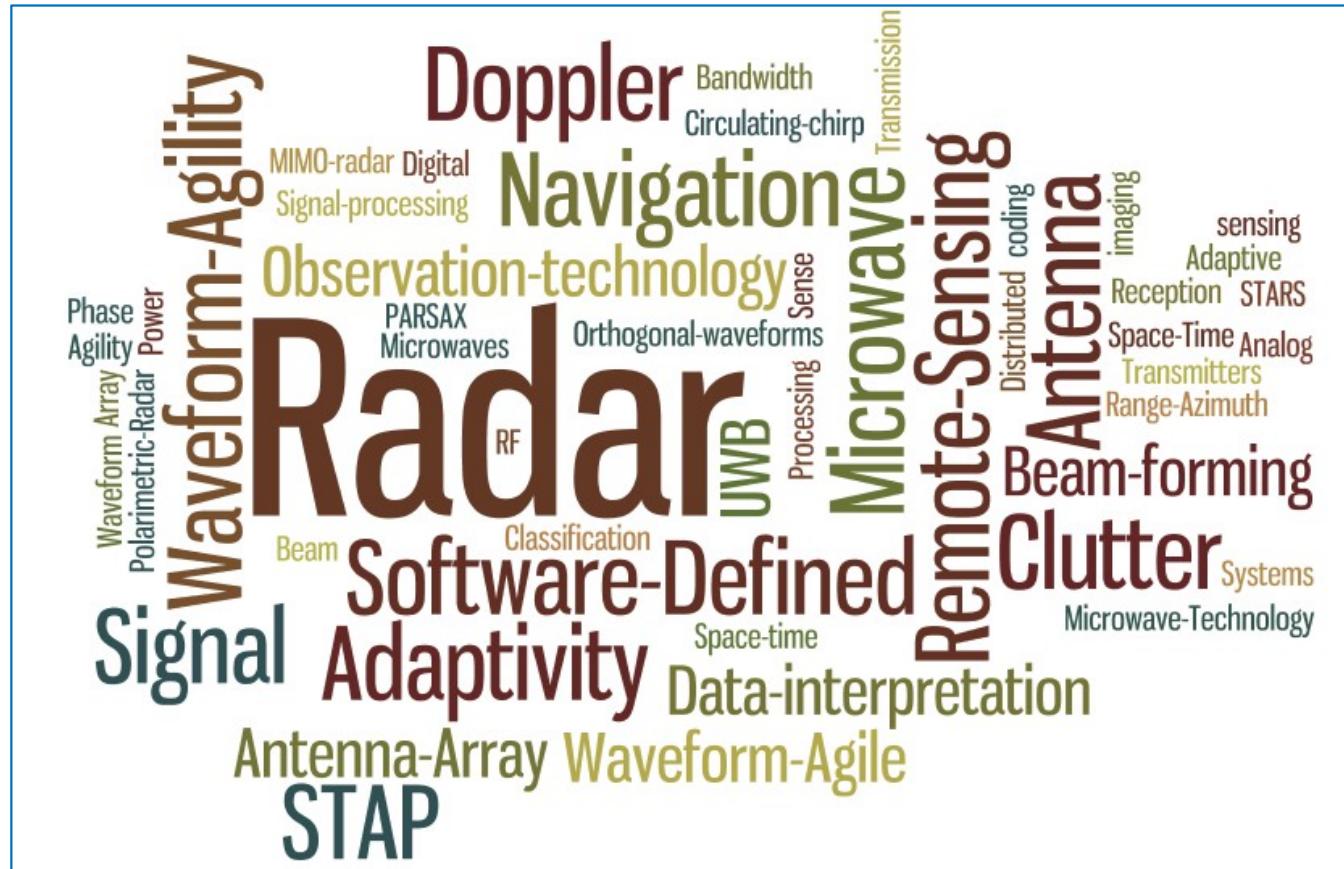# MS3 Group - Microwave Sensing Signals & Systems

# One step back, who are we?

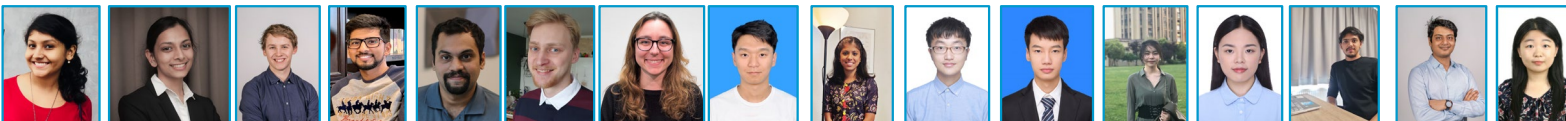One of the Groups at the Microelectronics Department of TU Delft (-> *radar.tudelft.nl*).

Academic staff

Postdocs & PhD candidates
(including industrial PhDs)
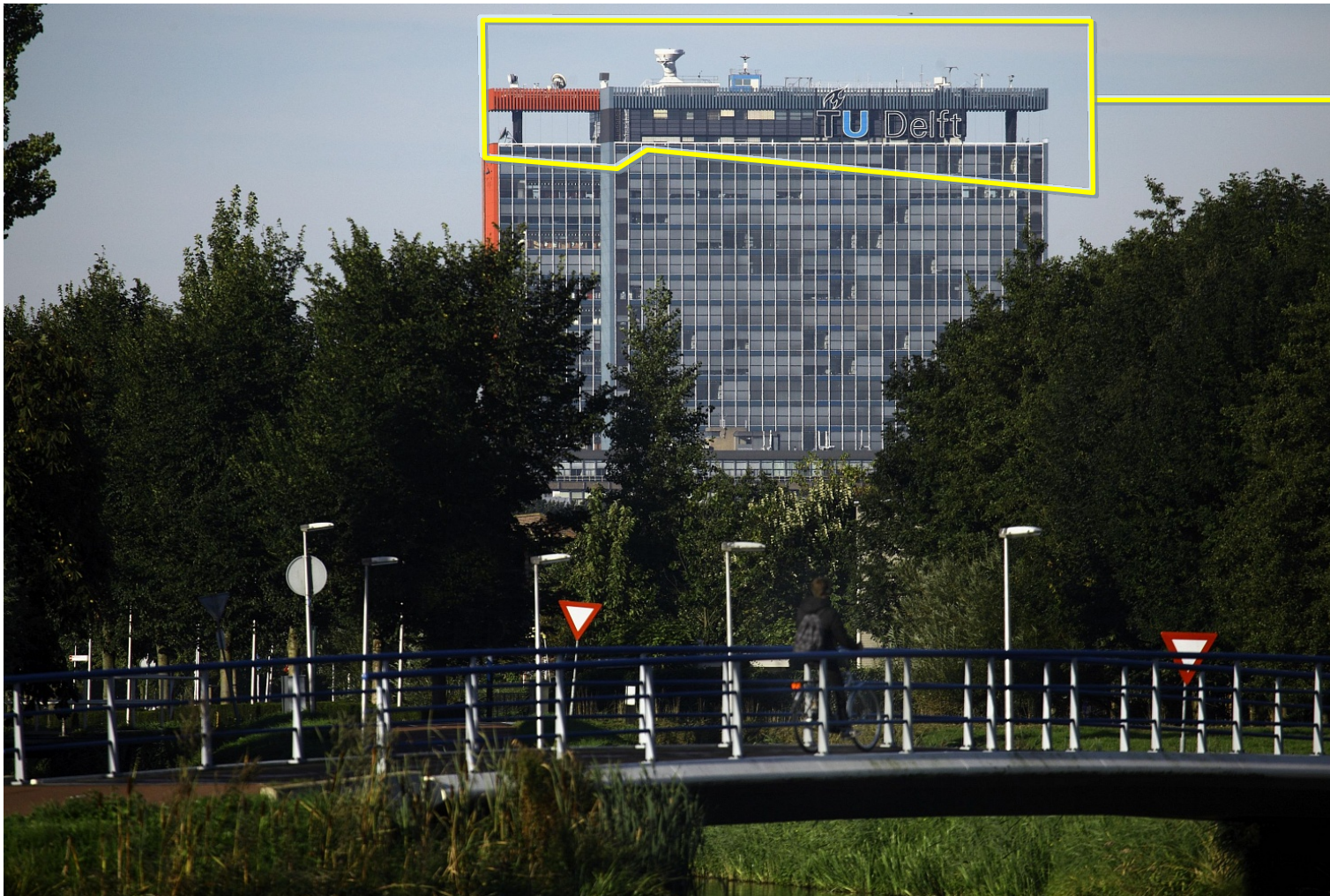
Supporting/technical staff
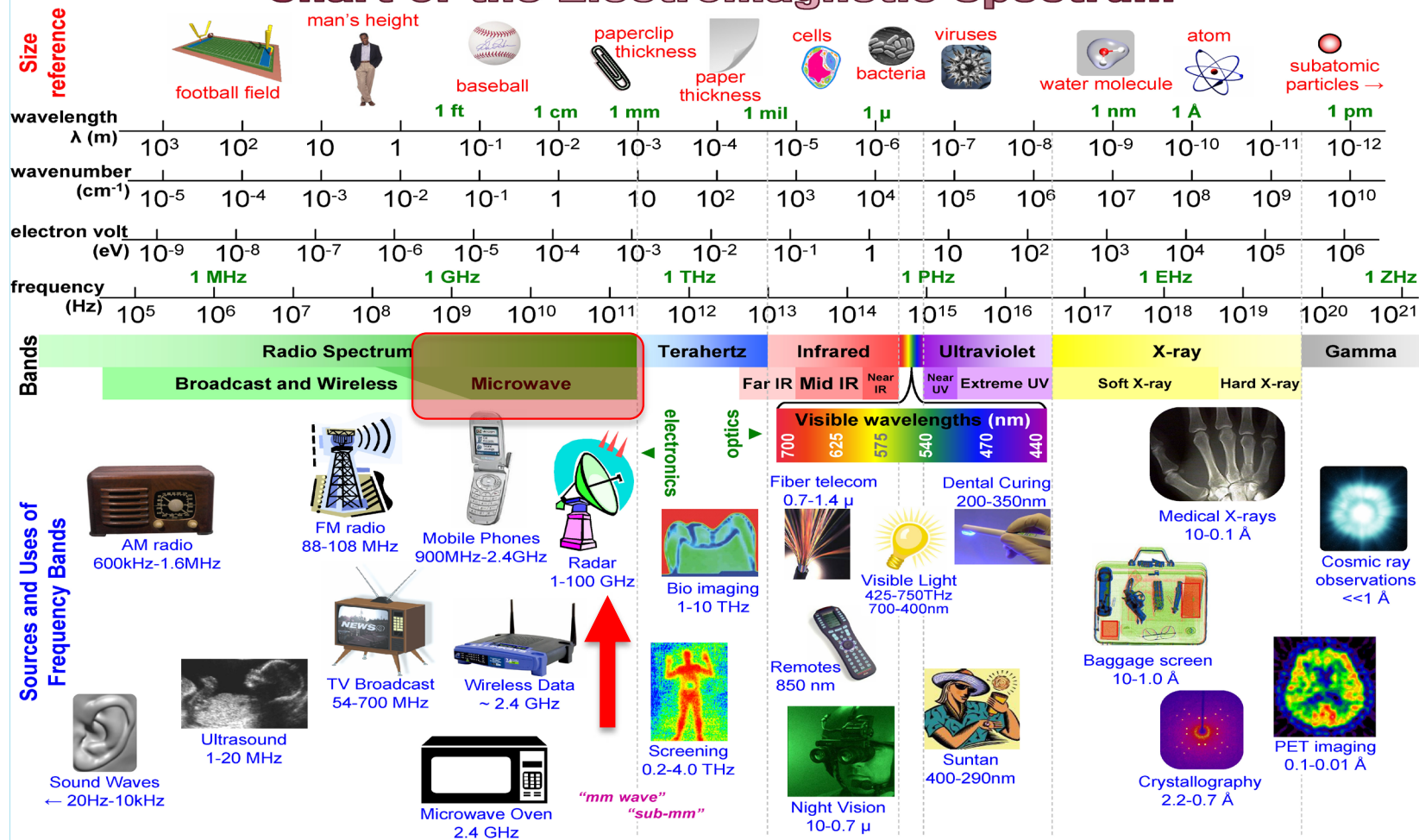
Last year Master students

# Where are we?



MS3

EWI building

21 - 22 Floors + Roof



*Visits to the facilities (+roof view) can be arranged…*

3

# Electromagnetic Waves



## Chart of the Electromagnetic Spectrum

**Size reference**

man's height — football field — baseball — paperclip thickness — paper thickness — cells — bacteria — viruses — water molecule — atom — subatomic particles →

| wavelength λ (m) | $10^3$ | $10^2$ | 10 | 1 | $10^{-1}$ | $10^{-2}$ | $10^{-3}$ | $10^{-4}$ | $10^{-5}$ | $10^{-6}$ | $10^{-7}$ | $10^{-8}$ | $10^{-9}$ | $10^{-10}$ | $10^{-11}$ | $10^{-12}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

1 ft — 1 cm — 1 mm — 1 mil — 1 μ — 1 nm — 1 Å — 1 pm

| wavenumber (cm⁻¹) | $10^{-5}$ | $10^{-4}$ | $10^{-3}$ | $10^{-2}$ | $10^{-1}$ | 1 | 10 | $10^2$ | $10^3$ | $10^4$ | $10^5$ | $10^6$ | $10^7$ | $10^8$ | $10^9$ | $10^{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

| electron volt (eV) | $10^{-9}$ | $10^{-8}$ | $10^{-7}$ | $10^{-6}$ | $10^{-5}$ | $10^{-4}$ | $10^{-3}$ | $10^{-2}$ | $10^{-1}$ | 1 | 10 | $10^2$ | $10^3$ | $10^4$ | $10^5$ | $10^6$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

1 MHz — 1 GHz — 1 THz — 1 PHz — 1 EHz — 1 ZHz

| frequency (Hz) | $10^5$ | $10^6$ | $10^7$ | $10^8$ | $10^9$ | $10^{10}$ | $10^{11}$ | $10^{12}$ | $10^{13}$ | $10^{14}$ | $10^{15}$ | $10^{16}$ | $10^{17}$ | $10^{18}$ | $10^{19}$ | $10^{20}$ | $10^{21}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

**Bands**

Radio Spectrum — Terahertz — Infrared — Ultraviolet — X-ray — Gamma

Broadcast and Wireless — Microwave

Far IR — Mid IR — Near IR — Near UV — Extreme UV — Soft X-ray — Hard X-ray

electronics — optics

### Visible wavelengths (nm)
700 — 625 — 575 — 540 — 470 — 440

**Sources and Uses of Frequency Bands**

AM radio 600kHz-1.6MHz

FM radio 88-108 MHz

Mobile Phones 900MHz-2.4GHz

Radar 1-100 GHz

Fiber telecom 0.7-1.4 μ

Dental Curing 200-350nm

Medical X-rays 10-0.1 Å

Cosmic ray observations <<1 Å

Bio imaging 1-10 THz

Visible Light 425-750THz 700-400nm

TV Broadcast 54-700 MHz

Wireless Data ~ 2.4 GHz

Remotes 850 nm

Baggage screen 10-1.0 Å

Ultrasound 1-20 MHz

Screening 0.2-4.0 THz

Suntan 400-290nm

PET imaging 0.1-0.01 Å

Sound Waves ← 20Hz-10kHz

Microwave Oven 2.4 GHz

"mm wave" "sub-mm"

Night Vision 10-0.7 μ

Crystallography 2.2-0.7 Å

$$\lambda = 3\times10^8/freq = 1/(wn*100) = 1.24\times10^{-6}/eV$$

SURA Southeastern Universities Research Association ®

We work on **EM waves & radar systems** to sense the environment in many applications

MS³ Microwave Sensing Signals & Systems

**TU**Delft

# What is radar?

RADAR = *Radio Detection & Ranging*
Easy principle: send EM waves; they bounce on targets; you receive and process them
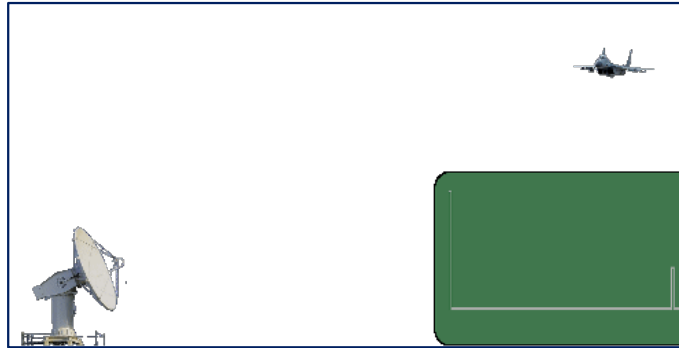
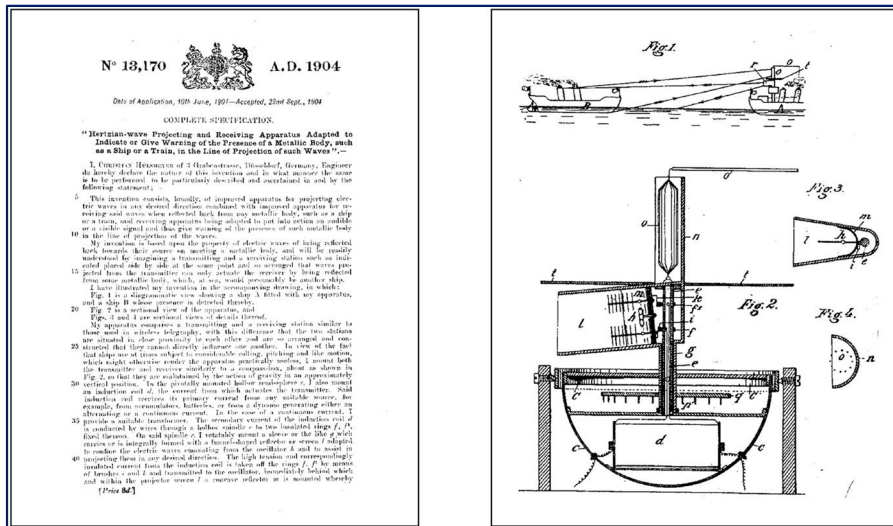*Courtesy of ww.radartutorial.eu*

Nature has known this "trick" since millennia of evolution, but using acoustic waves rather than EM waves

# What is radar?

Men arrived a little bit later, with the first demonstrator of radar technology in 1904
Invented and patented by the German Christian Hülsmeyer (*Telemobiloskop*)



**He was just 22 years old at the time of his invention** *(~your age?!)*

He had his 1st patent rejected in 1903. Continued to work on it and had a public demonstration in 1904 on the river of the Rhine in Köln (see the IEEE Milestone Plaque above).

More on: H. Griffiths, P. Knott, W. Koch, "Christian Hülsmeyer: Invention and Demonstration of Radar, 1904", IEEE AES Magazine Sep 2019, https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8826668

# What about radar today?



Synergy with many current technology trends!

Radar systems to become:
- **more intelligent** (with novel Artificial Intelligence, Machine Learning & Signal Processing);

- simultaneously operating **multiple beams;**

- **more compact and efficient** (with progress in Electronics and its components & sub-systems)

- capable to work in **new spectral regions** ("THz gap"), previously underexplored
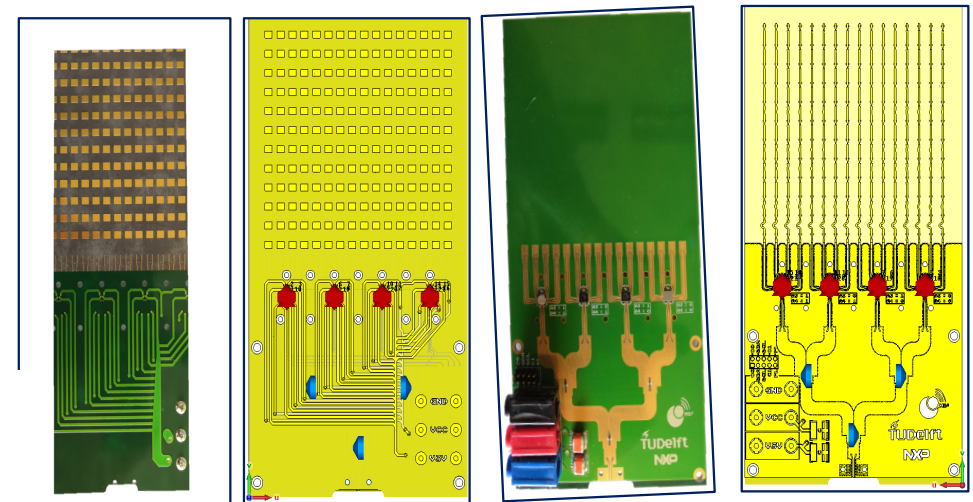
*So, what do we do here at MS3 group?*

# 1-Automotive & Autonomous Driving

Radar on autonomous vehicles.

Interested in the *hardware* (antenna design and beamforming) and *software* (multiple radar channels processing, detection and classification of targets)





S.Xu, A.Yarovoy, "Joint Features Extraction for Multiple Moving Targets Using (Ultra-) Wideband FMCW Signals in the Presence of Doppler Ambiguity", IEEE TrSP, 2020

Example of results from the group around automotive radar

# 2-Weather radar

Understand **atmospheric phenomena** based on their radar scattering properties.
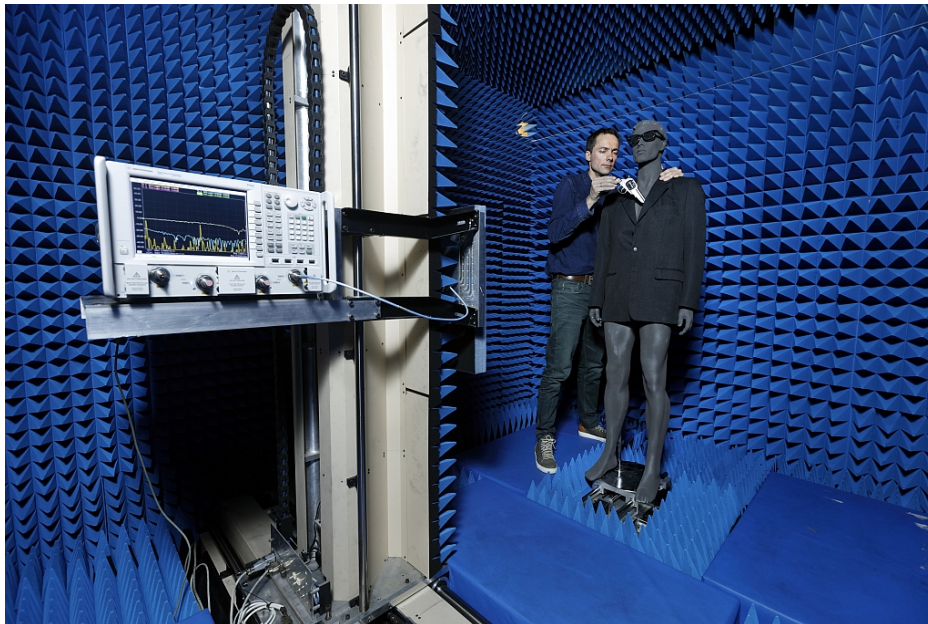Important, especially in the Netherlands, for resilience against extreme weather events.
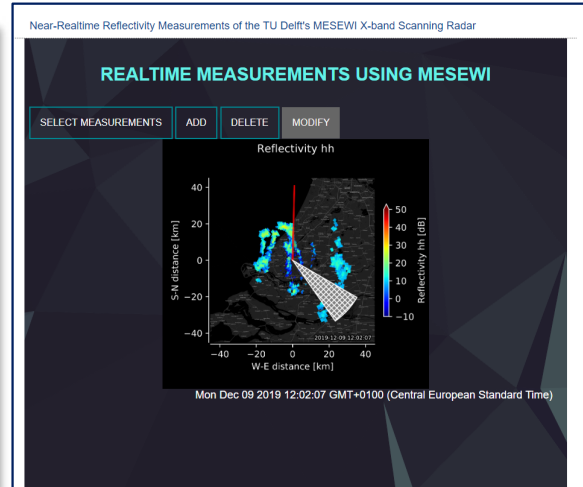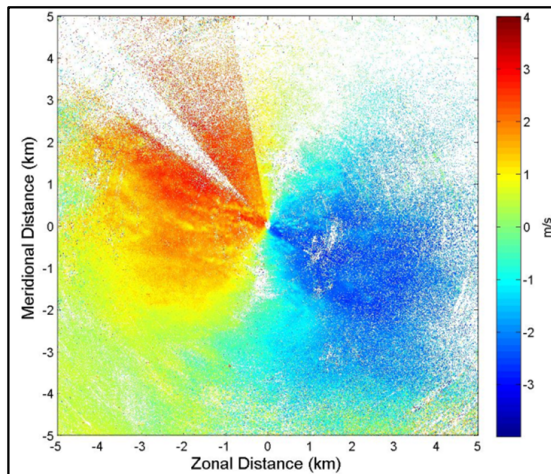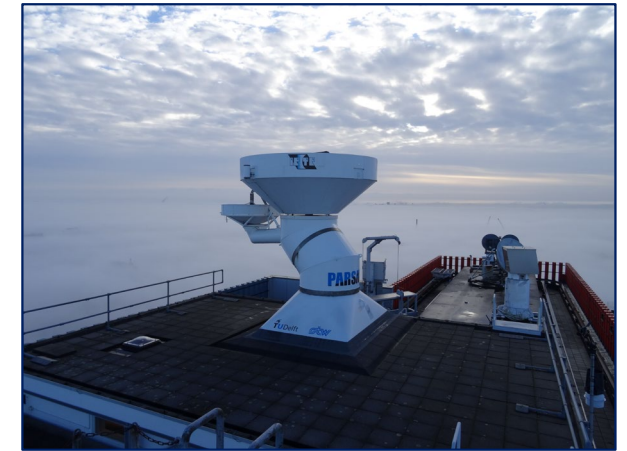








Quasi-real time measurements with our radar on the roof of EWI building
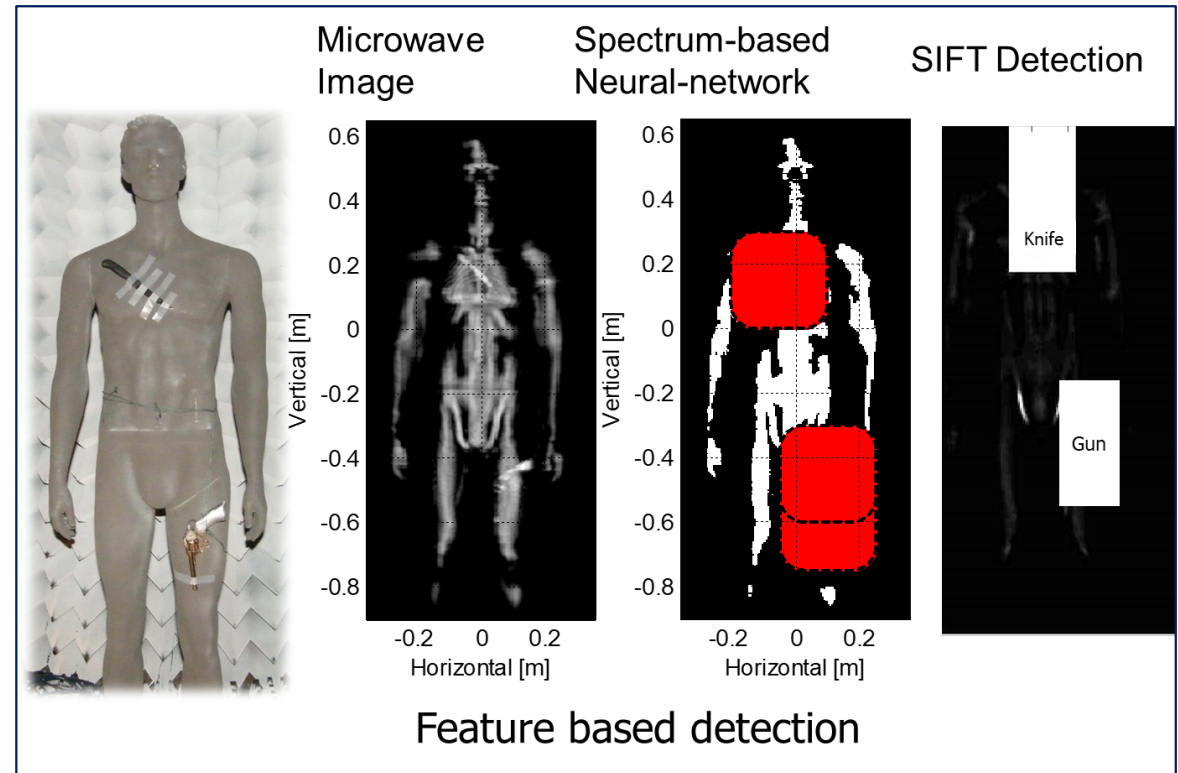
http://regenradar.tudelft.nl/index.php

# 3-Security

Interested in near-field & *through-materials imaging* for security.
How to use radar systems and principles to detect concealed objects.



Our anechoic chamber at EWI building, where Fred is preparing "our test subject"



Feature based detection

L. Carrer, A.Yarovoy, "Concealed weapon detection using UWB 3-D radar imaging and automatic target recognition," in *Proc. 8th European Radar Conference EURAD*, 2014.

10

# 4-Human wellbeing & gestures

Interested in using radar to observe **how people move** as a proxy for their healthcare.
Activity & mobility patterns, walking gait, critical events such as falls, vital signs
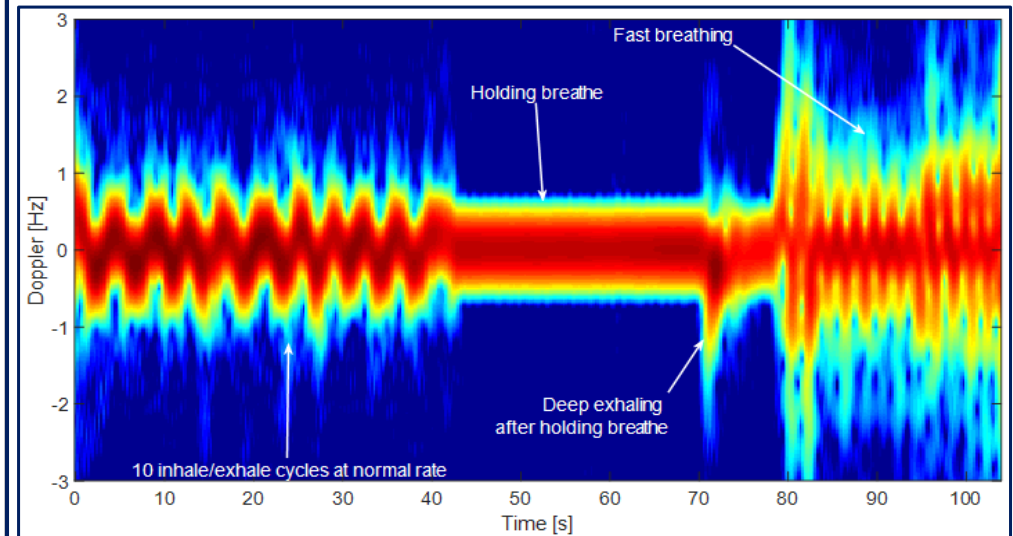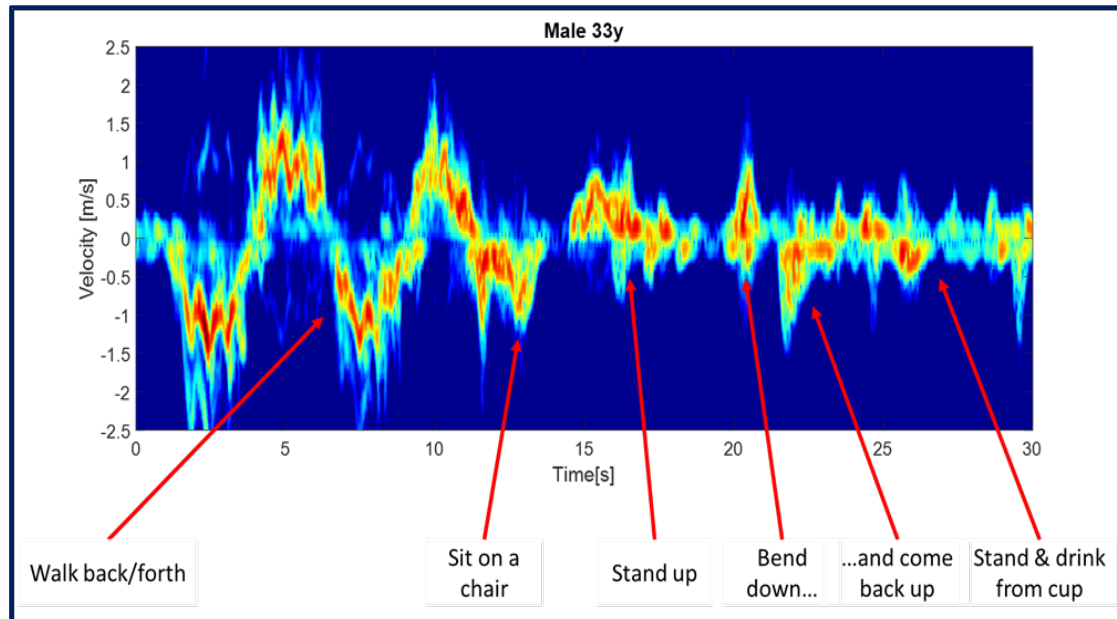


These are radar "*spectrograms*": plots of the velocity (of body parts) vs time
Full body and limbs (left) & Chest/abdomen wall for respiration (right)

F. Fioranelli, J. Le Kernec and S. A. Shah, "Radar for Health Care: Recognizing Human Activities and Monitoring Vital Signs," in *IEEE Potentials*, vol. 38, no. 4, pp. 16-23, July-Aug. 2019.

# 5-Surveillance of UAVs



Classification algorithms matter: if you turn on the radar you get tons of false alarms!

Radar display for single drone trial:
drone detections (orange),
ground truth track (bright yellow),
other tracks and objects (green and violet).

**Left** naïve algorithm vs **right** enhanced version
-> great reduction of false alarms for the operator!

# What about our graduates alumni?

**Marc Vizcarro i Carretero** · 1st
Antenna Design Engineer at HENSOLDT
Ulm, Baden-Württemberg, Germany · **500+ connections** ·
Contact info

**Lisa Audenaert** · 2nd
Data Scientist in het DEEP programma voor Waterschap Vallei&Veluwe
The Hague Area, Netherlands · 130 connections · **Contact info**

**Jeroen Overdevest** · 1st
Signal Processing Engineer bij NXP Semiconductors
The Hague Area, Netherlands · **500+ connections** · **Contact info**

**Wietse Bouwmeester** · 2nd
PhD Candidate bij TU Delft
The Hague Area, Netherlands · 180 connections · **Contact info**

**Roeland Trommel** · 1st
Advanced Development Engineer at Thales Nederland
The Hague Area, Netherlands · **284 connections** · **Contact info**

**Vassilis Papanastasiou** · 1st
Deep Learning Software Test Engineer at MathWorks
Greater Cambridge Area · **497 connections** · **Contact info**

MS³
Microwave Sensing
Signals & Systems

TUDelft

# Thank you for your attention

Any questions?
visit radar.tudelft.nl
or
send e-mail to
[A.Yarovoy@tudelft.nl](mailto:A.Yarovoy@tudelft.nl)