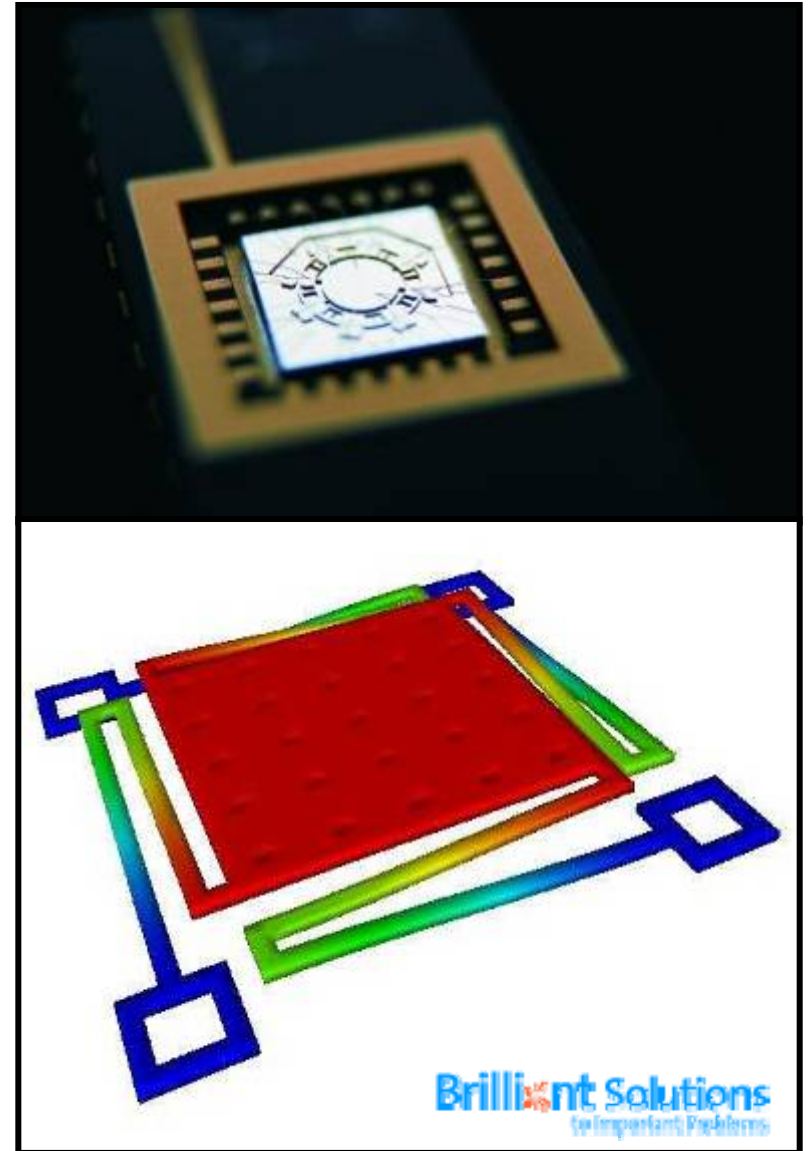


QinetiQ Proprietary

# QinetiQ Microsystems MEMS Microphone Technology

Chris Reeves



**QinetiQ**

[www.QinetiQ.com](http://www.QinetiQ.com)

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- Acknowledgements

# Microsystems at QinetiQ

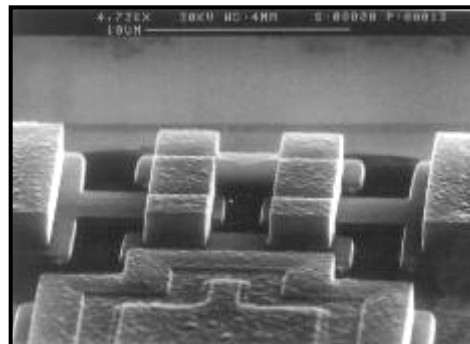
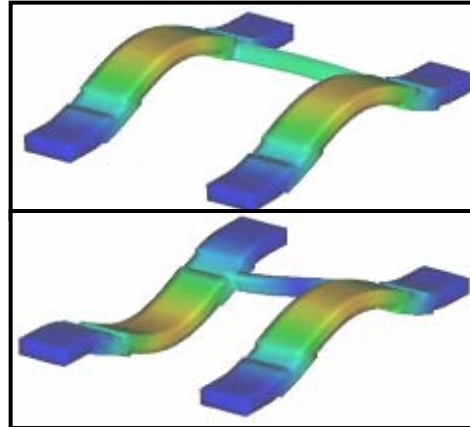
- MEMS activities started c.1991/2
  - Identification of MEMS as emerging disruptive technology
  - Silicon technology base from IC industry
- One of the largest MEMS groups in the UK
  - An integrated team of about 35 staff
    - Diverse range of device and system applications
    - Advanced CAD capability
  - Dedicated MEMS fabrication facility
    - ~450m<sup>2</sup> Class 100/1000 clean room
    - Stable production worthy fabrication processes
    - MEMS materials development
  - Portfolio of MEMS based solutions

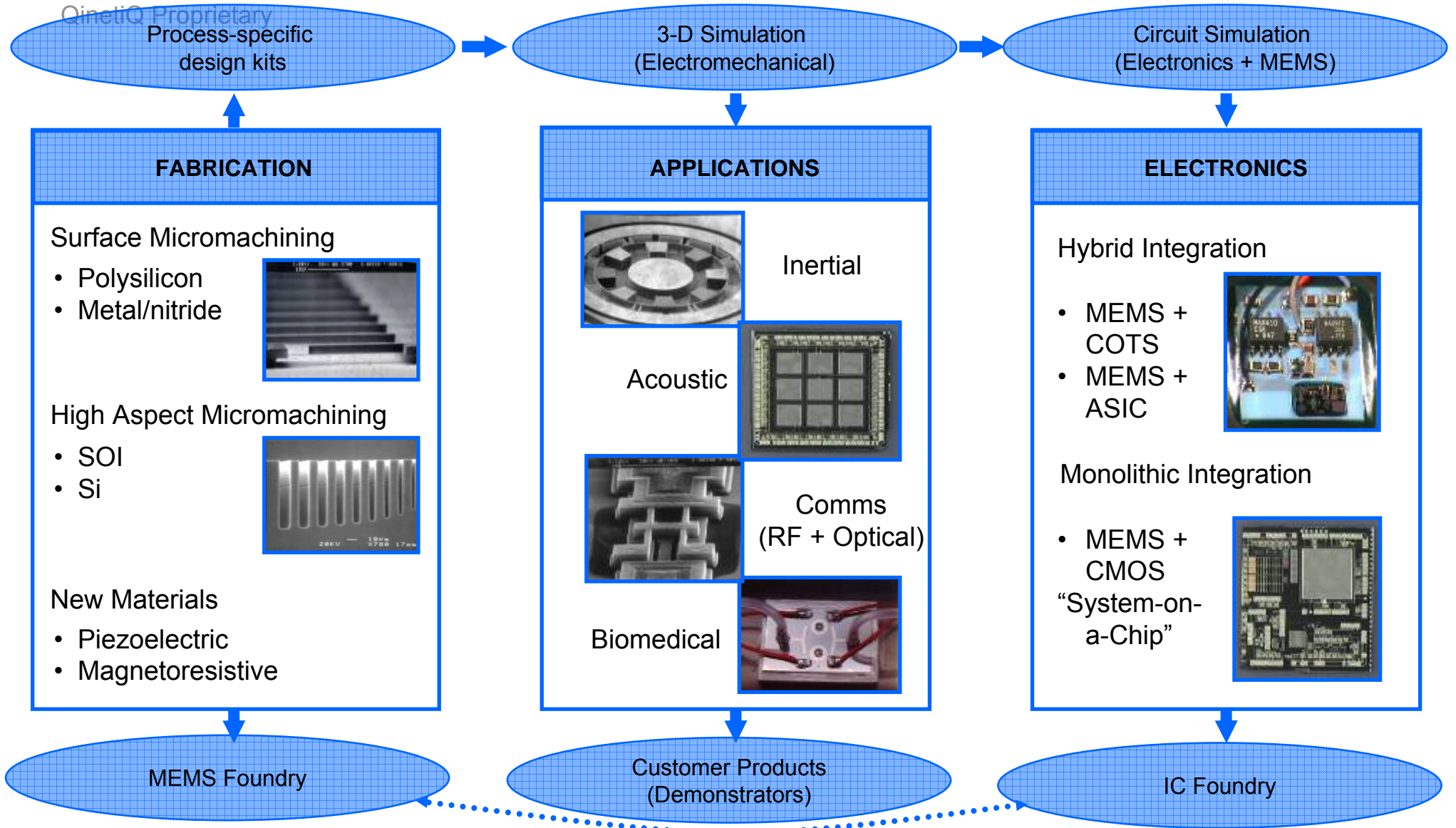


## Microsystems at QinetiQ

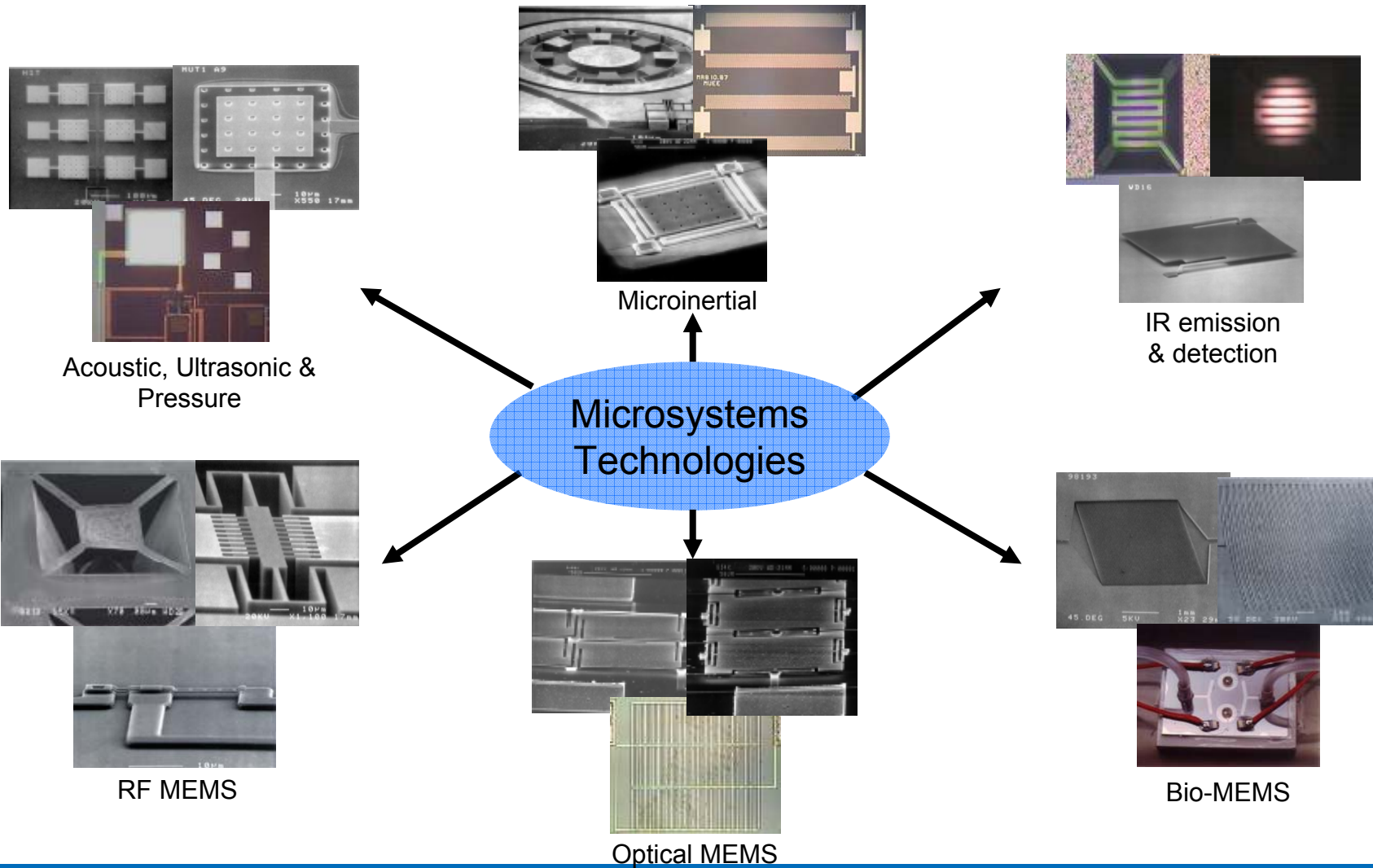
• 'One Stop Shop' for microsystems solutions:

- Device Physics & Modelling
- Microsystems design
- Layout
- Fabrication
- Evaluation
- Electronics & system design
- Materials Characterisation

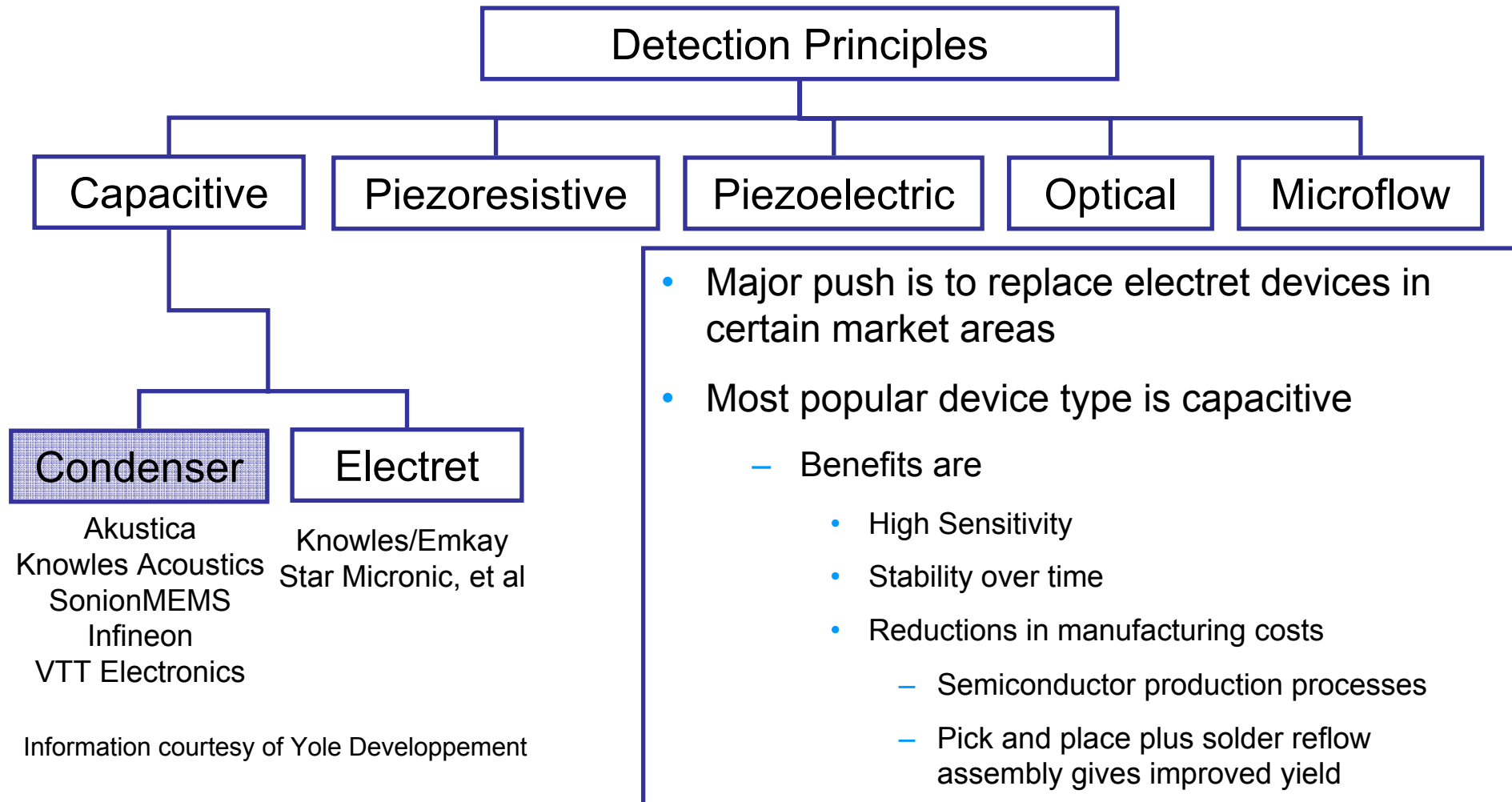




# Key Microsystems Application Areas



# MEMS Microphone Technologies



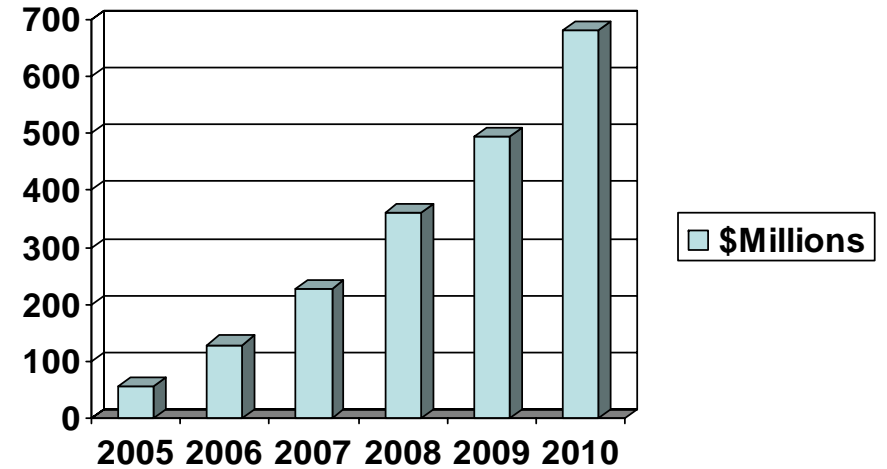
**Condenser**  
Akustica  
Knowles Acoustics  
SonionMEMS  
Infineon  
VTT Electronics

**Electret**  
Knowles/Emkay  
Star Micronic, et al

Information courtesy of Yole Developpement

## Major Market for MEMS Microphones (mobile)

	<b>QinetiQ</b>	<b>Typical Mobile Phone</b>
Max Acoustic Signal	~130dB	110 dB SPL
Noise Floor	~40dBA	55dB
Bandwidth	5Hz – 20KHz	100Hz – 10KHz
Linearity (@ 120dB)	1%	10%
Sensitivity	-22dBV	22 - 42dBV
Power consumption	400µA	75µA
Supply voltage	3.0 to 5.5V	1.5 to 5.5V



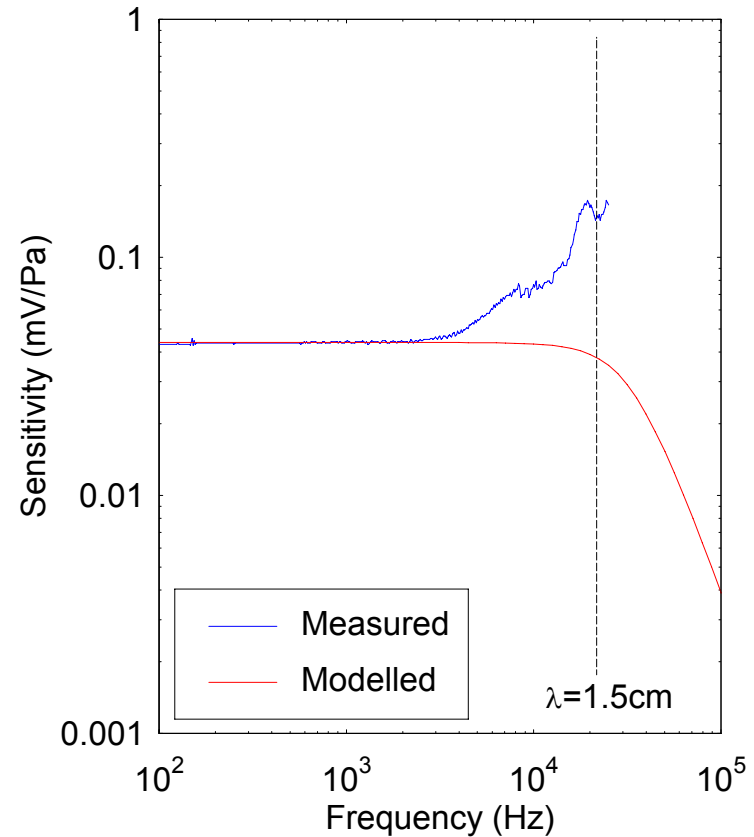
Market for MEMS Microphones 2005-2010

- 2006 ~90% of the MEMS microphone market was for wireless communications devices ~\$100M
- Many players and the market is driven by low cost – high volume (target price <50c)

Information courtesy of Yole Developpement

# QinetiQ's Primary Interests

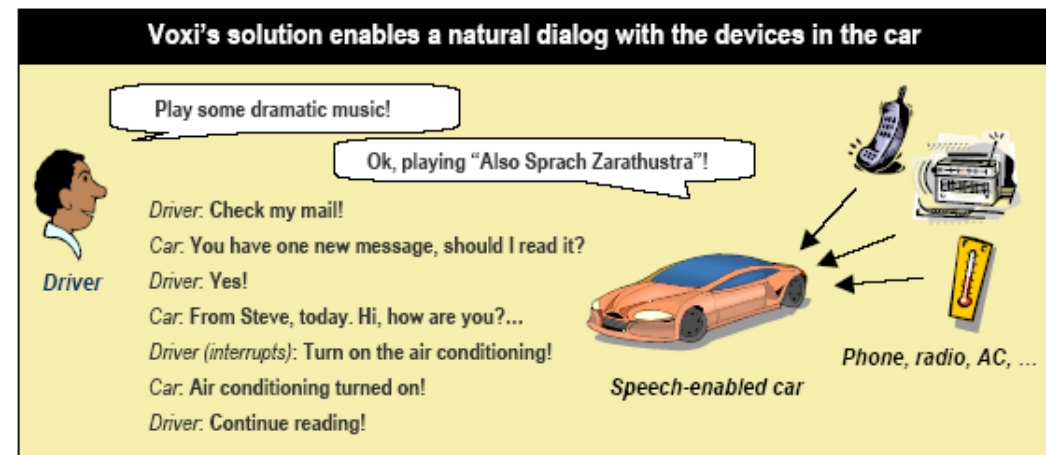
- Near-instrumentation quality microphones
  - Good phase and amplitude matching
  - Wide frequency response
    - a few Hz to 20KHz
- Environmentally robust
  - Tolerate high shock and pressure levels (150 dB – SPL)
  - Vibration tolerant: 50dB (SPL) / g @ 1kHz
  - Long shelf life stability (10 years)
- Tight control of microphone sensitivity
  - $\pm 1\%$  across silicon wafer
  - $\pm 3\%$  from wafer-to-wafer
    - Excellent control needed on MEMS layers & intrinsic membrane stress
    - Also investigating self-calibration techniques
- Small footprint
  - $<4\text{mm} \times 4\text{mm} \times 1.5\text{mm}$  (mobile communications requirement)



Microphone frequency response

# Some Target Markets for QinetiQ MEMS Microphones

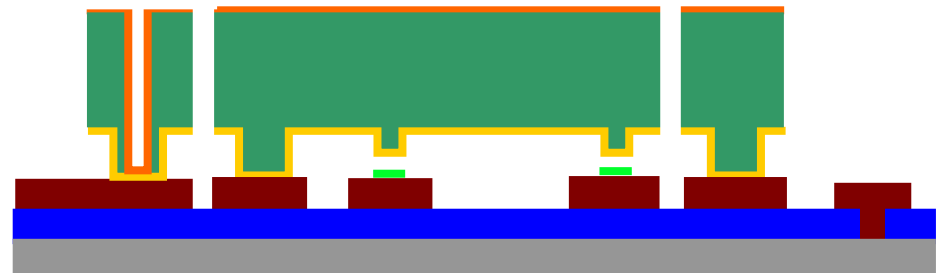
- Lower-volume applications for silicon MEMS microphones
  - requiring a higher microphone acoustical performance
  - Supporting a higher unit price
- Defense applications
  - Unattended Ground Sensors
- Industrial applications
  - Acoustic environment monitoring (SLM)
  - Machinery condition monitoring
  - Personal dosimetry (PSEM)
- Non-industrial applications
  - Voice ID & control (automotive & security)
  - High grade reference devices
  - Integrated headsets
  - Next generation (high end) mobile phones



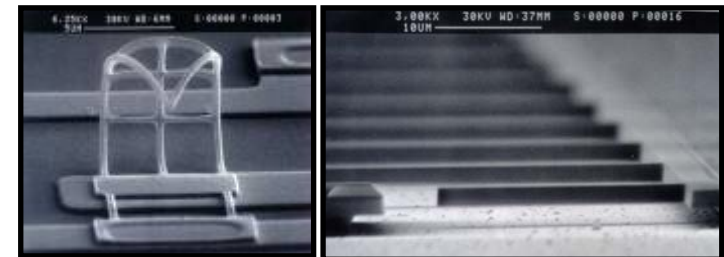
## Generic Fabrication Process Metal-Nitride Sacrificial Surface Micromachining

### Sacrificial Release

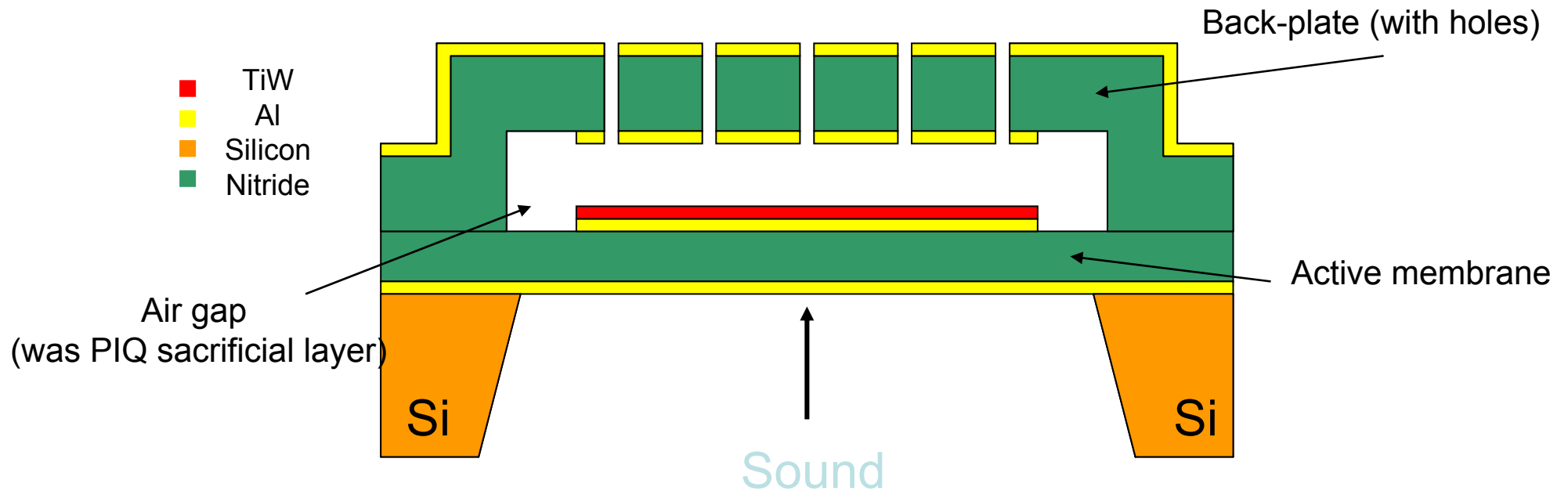
- Remove polyimide layer in a dry process



- Stress optimised mechanical layer with low stress gradient ( $<20\text{MPa}/\mu\text{m}$ )
- Dry release for high yield
- Process is CMOS compatible for monolithic integration

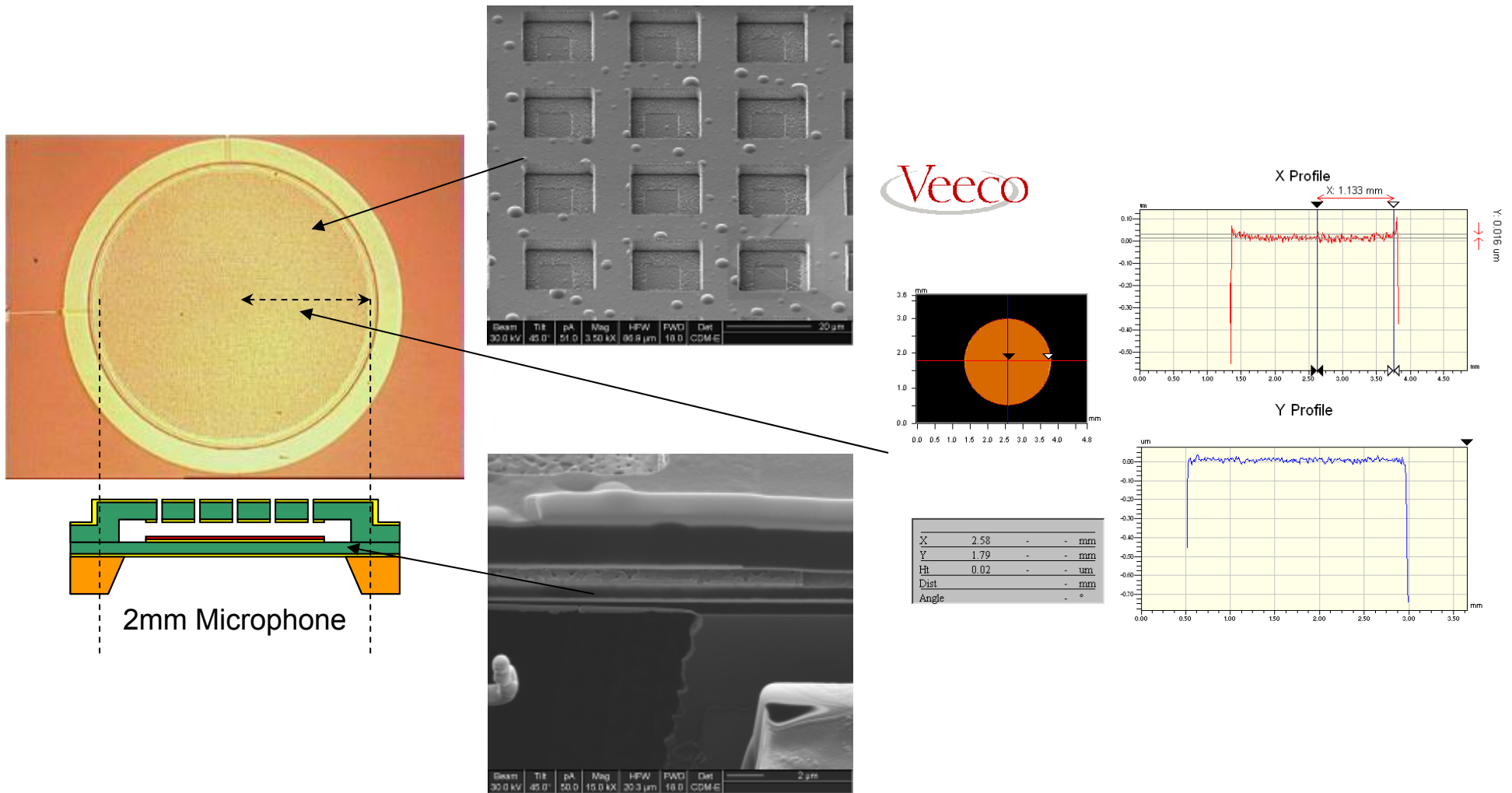


## QinetiQ Microphone Cross-Section

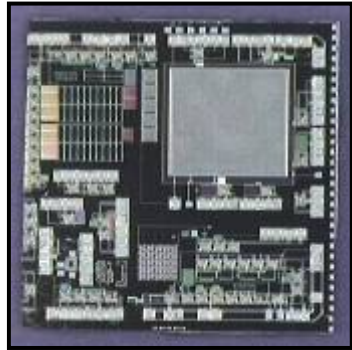


- Microphones fabricated using CMOS compatible Metal-Nitride surface machining process
  - membrane: 0.2um metal / 1.0um nitride / 0.2um metal composite
  - Gap between plates: 1.2um
- Excellent control of layer geometry and thicknesses
  - Required for tight control over microphone sensitivity

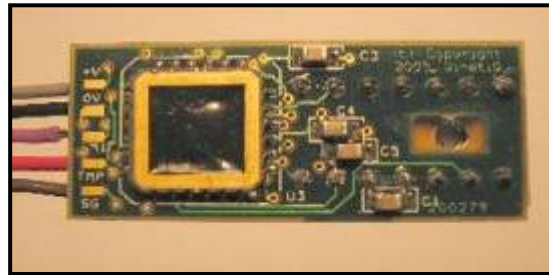
# Fabrication control on the Macro → Micro → Nano-scale



# Miniaturised High Fidelity Microphones

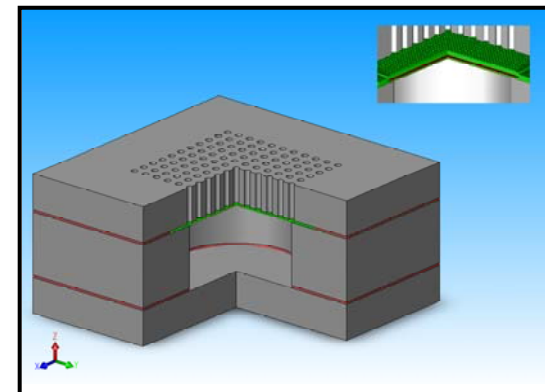


2mm monolithically integrated with CMOS electronics



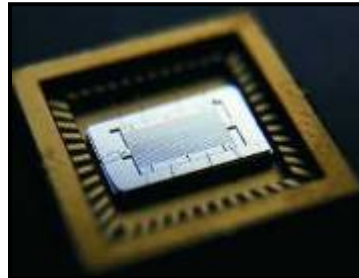
Hybridised microphone

- Including the technology transfer of the microphone fabrication process to a volume foundry partner



Small package foot print  
<4mm×4mm×1.5mm  
(WLP)

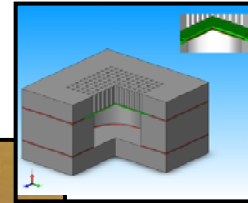
# Personal Exposure Monitoring



Inertial sensors



Autonomous data loggers



Docking for data download

- Measurement of shock and environmental factors detrimental to health
- Autonomous data logging and download
- Real time or off line data mining for risk analysis
- Incorporate a small foot print HiFi microphone for PSEM

# Acknowledgements

- UKMoD RAO (ES Domain), European Commission and the National Physical Laboratory for part funding this work.

Any questions?

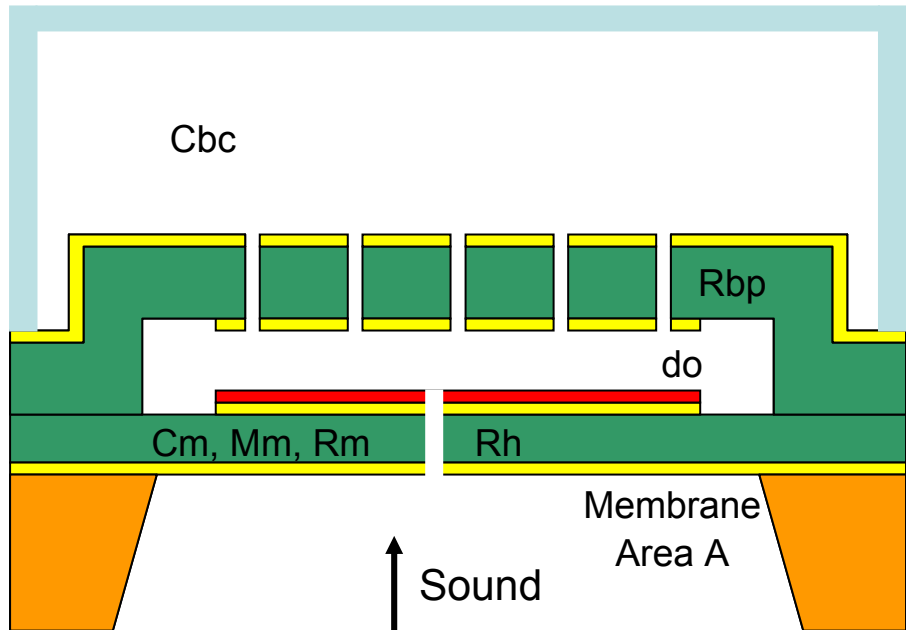
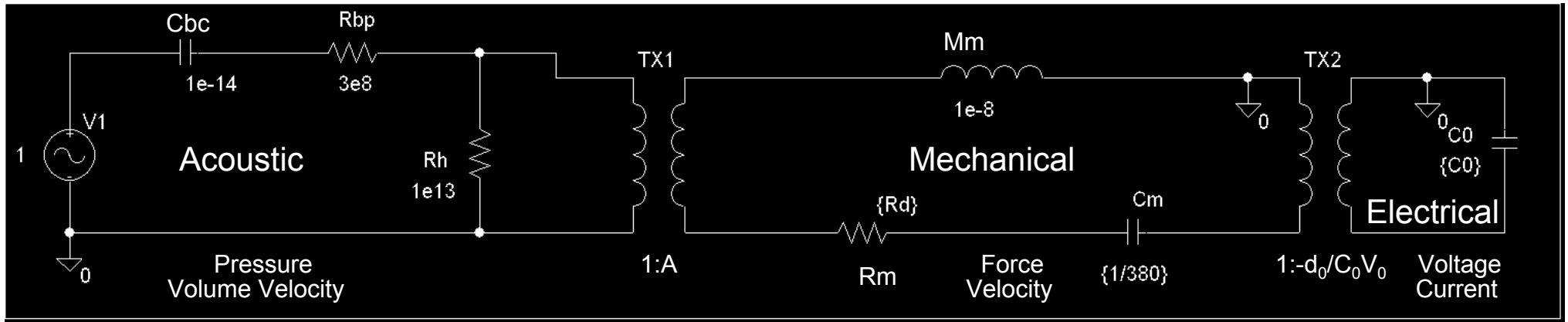
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The Global Defence and Security Experts

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# Microphone Frequency-Domain Equivalent Circuit (Electro-Acoustic Response)



Can

- TiW
- Al
- Silicon
- Nitride

$$\text{Sensitivity} = \frac{I(\omega)}{J \omega \text{ Pressure}(\omega)}$$