THALES

Current and emerging EMC activities within THALES (& University of Twente)

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Chair for EMC, University of Twente

Presented at the Politecnico di Torino, 10 october 2007

Content

Introduction THALES

EMC within THALES

Some cases (applied EMC)

Current research activities

- THALES group
- THALES Nederland
- University of Twente

Emerging issues

World leader for mission-critical information systems

- **Three core businesses**
  - **Aerospace**
  - **Defence**
  - **Security**

  } **More than €12bn annual revenues**

- **A Worldwide Group**
  - **68,000 employees worldwide**
  - **Presence in 50 countries**

2007 outlook

Three core businesses

Defence

50 %

- Air
- Land
- Naval
- Joint

Aerospace

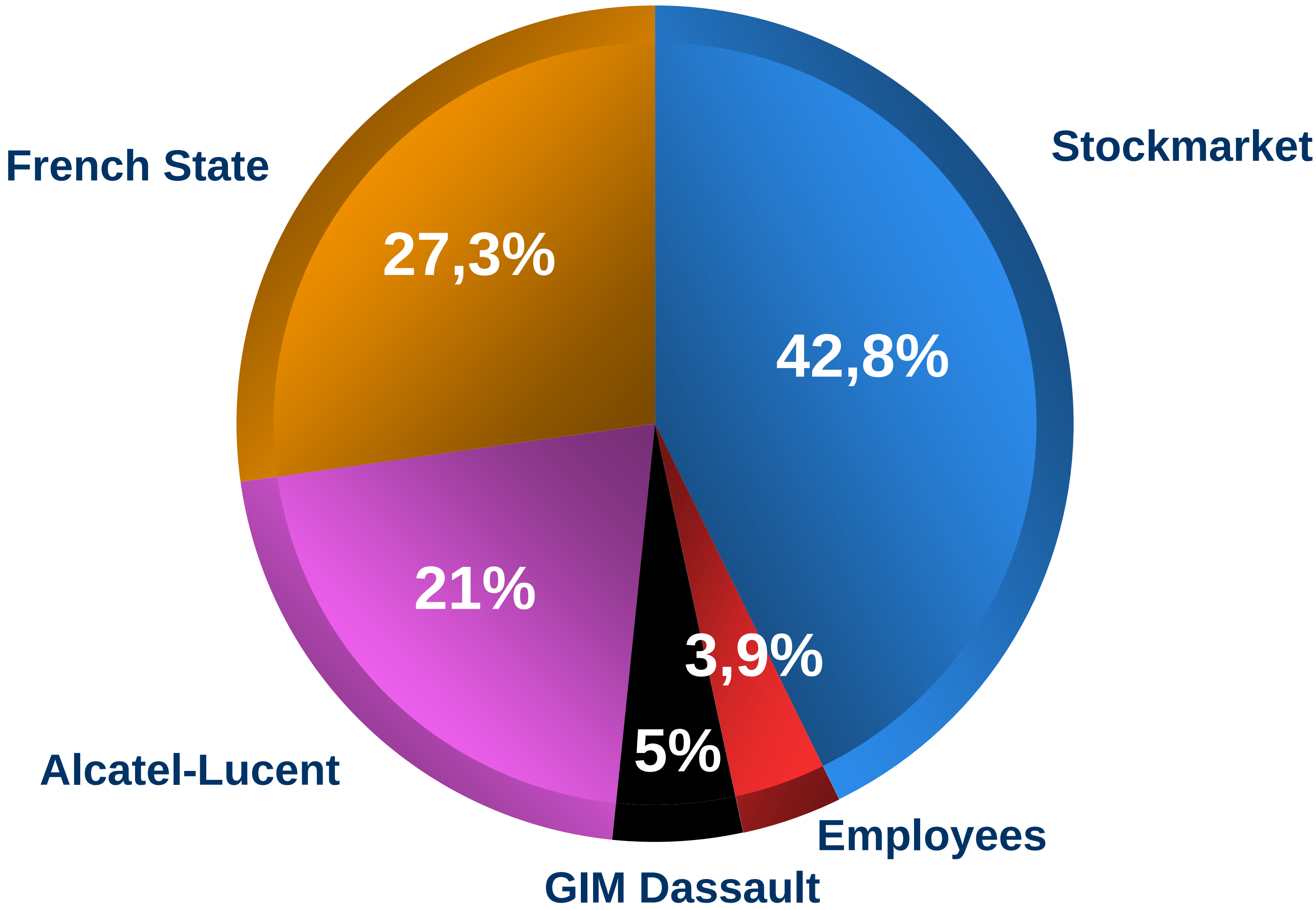
25 %

Security

25 %

2007 outlook

Thales's shareholding



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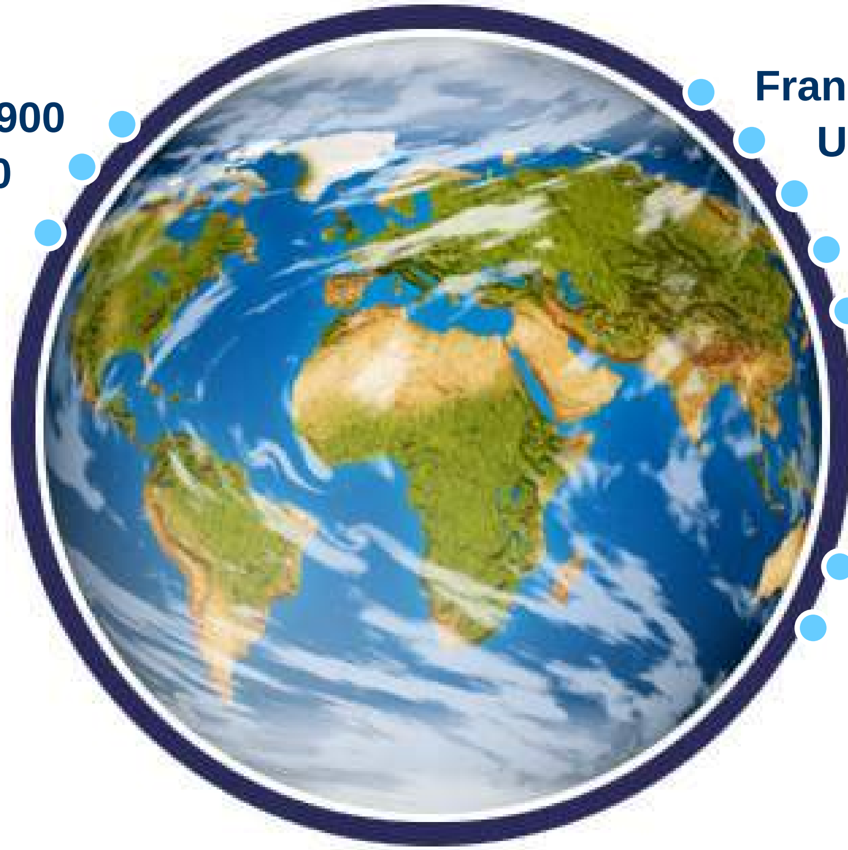
Main country headcounts

> 1,000 people



- USA: 2,900
- Canada: 1,100
- South America: 600
- France: 35,200
- UK: 8,800
- Germany: 4,700
- Spain: 2,600
- Italy: 2,600
- Netherlands: 2,000
- Belgium: 1,000
- Australia: 3,300
- Korea: 1,300

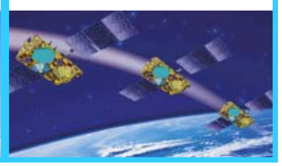
Others: Saudi Arabia: 530 / South Africa: 330 / China: 300 / Switzerland: 280 / Norway: 227 / Austria: 170 / Singapore: 170 / Portugal: 160 / Poland: 110

THALES

Innovation and technological excellence

- 68,000 employees of whom 50% outside France
- 25,000 researchers on cutting-edge technologies
- Highly skilled (e.g. 60% of workforce are engineers or managers)
- R&D at Thales totals €2.2bn (18% of revenues)
- 300 inventions per year
- Over 15,000 patents
- Cooperation with universities and public research laboratories in Europe, the United States and Asia

Three market-driven core businesses

Aerospace		Defence			Security
Aerospace	**Space**	**Air Systems**	**Land & Joint Systems**	**Naval**	**Security Solutions & Services**
					

A coherent organisation

Bringing customers the benefit of technology expertise and international presence

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Thales in Italy

2,600 employees

12 main sites

Aerospace & Defence

- Strategic networks for Armed Forces (RIFON backbone, RNI radio network)
- Tactical comms (HF, V/UHF, Satcom, SW radio), NBC vehicles/labs and C2 systems
- Electronic warfare systems for Armed Forces and export (Germany, Netherlands, Switzerland)
- Tactical multimedia radio for military and quasi-military applications
- Equipment and systems for Agusta, Aermacchi, Alenia, Piaggio, airlines and Armed Forces
- Navaids and air traffic management systems for defence and civil (Italy and export)
- FREMM (Franco-Italian multimission frigate) and Orizzonte naval programmes
- Agusta A129 simulators
- Secure satellite telecommunications (Sicral) and navigation (Galileo) programmes
- Earth observation systems: COSMO-SkyMed
- Orbital infrastructure: more than 50% of pressurised modules for the International Space Station
- Deep space exploration: Mars Express, Venus Express, Rosetta, Integral, Herschel and GOCE
- Production of instrumentation for satellite systems: antennas, onboard computers and electronic equipment

ThalesAlenia Space
A Thales / Finmeccanica Company

Security & Services

- Rail signalling solutions for RFI (Rete Ferroviaria Italiana)
- Integrated security, communication and supervision systems (ground and onboard) for Urban Transport in Italy (Brescia, Napoli, Firenze) and abroad (Copenaghen, Dublin, Cairo, Dubai)
- Revenue collection systems for urban transport (Torino, Napoli, Firenze) and large events
- Integrated security, communication and supervision systems for Oil&Gas (ENI Group), for Airports (Dubai) and for Roads/Highways
- IT Services for Enterprises (Fiat group, service providers)

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Thales in the Netherlands

2,000 employees

3 sites: Huizen, Eindhoven, Hengelo

Sales €420M 2005, €735M 2006, 75% export

R&D: 18% of sales

Two part-time professors: Prof. Piet van Genderen, Radar, Delft
Prof.dr. Frank Leferink, EMC, Twente

Current projects:

- **The Netherlands: TBMD, TACTIS, SIRIUS, Flight simulator Air France / KLM, E-ticketing Dutch public transport**
- **Germany: TBMD, K130 Corvettes, F122/F123 Modernization**
- **UK/France/Italy: S1850M for PAAMS (resp. Type 45 / Horizon)**
- **Greece: Gunboats & Fast Attack Craft, Modernization Elli Class Frigates**
- **Japan: FCS-3 ICWI for 16 DDH**
- **Poland: Modernization Orkan Corvettes**
- **South Korea: SMART-L for LPX, GOALKEEPER for KDX III**
- **Turkey: frigates & Fast Patrol Boats, FPB Modernization, IMSS**
- **Venezuela: FLYCATCHER Mk2**
- **Spain: Trailer Mounted PAGE, Patrol Vessels Navantia**
- **South Africa: Portable PAGE**
- **Denmark: SMART-S Mk2 for FSS, APAR+SMART-L for AAW**
- **Indonesia: Sigma Corvettes**
- **Thailand: Mirador for Coastal Patrol Craft**
- **Canada: SIRIUS**


Deurningen
N342
N734
A1
Twenthe
Hengelo
Lonneker
N733
N732
N739
Haaksbergerstraat
Boekelo

Enlarge
Zoom in
Het Stift
Weerselo
Saasveld
Zenderen
Hertme
Tusveld
Stroomesch
Deurningen
Borne
Hasseler
Bornerbroek
Tilpelo
Twentekanaal
KN. AZELO
Azelo
A 35
A 1-E 30
Deldenerbroek
KN. BUREN
Twickel
Delden
N 346
Hengelo
Driene
HET VEELSVELD
HET HONNEKERMEER
Lonneker
ENSCHEDE
De Waarbeek
Twekkelo
Boekelo
Usselo
Het Hulsbeek
De Zoeker
Losser
Losserhof
Kloster
Overdinkel
Glane
Glanerbrug
Dolphia
N 35
Stroinkslanden
Wesselerbrink
Het Rutbeek
N 18
Buurserzand
Epe
Brook
Amtsvenn
Key of symbols
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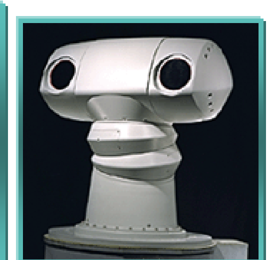
THALES Naval and Air Systems

- Above Water Systems

Command & Control

System integration

- Surface Radar



Surveillance

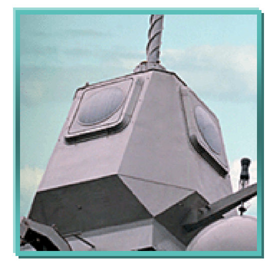
Fire control

Integrated air defence surveillance, track and fire control

Border / battlefield surveillance

Air defence fire control

Air defence surveillance



Multifunction radars

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THALES

Was founded in 1961 and offers education and research in areas ranging from public policy studies and applied physics to biomedical technology.

Three technical universities in The Netherlands: Delft, Twente, Eindhoven

Faculties:

- Electrical Engineering, Mathematics and Computer Science (EEMCS) (656 employees, 1500 students)
- Science and Technology (TNW) (655, 1300)
- Engineering Technology (CTW) (261, 1700)
- Behavioral Sciences (GW) (236, 1500)
- Management and Governance (329, 2000)

8000 B.Sc+ M.Sc. students
1200 PhD students
2200 scientific staff
1000 support

Note: EEMCS and Science&Technology have large staff because of the many research activities

Electrical Engineering department

Biomedical and Environmental Sensorsystems (BIOS)
Biomedical Signals and Systems (BSS)
Computer Architecture for Embedded Systems (CAES)
Control Engineering (CE)
Design and Analysis of Communication Systems (DACS)
Integrated Circuit Design (ICD)
Integrated Optical MicroSystems (IOMS)
Nano Electronics (NE)
Signals and Systems (SAS)
Semiconductor Components (SC)
Telecommunication Engineering and EMC (TE)
Transducers Science and Technology (TST)

EMC engineers Nederland

- **Surface Radar:**
  - **TC Engineering: Frank Leferink (Technical Authority)**
  - **TC Design: Environmental Competence Center:**
    - **Jasper van der Graaff**
    - **Frits Buesink**
    - **Hans Schipper**
    - **Mathieu Melenhorst**
    - **Jaap Schuurmans**
    - **Koen Lommers**
    - **Karl Dummel**
  - **Studies (Delft): Maarten Clement, Rogier van Aken**
  - *In France (Limours): Alain Bresson + 5 colleagues*
- **AWS (Above Water Systems): Hans Bergsma**
- **Marie Curie fellows: Gaelle Kergonou, Karine Pillet**
- **M.Sc. Final assignment student: Rikkert Koppes**
- **4 stagiairs**

University of Twente:

- **Frank Leferink, Anne Roc'h (PhD), Alex Blaj (PhD), 1 PhD vacancy, 1 postdoc**

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THALES Network of Excellence on EMC

EMC: in many business units, but <u>scattered</u> all over Europe

Example:
Number of EMC engineers > number of antenna engineers

Network of Excellence on EMC, to combine efforts. Objectives

- <u>Elaborate exchange</u> and <u>cooperation</u>, for instance
  - studies
  - experience (sharing knowledge)
  - test facilities (sharing)

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Thales EMC NoE in <u>Europe</u>:

~ 100 researchers and engineers, scattered:

~ 30 sites

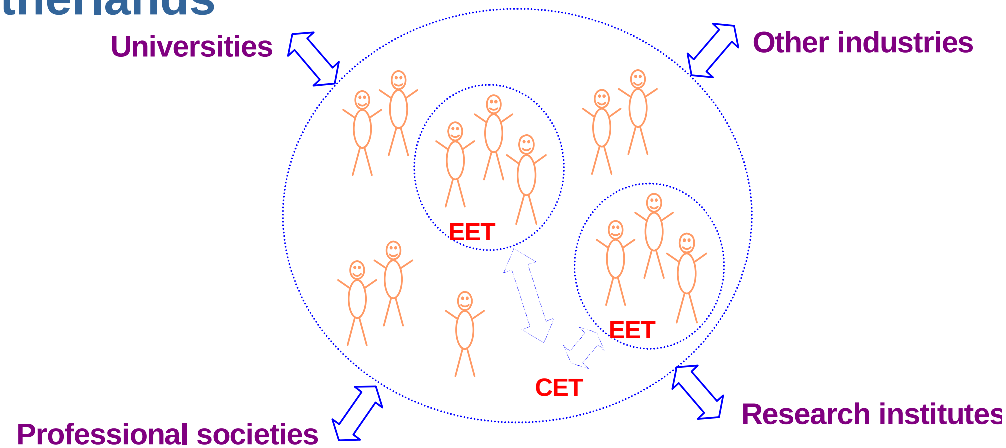
~ 12 test facilities

Thousand hardware engineers apply the knowledge

EMC Network of Excellence

Meetings:

- 2 plenary meetings per year: Paris (june) and London (jan)
- 6 topical meetings/yr in France (continent)
- 4 topical meetings/yr in UK
- 4 topical meetings/yr in Netherlands



Communication

- Phone
- E-mail
- Meetings
- Workshop (2006: on tools in use within Thales)
- Website: Knowledge Management portal
  - Conferences, meeting reports, contact-specialist, courses, hardware design guides etc.

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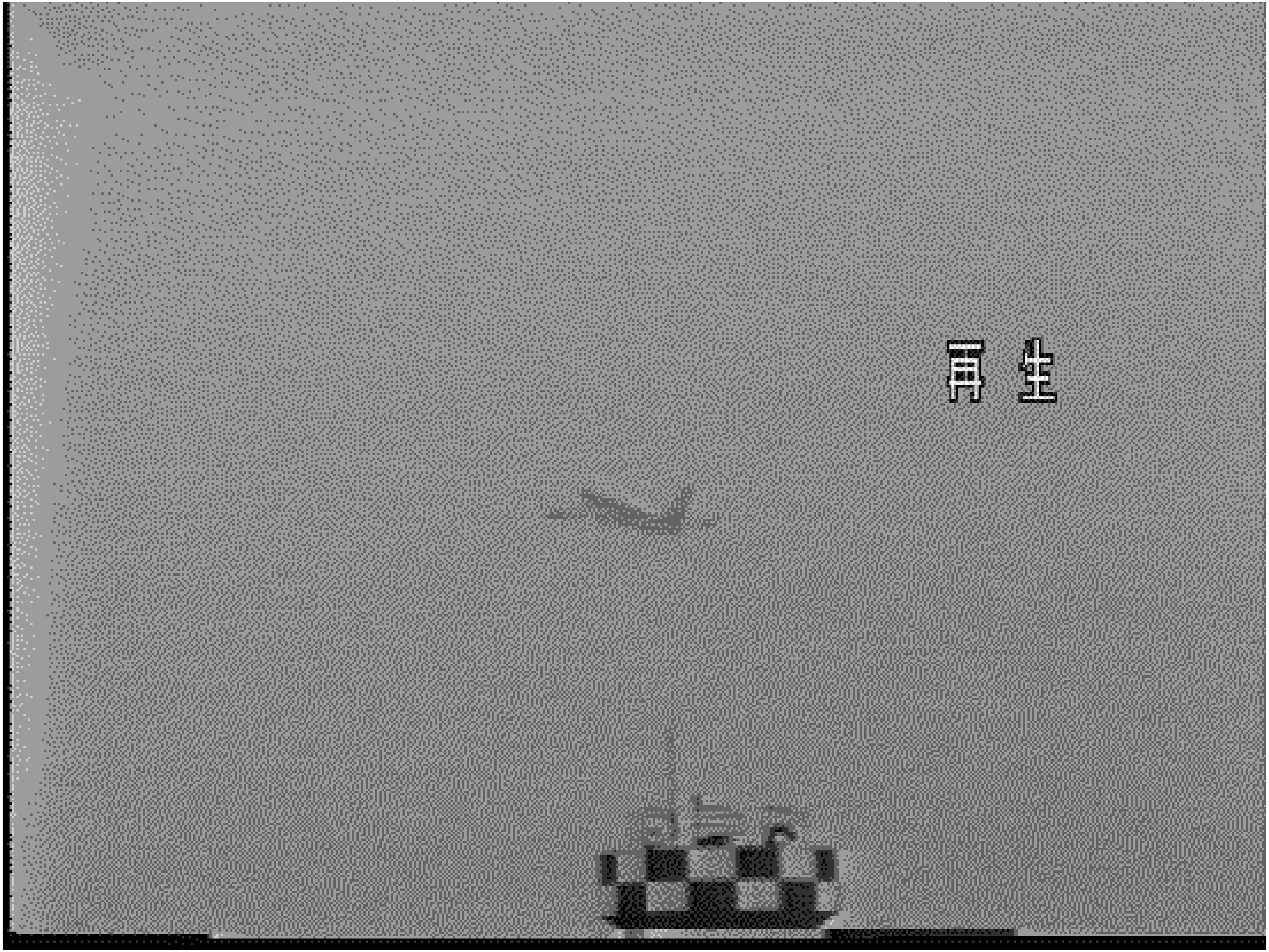
EMC is a **key issue** for Thales!

- Cost of interference can be very high due to
  - **Direct costs: repair**
  - **Delay in shipment**
  - **Loss of reputation**

EMC is therefore an important issue

But EMC is also important for <u>you,</u> because you are here

USS Forrestal: 134 men died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EMC Methodology, 1

1. Awareness
2. Network
3. Design guidance
4. Program support

ad. 3: Rules and guidelines:

EMC design rules and guidelines (R&G) have been upgraded gradually and made available via modern media such as the corporate wide web (CWW). The rules and guidelines are dedicated to technology and not to specific programs and thus business independent: THALES EMC Expert System (EES) (now within TWiki):

- An electronic expert, on-line available
- Comparable to knowledge based tools
- Implemented on the Corporate Wide Web making fast and simple access possible for everyone within the Group
- Core element: designable parameter: find the solution needed by the design engineer.
- The system is built using rules and guidelines available and in use within the Group. It is our destiny to continuously improve the system in order to follow new technologies.

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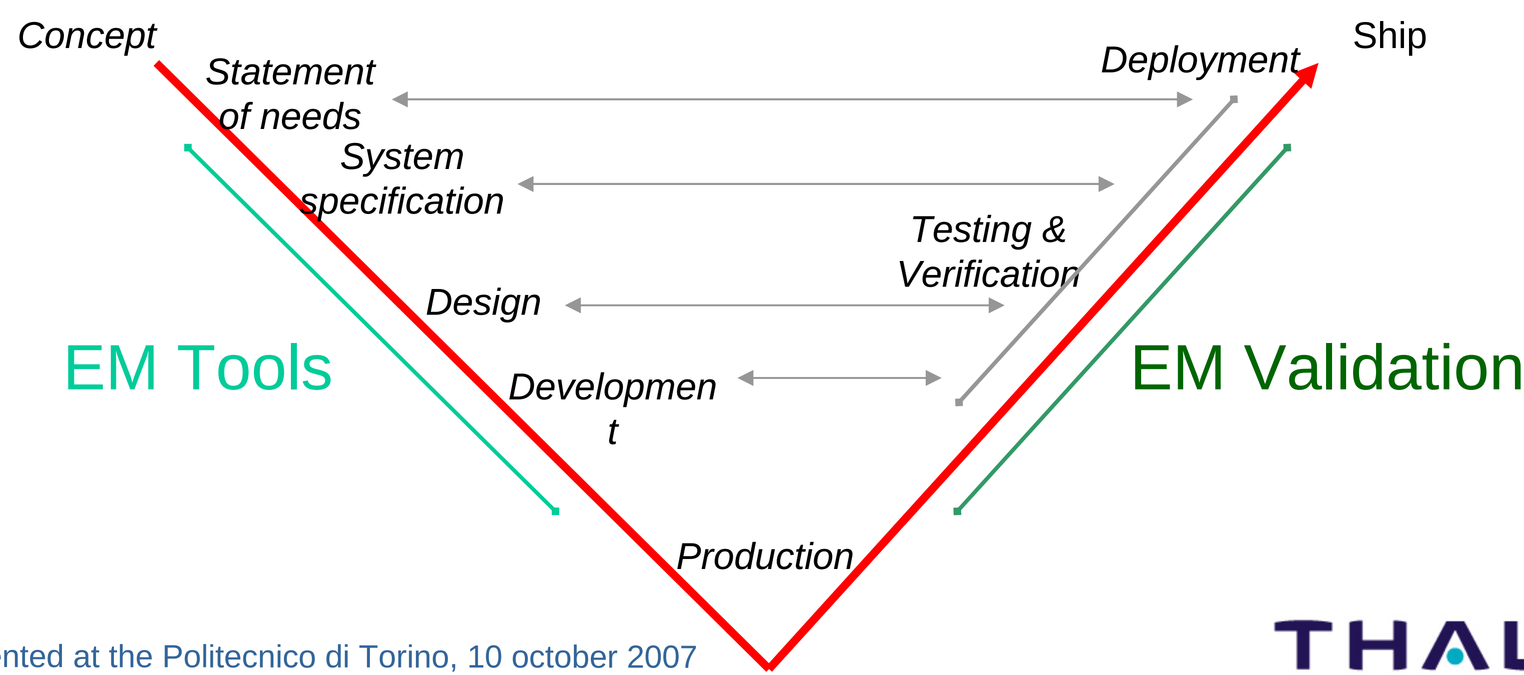
ad. 4: Program support:

Senior EMC consultants are attached to a product development (new design) from concept phase until deployment. He/she is responsible for EMC analyses, for engineering tests and for continuous support during the process.

For large programs where several companies are involved, similar support is given, but with other topics and via an EMC Advisory Board

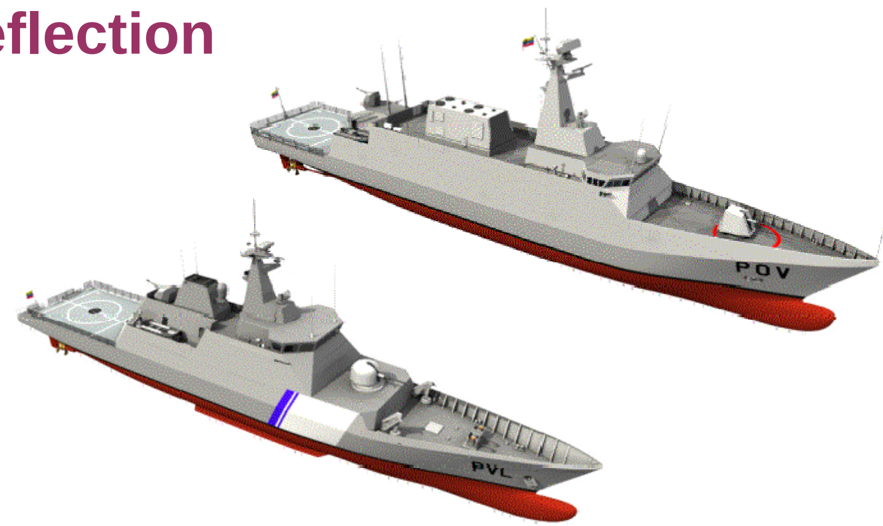


Case 1: Platform (ship) design

Case 1:

The next sheets give an overview of activities around the EMC design of a platform (ship)

- **frontdoor EMI (via antennas)**
- **backdoor EMI (system and equipment EMC)**
- **radiation hazards**
- **blocking and multiple reflection**



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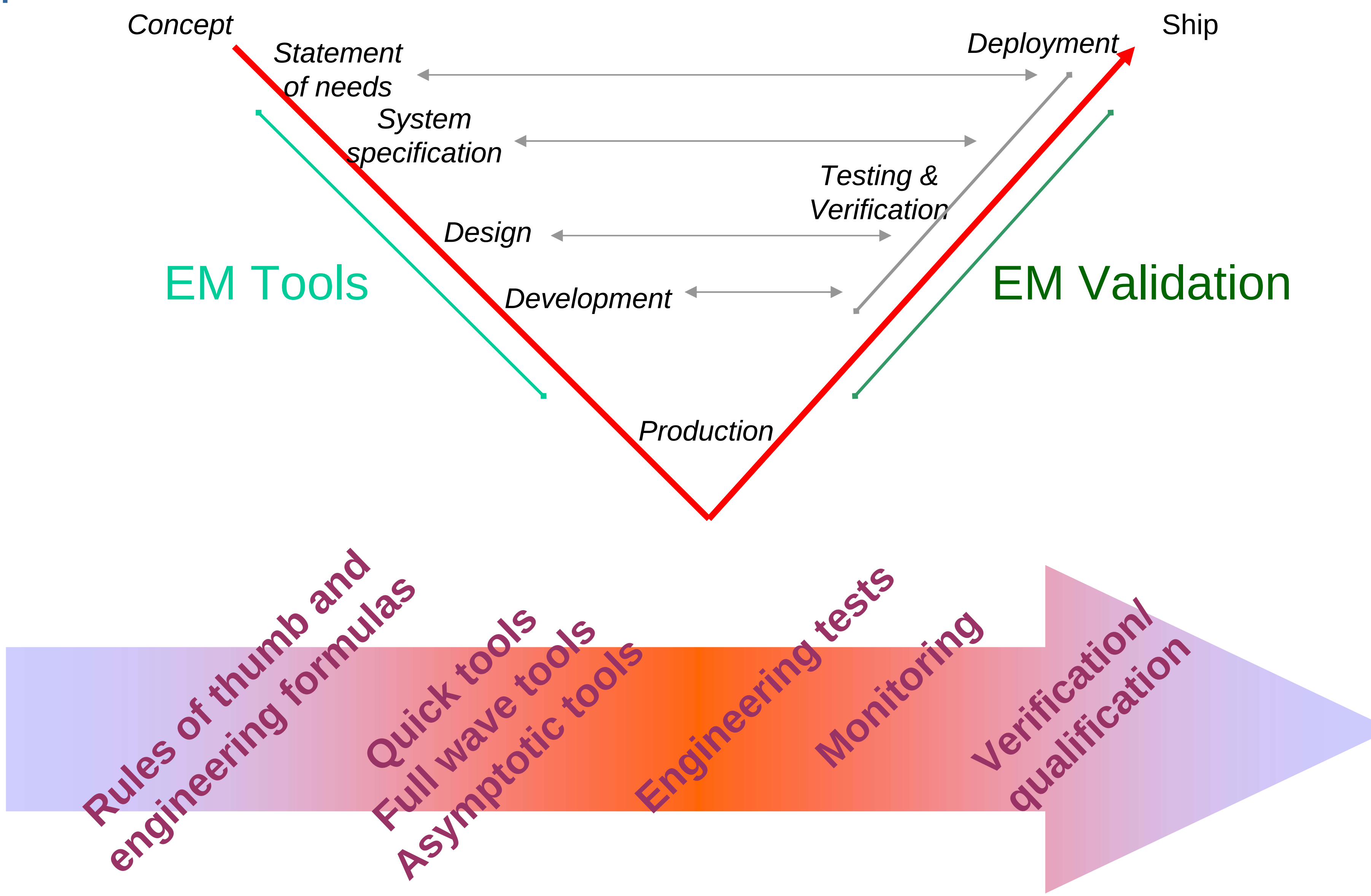
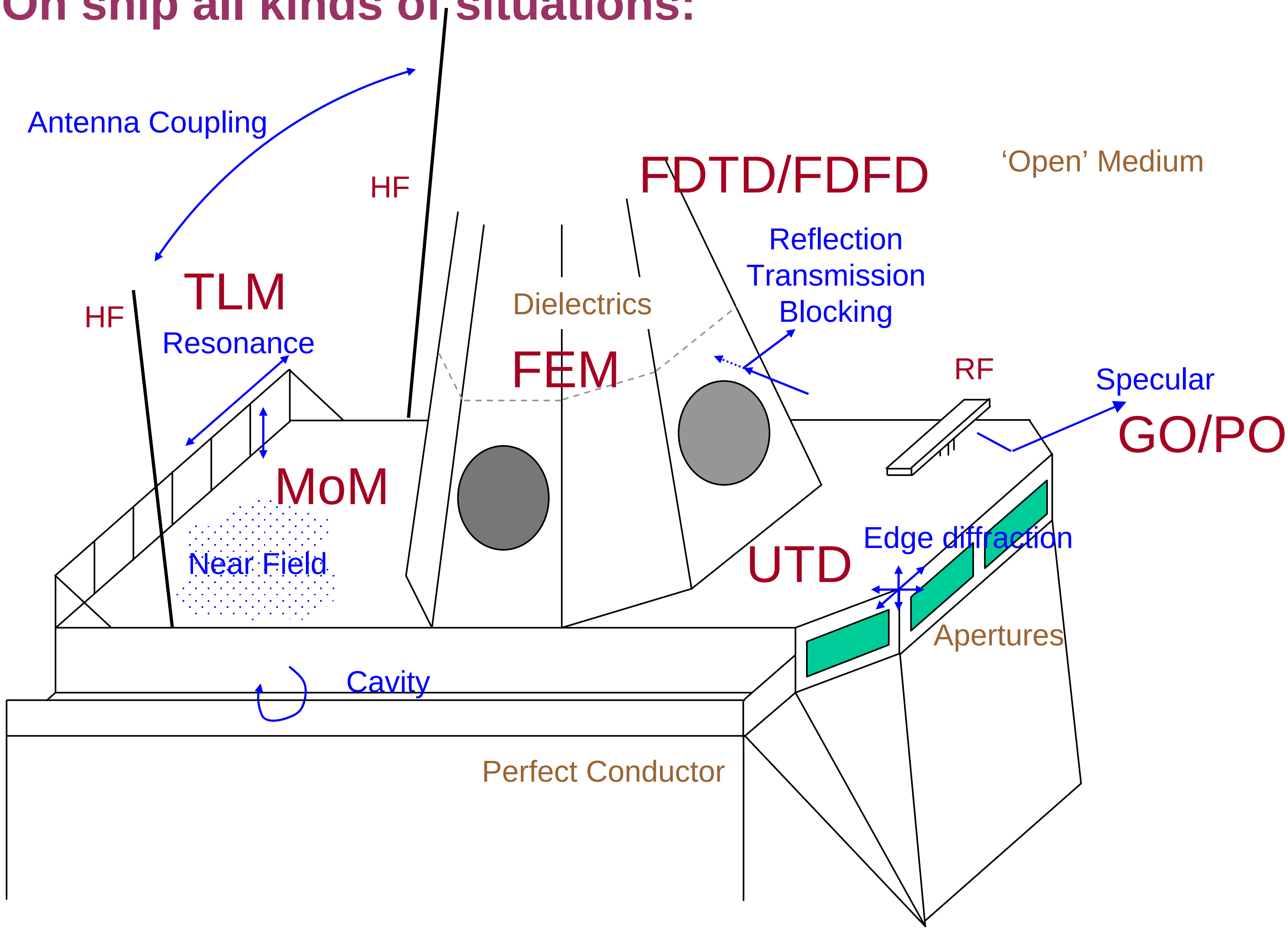
Case 1: Platform design: Phases



Case 1: Platform design: Simulation Methods

On ship all kinds of situations:



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Case 1: Platform design: Simulation Methods

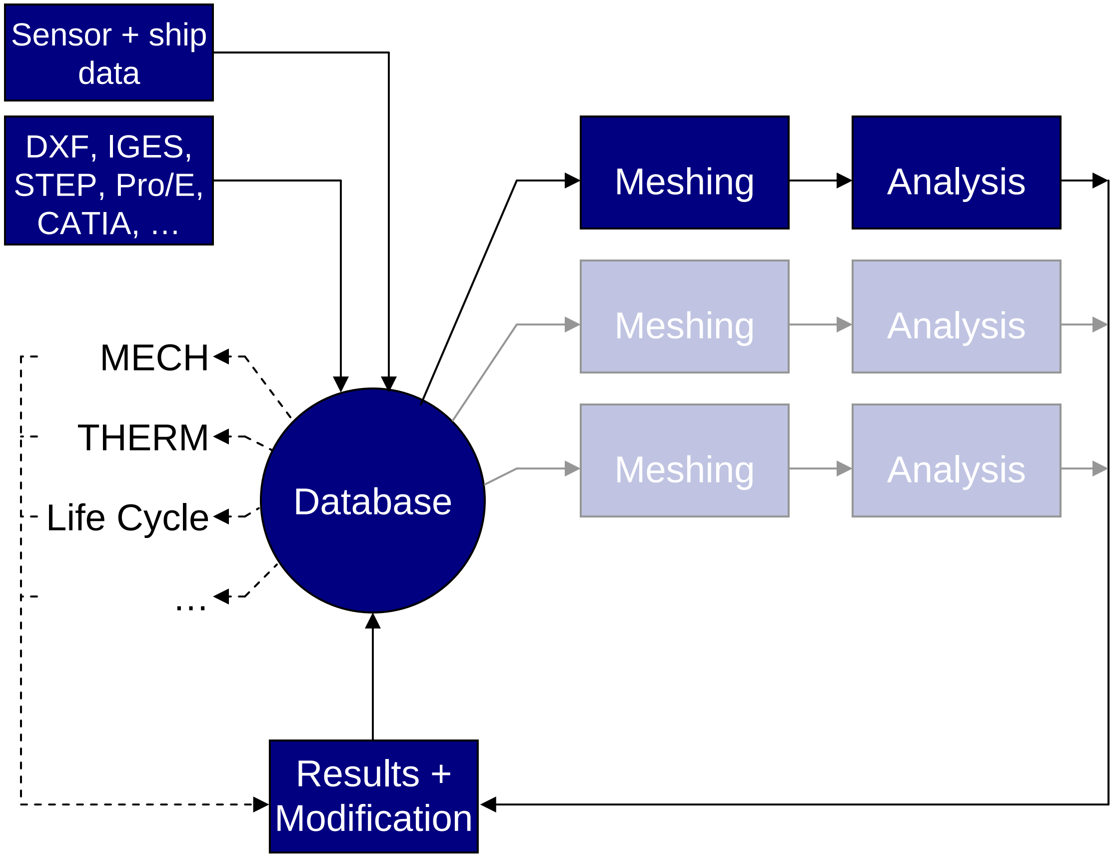
On ship all kinds of situations:

Not one EM Tool,
But Toolbox required!

Case 1: Platform design: EM workbench

Integrated EM workbench (EM, and more) containing:

- Database
  - CAD
  - EM parameters
- Conversion
- Simulation
- Storage of results



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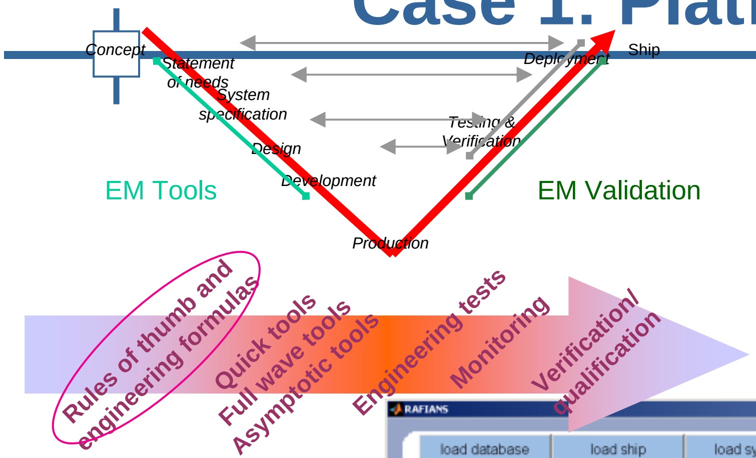
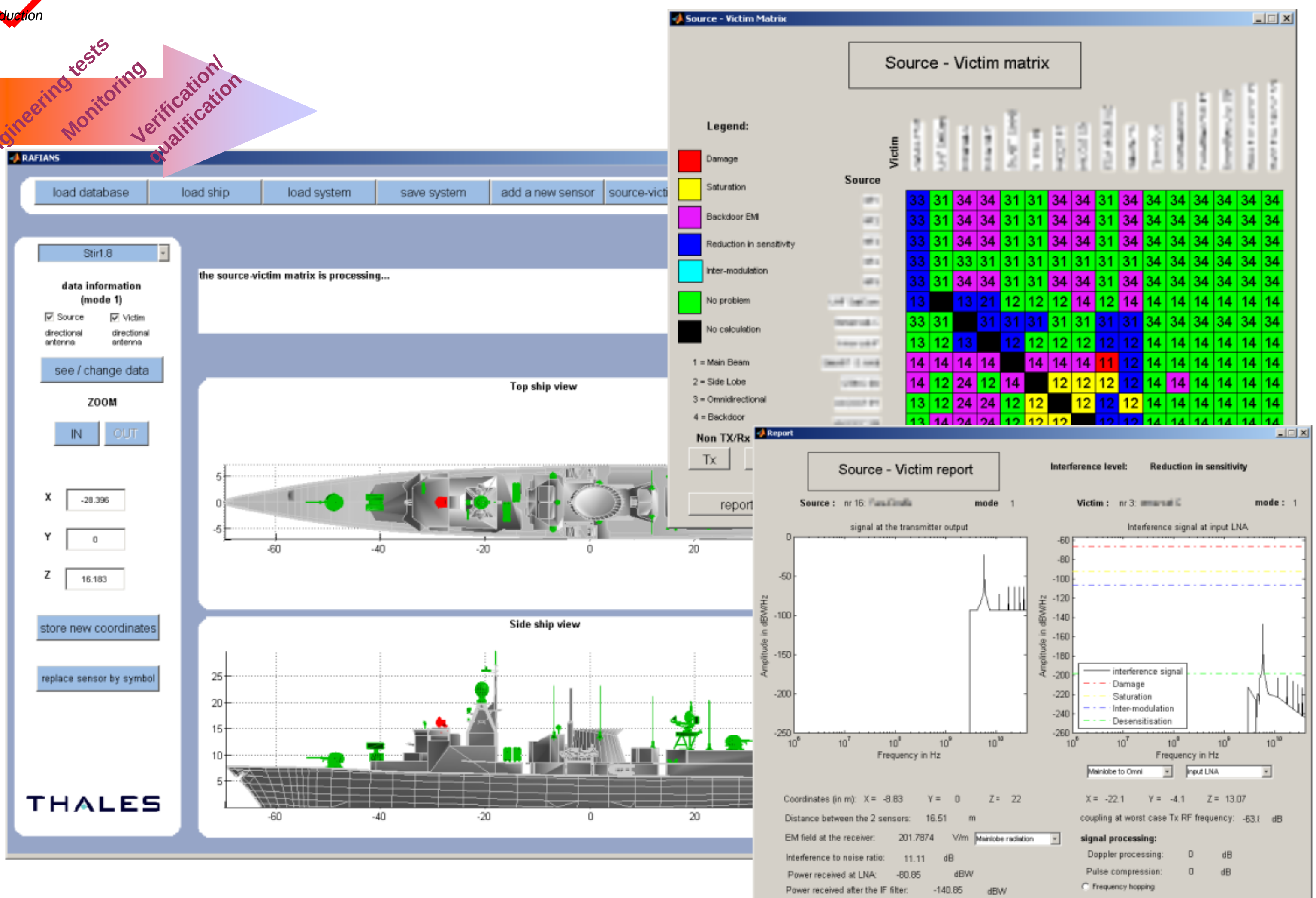
Case 1: Platform design: Central database

Case 1: Platform design: Rapid prototyping





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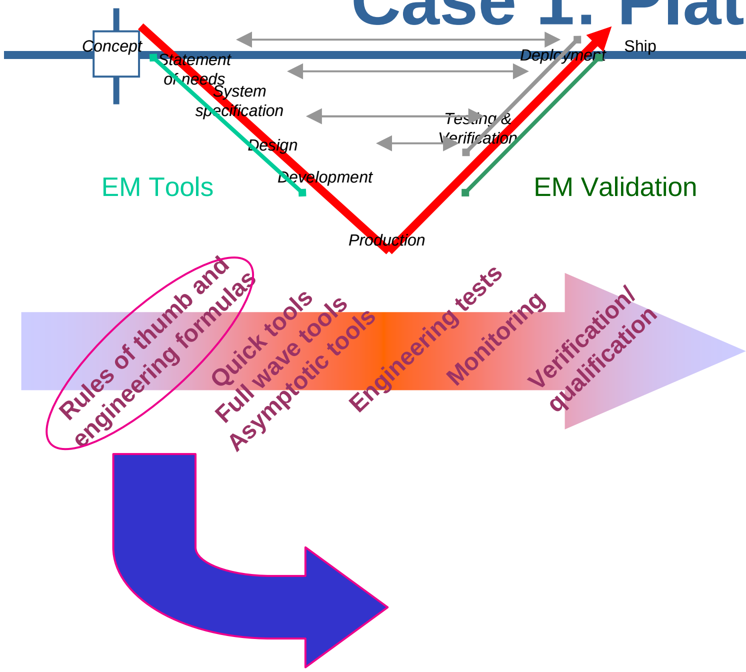
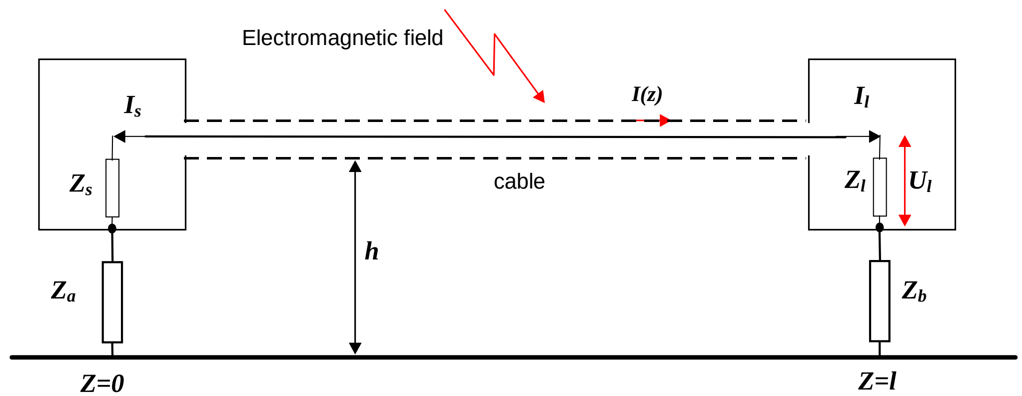
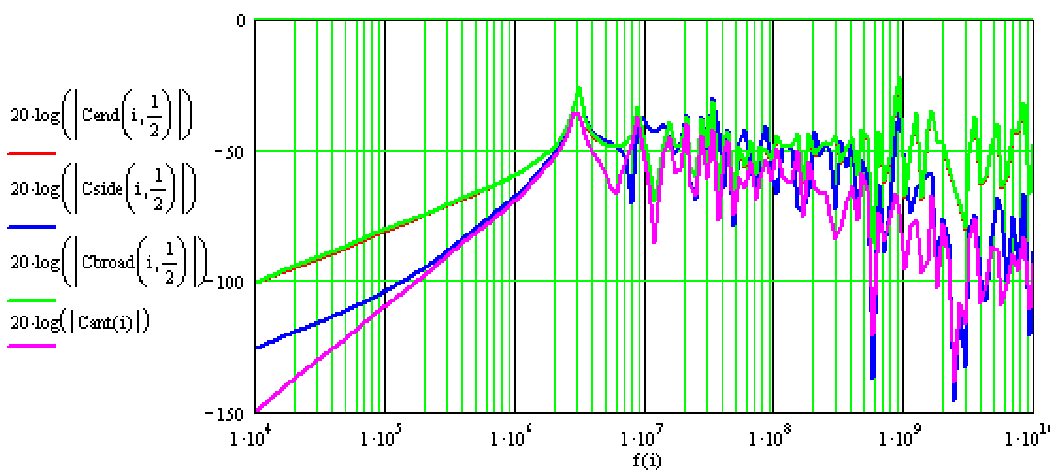
Case 1: Platform design: Rapid prototyping



Engineering tools

(Matlab, MathCad)





$$Cend\_int(i) := \frac{\int_0^l Cend(i,z)\cdot(Zcc\cdot\cos(\beta c(i)\cdot z) + j\cdot Zs\cdot\sin(\beta c(i)\cdot z))\,dz}{(Zcc\cdot Zs + Zcc\cdot Zl)\cdot\cos(\beta c(i)\cdot l) + j\cdot(Zcc^2 + Zs\cdot Zl)\cdot\sin(\beta c(i)\cdot l)}$$

$$Cside\_int(i) := \frac{\int_0^l Cside(i,z)\cdot(Zcc\cdot\cos(\beta c(i)\cdot z) + j\cdot Zs\cdot\sin(\beta c(i)\cdot z))\,dz}{(Zcc\cdot Zs + Zcc\cdot Zl)\cdot\cos(\beta c(i)\cdot l) + j\cdot(Zcc^2 + Zs\cdot Zl)\cdot\sin(\beta c(i)\cdot l)}$$

$$Cbroad\_int(i) := \frac{\int_0^l Cbroad(i,z)\cdot(Zcc\cdot\cos(\beta c(i)\cdot z) + j\cdot Zs\cdot\sin(\beta c(i)\cdot z))\,dz}{(Zcc\cdot Zs + Zcc\cdot Zl)\cdot\cos(\beta c(i)\cdot l) + j\cdot(Zcc^2 + Zs\cdot Zl)\cdot\sin(\beta c(i)\cdot l)}$$

$$Cant\_int(i) := \frac{\int_0^l Cant(i)\cdot(Zcc\cdot\cos(\beta c(i)\cdot z) + j\cdot Zs\cdot\sin(\beta c(i)\cdot z))\,dz}{(Zcc\cdot Zs + Zcc\cdot Zl)\cdot\cos(\beta c(i)\cdot l) + j\cdot(Zcc^2 + Zs\cdot Zl)\cdot\sin(\beta c(i)\cdot l)}$$

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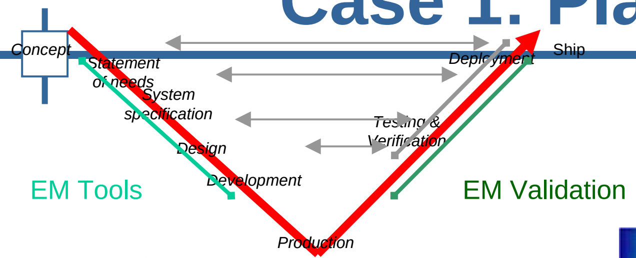
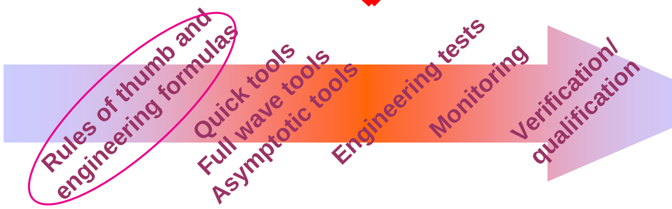
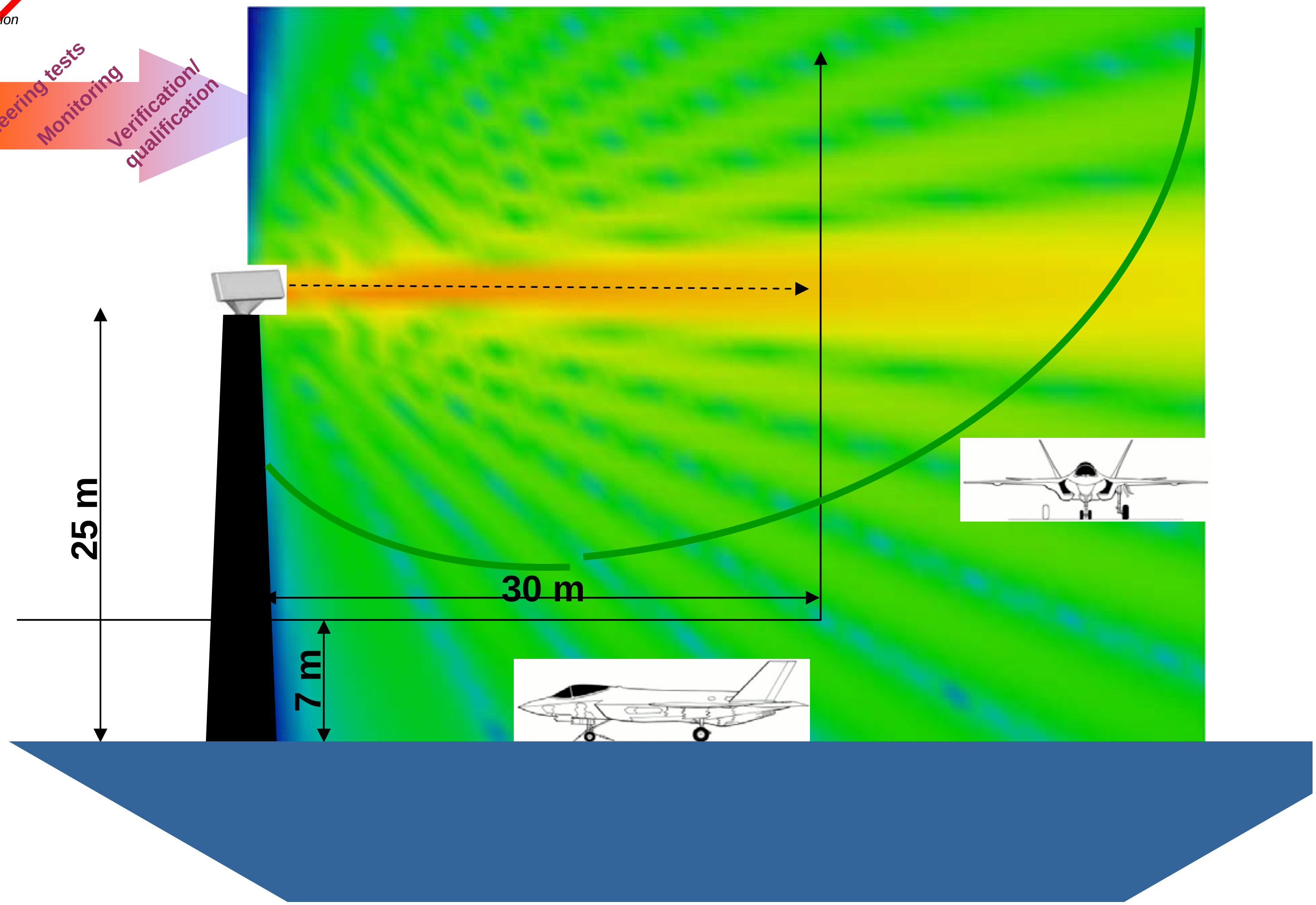
Case 1: Platform design: Rapid prototyping





Prediction of near field levels:



Exact calculation,
n striplines,
m elements,
tapering
included

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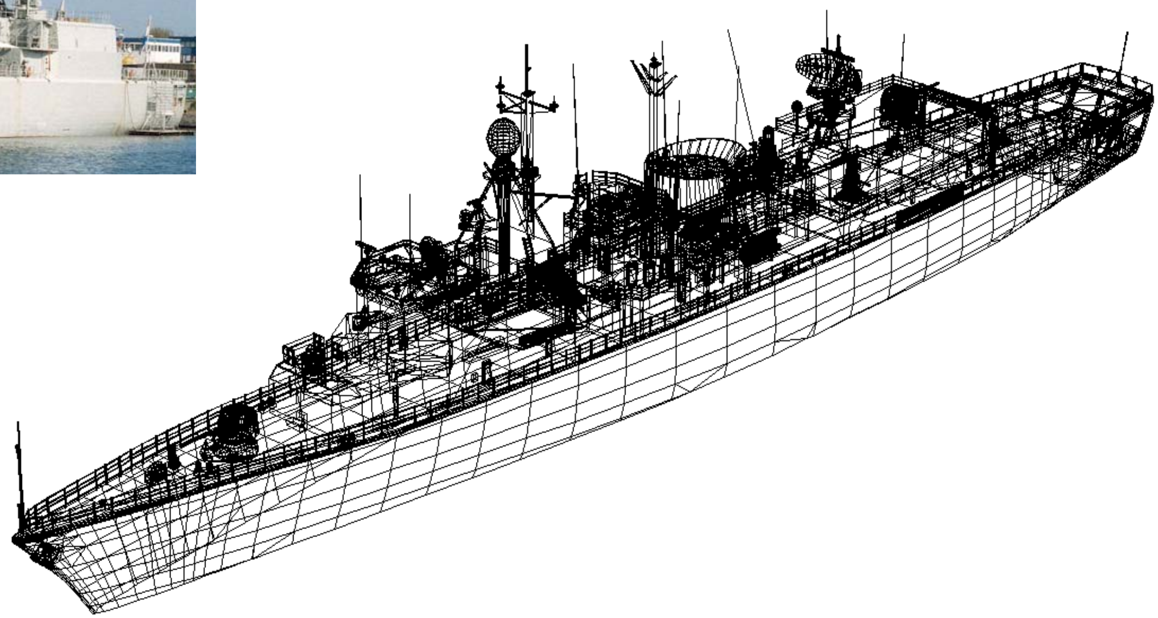
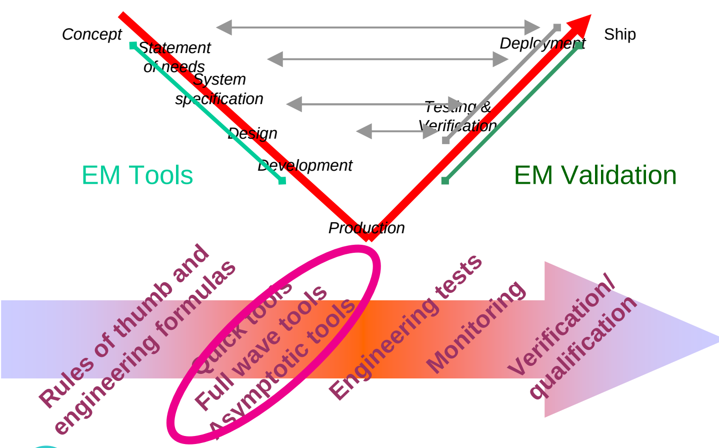
Case 1: Platform design: Details modeling

First step: convert 2D drawing to 3D computer model.





Use general file format (.dxf, .igs, .stp, …)

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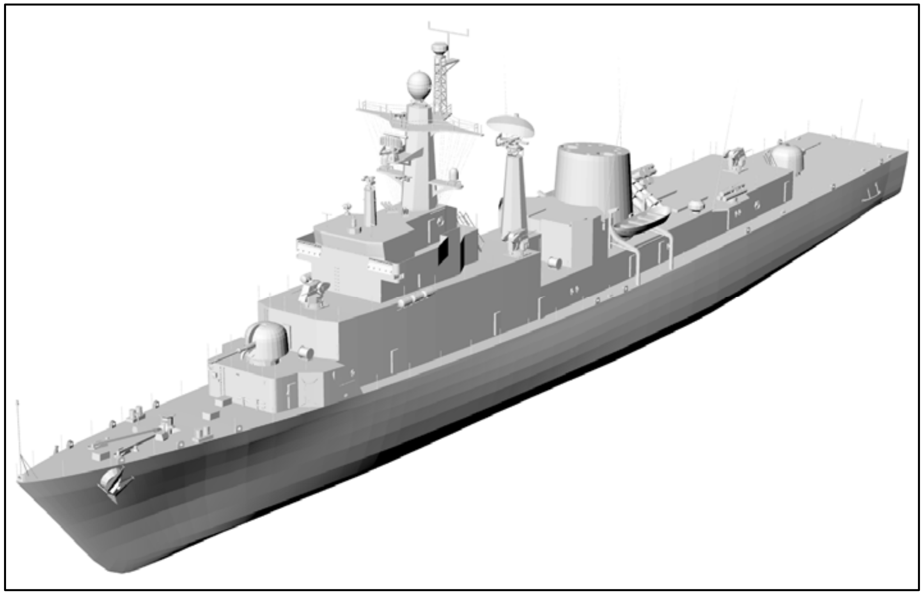
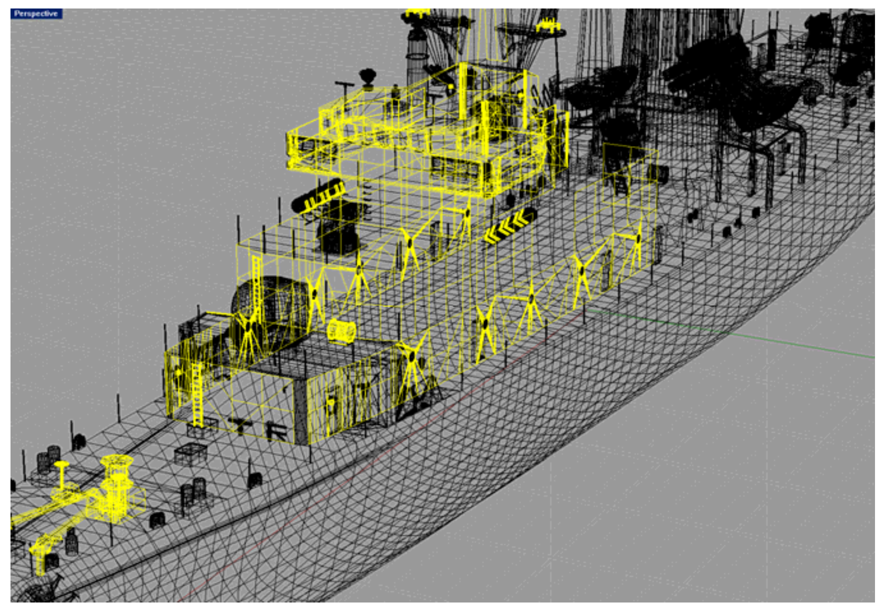
Case 1: Platform design: Modeling



Although a model looks good at first inspection, a closer inspection shows that this model is totally unusable for simulation purposes.

Problem areas:
- Crossing planes
- Planes continue underneath structures
- Curves are ‘pre-meshed’
- Portholes



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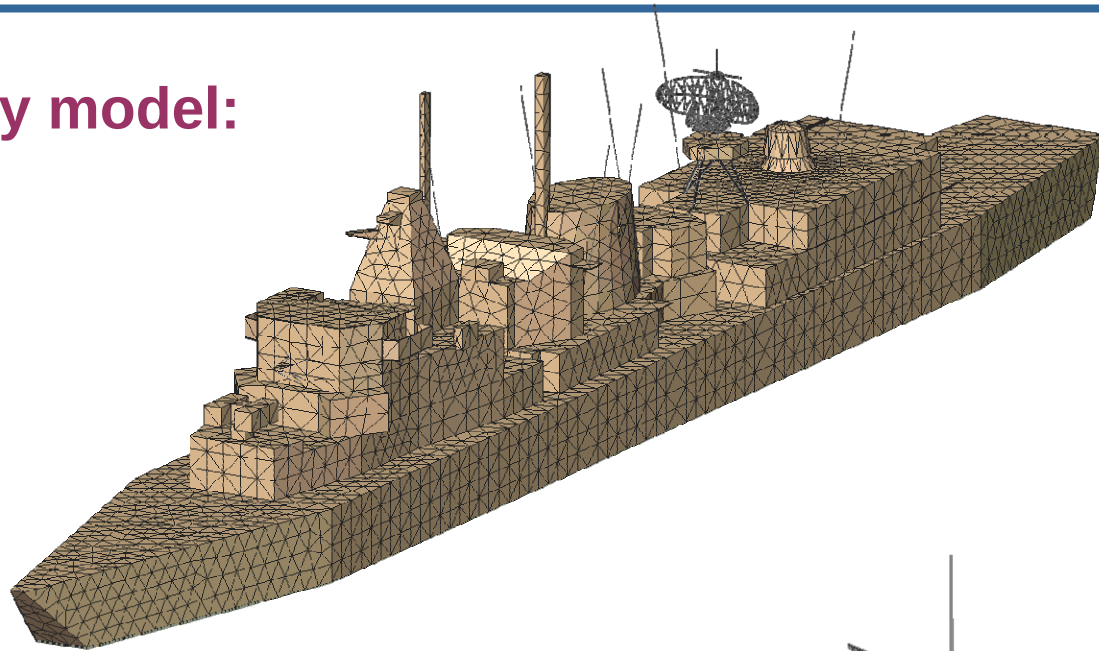
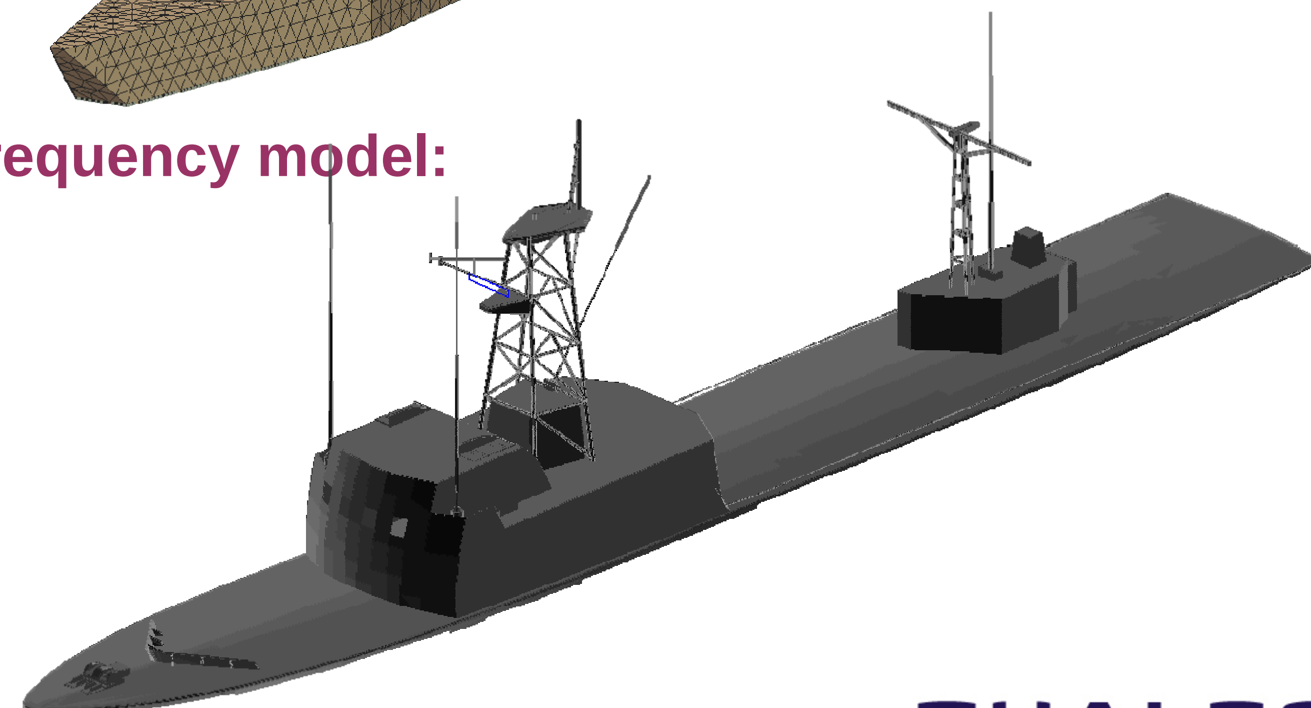
High Frequency model:



Microwave Frequency model:



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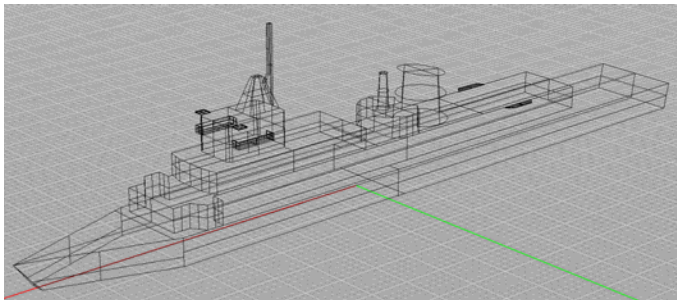
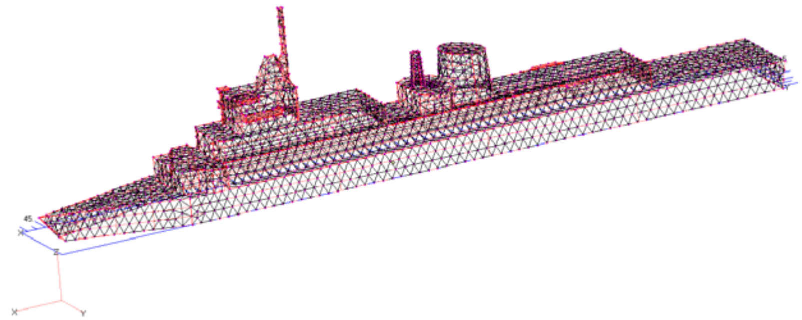
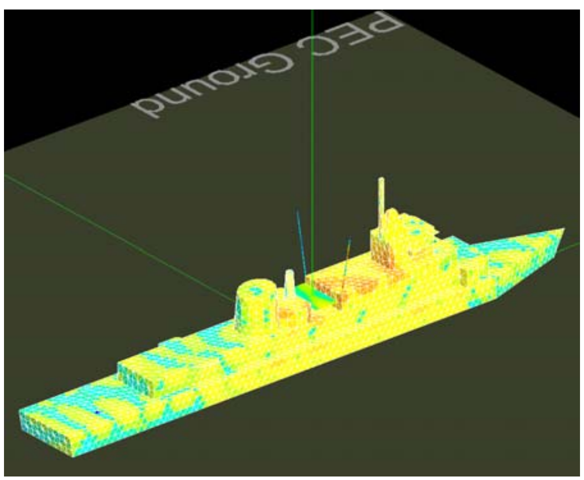
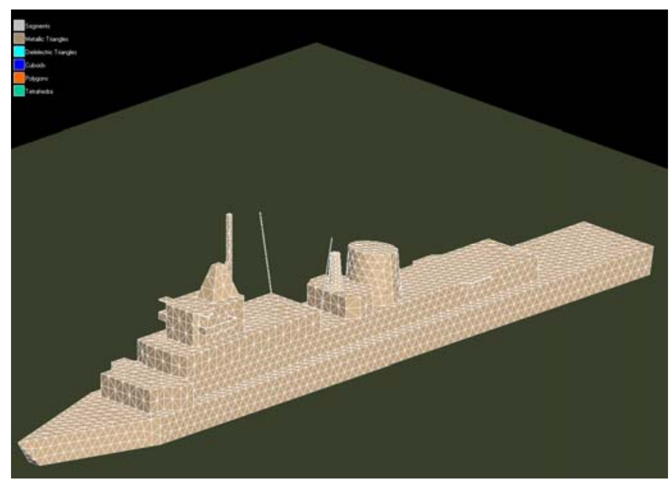
Case 1: Platform design: Simulation





EMENG+ workbench





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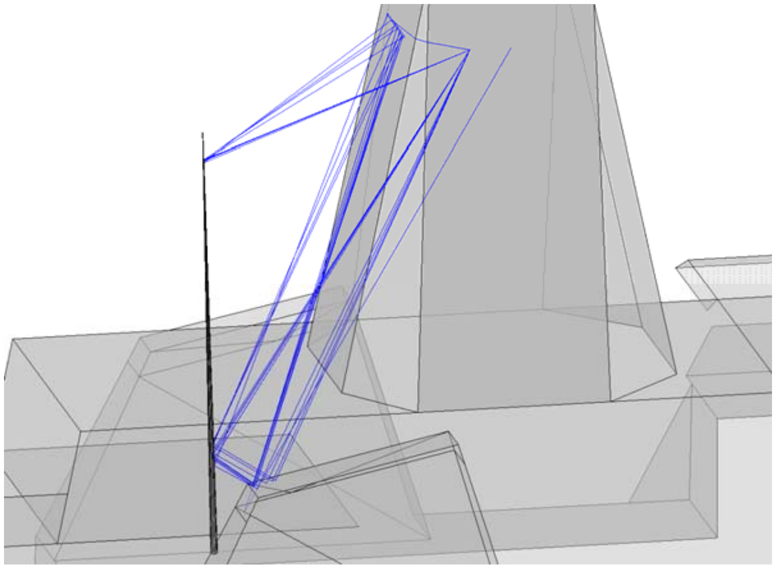
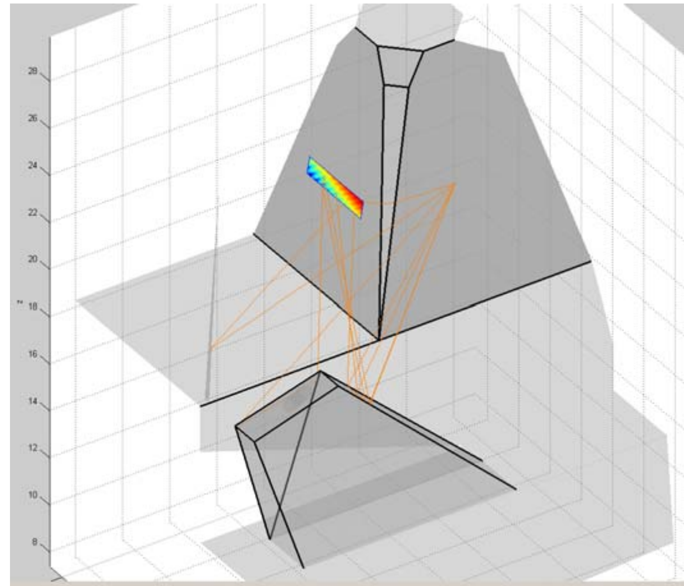
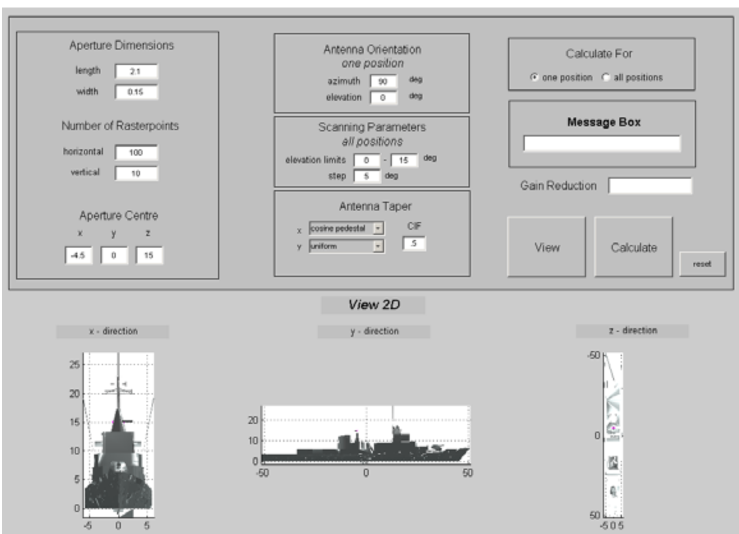
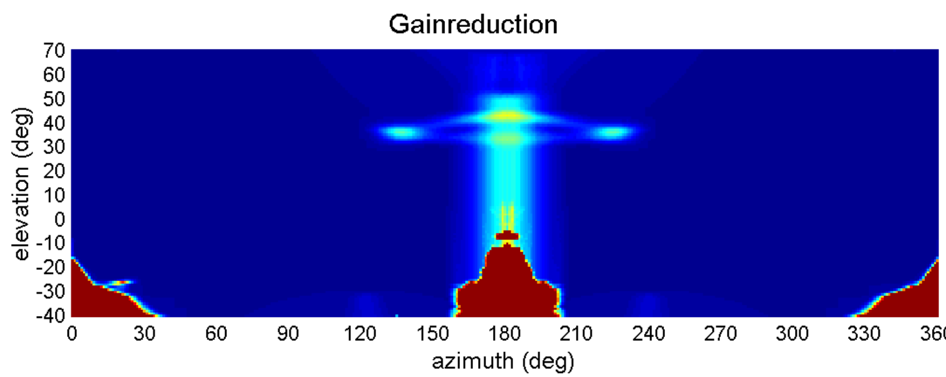
Case 1: Platform design: Simulation







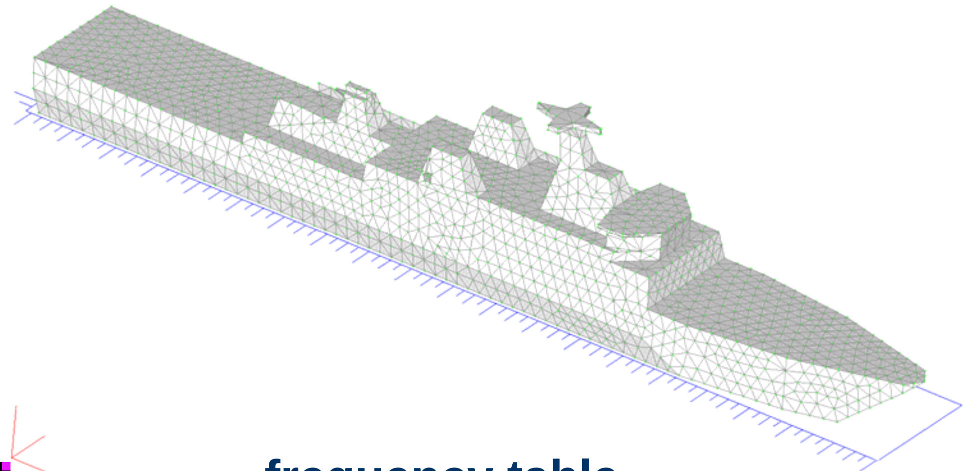
other tools



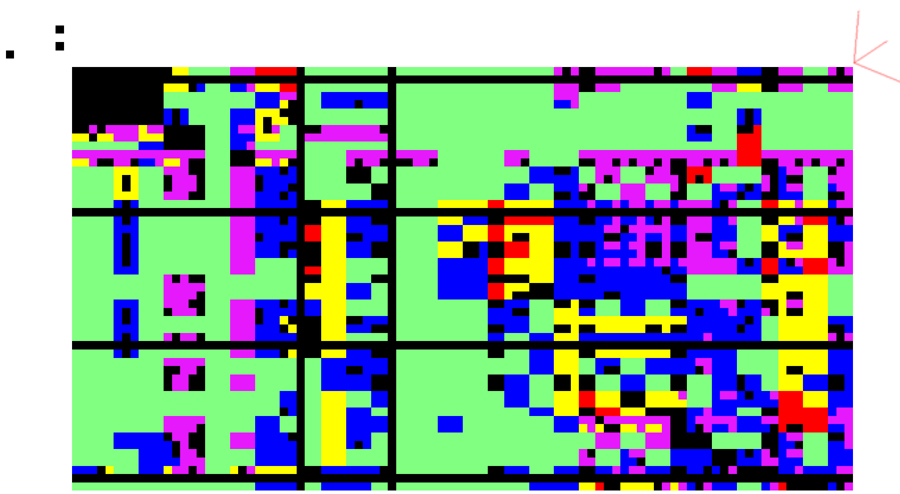
Case 1: Platform design: Example 1

New ship project
All THALES sensors i.c.w. 3rd party equipment

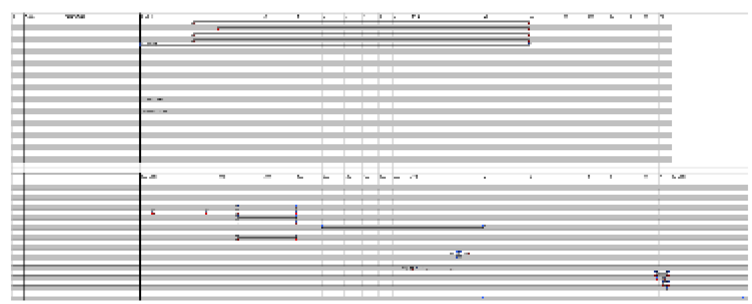
Topside arrangement
Field level prediction (EMI, RadHaz)
Performance prediction (blocking)



source-victim matrix



frequency table



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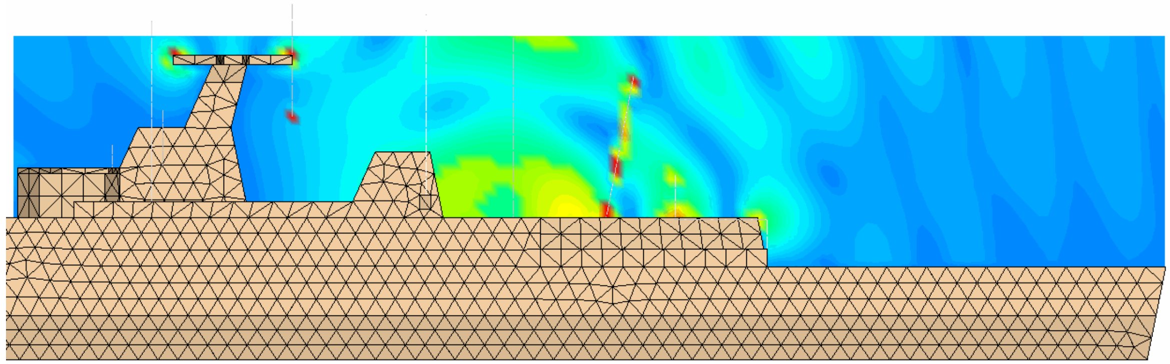
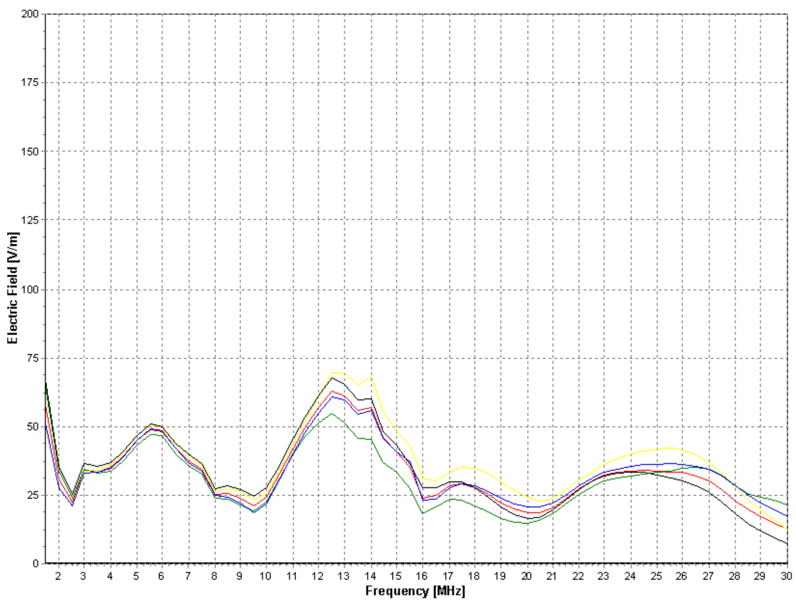
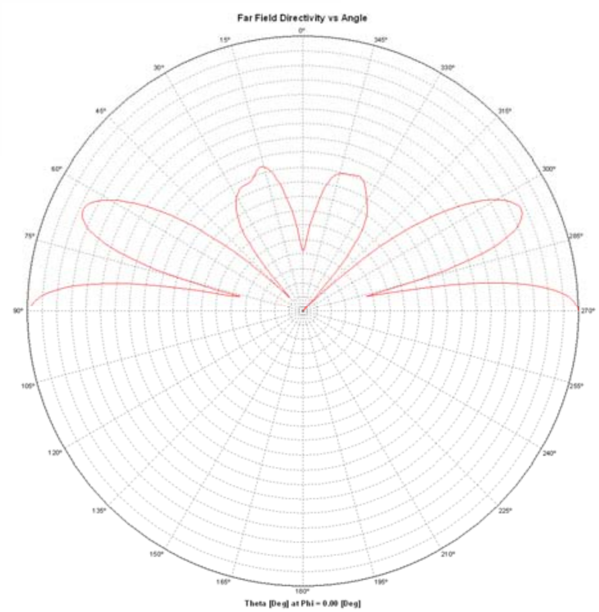
Case 1: Platform design: Example 1







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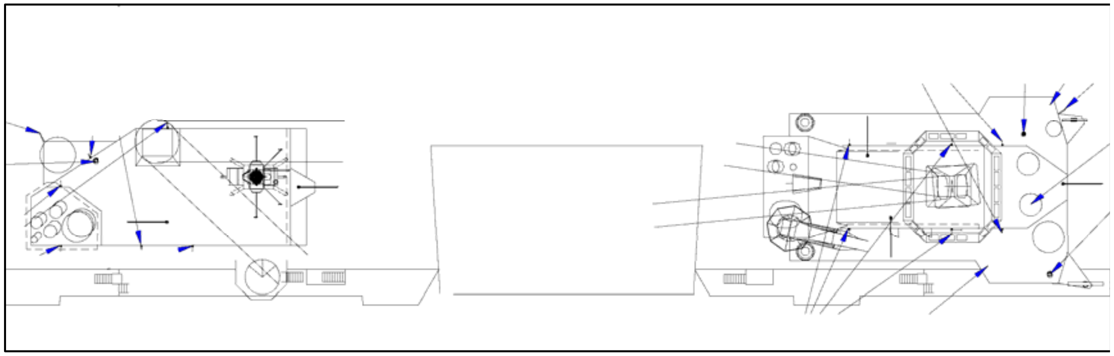
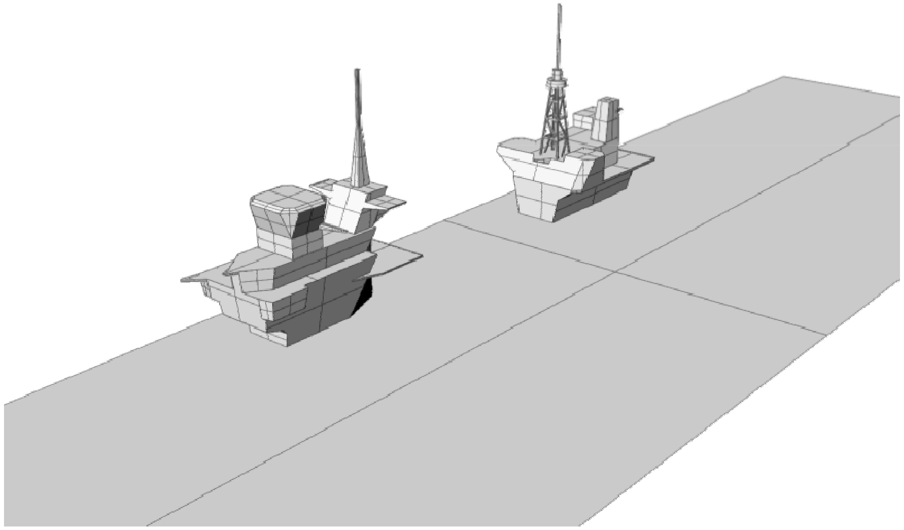
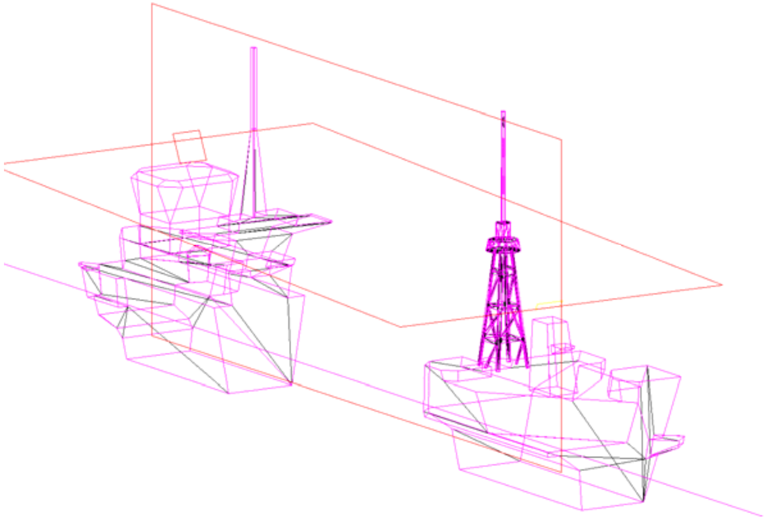
Case 1: Platform design: Example 2

Design phase project
THALES sensors in same frequency band

Field level prediction (EMI)

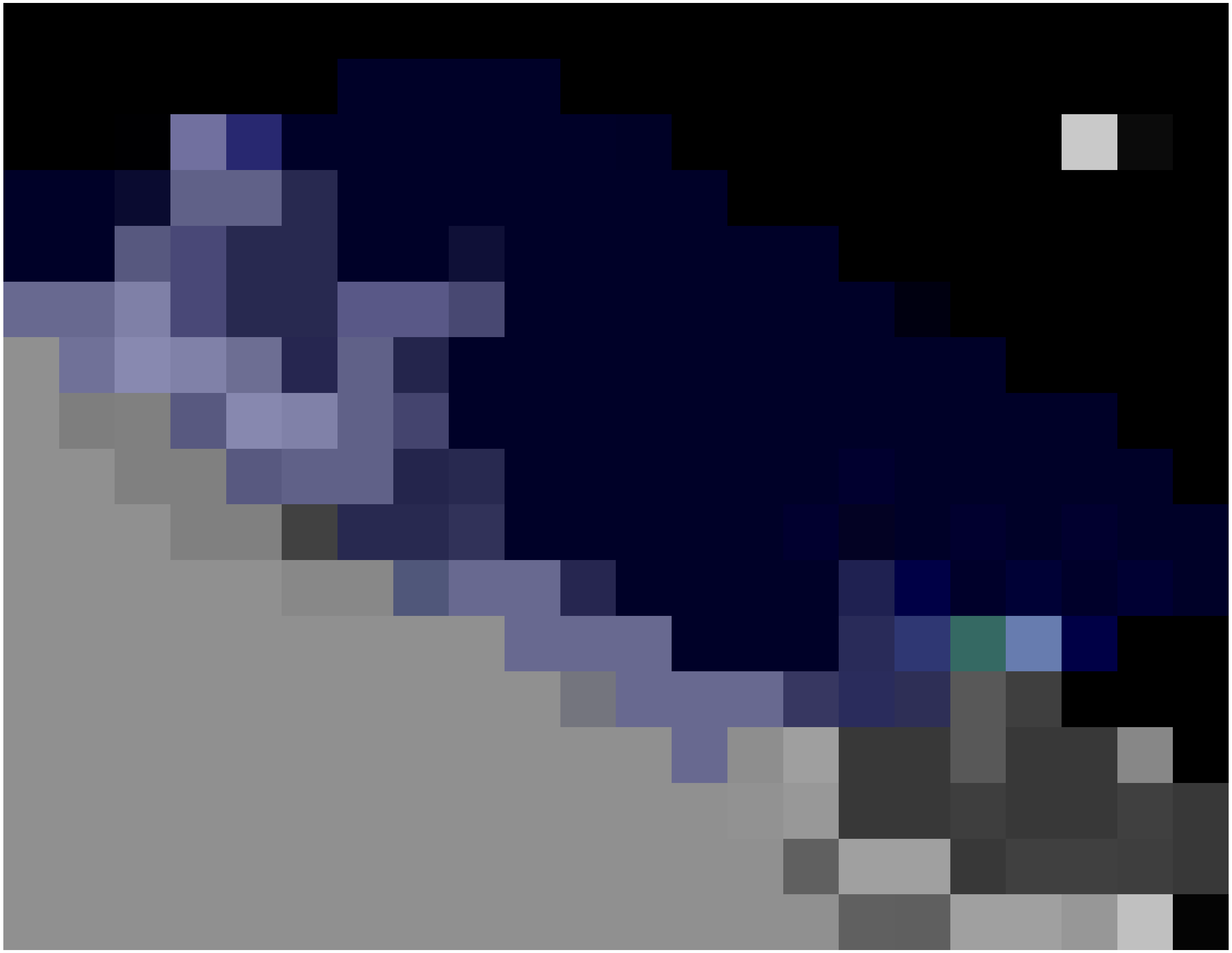






Case 1: Platform design: Example 2

Prediction of possible interference between two S-band radars on aircraft carrier



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Case 1: Platform design: Example 2

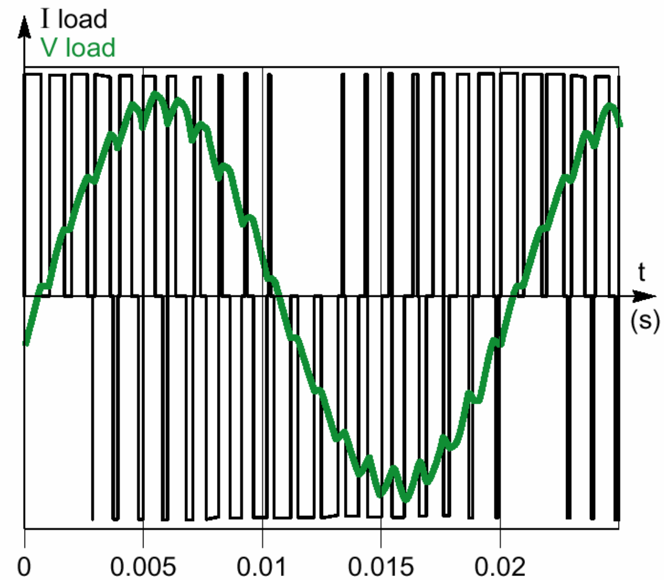
verification via measurements

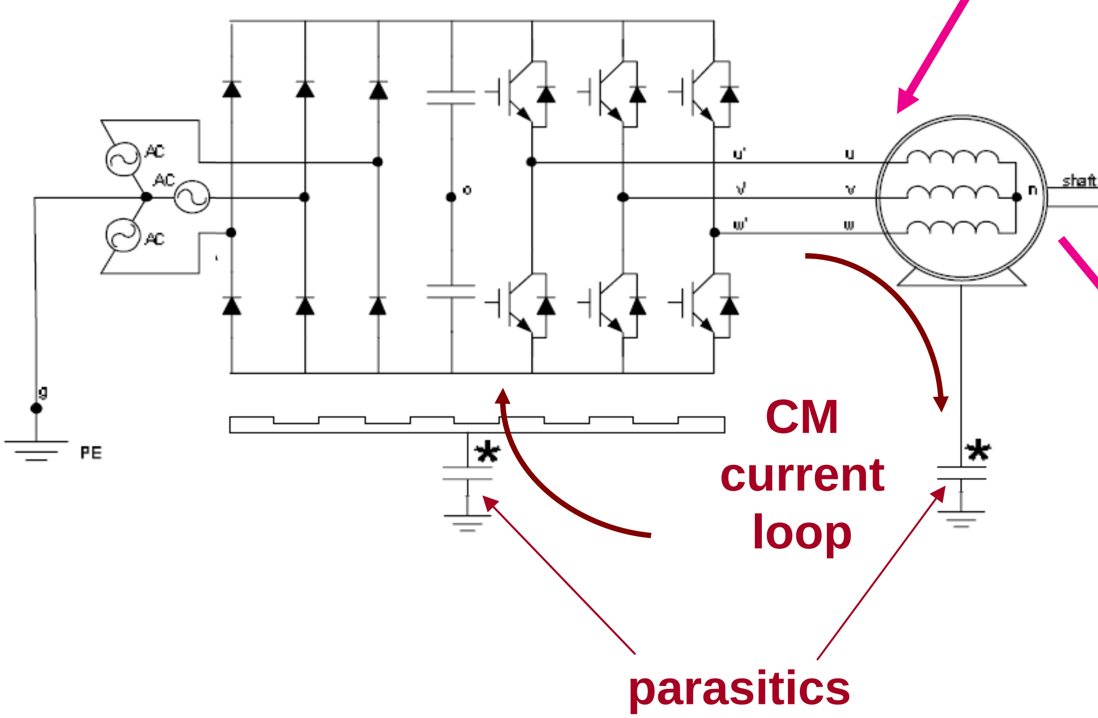
Case 2:

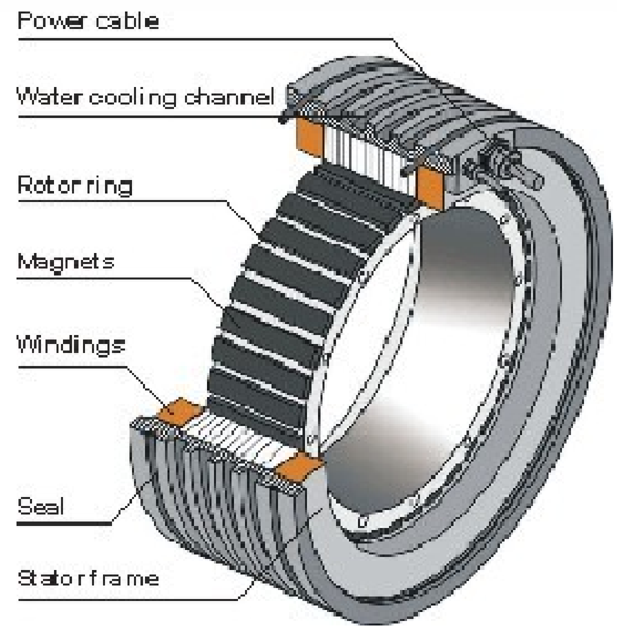
In the next sheets we will discuss some EMI issues of Electrical Drive Systems

Case 2: Electrical Drive System

- Basic structure:
  - **Rectifier (AC-DC)**
  - **DC capacitor**
  - **Converter (DC-AC)**







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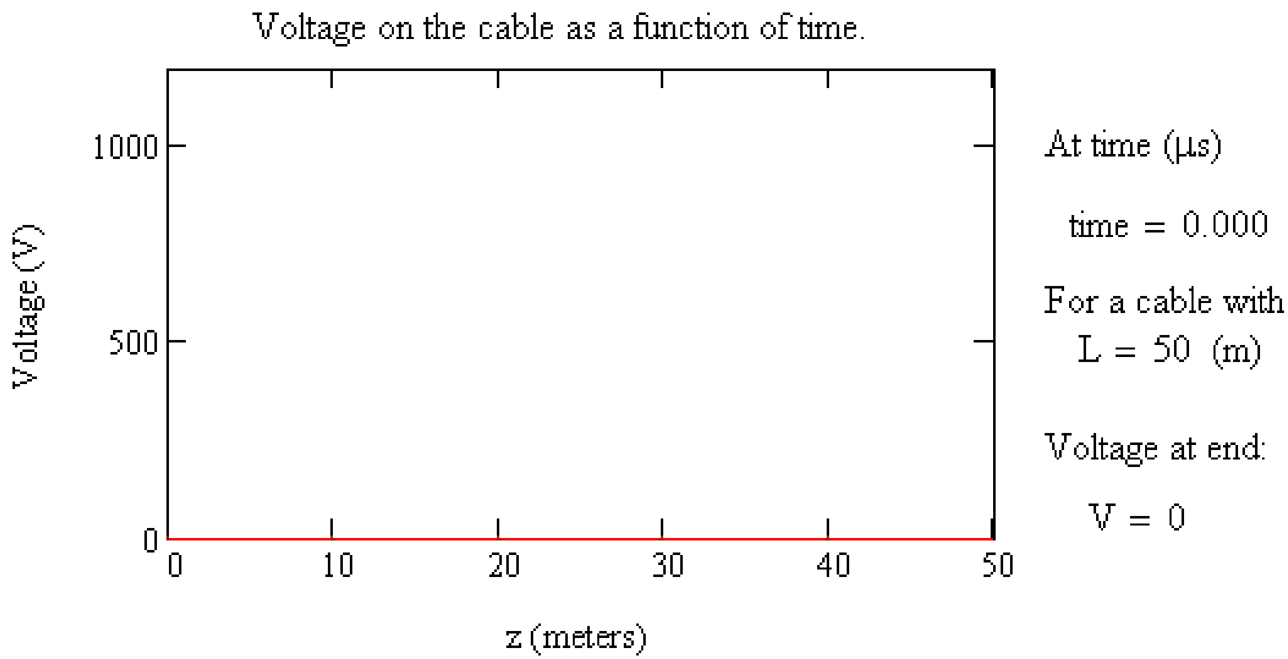
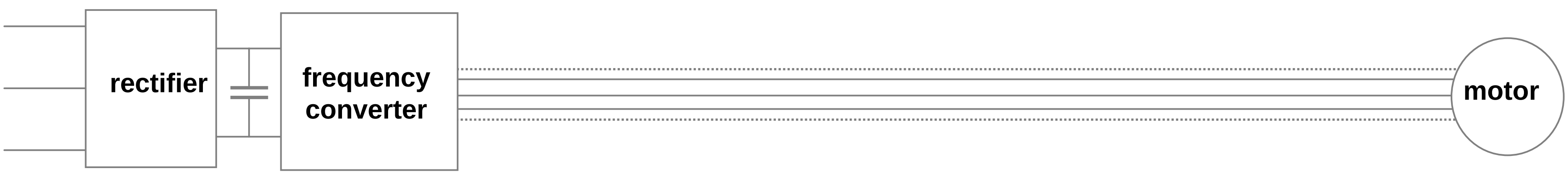
Case 2: Electrical Drive System: IGBT

- **IGBT: Performance evolution 1980s to 2007:**
  - **Current handling capability increased 4 times**
  - **Voltage handling capabilities increased 5 times**
  - **Turn-off time dropped 20 times, to around 100ns**
  - **Switching frequency, from 2 kHz to 200 kHz**
- **Most electromagnetic interference effects are mainly due to the common mode current.**
  The common mode current is determined by the *dV/dt*
- **This most crucial parameter *dV/dt* has increased a factor 100, i.e. 40 dB: 5 times voltage, and 20 times the turn-off time**
- ***EMI is now a key issue in designing electrical drives***
- **Interference:**
  - **Conducted EMI often upto 80 dB above requirement**
  - **Radiated emission also 80 dB too high (over 300 MHz)**
  - **Interference to other equipment: Communication links, control signals, encoder feedback, programmable controllers, etc.**





- This high voltage can cause damage in motor insulation
- Standard solution: ***dV/dt*** filter
- Not suitable for EMI reduction
  due to high parasitic capacitance

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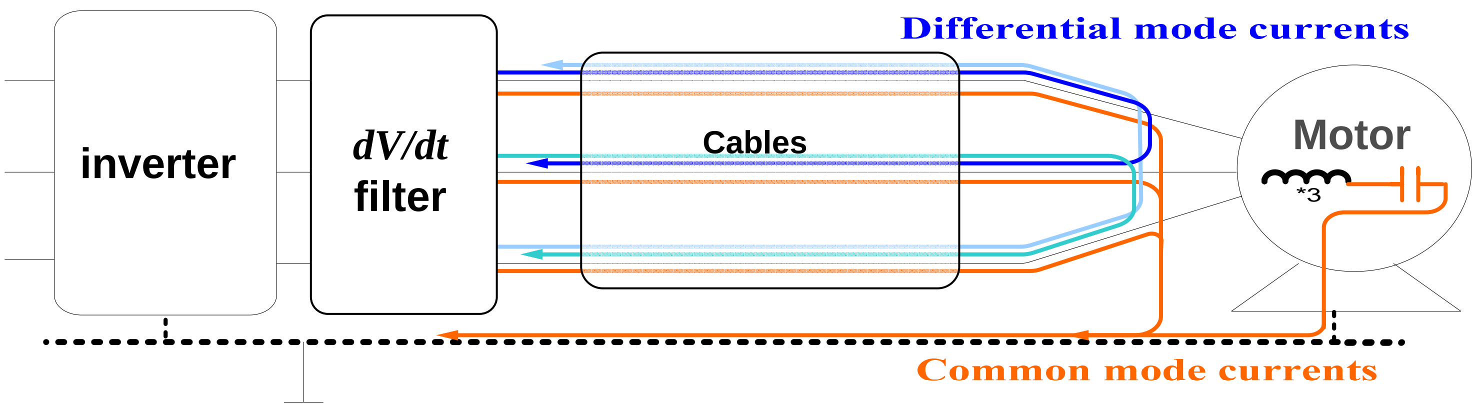
Case 2: Electrical Drive System: output filter

- Many commercial of the shelf (COTS) filters are not functioning properly due to the high common mode currents. These currents saturate the inductors, resulting in even more problems
- EDS, diode rectifier, Power: 15 kVA, Voltage: 440 V, Current: 30 A, Frequency: 60 Hz , IT system, 3 phase, no neutral (ungrounded)
- Key issue: low capacitance towards ground allowed, otherwise the switches (IGBT's) will be damaged due to a large loop current. Here: 4.7 nF max. If we want 50 dB at high frequencies then the parasitic capacitance of an inductor shall be less than ~10 pF!



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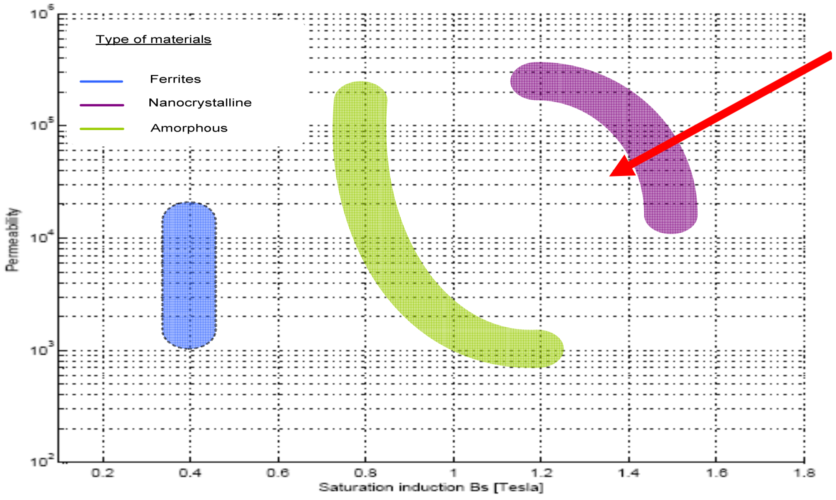
Case 2: Electrical Drive System: output filter

- High common current saturates ferrite or amorphous cobalt based alloy inductors: useless.
- Iron lamel inductors have high saturation levels, but are heavy and have limited quality for higher frequencies (>1MHz).
- We use a core material has been used which is basically a bunch of very small iron particles, called nano-crystalline inductor.

MnZn ferrite	μ_r **= 15.000**	B_{sat} **= 0.38**
Iron powder	μ_r **= 90**	B_{sat} **= 1.6**
our material	μ_r **= 30.000**	B_{sat} **= 1.2**



Permeability vs. Saturation

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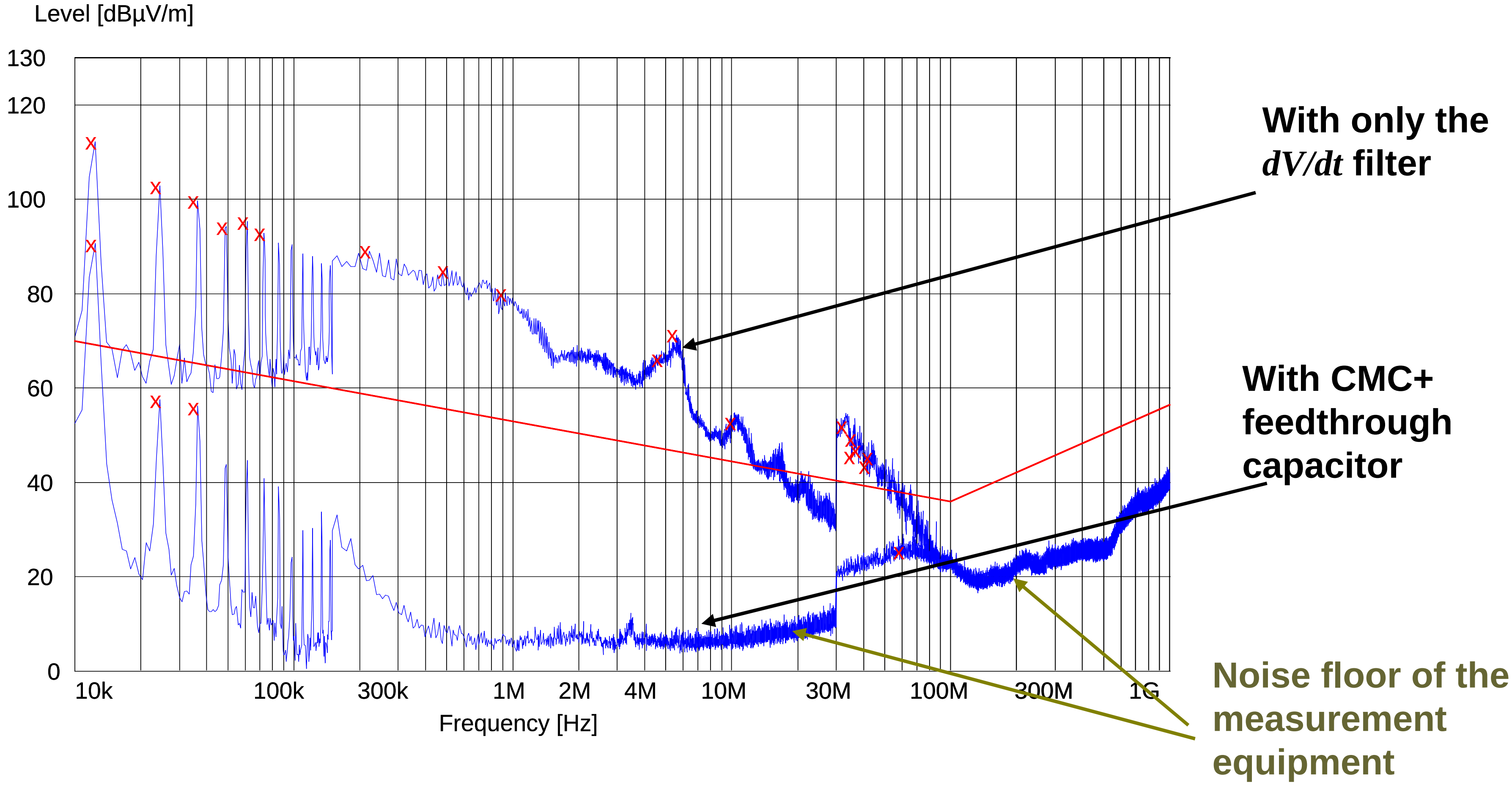
Case 2: Electrical Drive System: output filter

Effect on radiated emission



Switching frequency has been moved below 10 kHz

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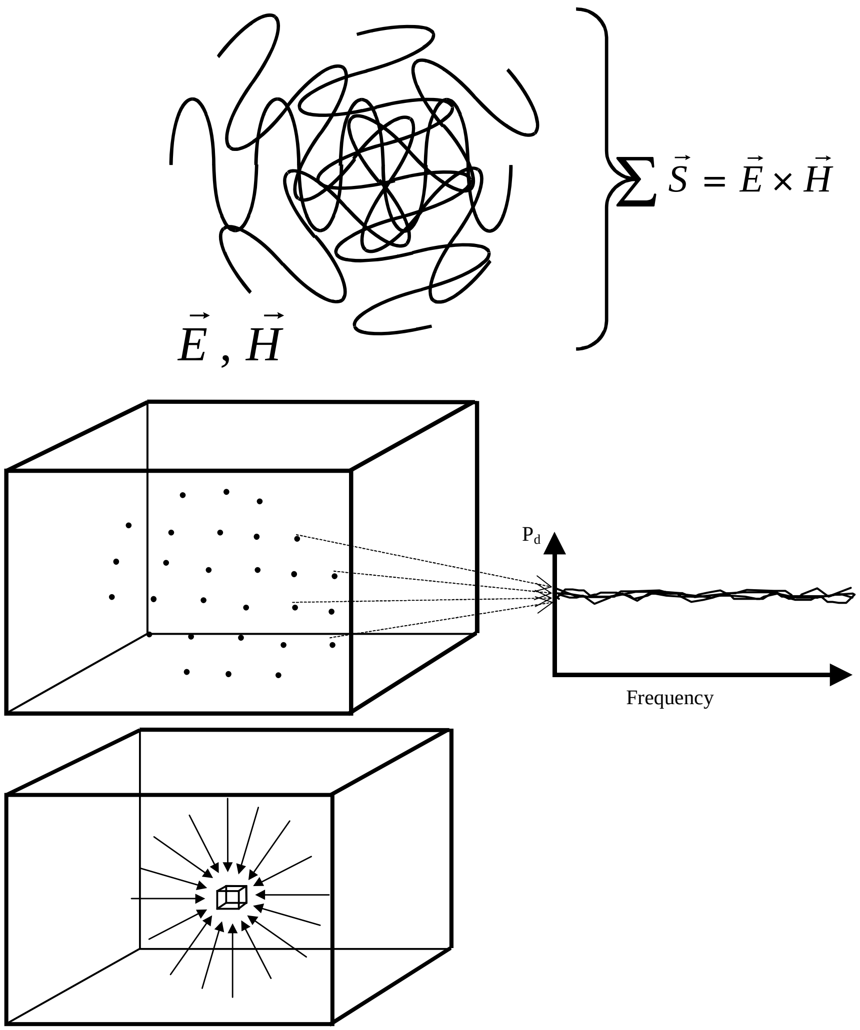
Case 3:

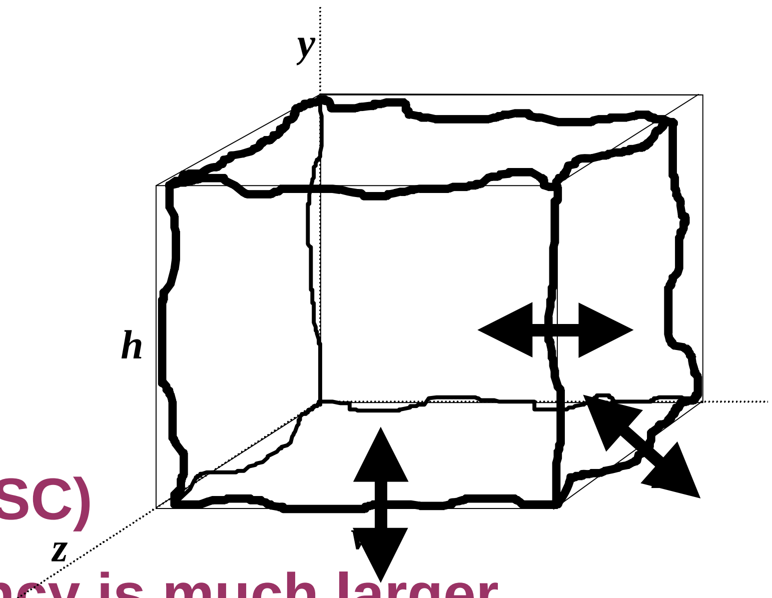
The next sheets show some practical approaches to measurements on large systems in-situ

RC provides a periodic electromagnetic environment, which is

- **randomly polarised,**
  i.e. the phase between all waves is random
- **spatialy uniform,**
  i.e. the energy density in the chamber is uniform everywhere and
- **isotropic,**
  i.e. the energy flow in all directions is the same.



Case 3: In-situ testing: VIRC



- An RC made of flexible material
- By moving the walls the modes (resonance frequencies) are changed
- The mode variation is much faster compared to the classic mode stirred chamber (MSC)
- The change in resonance frequency is much larger compared to the MSC
- The VIRC can therefore be used from a lower frequency than a MSC with comparable size
- The VIRC can be used for in-situ testing

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Case 3: In-situ testing: testing APAR

Material:
- metalised (copper) fabric

Production VIRC:
- regular tent manufacturer

Shielding:
- good (>60dB)

Dimension:
- 5 x 3 x 3 m (F_{res110}= 58 MHz)

Connection with EUT:
- overlapping flaps, electrically connected with EUT

Vibration:
- wiper motors with excentric

Cost:
- <25 kEuro

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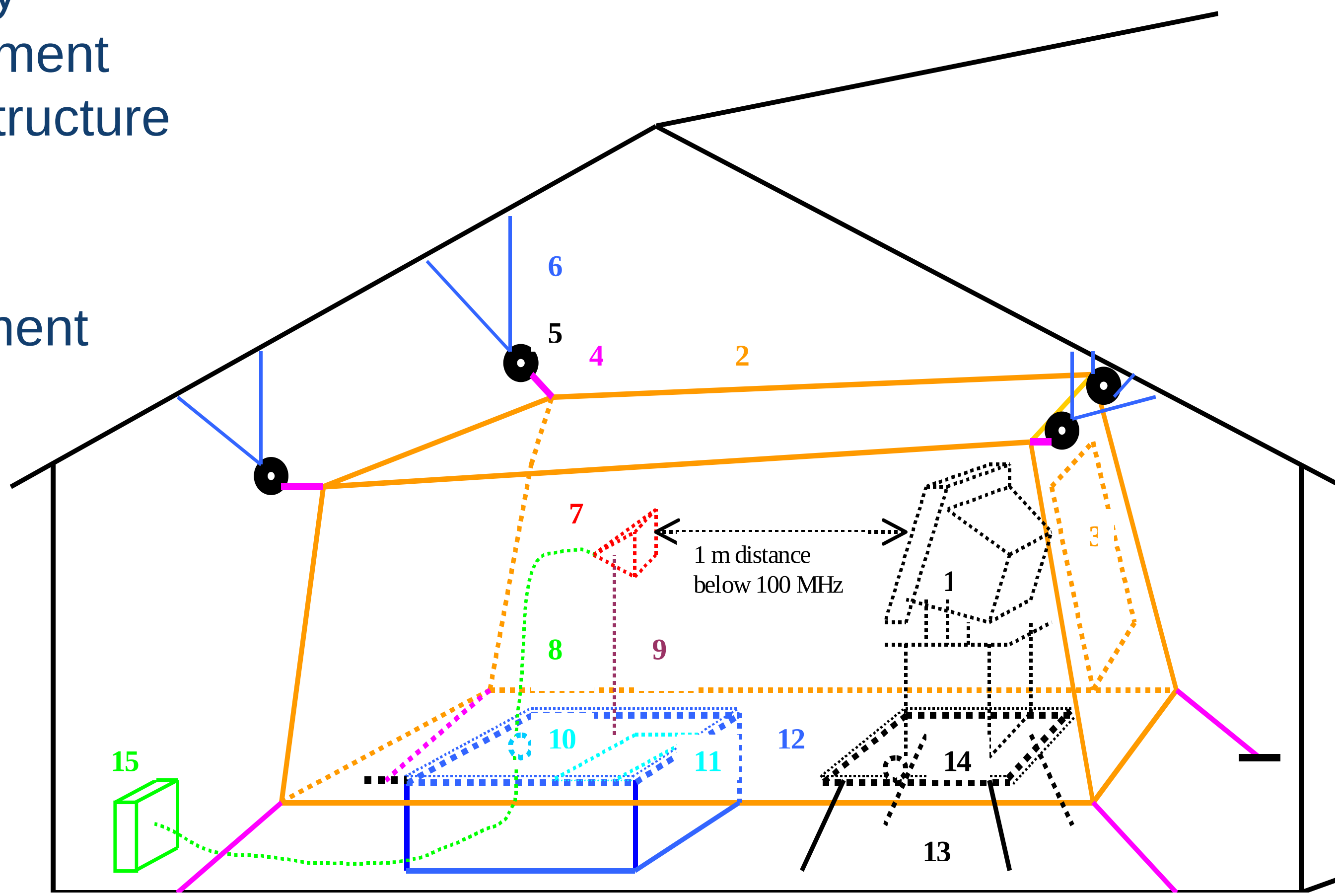
[redacted]

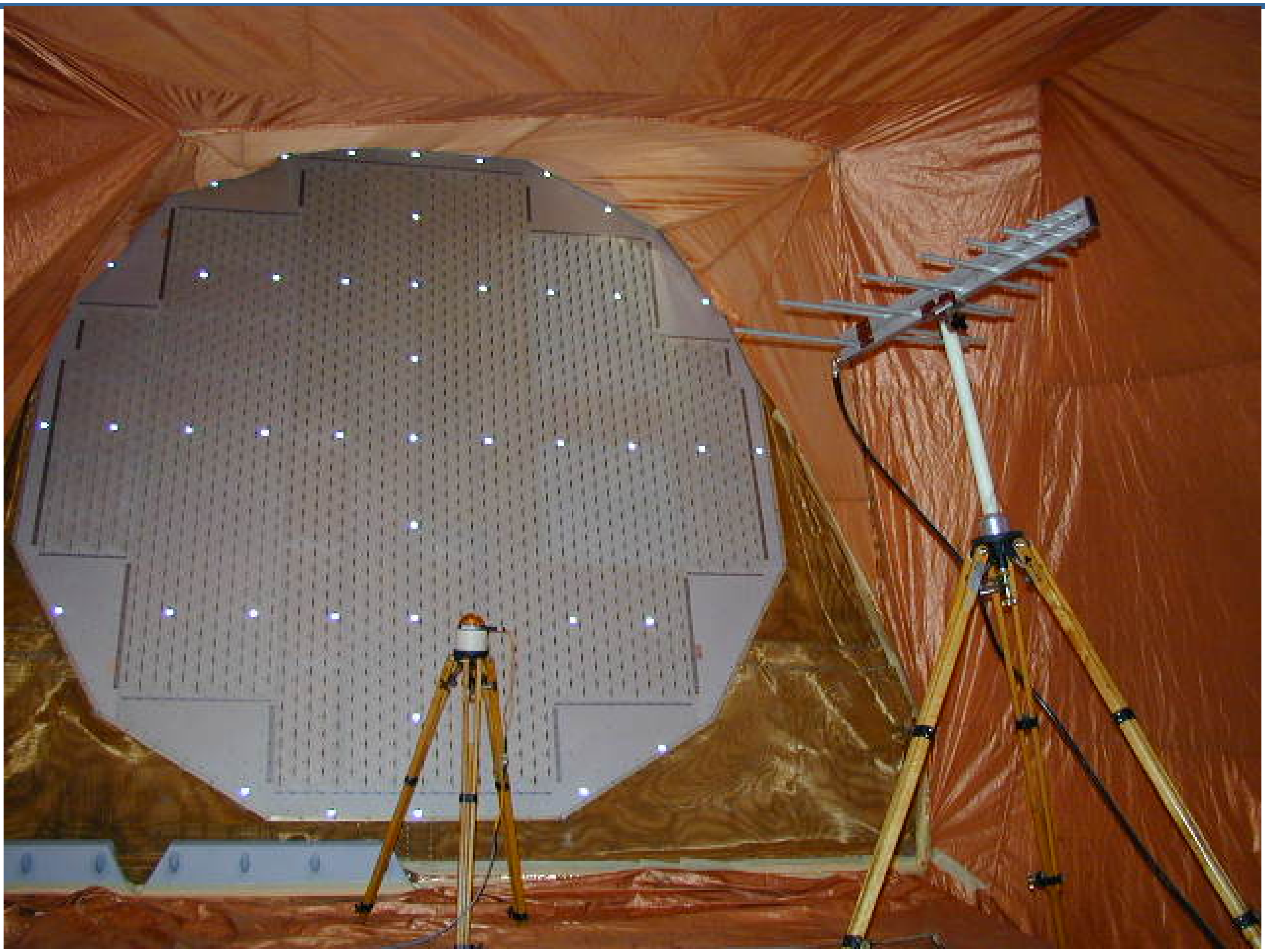
Case 3: In-situ testing: system X and system Y

Thales France

- Conventional
  250kEuro facility
  xxxkEuro equipment
  xxxkEuro infrastructure
- With VIRC:
  10kEuro VIRC
  20kEuro equipment



Case 3: In-situ testing: system Y



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Case 3: In-situ testing: system X

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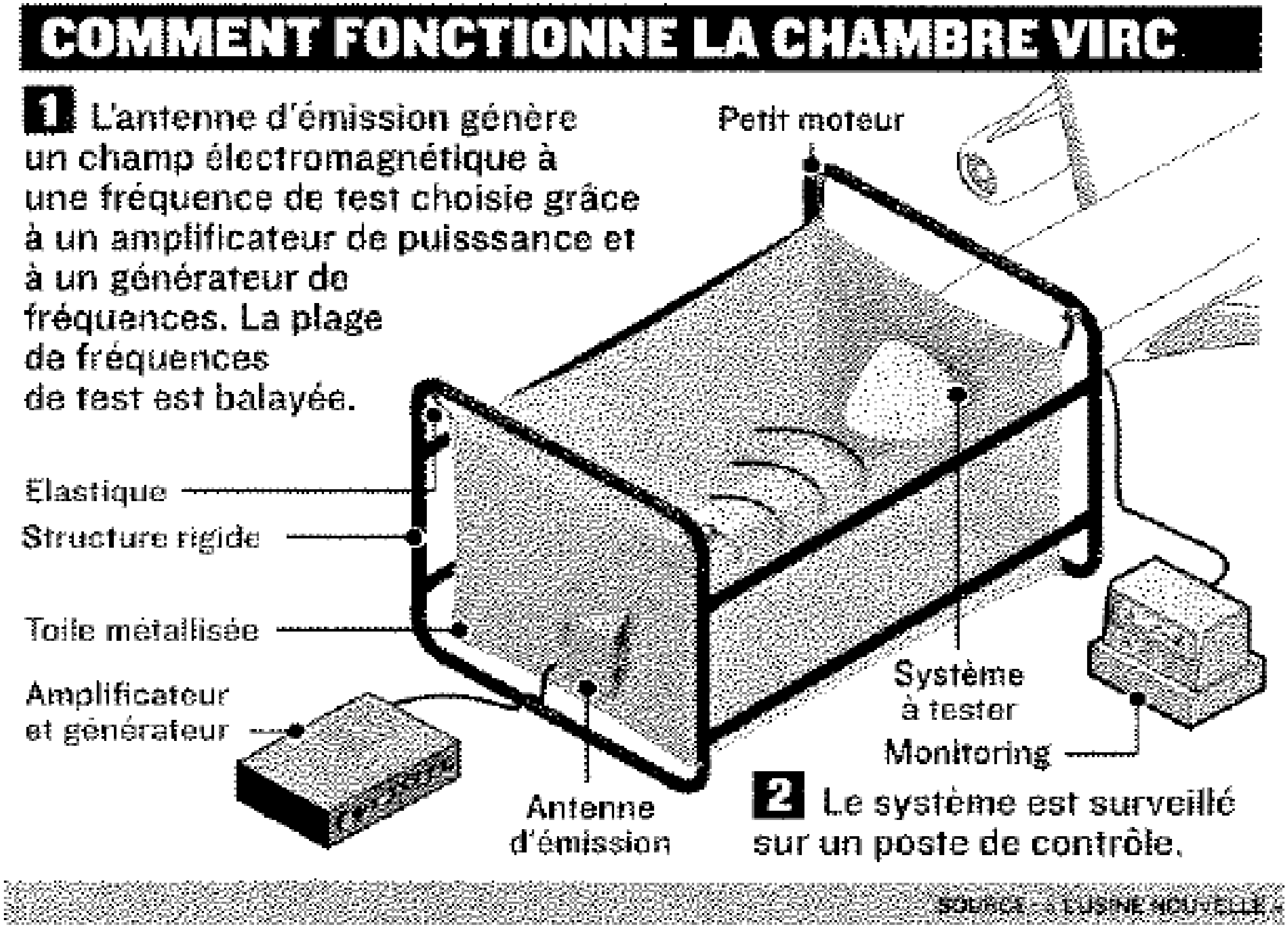
Case 3: In-situ testing: cockpit



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Studies THALES and THALES Netherlands

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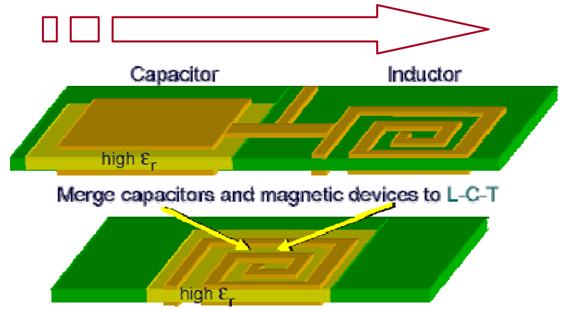
Questions: contact the author

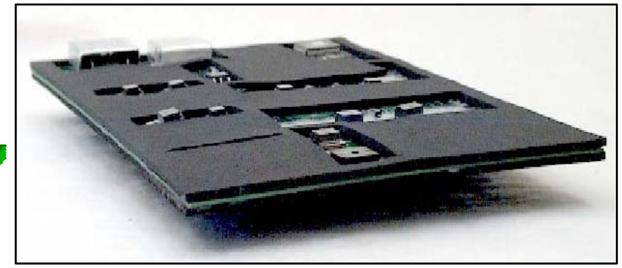
Studies University of Twente

- Multi-domain Optimization of Power Electronics (frequency converters) (With Technical University Delft, 2 PhD)
- Embedded metamaterials (With Technical University Delft, 2 PhD)
- Effects of lightning on electronic systems in composite structures
- Several applications
  - HIRF-SE
  - EMF
  - Radio spectrum
  - Reverberation chamber (to be submitted)
- Many M.Sc. final assignments activities
  - SI and EMC demo's at PCB level
  - EMC Expert System demonstrator for system engineers

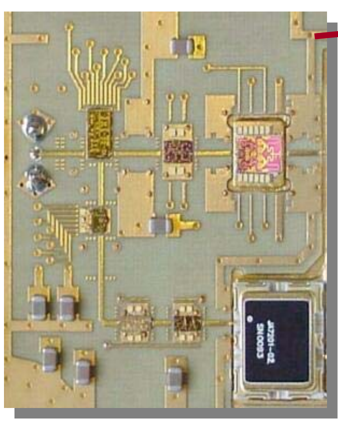
Studies University: embedded metamaterials

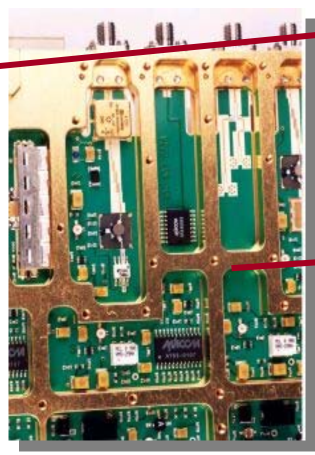
Delft:

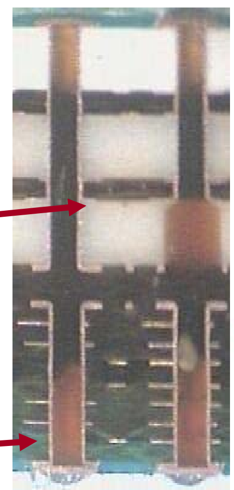




THALES NL: multifunctional carrier

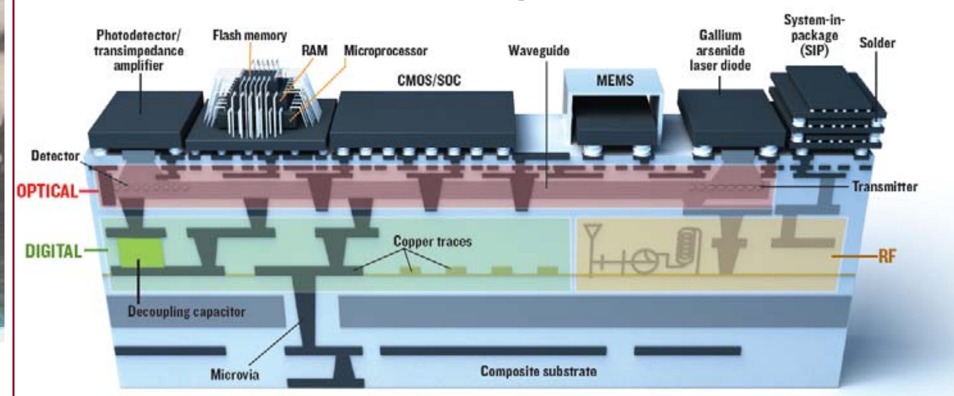






μwave **digital**

Georgia Tech:



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Important issues w.r.t. EMC, as seen by THALES

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Questions: contact the author

Future?

Brain-implants

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