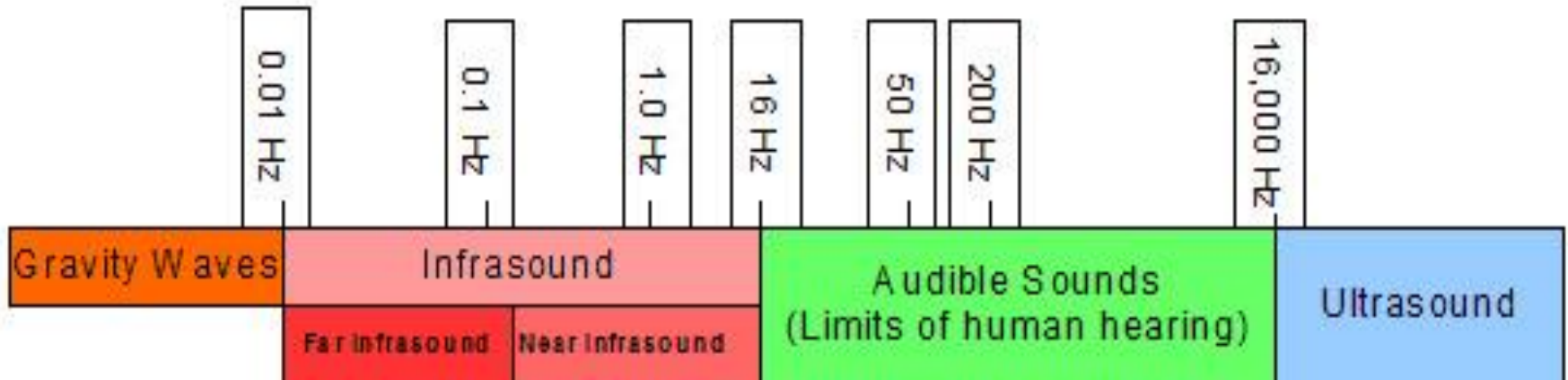
# Radiation



- Humans do not perceive x-rays.
- Excessive exposure to x-rays can be harmful.
- A chest x-ray, once a year, is not considered harmful.



# Acoustics

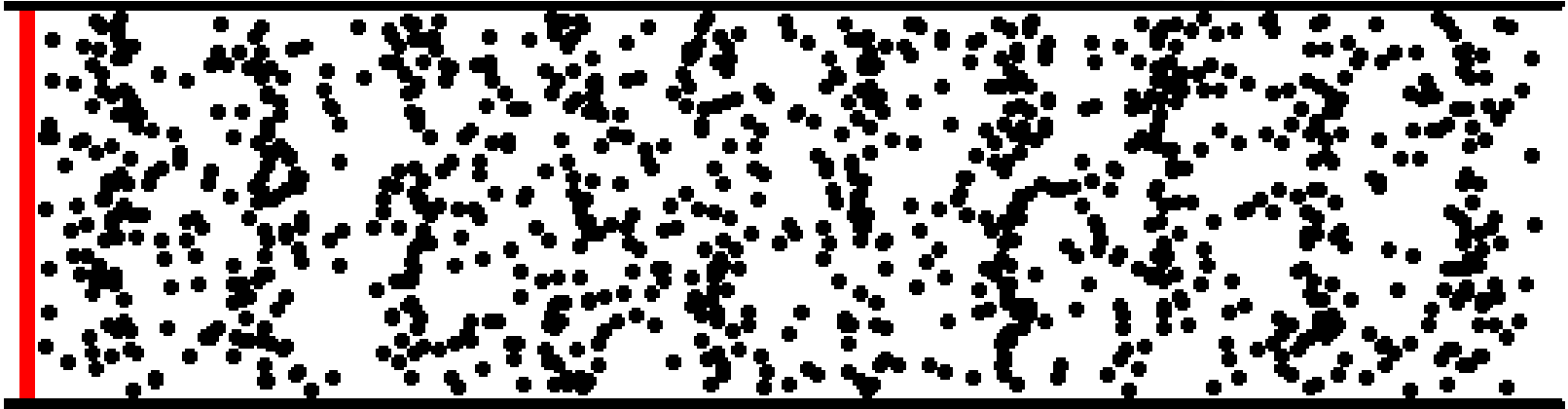


Wavelength of airborne sound at:

<u>3000 Hz</u>	is	<b>0.11 m</b>
<u>500 Hz</u>	is	<b>0.68 m</b>
<u>100 Hz</u>	is	<b>3.43 m</b>
<u>20 Hz</u>	is	<b>17.1 m</b>

*Low frequency waves can propagate over larger distances than higher frequency waves.*

# Acoustic Waves

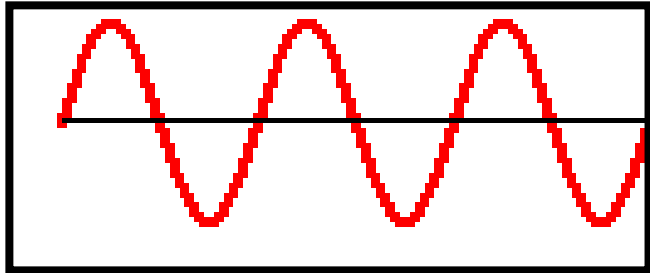


**Acoustic wave = Pressure wave (longitudinal wave)**

An acoustic wave = “sound”  
**if and only if**  
humans can perceive it with the ear.

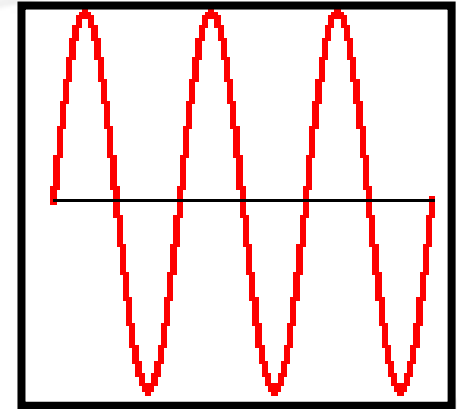
World Health Organization:  
Noise = Inanimate Mechanical Forces

# Acoustic Waves



Lower Amplitude

*The deciBel unit, dB, is used to measure the amplitude of the acoustic waves*



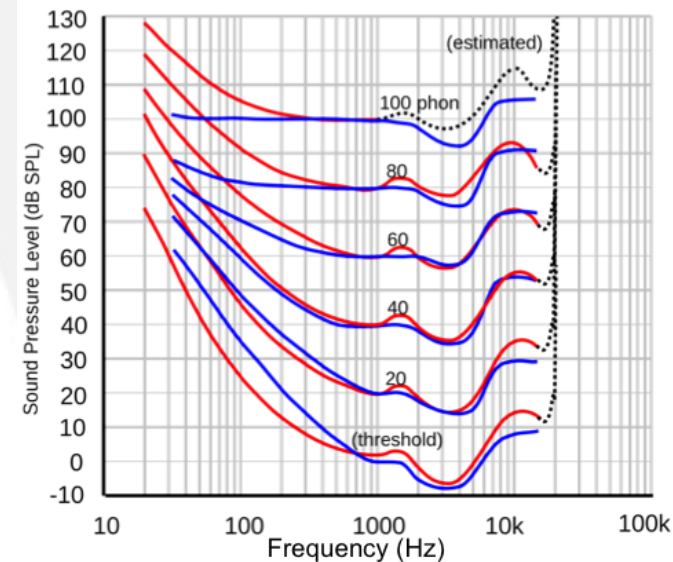
Higher Amplitude

## 1920

- 23 healthy, young males
- with good hearing (*assumed*)
- exposed to series of different, single, pure tones at different levels of loudness via telephone earpieces - occluded ear
- asked to score the sounds for equal loudness.



Harvey Fletcher  
(1884-1981)

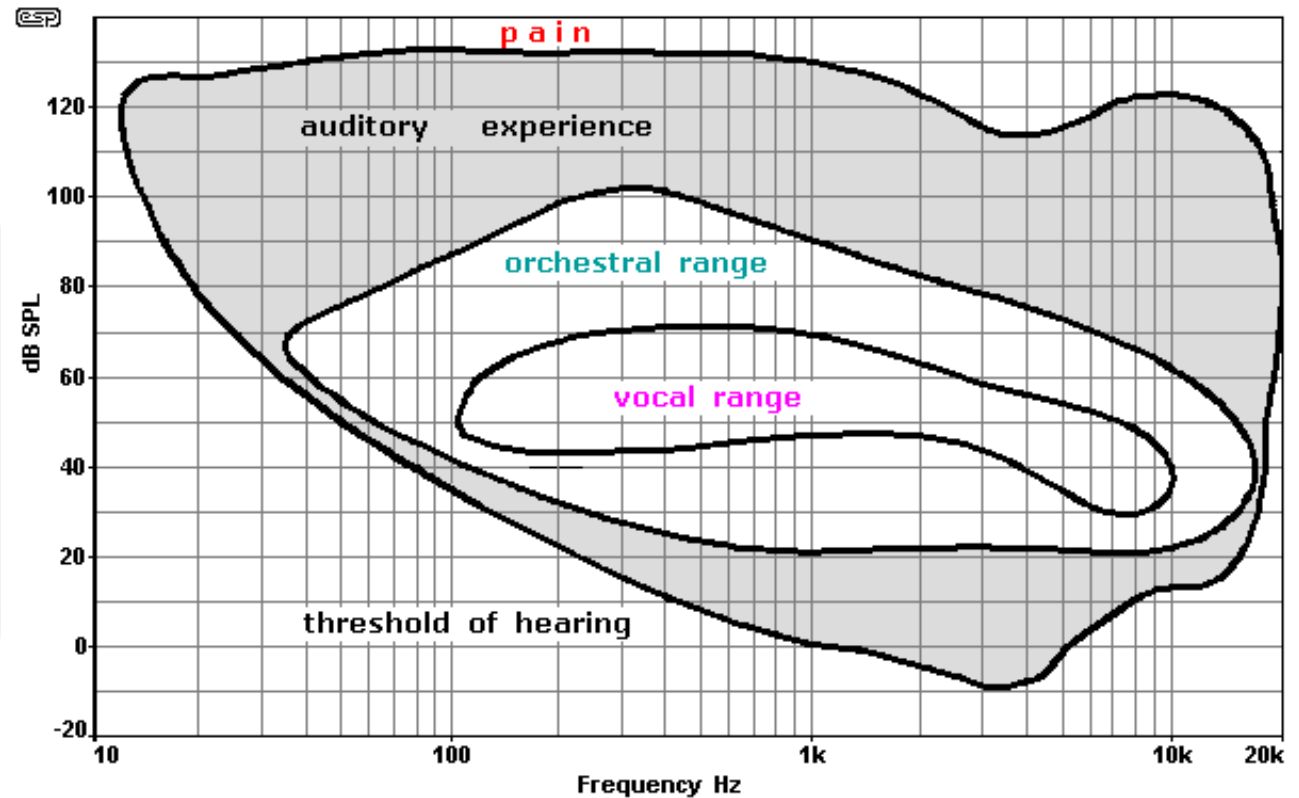


Fletcher-Munson  
Equal Loudness Curves

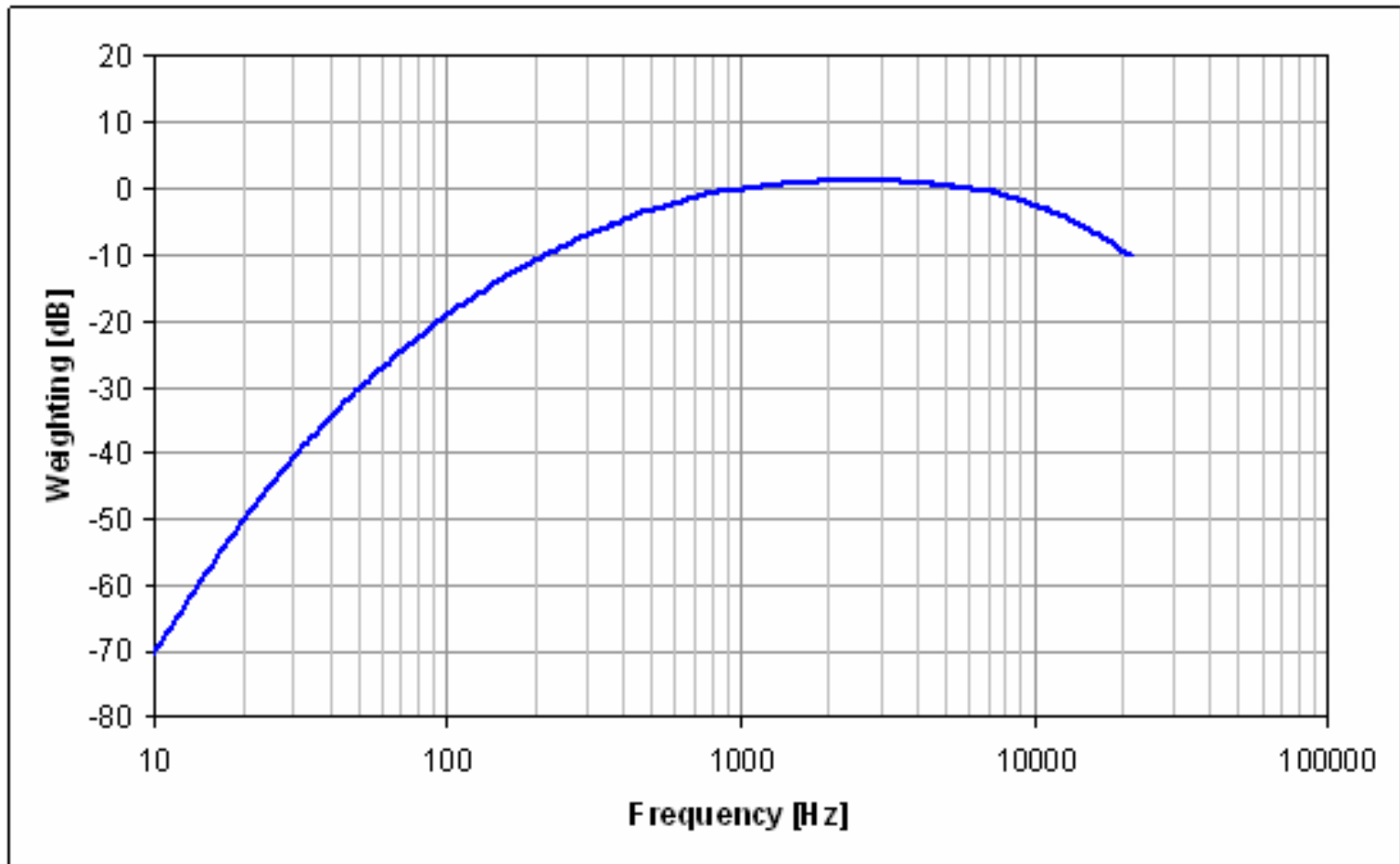


# Human Hearing & Noise Protection

1932



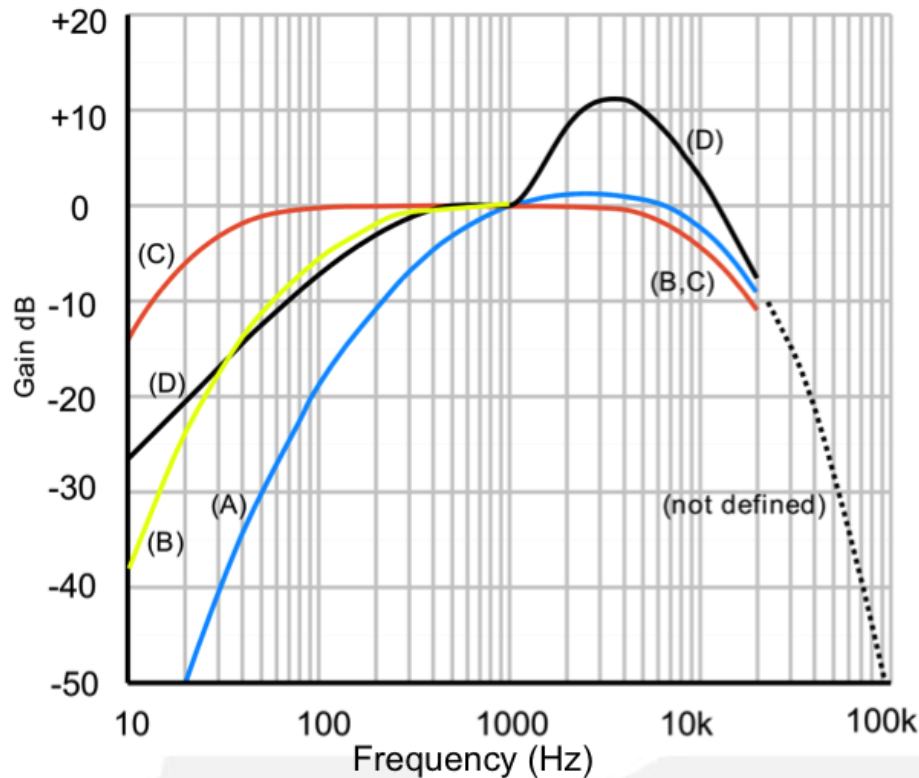
# The dBA metric



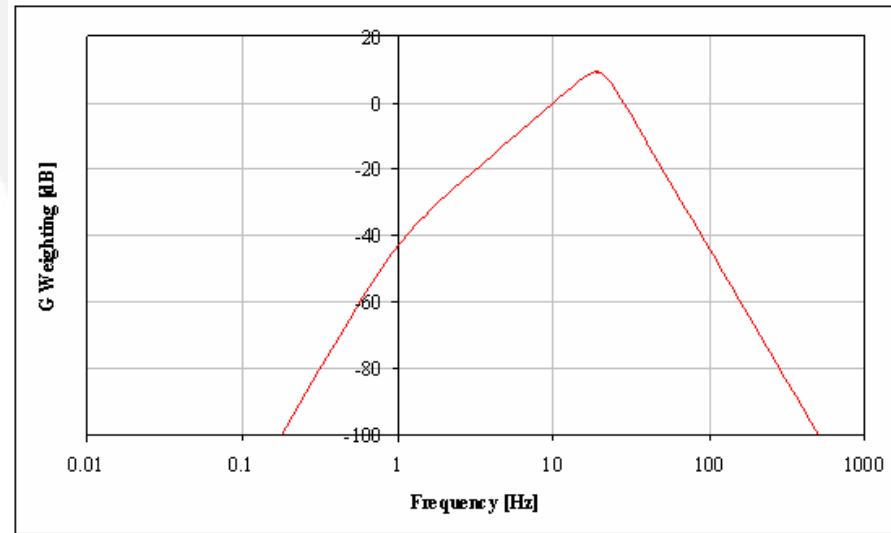
Specifically designed (decades ago)  
to protect the human hearing function.



# Other dB metrics



dBA - blue  
dBB - yellow  
dBC - red  
dBD - black

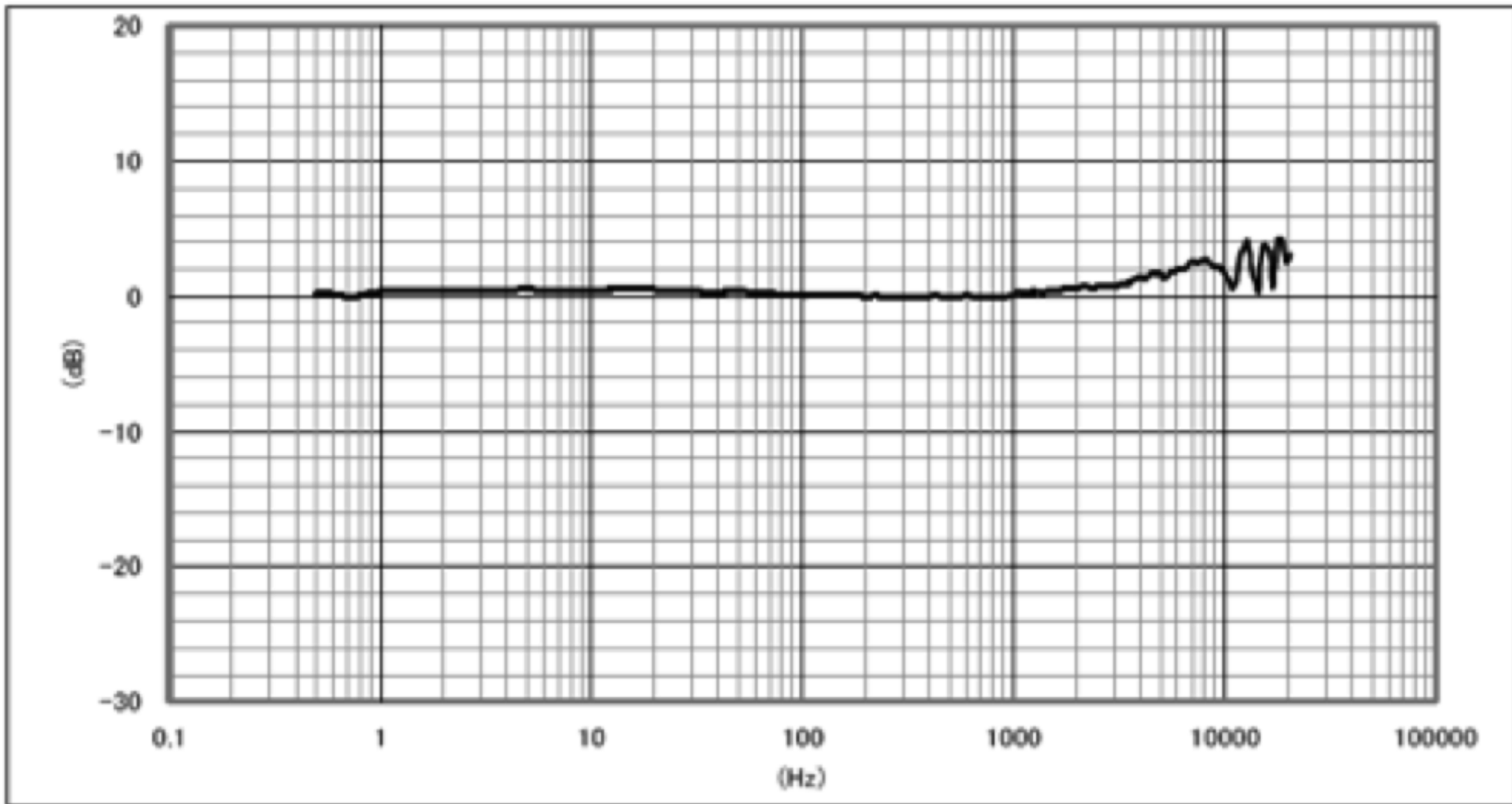


**dBG**

This team of scientists  
prefers **dB Linear**.

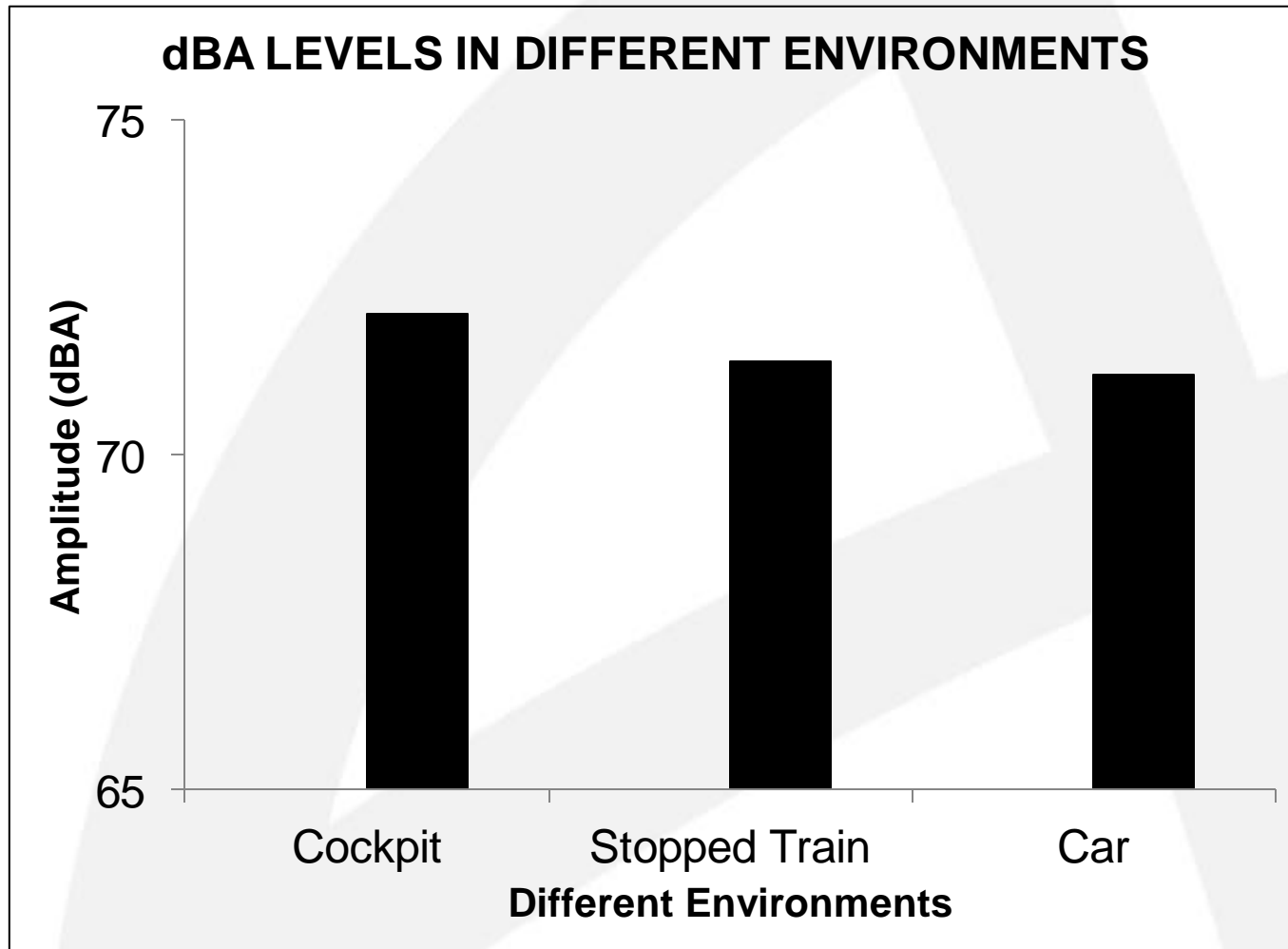
**NO weighting network!**

# Linear capture



Microphone frequency response curve,  
as used by this team.

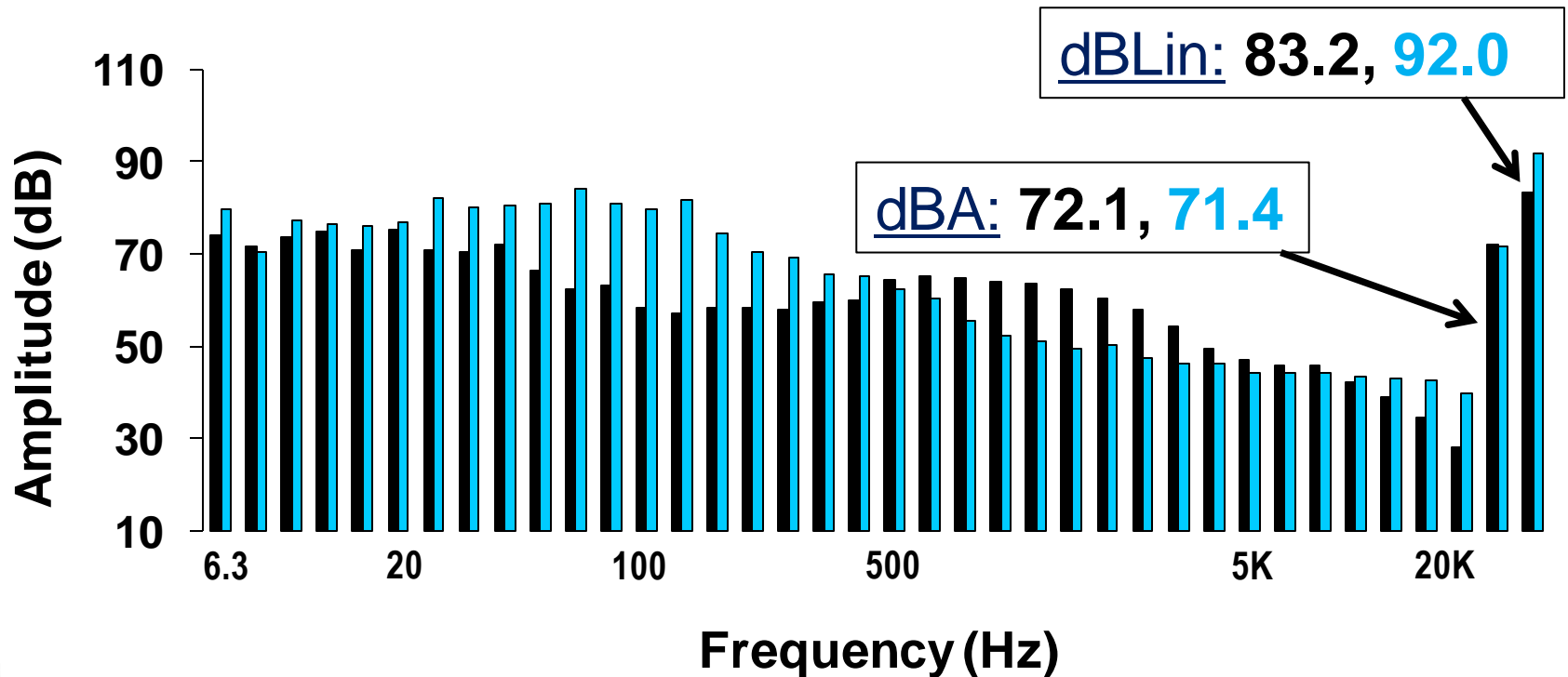
# dBA vs. dBLinear



- *Cockpit:*  
72.1 dBA
- *Train:*  
71.4 dBA
- *Car:*  
71.2 dBA

# Similar dBA, but not acoustically equivalent environments

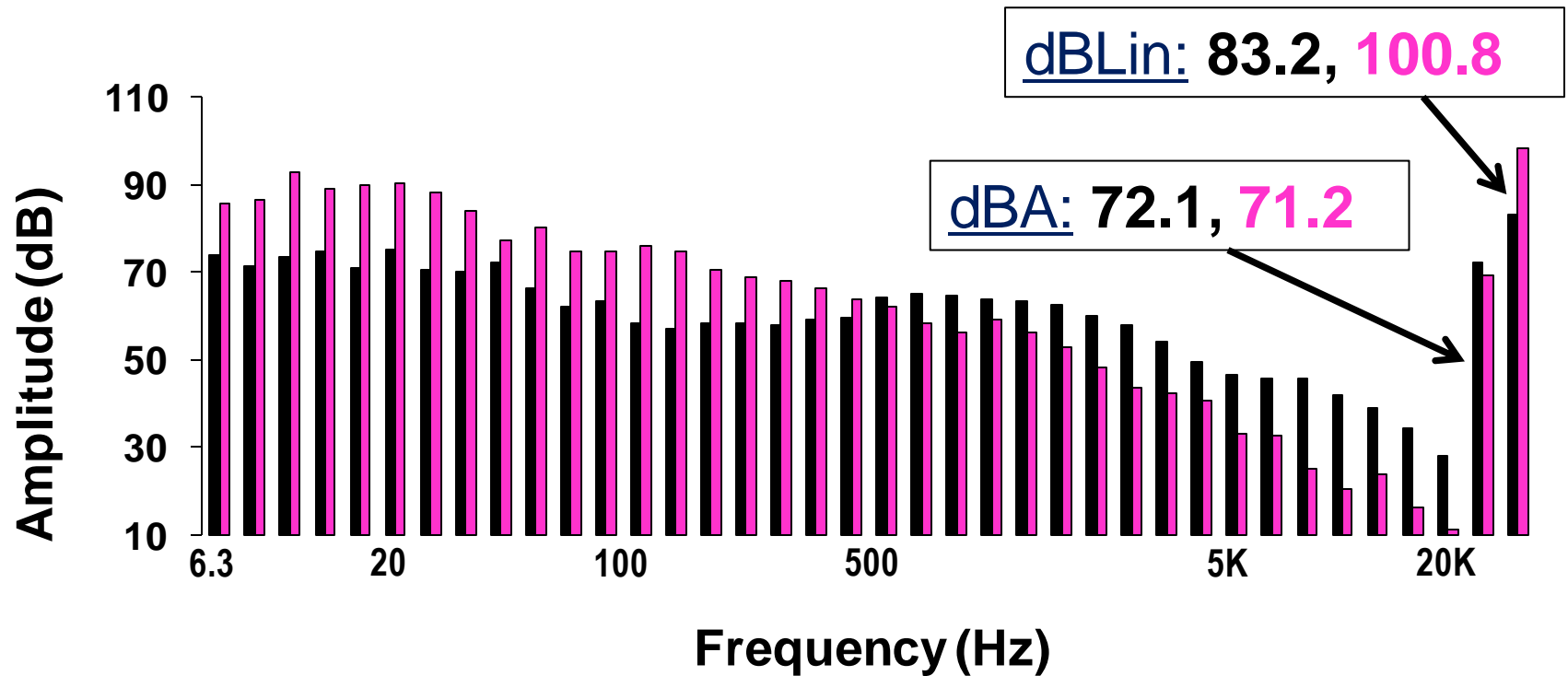
## Cockpit vs. Stopped Train



The person hears 72.1 in the cockpit and 71.4 on the stopped train.  
The person is exposed to 83.2 in the cockpit and 92.0 on the train.

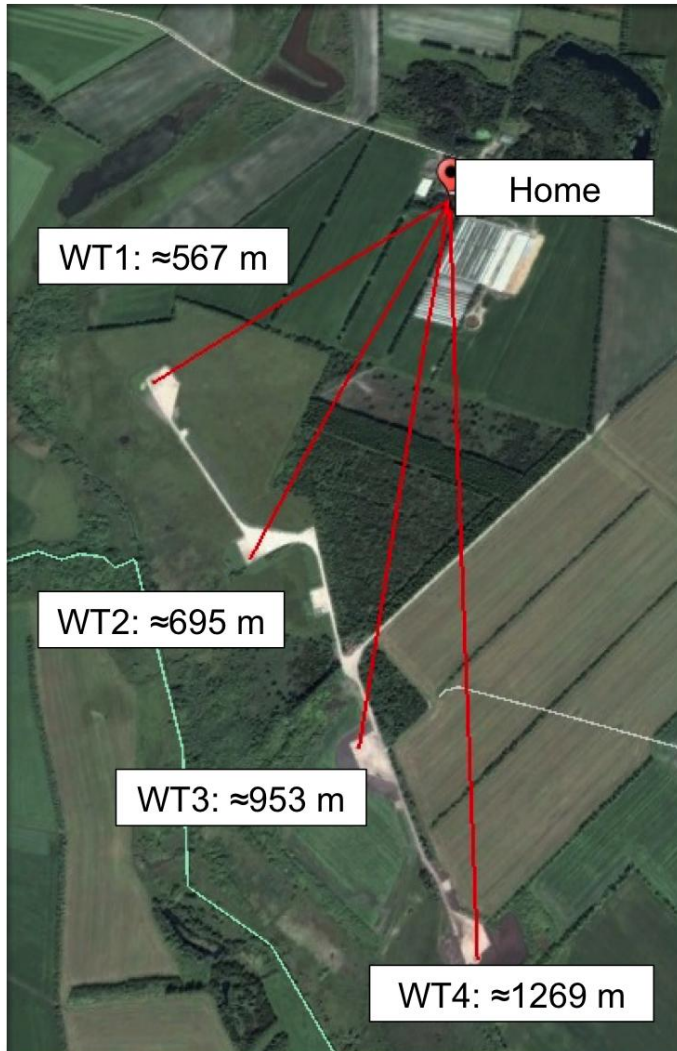
# Similar dBA, but not acoustically equivalent environments

## Cockpit vs. Car



The person hears 72.1 in the cockpit, and 71.2 in the car.  
The person is exposed to 83.2 in the cockpit, and to 100.8 the car.

# Mink Farm



3 MW, Total Height: 150 m



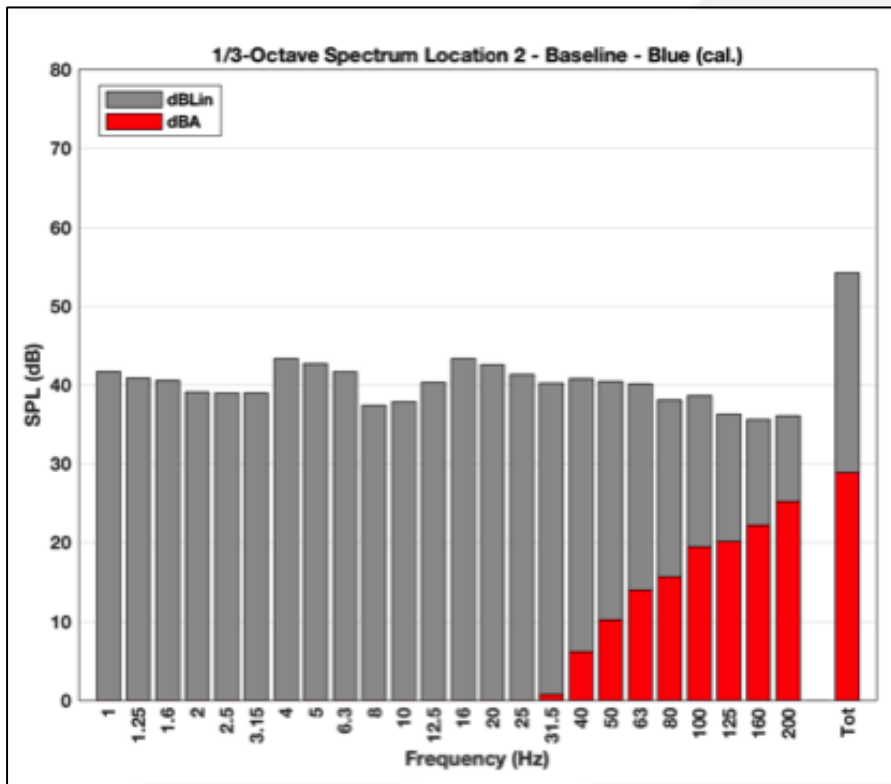
Location 1



Location 2



# Location 2



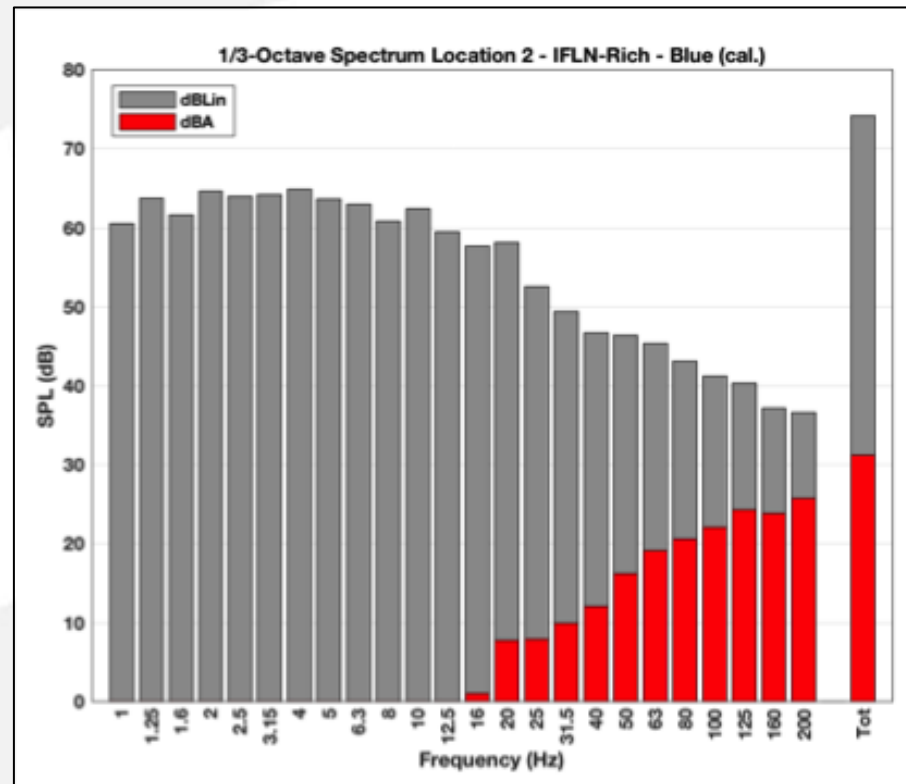
## No rotation of WTs

Windspeed: 0.5 – 1.5 m/s

Wind Direction: S SW

Temperature: 0-1 °C

Date: 16DEC16



## WTs rotating

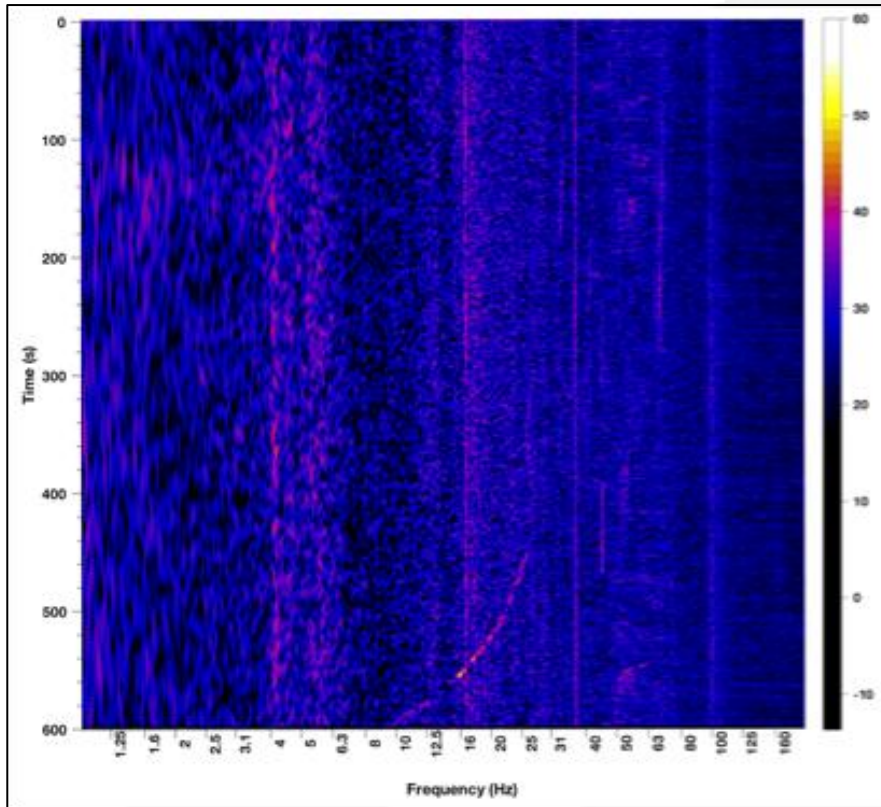
Windspeed: 4.0 – 6.5 m/s

Wind Direction: SW

Temperature: 6-8 °C

Date: 30DEC16

# Location 2



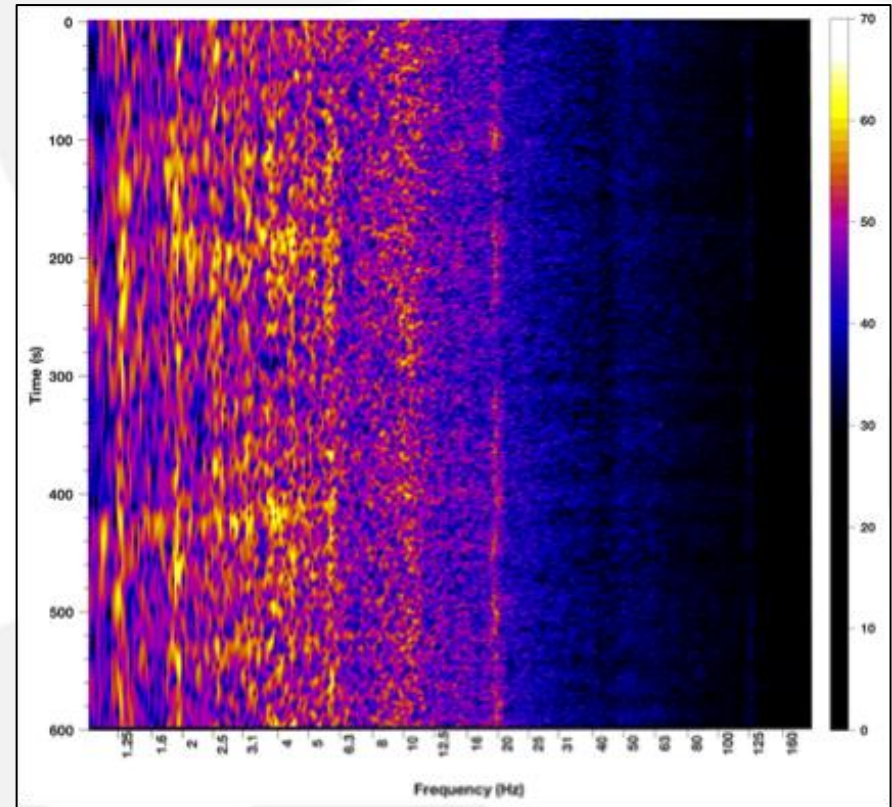
## No rotation of WTs

Windspeed: 0.5 – 1.5 m/s

Wind Direction: S SW

Temperature: 0-1 °C

Date & Time: 16DEC16



## WTs rotating

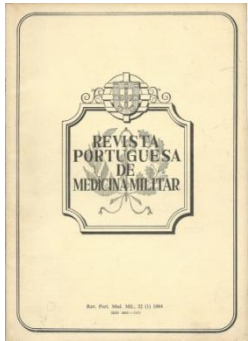
Windspeed: 4.0 – 6.5 m/s

Wind Direction: SW

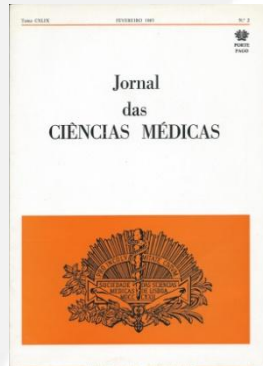
Temperature: 6-8 °C

Date & Time: 30DEC16

# Consequences of excessive infrasound and low frequency noise exposure: Vibroacoustic Disease (VAD)



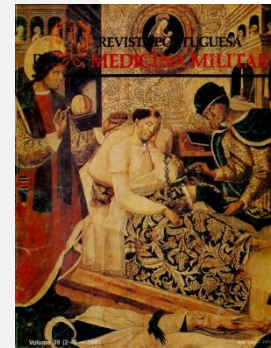
1984



1985



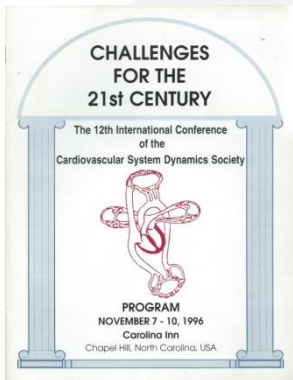
1989



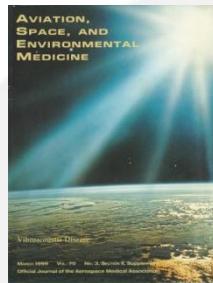
1991



1993



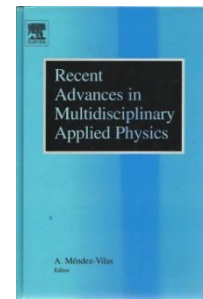
1996



1999



2003



2005



2007



2017

# 1980

## *Portuguese Air Force Aeronautical Plant*



- Dr. CB is chief medical officer
- Observation of automatism in worker
- Evaluation of cases of epilepsy
- 10% of aeronautical technicians already diagnosed with late-onset epilepsy

***Portuguese General Population: 0.2%***



# 1980-1986

## Neurological Changes

- Evoked Potentials: Measuring brain response time to a stimulus.
- Brain Mapping: Evaluates spatial distribution of brain potentials
- Brain MRI: Evaluates brain morphology and lesions
- Humor and Cognition: Increased aggressiveness, depression, memory and attention disorders

# 1987

## *Autopsy of Mr. Filipe Pedro*

- 2 tumors (kidney and brain)
- Scars from 11 prior, silent cardiac infarcts
- Cause of death: 12<sup>th</sup> small infarct (<2mm)
- Abnormal thickening of cardiovascular structures
- Pulmonary fibrosis

***Pathology not restricted to  
Central Nervous System !!***



# Respiratory Pathology in VAD

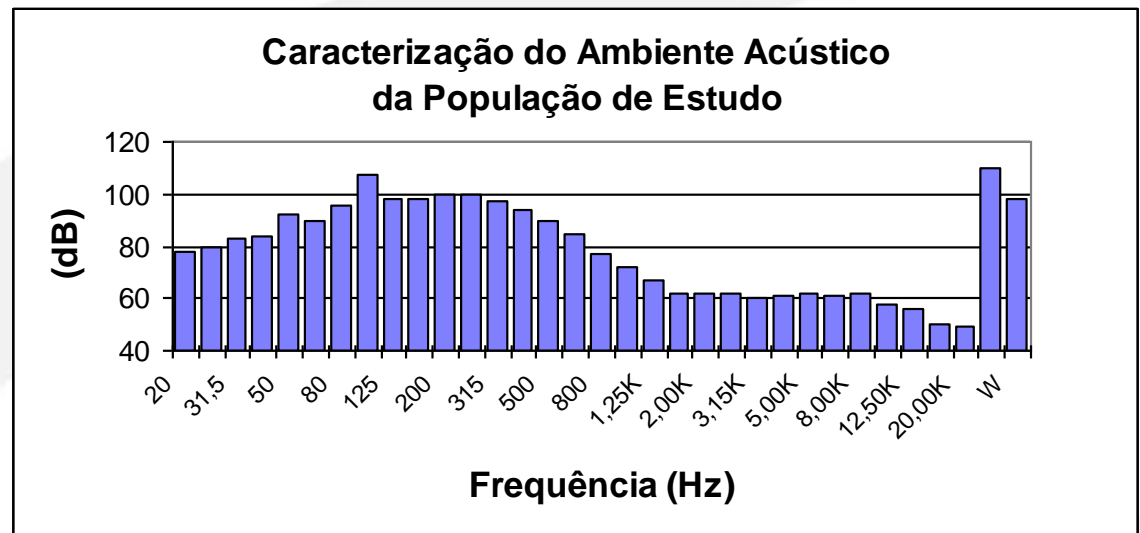
*In smokers and non-smokers alike:*

- Bronchitis
- Repeated Throat Infections
- Unexplained Hoarseness
- Dry Cough
- Unexplained Cases of Pleural Effusion

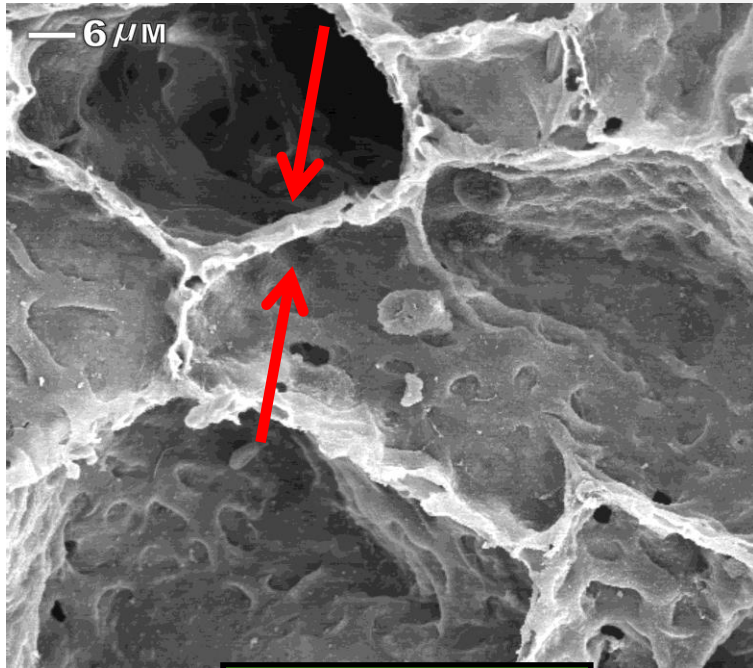
# 1992

## Begin using laboratory animal models

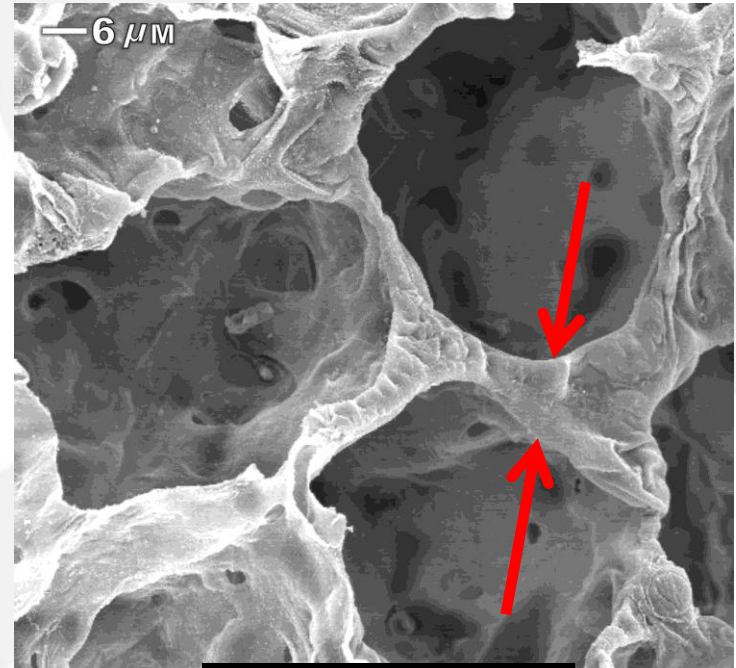
- Exposed to low frequency noise
- Occupationally-simulated schedule: 8 hrs/day, 5 days/week, weekends in silence



# Alveolar Wall Thickening



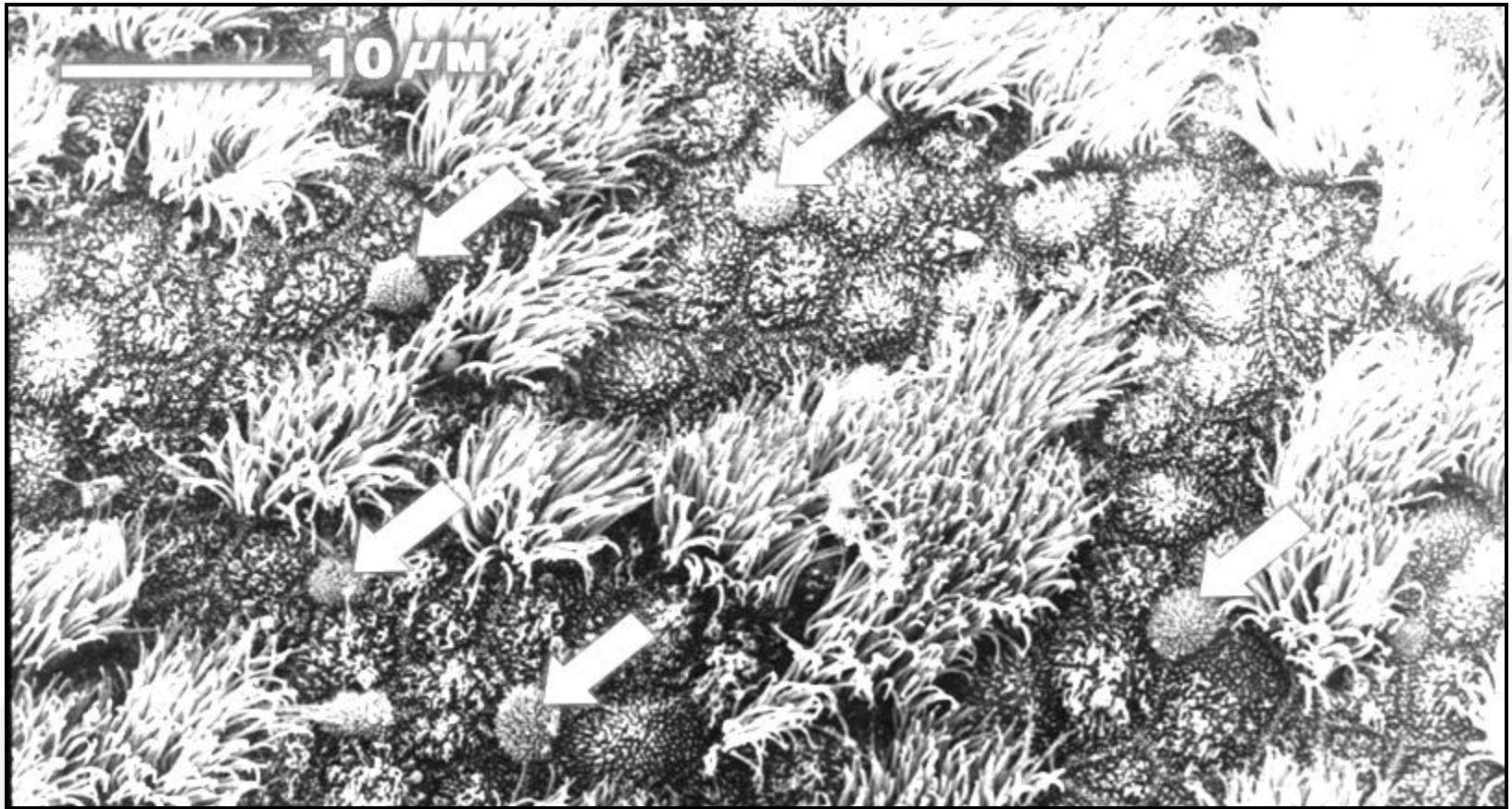
NORMAL



EXPOSED

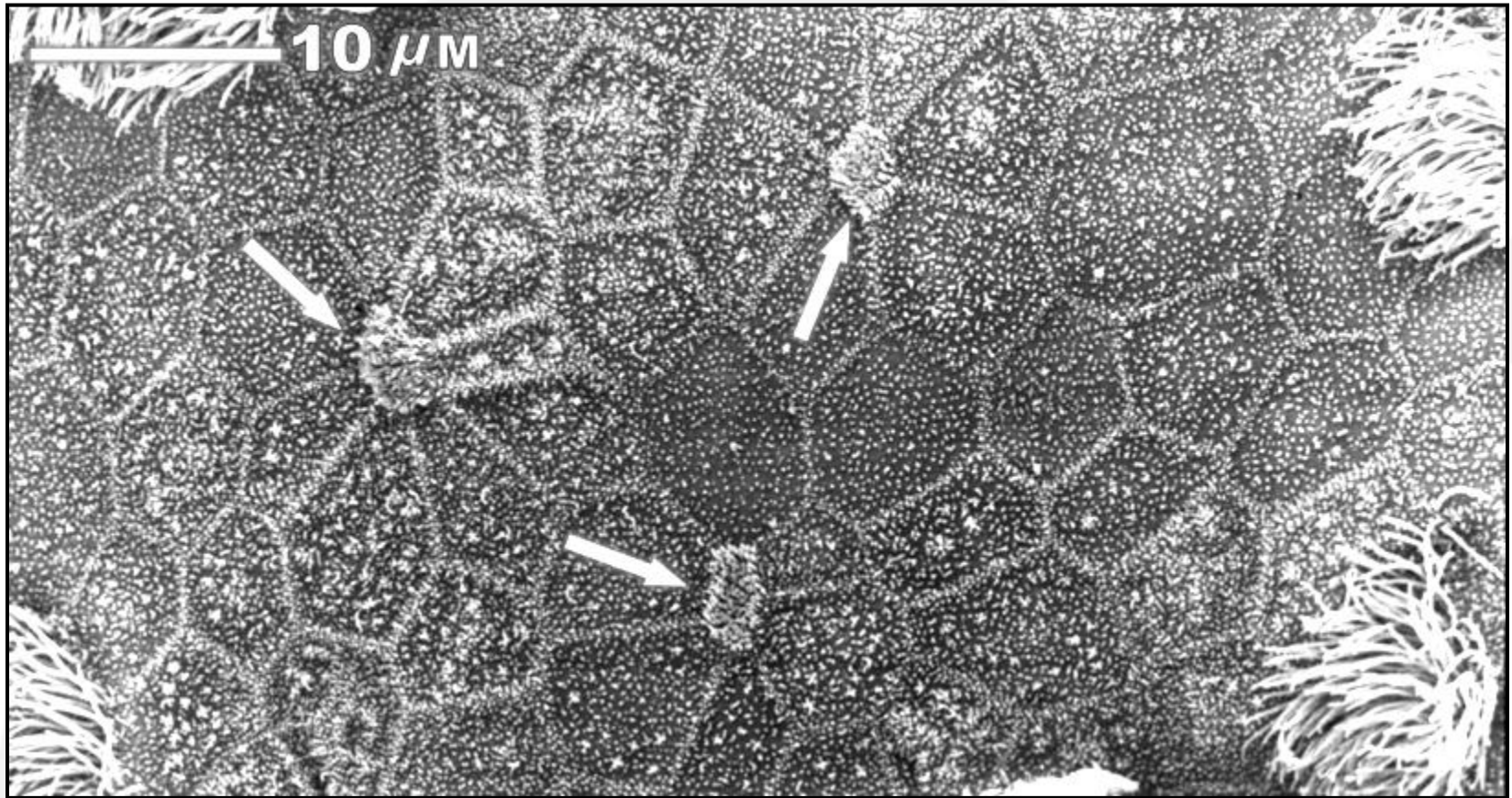
*The scale of these two micrographs is the same.*

# Normal Rat Trachea





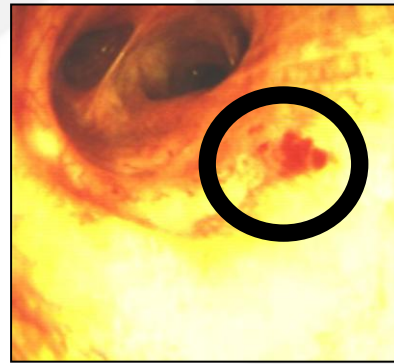
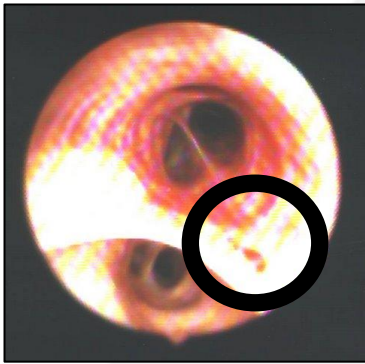
# Rat Trachea - 2213 hrs



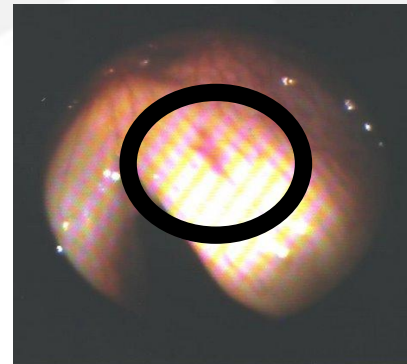
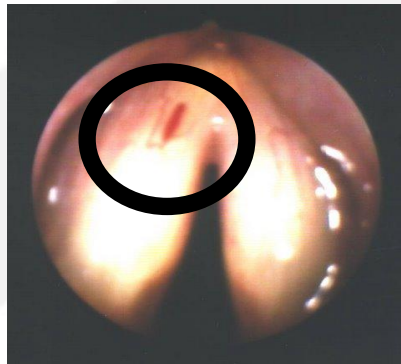
# Case of Environmental ILFN

*The Irish Lady and the Dublin Bus company*

**Bronchoscopy:** Appearance of “pink lesions”



**Voice Acoustic Analysis:** Fundamental frequency of three vowels significantly increases with increasing ILFN exposure time.

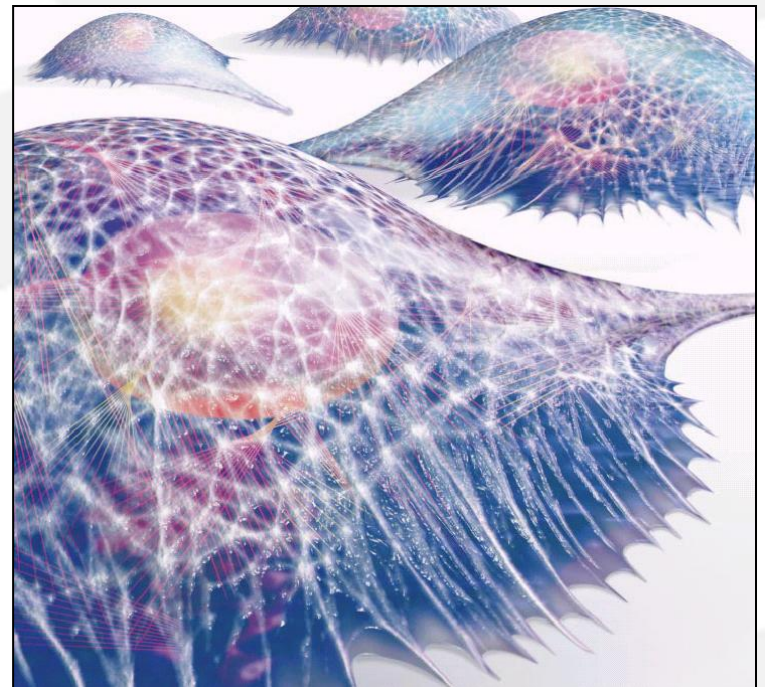
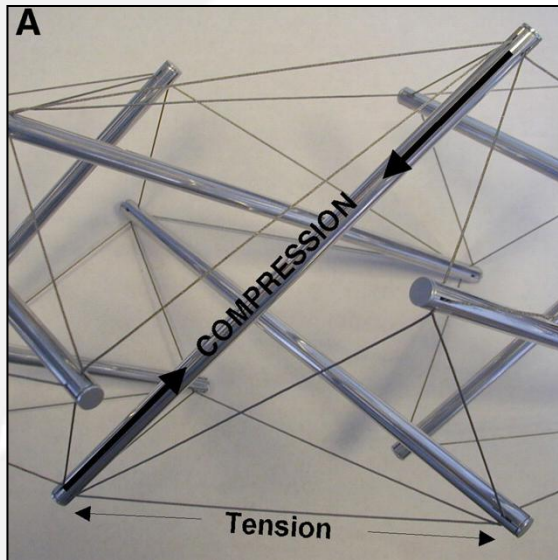
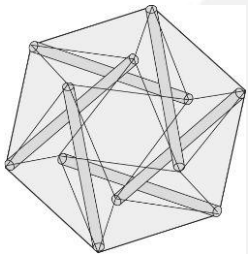
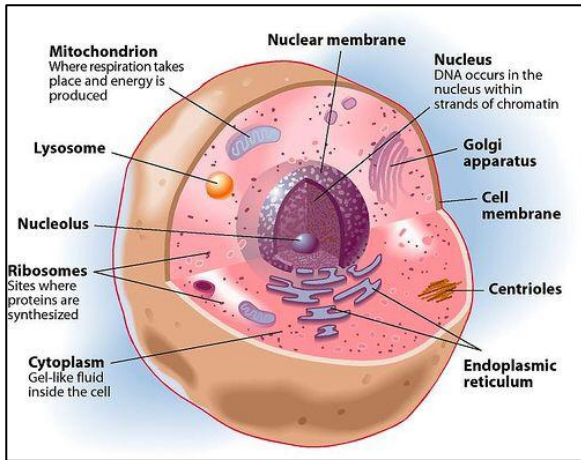




# Cell Biology

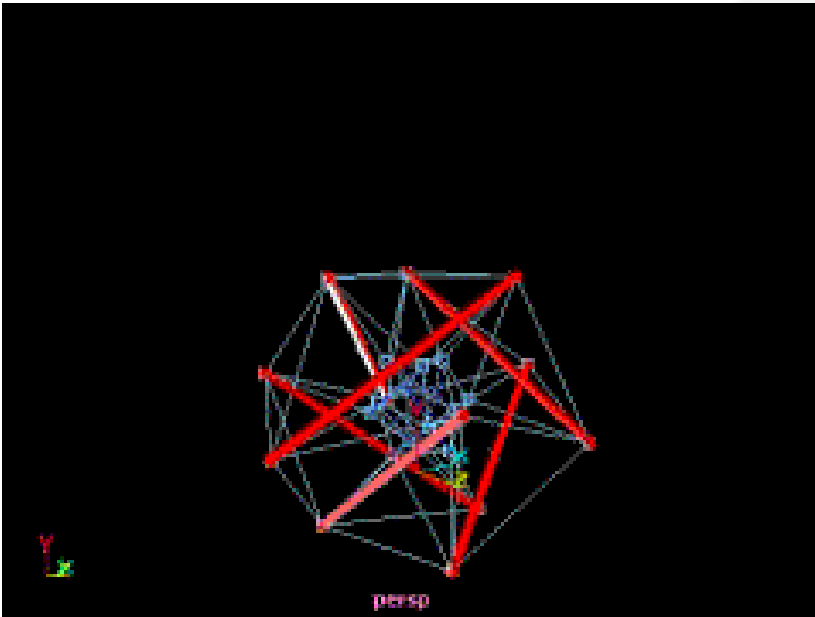
-- Cells are **not** like elastic balloons with floating organelles.

-- Cells communicate through biochemical and **mechanical signals**.



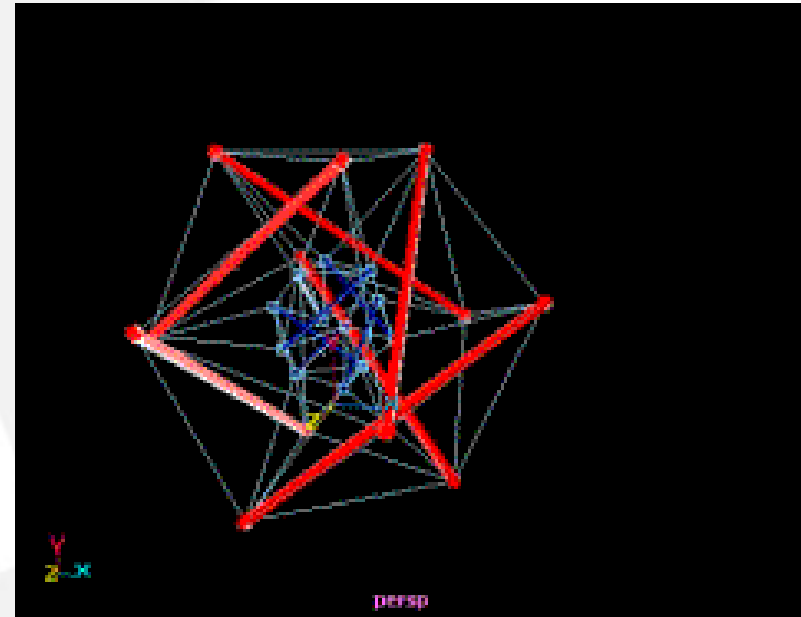
**Tensegrity:** Continuous Tension and Discontinuous Compression.

# Tensegrity Structures

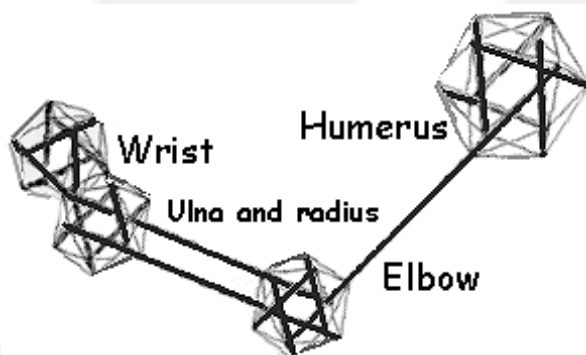


Ingber Lab  
Harvard U.

Cellular response to force  
along the vertical axis.

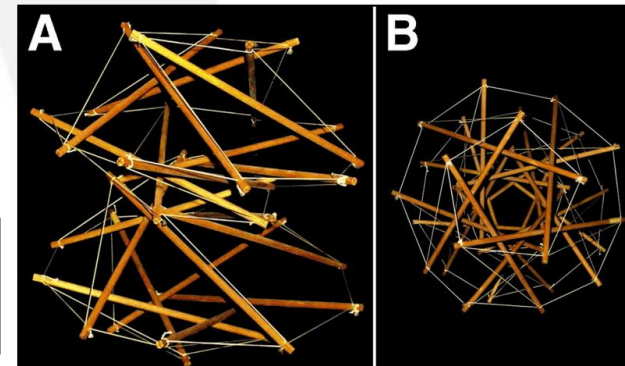


Cellular response to  
laminar flow.



*Human Arm*

*Tensegrity model of  
cellular membrane pore*



# ILFN effects on hearing

- **ILFN-Exposed People:**

- Cannot stand any noise -- Say: “I hear too much” --
- Lower TV volume to where others cannot hear it -- Rage reactions -- Audiograms show losses at 250 Hz and 500 Hz

- **ILFN-Exposed Rats:**

Control rats respond to the sound of a blown kiss by becoming tense and frozen, while ILFN-exposed rats would develop a seizure-like episode, falling backwards while shaking.

## **VAD TEAM:**

- Considers noise annoyance a **SUBJECTIVE PARAMETER;**
- In the presence of a “noise annoyed person”, prior noise exposure is suspected, and **OBJECTIVE MEDICAL TESTS** are provided.

# Clinical Stages of Vibroacoustic Disease for Occupational Exposures (1999)

## MILD

*1-4 years of ILFN exposure*

Slight mood swings, indigestion & heartburn, repeated mouth & throat infections, bronchitis.

## MODERATE

*4-10 years of ILFN exposure*

Chest pain, back pain, fatigue, fungal & viral skin infections, allergies, blood in urine, inflammation of stomach lining.

## SEVERE

*> 10 years of ILFN exposure*

Psychiatric disturbances, headaches, hemorrhages of nasal & digestive mucosa, duodenal ulcers, spastic colitis, varicose veins & hemorrhoids, decreased vision, severe joint pain, severe muscular pain, neurological disturbances.

# Occupational vs Environmental

## VAD Researchers' Experience:

- In-home ILFN levels have been *much lower* than within the occupational environments studied by VAD researchers.
- In-home time exposure patterns are different from occupational time exposure patterns: people *sleep* in ILFN-rich home environments.
- People most annoyed with in-home ILFN already have *non-trivial noise exposure histories* (fetal, childhood, leisure, previous or present occupations).
- The *work-at-home person* is more sensitive to in-home ILFN than other members of the family, unless these other members have additional ILFN exposure histories.

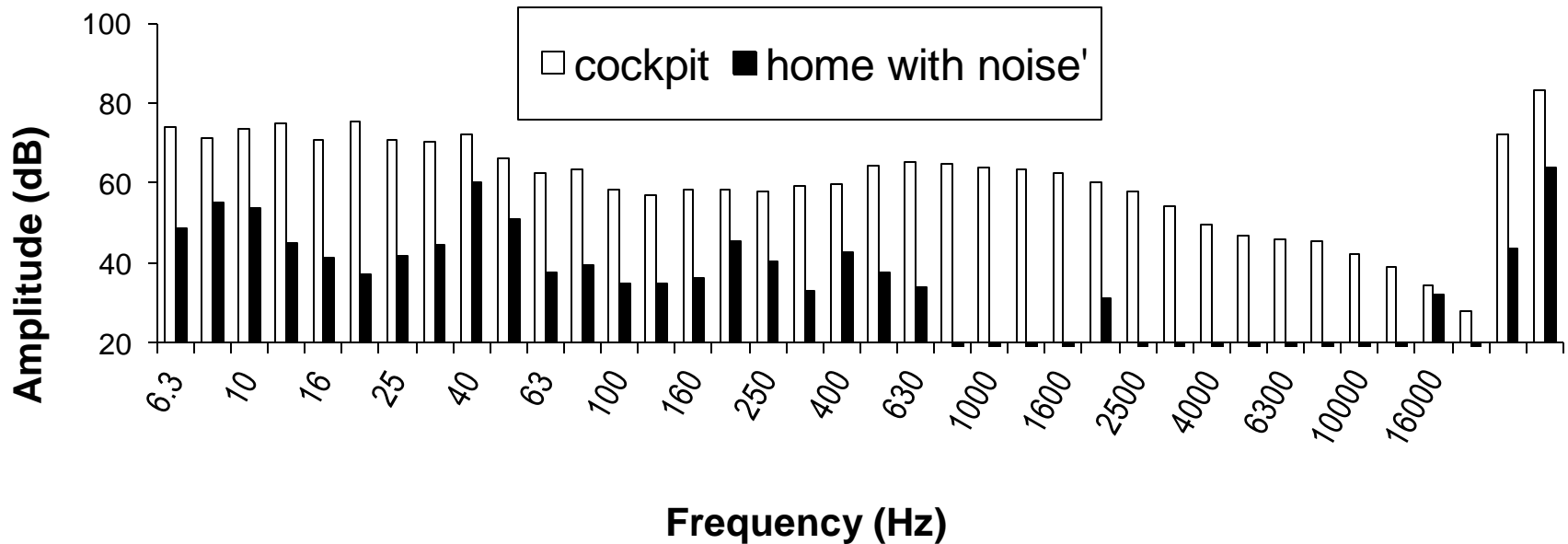


# Cases of Environmental ILFN

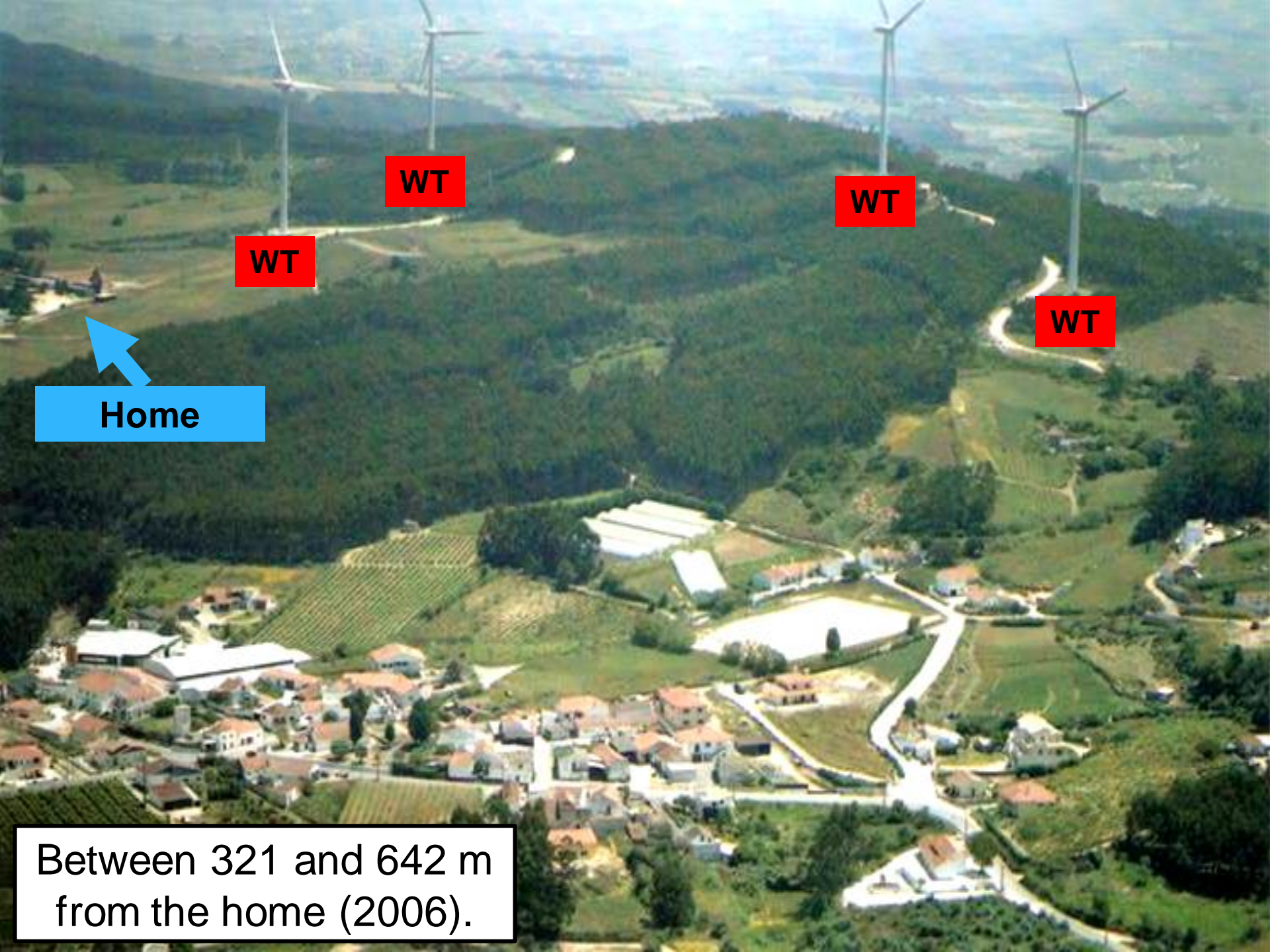
(2004)



## Cockpit vs. Restelo Home With Noise







WT

WT

WT

WT

Home

Between 321 and 642 m  
from the home (2006).

# November 2006

- Four 2-MW wind turbines (WT) began operation.
- Located between 321 m and 642 m.
- Family seeks legal advice.



2 adults.

2 children.

Farm for breeding:

-- bulls for bullfights,

-- thoroughbred

Lusitanian horses.

# March 2007

## Letter from school-teacher:

*“... it seems that [the child] has lost interest, makes a lesser effort, as if he were permanently tired. In Physical Education, an abnormal amount of tiredness is also observed. Is [the child] leading a healthy life? Does he sleep sufficient hours during the night?”*

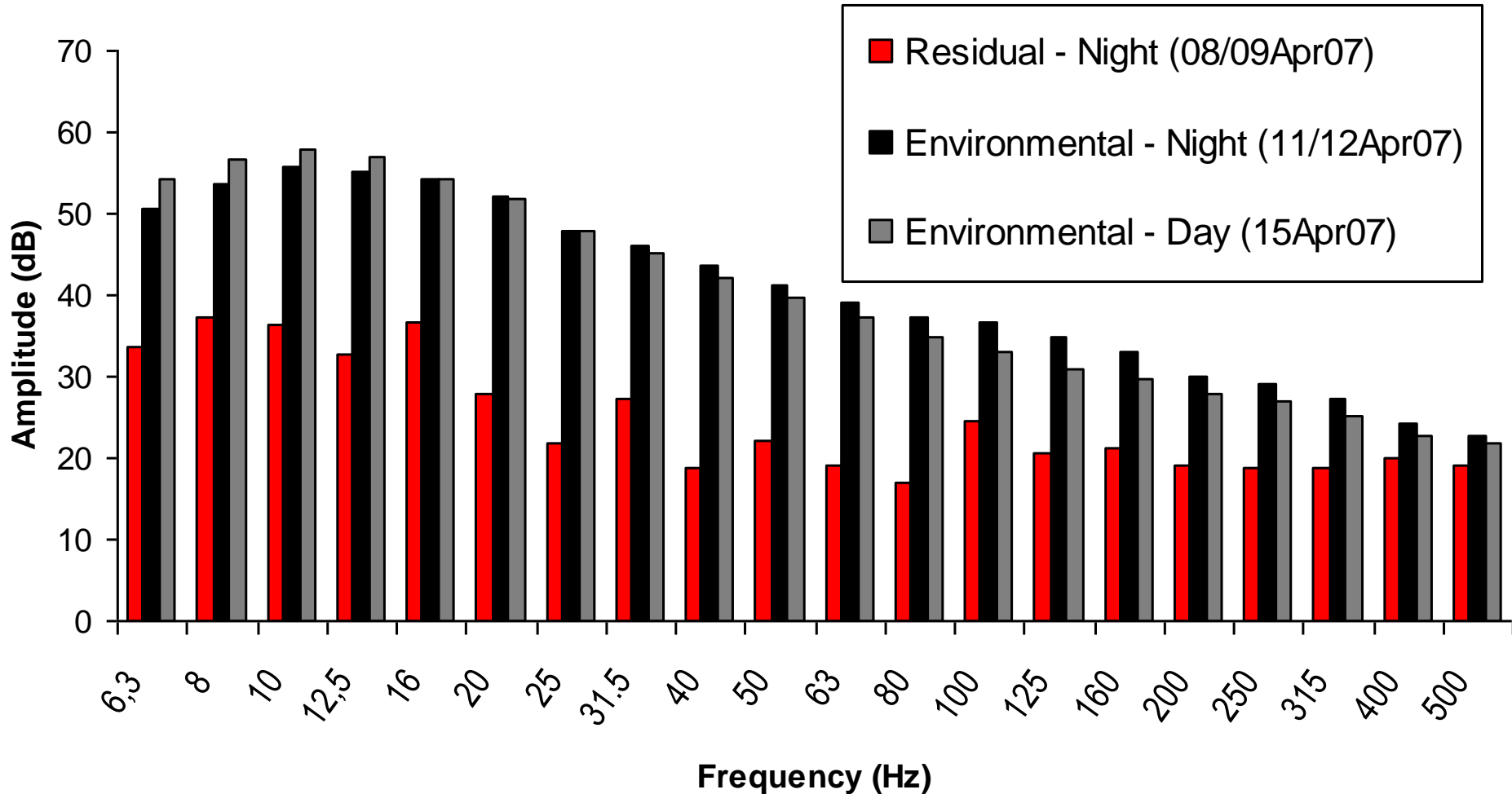
## VAD TEAM is contacted by “Family R.”:

*“... Inability to obtain restful sleep, increased irritability ... Odd behavior of dogs, horses and ants ... like an airplane flyover that never ends...”*

# In the Master Bedroom

(2007)

Wind Turbine Home With Same Wind Speed (5.4 Km/h)





# Clinical Evaluation

## P300 event related potentials in child

Jun 2007: **352 ms**

Sep 2007:  
(after 2 mo. Holiday)

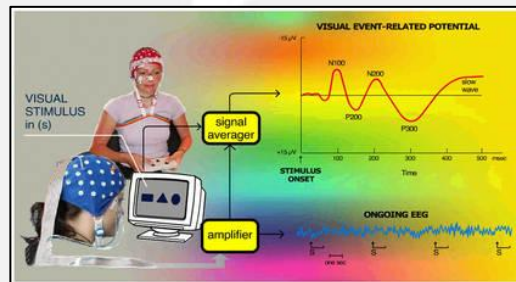
**322 ms**

(norm: **300 ms**)

## PCO<sub>2</sub> respiratory drive

39-year-old father: **46%**

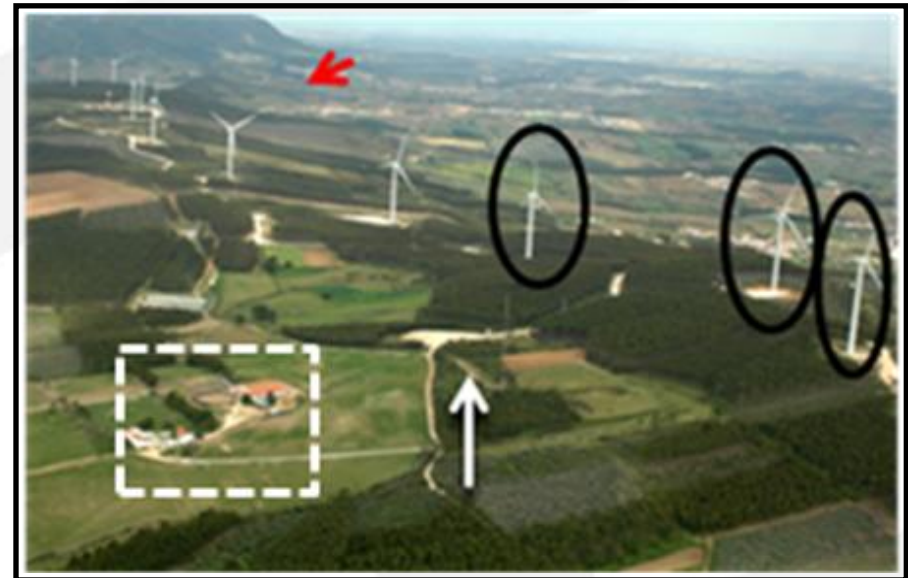
42-year-old mother:  
**53%**(norm: **>60%**)





# Legal Proceedings - 2007

- WT No. 2, closest to home, at 322 m was ordered shut down.
- All other (3) WTs were ordered to be shut down during the evening (8-11 pm) and night hours (11 pm – 7 am).
- Meanwhile, the installation of WT continued in the contiguous vicinity of the R family home.

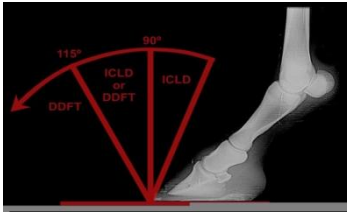


# Situation in 2010



- Child has normal P300 values.
- Mrs. R and the children have moved out of the home.
- Mr. R. must stay to care for Lusitanian horses.
- Mr. R's health is visibly deteriorating, with increased cognitive impairment and severe noise intolerance.
- Between 2000 and 2006, 13 healthy thoroughbred Lusitanian horses were born and raised on Mr. R's property.
- Horses raised after 2007 developed asymmetric *equine flexural limb deformities* (EFLD).
- Four were studied plus 1 control.

# EFLD Study



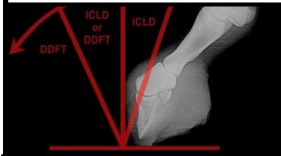
**Normal forelimb:**  
Hoof wall-to-floor angle  $>115^\circ$



**Espartaco – Case 4**  
Born: 02May09 and raised on R's Farm.

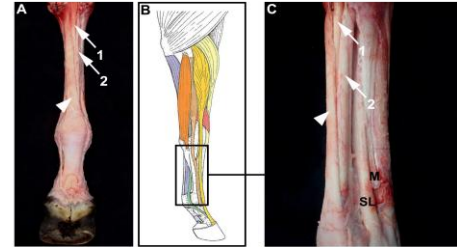


**Engenheiro – Case 5**  
Born: 17May09 and raised on R's Farm.



**EFLD forelimb:**  
Angle  $<115^\circ$

## Corrective Surgery:



During corrective surgery, fragments were removed for histological analyses. Results were the same as those from ILFN-exposed humans and animal models:

**Thickened vascular structures due to abnormal growth of collagen in the absence of an inflammatory process.**

# Limb Deformities



VAD Team  
Laboratory  
Rat exposed  
*in utero*



Chicken exposed to Infrasound  
and Low Frequency noise  
generated by coal mining  
operations before hatching

Wind Turbine Home Horses





# Today

## **May 2013-- Supreme Court of Justice Decision:**

All 4 WT must be permanently removed;  
Increased monetary compensation.

## **Living arrangements:**

Mrs. R & children still live in separate home.

## **Mr. R's health:**

-- PCO<sub>2</sub> value at **28%**

(norm: > 60%; 46% in 2007)

-- Balance disturbances with loss of consciousness, apparently causing falls leading to facial and rib fractures. Suspected late-onset epilepsy.

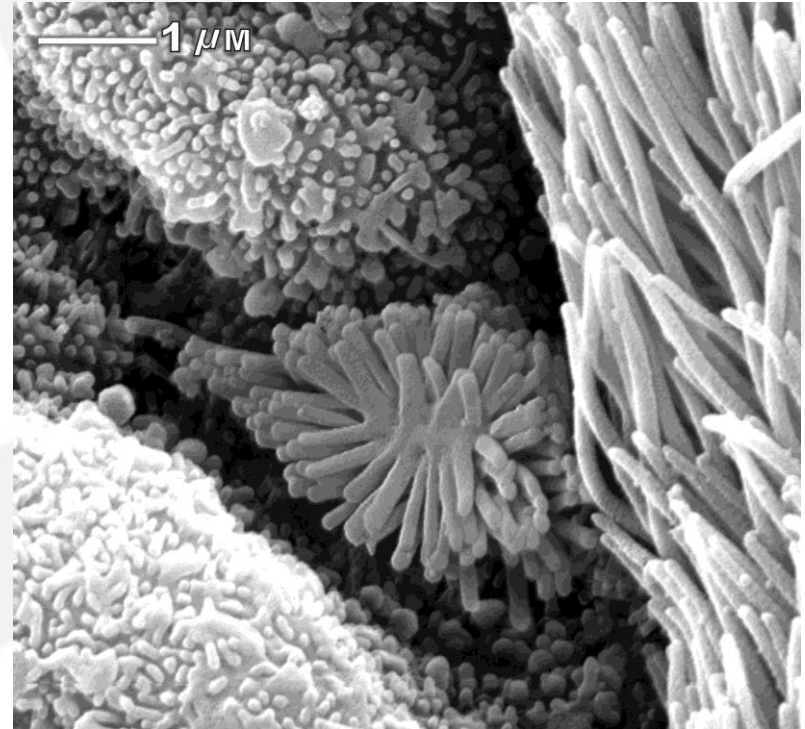


**Thank you for your attention!**

*m.alvespereira@gmail.com*



Succulent plant exposed to Northern winds on Madeira Island – North Atlantic Ocean.



Bronchial brush cell of Rat exposed to infrasound and low frequency noise.