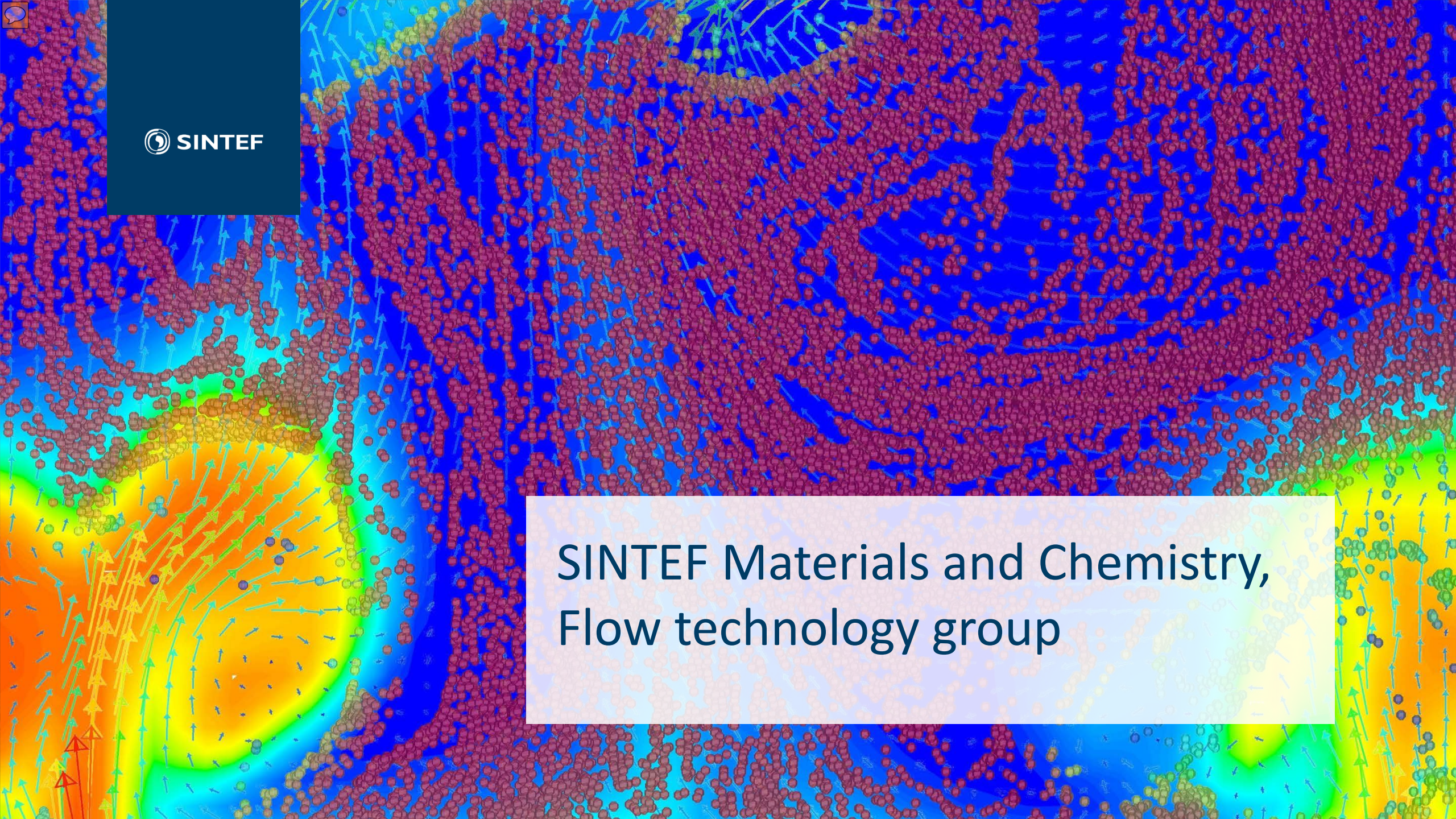
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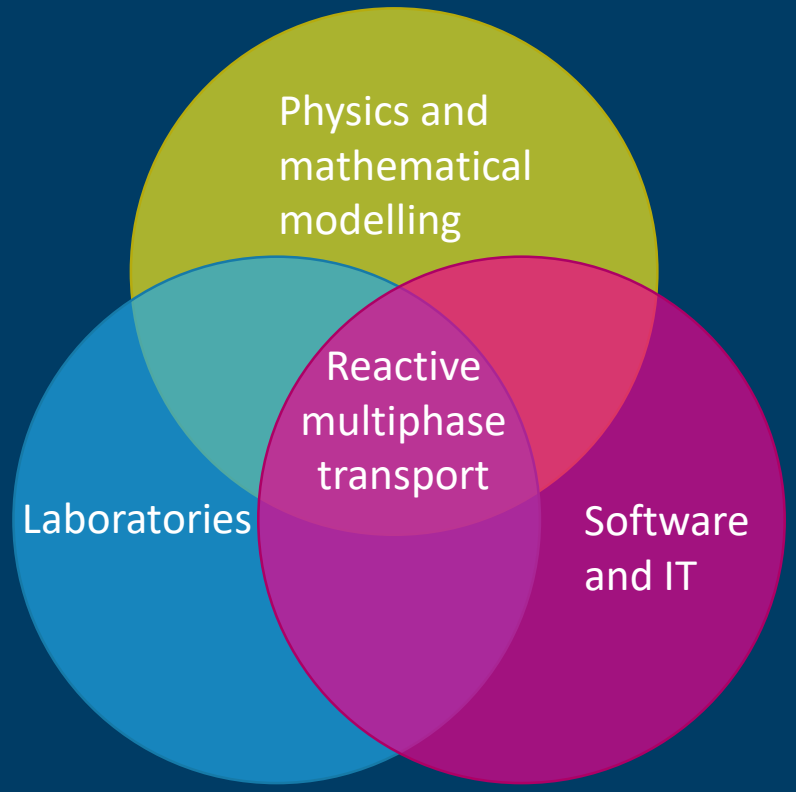
SINTEF Materials and Chemistry,
Flow technology group

Expertise

Typical competence background of people

- Mechanical Engineering (includes Fluid Dynamics)
- Chemical Engineering
- Fundamental Physics
- Numerical Mathematics
- Software development



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SINTEF Flow Technology group


Daniel B. Blücher


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Amit Patil


Torbjørn Pettersen


Schalk Cloete

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SINTEF Flow Technology group

- The Flow Technology department has a strong competence on pragmatic multiphase flow modelling of industrial processes. We apply our competence on Computational Fluid Dynamics (CFD) to a variety of industrial applications to reduce risks / costs and optimize operations.
- Our work is divided in five umbrellas

Umbrella 1:
Metal production

Umbrella 2:
Infrastructure

Umbrella 3:
Green Energy

Umbrella 4:
Upstream Oil and Gas

Umbrella 5:
Health

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Metal production

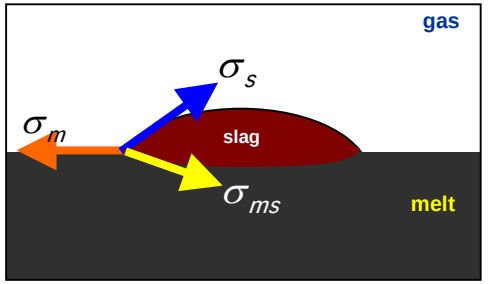
CFD Modelling of Oxidative Ladle Refining of Silicon Melt

Modelling Reactive Multiphase Systems

- Understanding complex large- and small-scale phenomena
- Thermodynamics
  - Thermophysical properties
  - Phase diagrams for multicomponent systems
  - Thermodynamics at interfaces (surface tension, chemical reactions,…)
- Chemistry
  - Complex chemical reactions (homogeneous / heterogeneous)
  - Reactions schemes / reaction rates
- Hydrodynamics (momentum transfer)
- Heat & Mass transfer
  - Interfacial phenomena
  - Mass transfer coefficients (diffusion controlled)

Creation of Interfacial Slag

- What is the morphology of the created slag at gas-melt interface?
- Introducing the spreading coefficient as a function of interfacial tensions:



$$S = \sigma_m - (\sigma_s + \sigma_{ms})$$

$S > 0$: **slag spreads at the interface and create a film**

$S < 0$: **slag retracts and create droplets at the interface**

$S<0$
Droplet precipitation model

$S>0$
Bubble covering model
(small bubbles)

$S>0$
Exposed cap model
(large bubbles)

Modelling Interfacial Mass Transfer

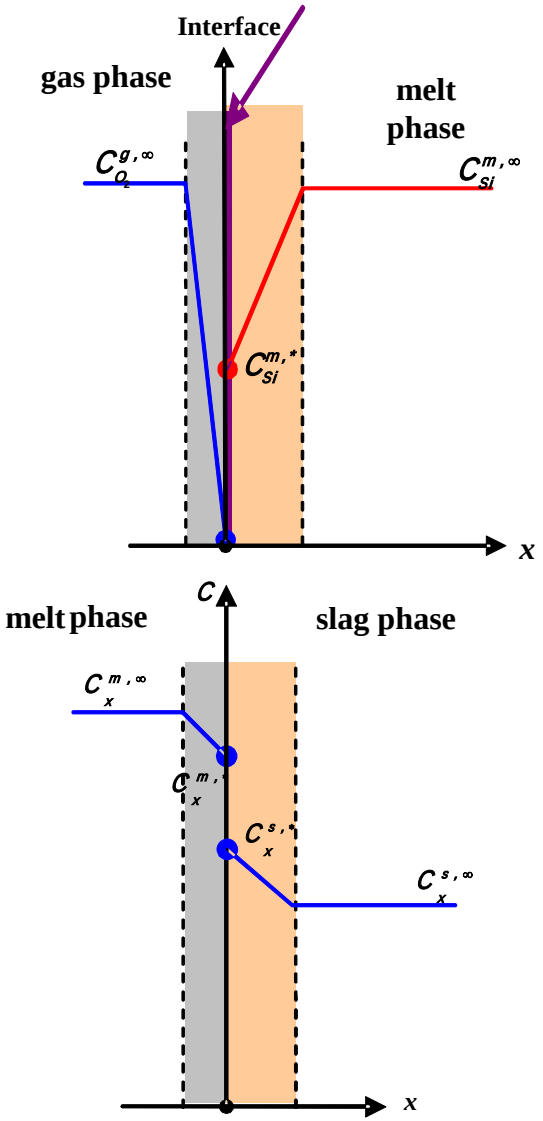
- Mass transfer with chemical reaction
  - Gas / melt reactions
  - Slag / melt reactions
- Two-film-theory formulation
  - Equilibrium concentrations calculated in CT
  - Data given in form of distribution coefficient

$$\gamma_x = \frac{C_x^{s,*}}{C_x^{m,*}}$$

$$J_x^{m \to s} = k_x^m (C_x^{m,\infty} - C_x^{m,*}) = k_x^s (C_x^{s,*} - C_x^{s,\infty})$$

- All reactions are instantaneous at the interface
  - Mass transfer coefficients based on empirical correlations together with enhancement factors

$$Sh = \frac{2}{\sqrt{\pi}} Re_b^{0.5} Sc^{0.5}$$



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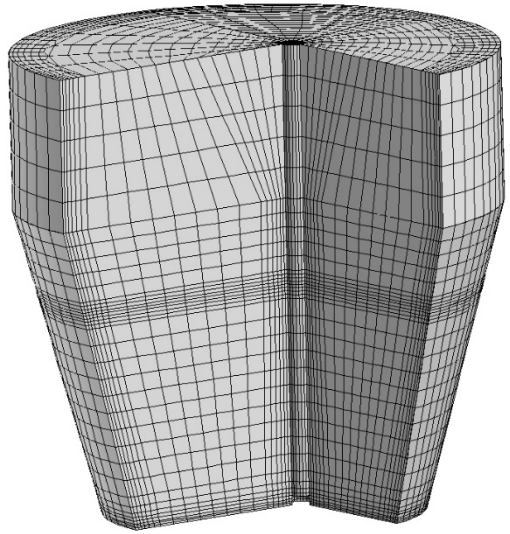
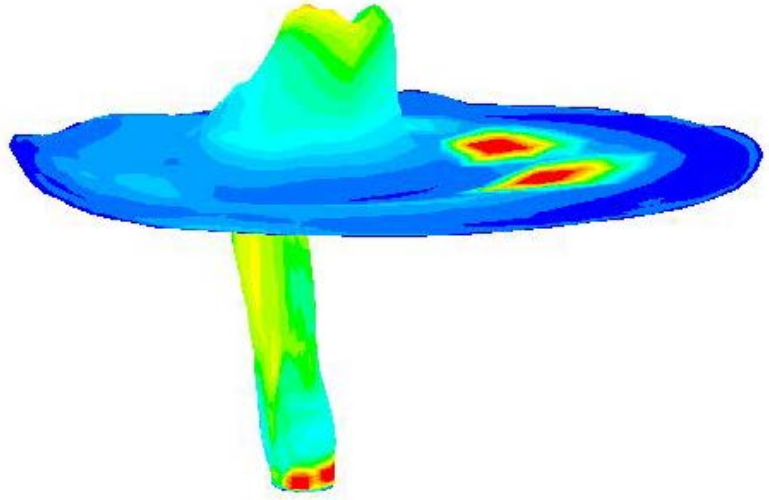
Metal production

Full 3D Simulations with Reactions

- 3D simulations on real ladle geometry
- Direct coupling between CFD and CT
  - Simple mathematical models implemented in the CFD code
  - All reactions included
- Substantially higher gas flow rates (45–70 Nm^3/hr)



Computational geometry



Gas plume in liquid metal

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Infrastructure

Urban wind

- Objective
  - Power generation in rural areas

Green Energy

Expertise

- To design, optimise and scale up multiphase reactors for energy/materials conversion with a strong emphasis on processes with integrated CO_2 capture. The validated reactive multiphase modelling by dedicated experiments is used to develop novel reactor concepts and to accelerate the scale up of promising technologies.

Expertise:

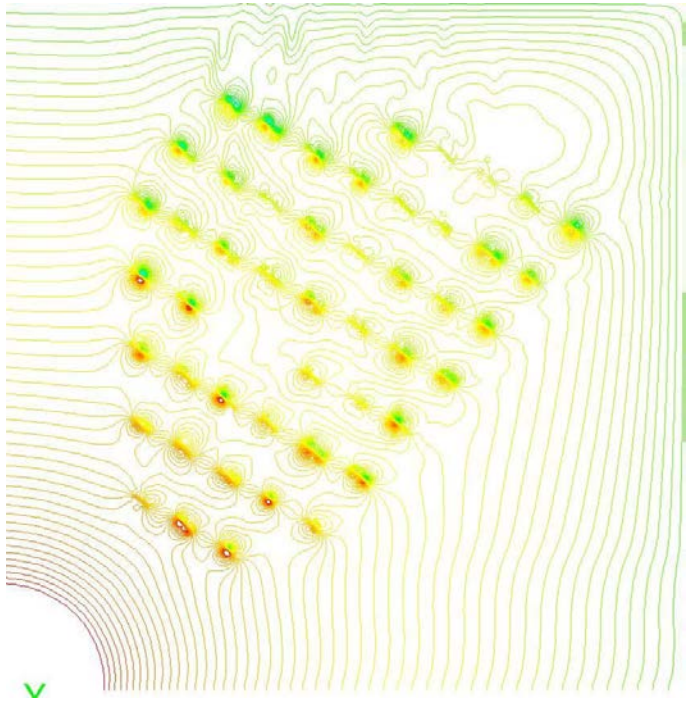
- Reactive multiphase flow modelling for the detailed simulation of fluidized and packed bed reactors
- Development of 1D modelling tools for rapid simulation of fluidized and packed bed reactors
- Development and scale up of Chemical Looping technologies

- Multiscale modelling for reactor design and scale up
  - DEM-CFD modelling for catalyst design in packed bed reactors
  - CFD-Process flowsheet modelling for process design and optimisation
- Dedicated lab scale experiments for
  - Demonstration of novel reactor concepts
  - Detailed multiphase model validation
- Electrolysis processes
  - Magnetohydrodynamics
  - Population balance modelling (PBM)
  - PBM-Volume of fluid coupling
  - Bubble-bubble interaction phenomena
- Wind farm design and wake turbulence

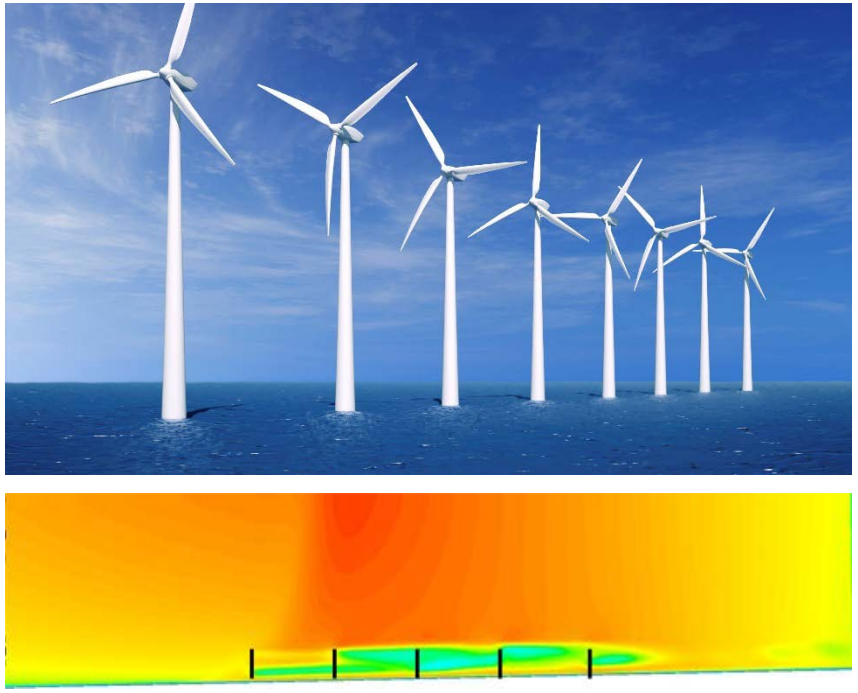
Green Energy

OFFWIND

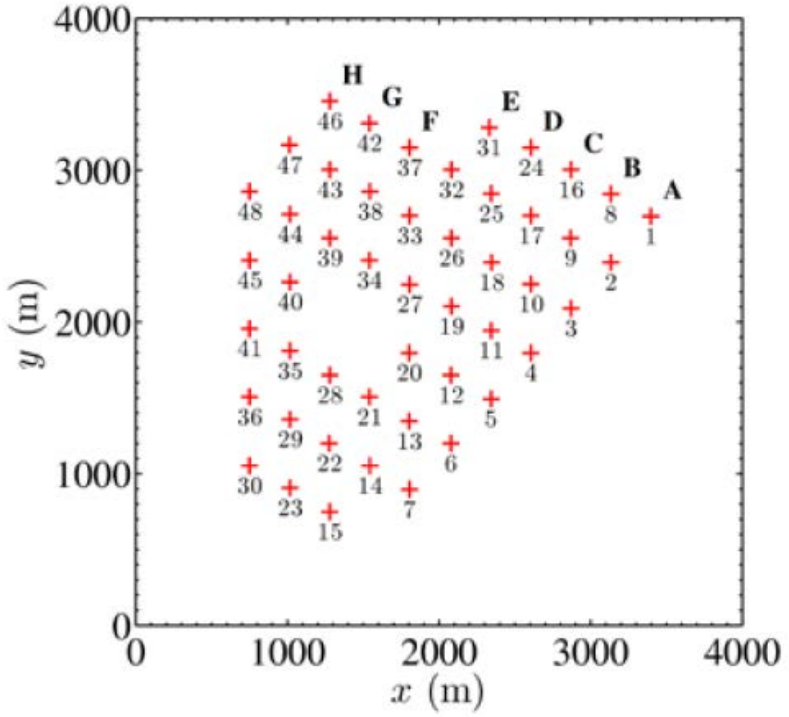
OffWindSolver based on OpenFOAM



Pressure distribution in the wind farm, t=115 s



Instantaneous velocity distribution in the row F of the wind farm, t=115 s



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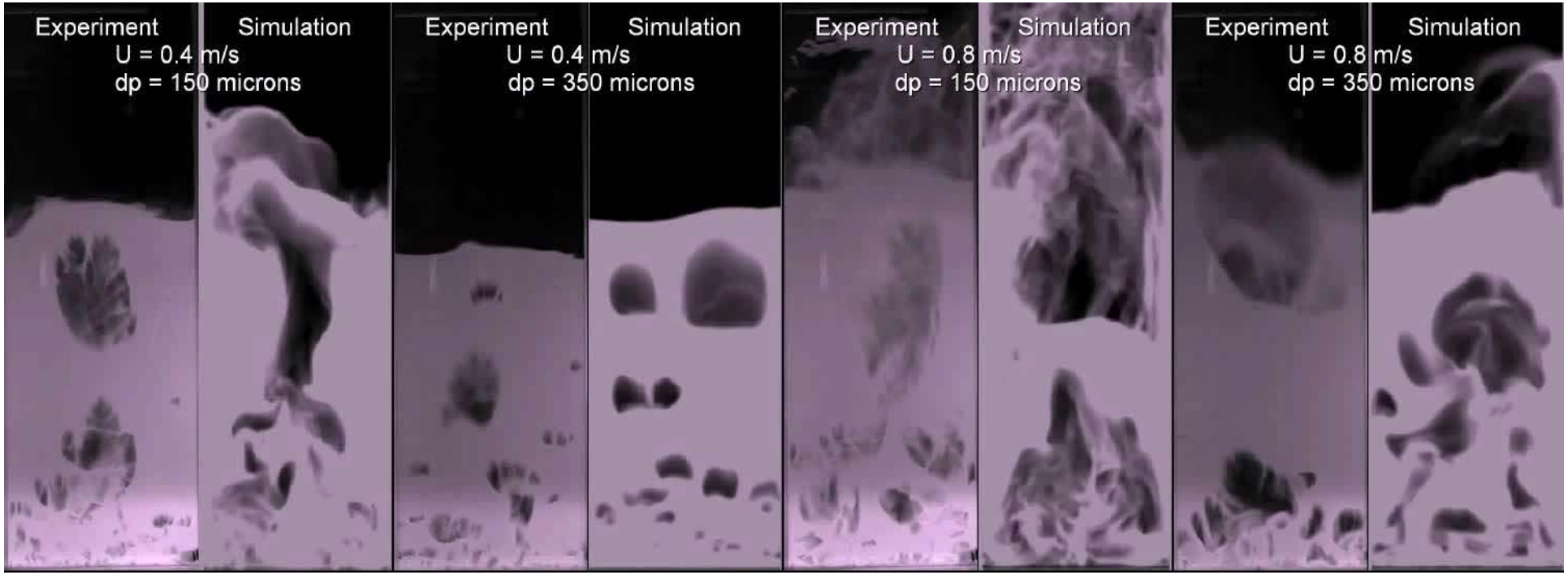
Green Energy

Fundamentals of Reactive Multi Phase Flows in Chemical Looping Combustion (Flow@CLC)

- Validated fluidized bed reactor models



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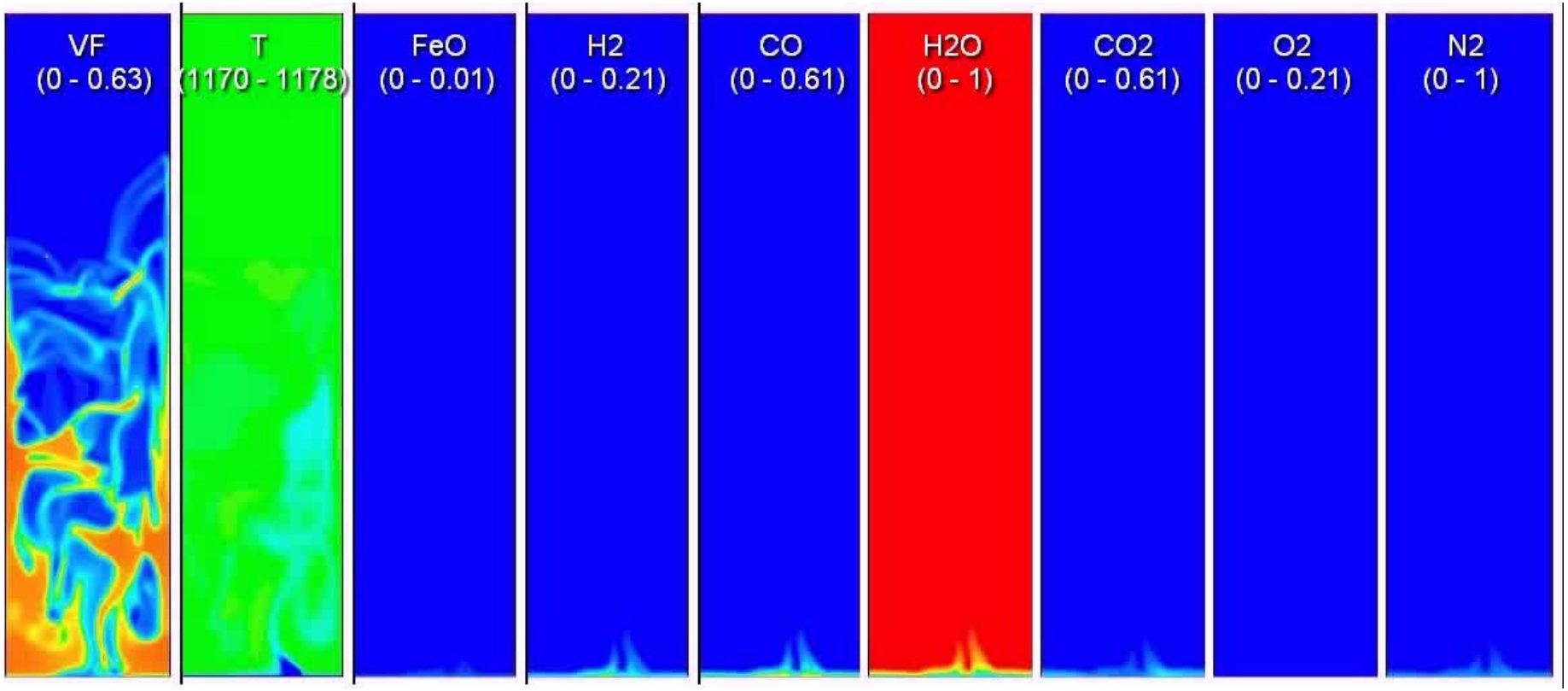
Green Energy

Fundamentals of Reactive Multi Phase Flows in Chemical Looping Combustion (Flow@CLC)

- Reactive multiphase flow models for CLC process



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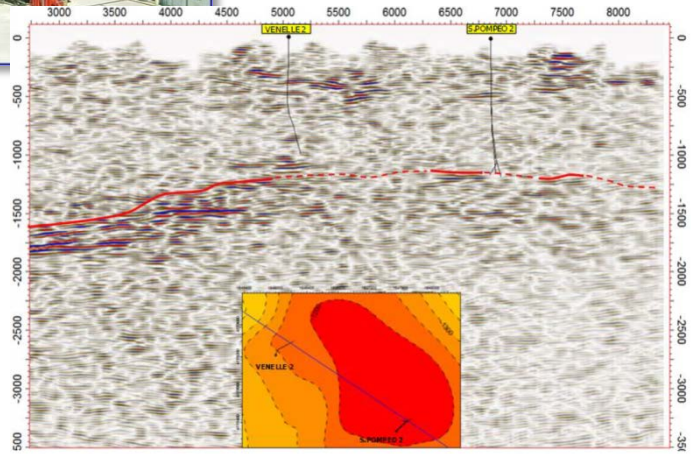
Green Energy

Geothermal Energy and Multiphase Flow Simulations

- Process modelling
  - Water: Supercritical, steam, liquid
- Design studies to select materials and equipment
  - Peak temperatures and pressure
  - Phase envelopes
- Production management
  - Limited instrumentation possible
  - Real-time models to support control systems
- Production of formation water
  - Multicomponent fluids: H_2O, CO_2, H_2S, ++
  - Dissolved minerals ➔ Problems with scaling



Horizon2020 project: Drilling in supercritical geothermal conditions (DESCRAMBLE), Pictures from Enel Green Power SpA.

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Upstream Oil and Gas

Expertise

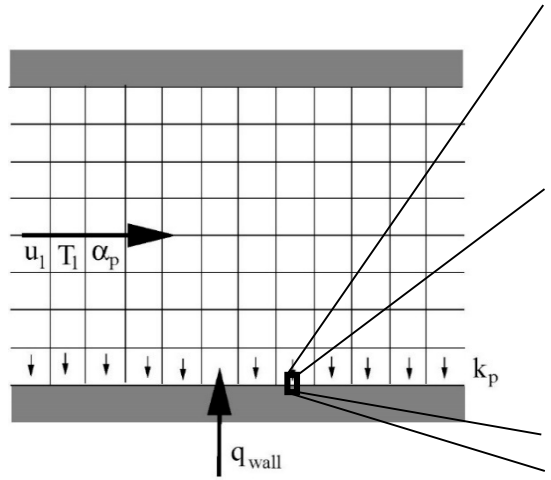
- To ensure safe and economical oil and gas processing and transport from the reservoir to point of sale efficient engineering tools are needed. This implies a continuous development and experimental validation of computer simulators for multiphase flow.

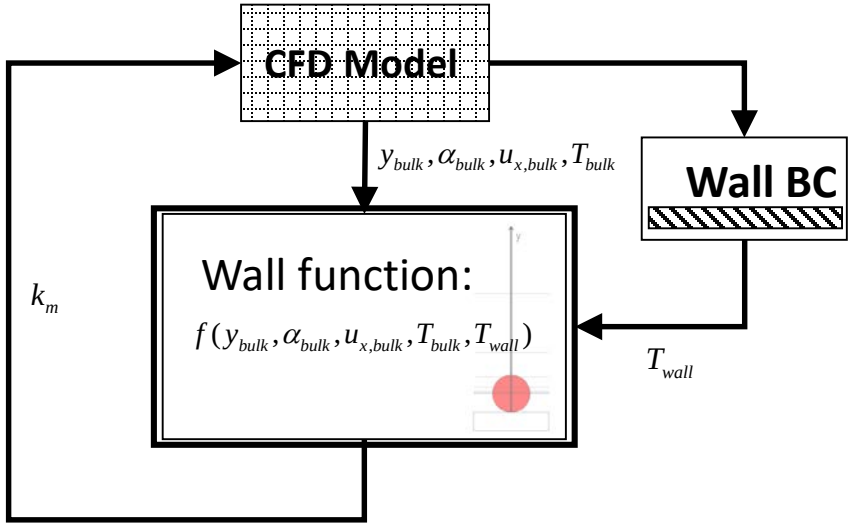
Expertise:

- Modelling multiphase flow phenomenon – from micro to MACRO scale
- The impact of surface chemistry
- Hydrates, wax, asphaltenes, scale and sand
- Separation
- Thermodynamics

CFD Wall Function for Particulate Deposition

- Coarse grid CFD model
- Sub-grid 1D model for particle transport
  - Fine-scale grid close to wall
  - Eulerian-Eulerian
  - BC from coarse grid
  - Particle deposition flux
- Wall-func. Act as mass source/sink at the wall





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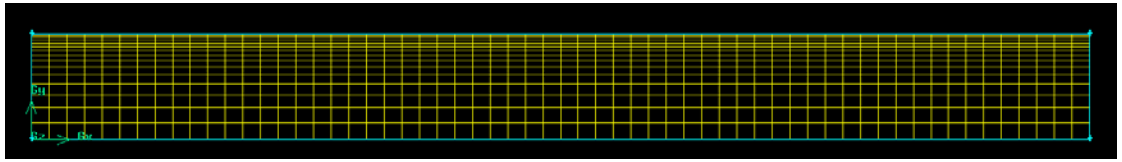
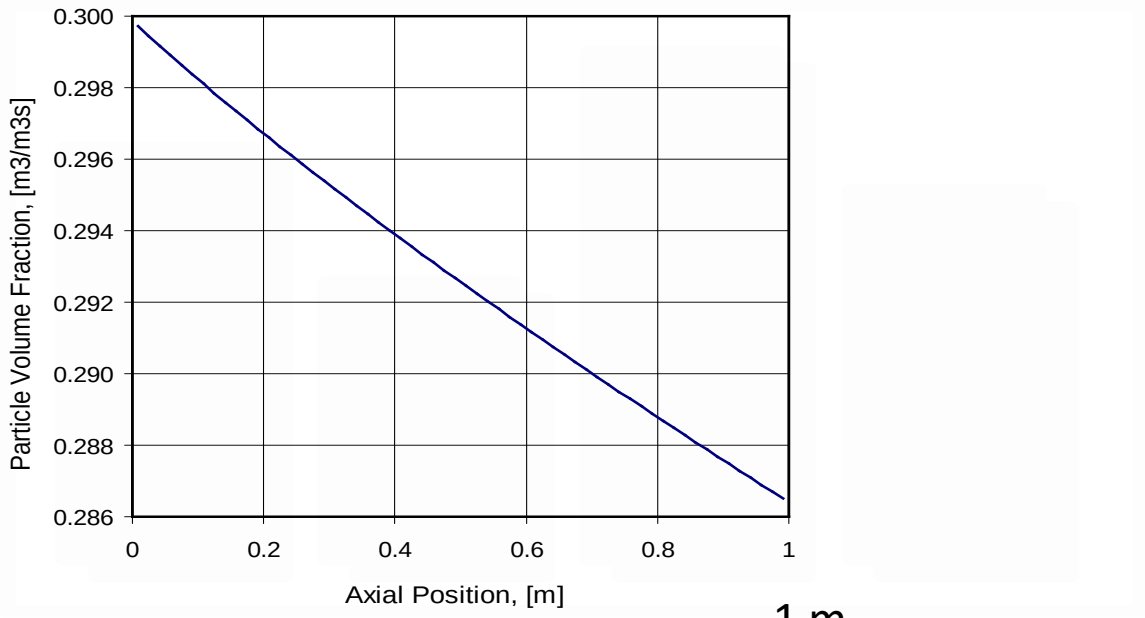
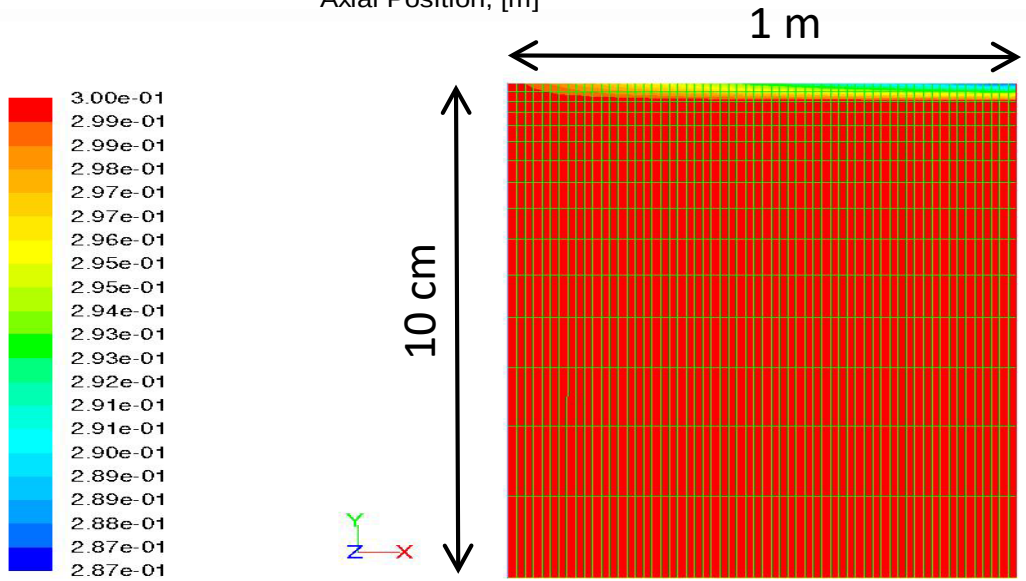
Upstream Oil and Gas

Simple Pipe Geometry

- 60x15 cells, 1m long, 10cm radius, Y^+~70
- Liquid water with 30 vol-% $CaCO_3$ particles (Eulerian).
- Standard k-ε model.
- Inlet velocity profile, , V_{max}=4.9m/s, n=1/7.6;







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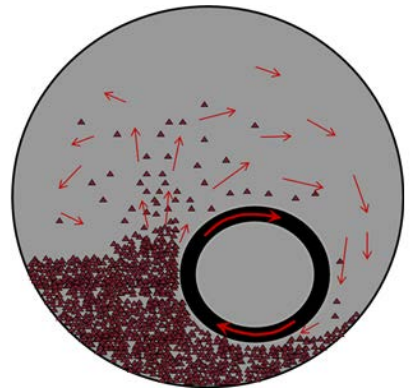
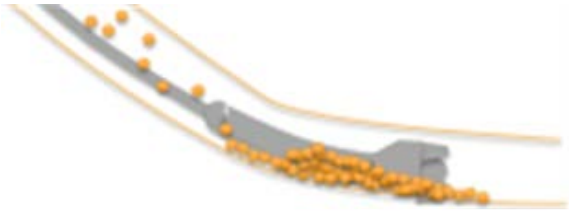
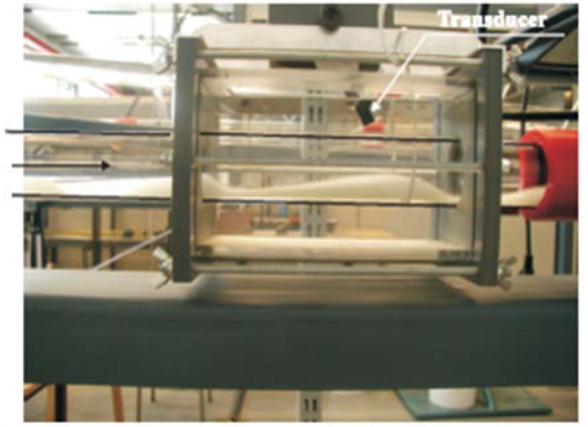
Upstream Oil and Gas

AdWell – Advanced Wellbore Transport Modelling



- **Project goals:**
  - Apply cutting edge mathematical tools and methods for detailed analysis of the transport processes during a drilling operation.
  - Further develop models using physical and physiochemical principles to achieve high accuracy process models with dynamic long term predictive capability.
  - Verify models with experimental data.
  - Apply improved understanding of the process to improve real-time models for drilling automation.





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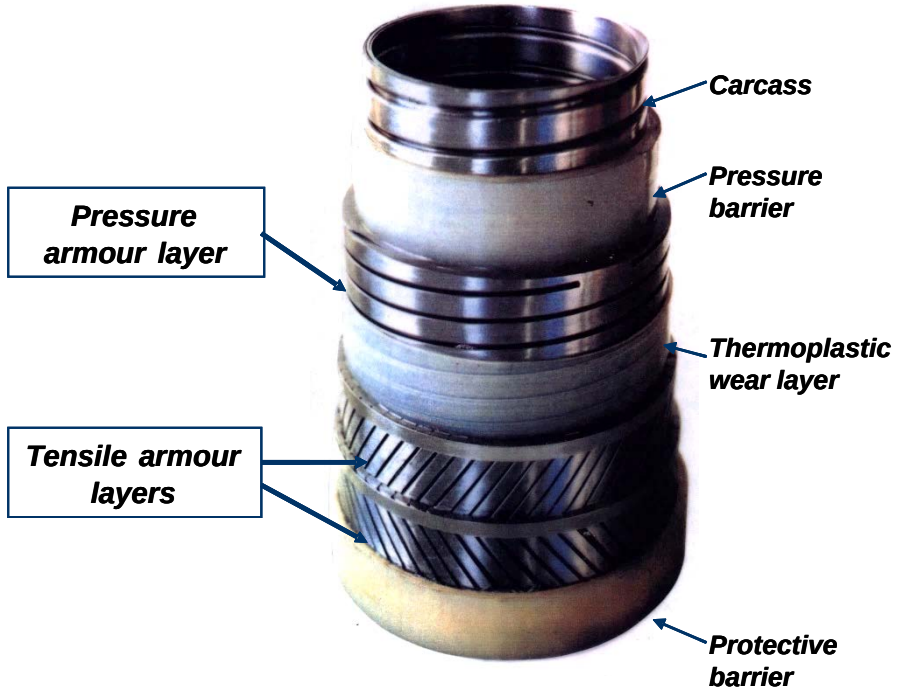
Upstream Oil and Gas

Singing Risers

- Corrugations in flexible risers lead to creation of vortices
- Vortices are source for pressure waves
- Interacting pressure waves creates standing acoustic waves
- Vibrations → fatigue with potential hazard risk



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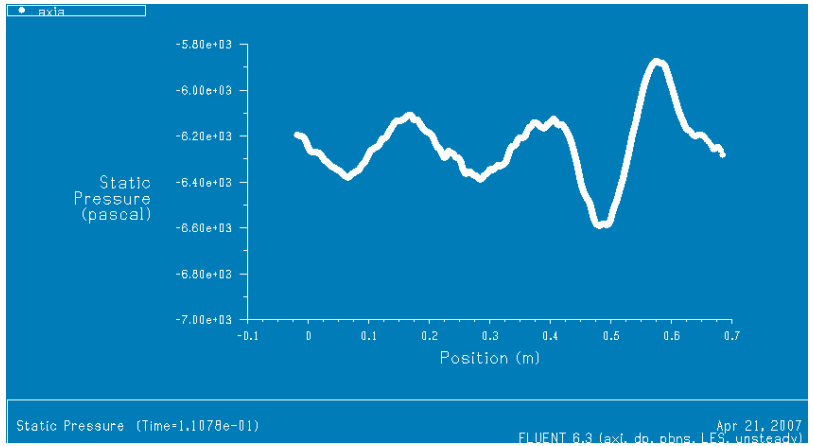
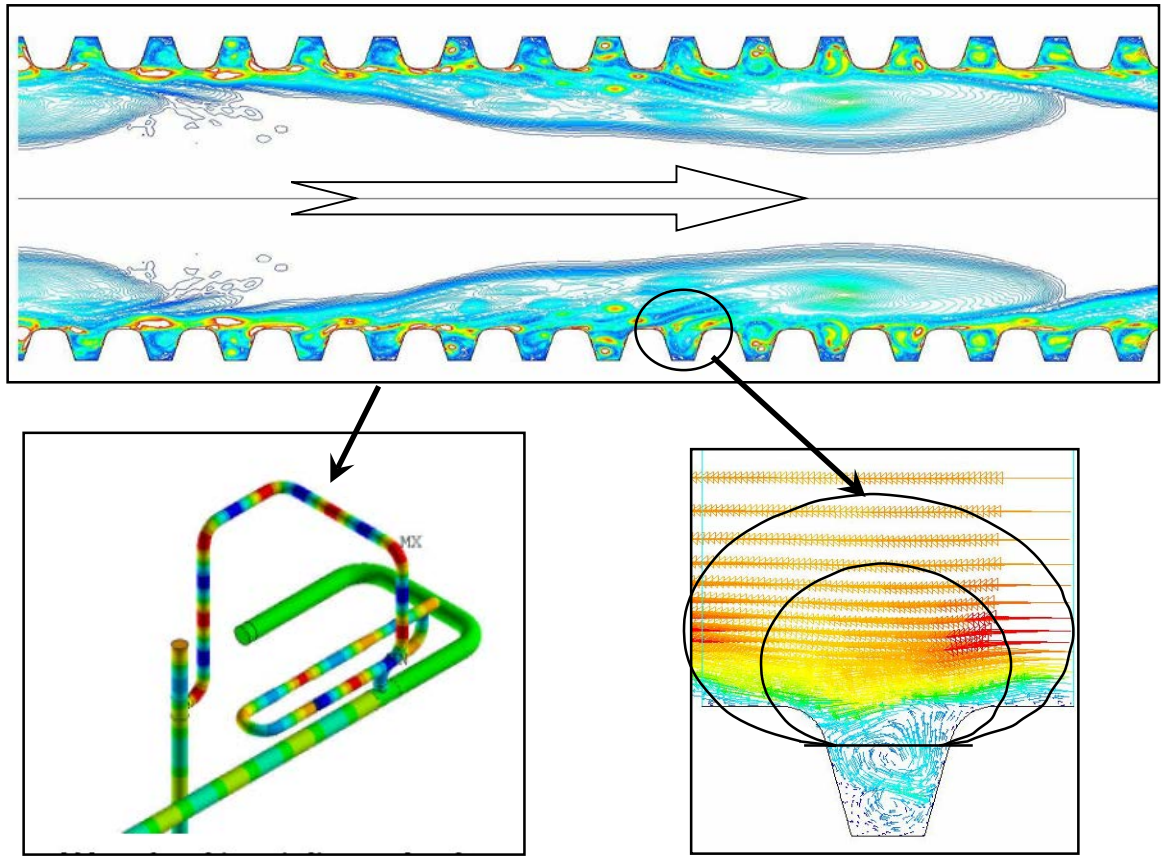
Upstream Oil and Gas

Singing Risers

- Observed phenomena reproduced by numerical simulations





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Upstream Oil and Gas

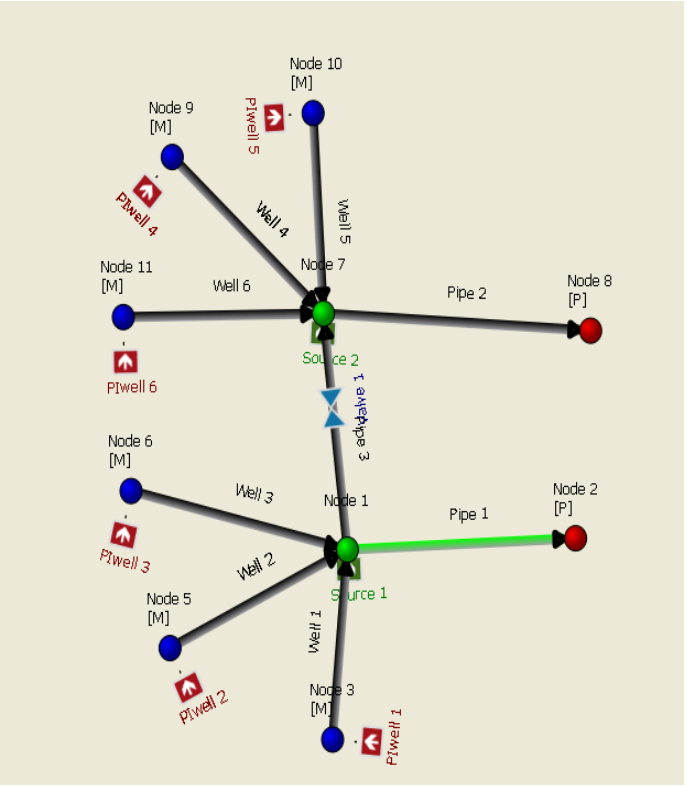
LedaFlow – Advanced transient multiphase flow simulator

LedaFlow® is used throughout oil & gas field development :

- Feasibility studies
- Conceptual studies
- Front end engineering design (FEED)
- Detailed design

LedaFlow® is used in oil & gas field operation through integration with K-Spice® dynamic process simulation tool

- Production Management Systems (PMS)
- Operator Training Systems (OTS)
- Virtual Multiphase Flow Metering Systems (VFMS)
- Leak Detection Systems (LDS)



K-Spice® is a product by Kongsberg Oil & Gas Technology

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LedaFlow – Joint Vision Statement of the Leda-partners

Successfully establish a novel commercial multiphase flow simulator that provides better foundation for decisions for the global oil & gas community

- Estimated global market around 80 million USD (Rystad Energy)
  - Current market share 5%, estimated growth to 10% by 2018, and 20% by 2021.
- More than 90 K-Spice®/LedaFlow® solutions installed globally
- Current SINTEF portfolio ~25 MNOK/year
  - Additional funding of ~15 MNOK/year applied for to the Research Council
- Participating SINTEF institutes: SINTEF Materials and Chemistry and SINTEF Petroleum

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Upstream Oil and Gas

LedaFlow

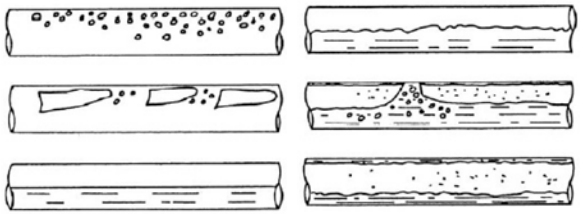
Oil & gas transport pipelines and field layouts – *From well to facility*

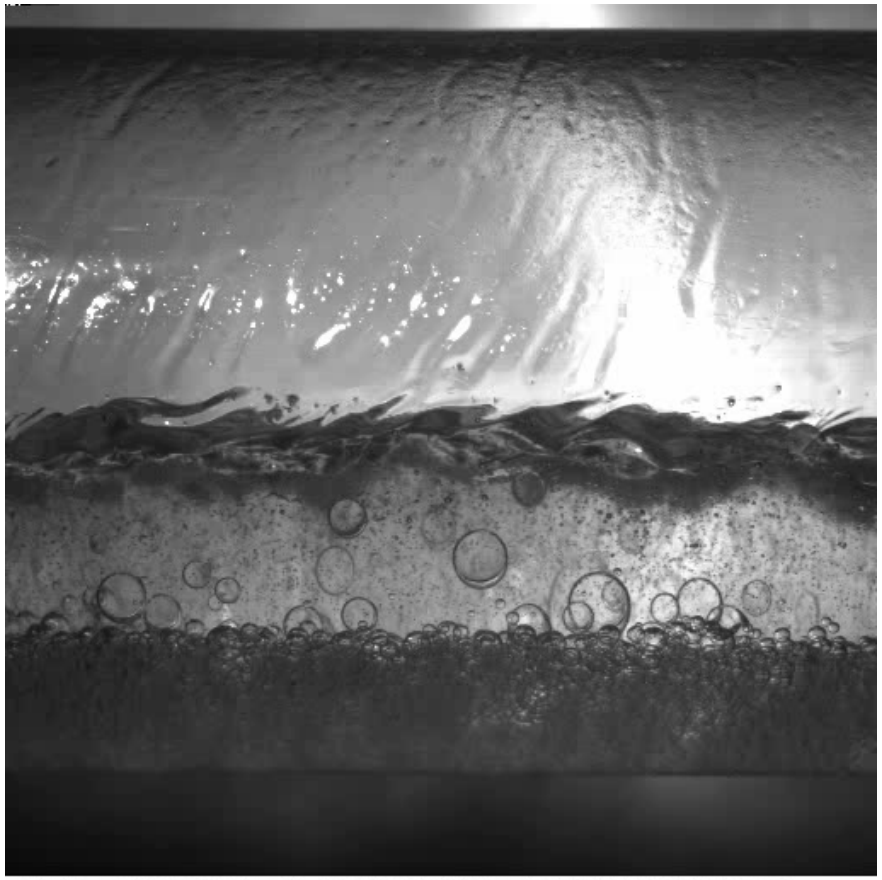
- Design studies
- Integrated simulators
  - Production management systems (PMS)
  - Operator training systems (OTS)
- Flow Assurance

Modelling based on experiments

- Friction forces
  - Toward walls
  - At interfaces between fluids
- Entrainment & deposition
  - Gas bubbles into liquid
  - Oil droplets into gas or water
  - Water droplets into gas or oil
- Turbulence
- Thermodynamics & Chemistry

Flow regimes





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Modelling based on experiments

Laboratoriet på Tiller utenfor Trondheim er enormt. Rørene er laget i samme størrelse som de som blir brukt på havbunnen ved oljeplattformene, for å sikre at resultatene av forsøkene stemmer med virkeligheten.

FOTO: SINTEF

Rørene gjorde oljeeventyret mulig

Flerfaseteknologien har gjort det mulig å bygge ut flere og mindre felt enn det ellers ville vært mulig.

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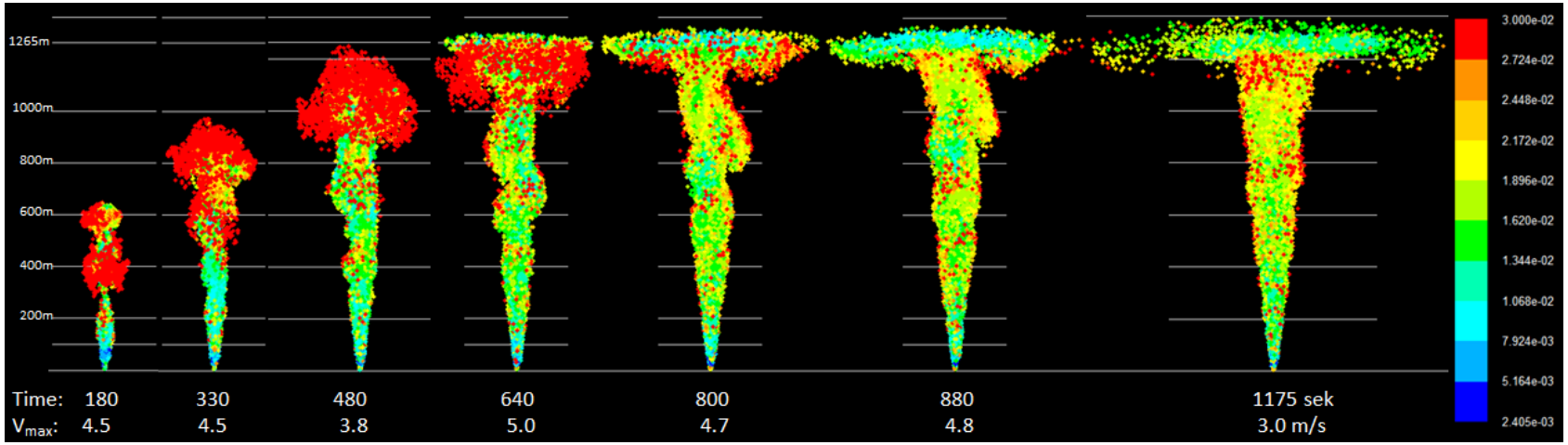
Modelling based on experiments

- Euler – Lagrangian (parcel based) simulation of a sub sea gas blowout



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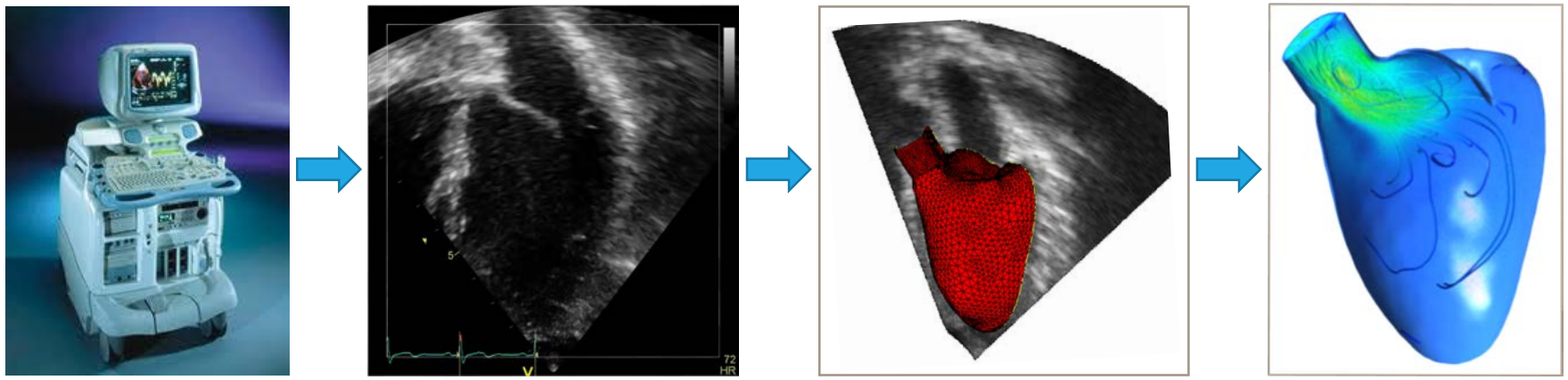
Health

CardioSim - Pasient-spesifikk simulering av blodstrømningen i hjertet

Imagine you need a heart surgery...

Imagine a surgery tailored for you...

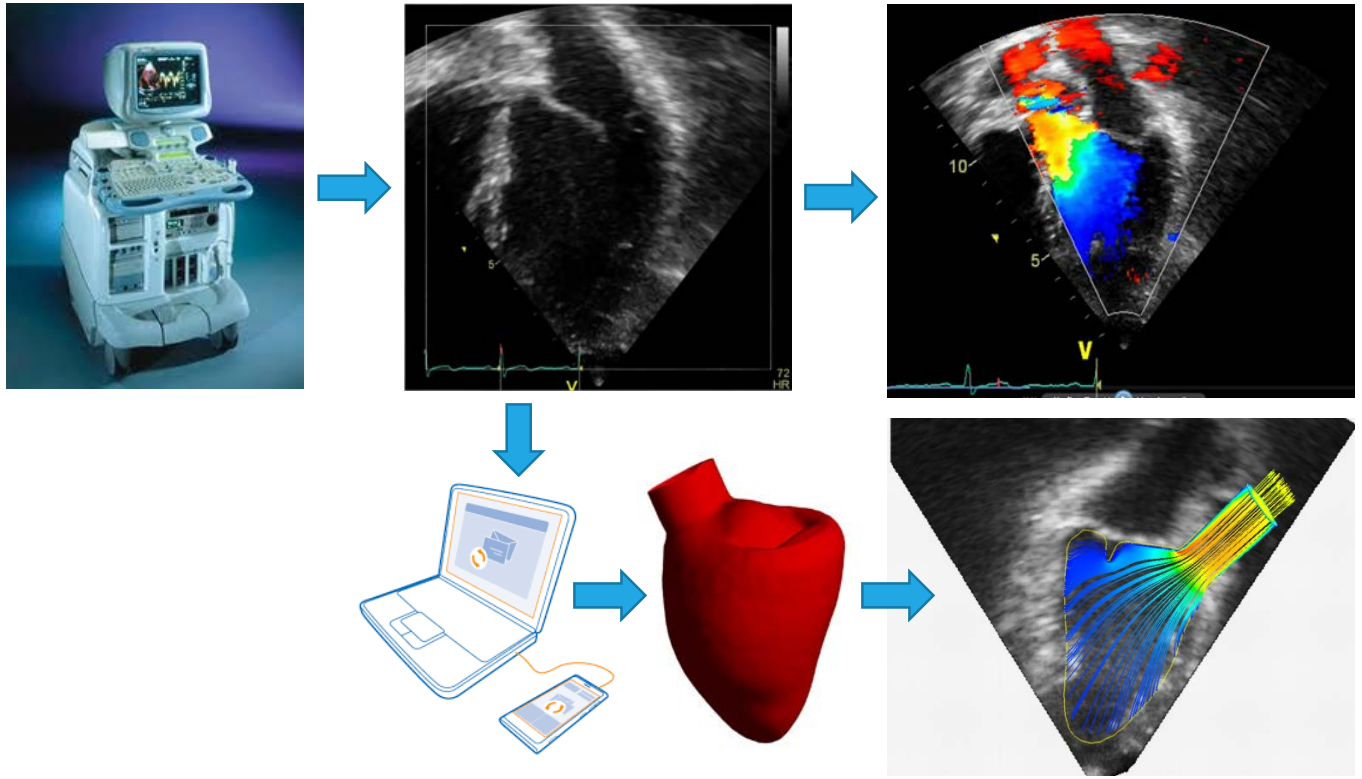


SINTEF

Health

CardioSim - Pasient-spesifikk simulering av blodstrømningen i hjertet

- øke kunnskapen om blodstrømningen i friske og syke hjerter
- finne årsakssammenhenger mellom blodstrømning og vevsoppførsel
- evaluere effekten av ulike kirurgiske inngrep
- skreddersy behandlingen til det enkelte individ



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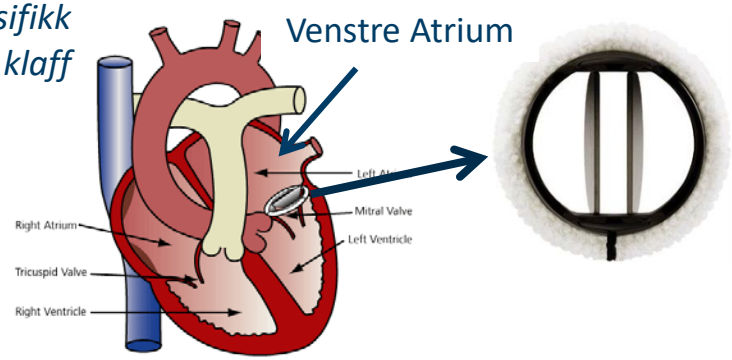
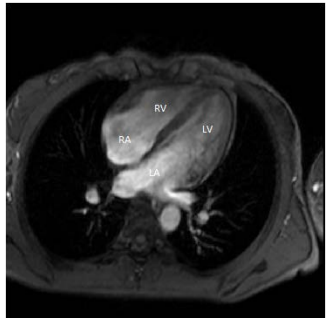
Health

CardioSim - Pasient-spesifikk simulering av blodstrømningen i hjertet

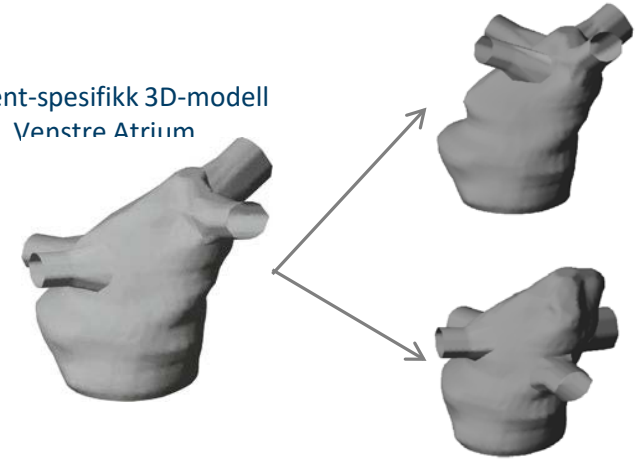
Eksempel 1: Orientering av ny klaff

Hypotese: *Pasient-spesifikk orientering av mekanisk klaff kan forhindre avleiring*



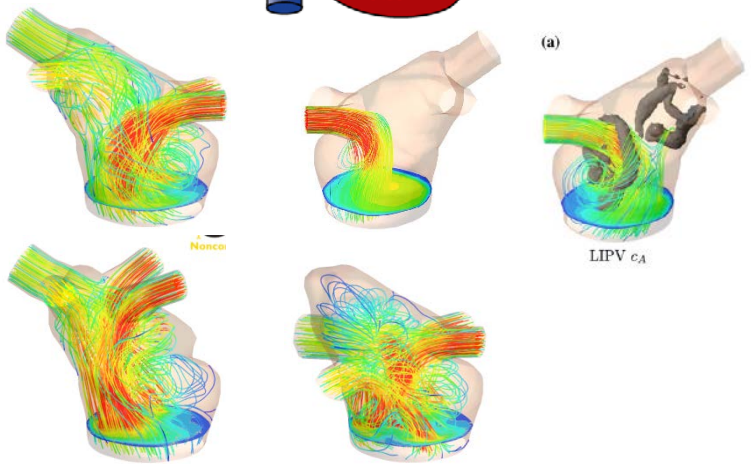


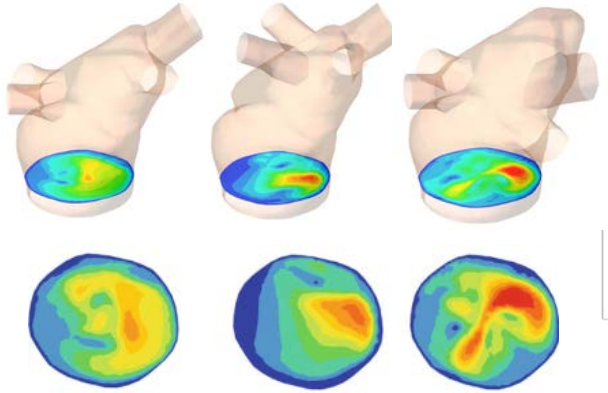
Pasient-spesifikk 3D-modell
Venstre Atrium



Modifiserte 3D geometrier

Simulering av blodstrømninger





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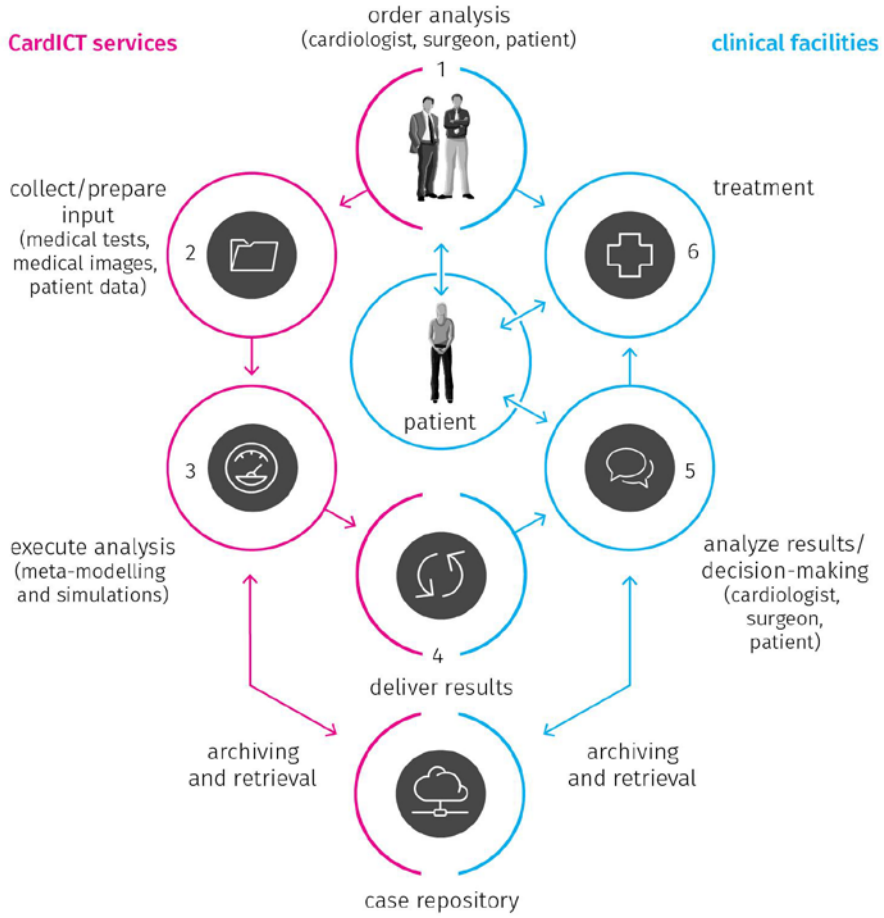
Health

CardioSim - Pasient-spesifikk simulering av blodstrømningen i hjertet

Vår visjon:

*Ved hjelp av **pasient-spesifikke datasimuleringer,***
*utvikle et **beslutningsstøttesystem***
for diagnostisering og behandlingsplanlegging
*av **hjerte- og karsykdommer***

*åpne for **kunnskapsbasert pasientinvolvering***



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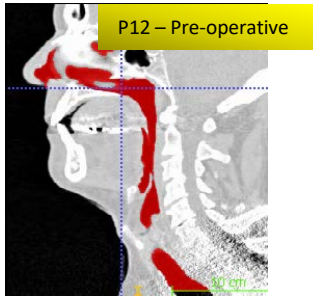
Health

Biomech-Vision

Establish **patient specific** simulation as an essential **clinical tool** in treatment planning.

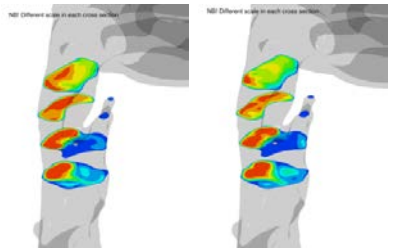
Medical Imaging / measurements

- CT
- MR
- Ultrasound
- ++



Planning

- Pre-op. CFD sim.
- Virtual surgery / treatment
- Post-op. CFD sim.



Optimized Treatment

- Surgery
- Others
  - MAD / MAS
  - CPAP
  - ++

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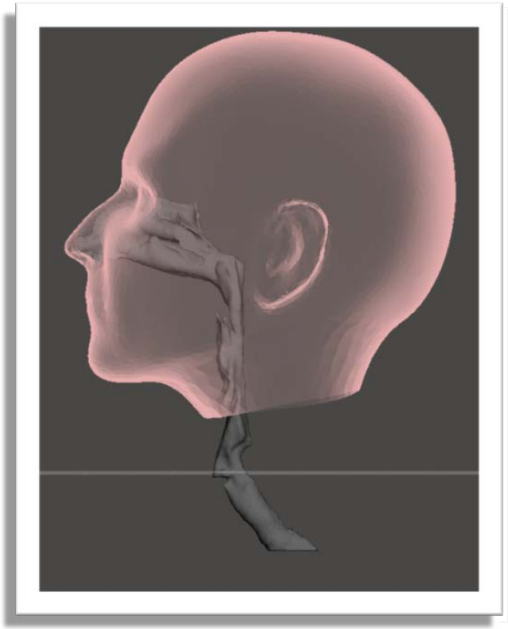
Health

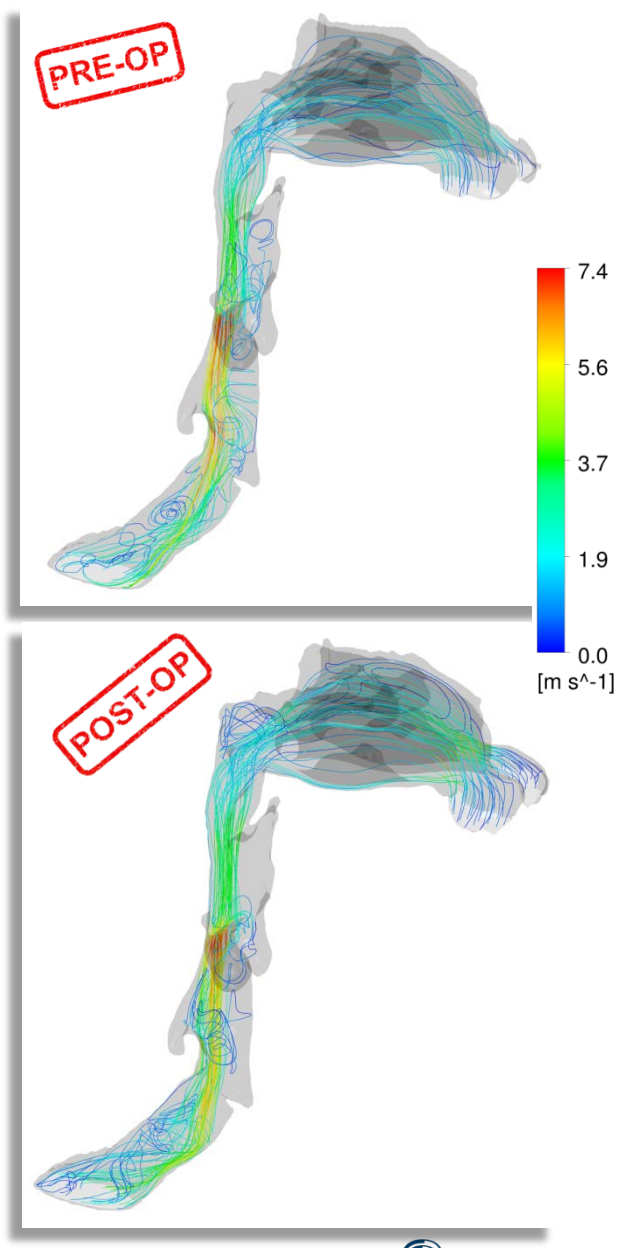
Current Work:

- Pre- and Post-operative CFD-simulations of nasal surgery patients.
- Correlation between change in AHI and flow pattern in upper airways.

- Project goal:

  Proof-of-concept on patient specific CFD simulations to improve sleep apnea treatment.

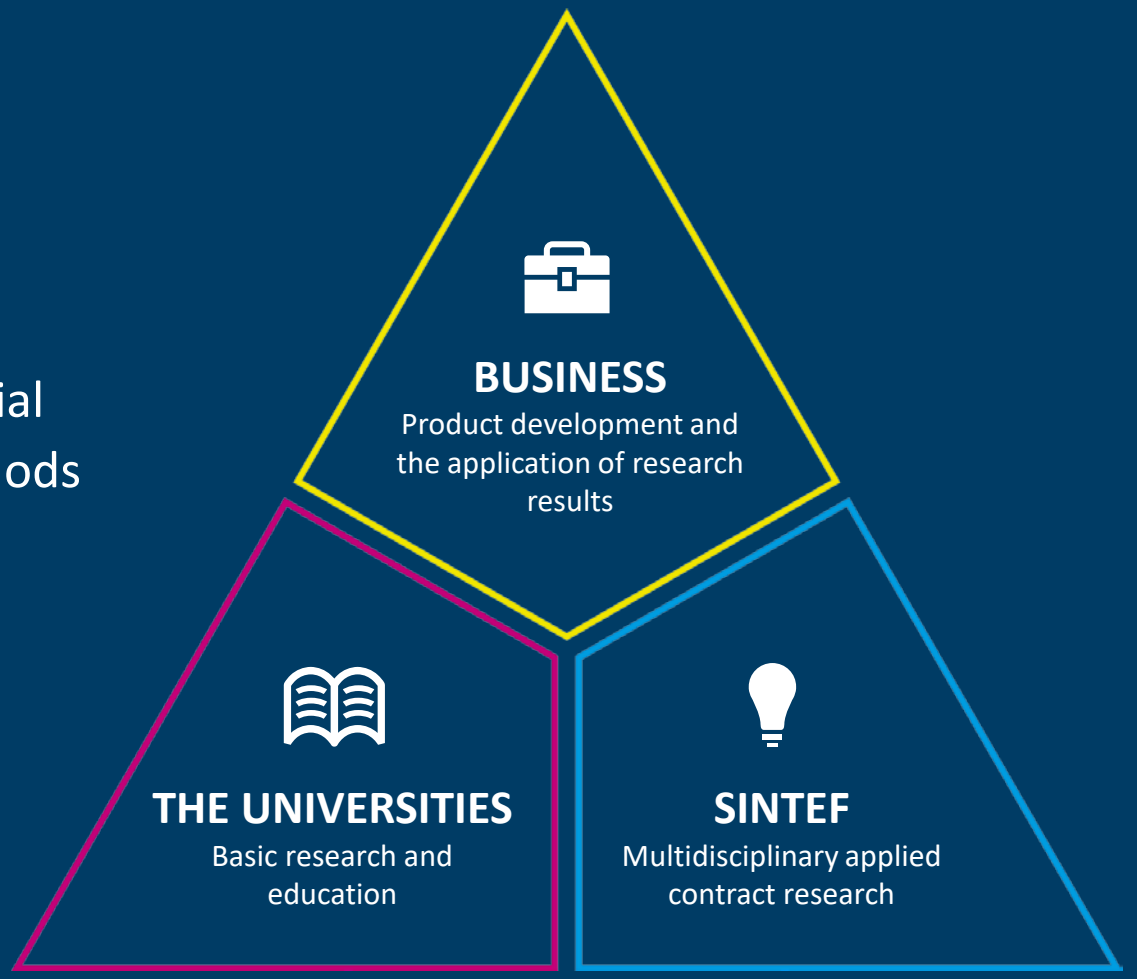




SINTEF

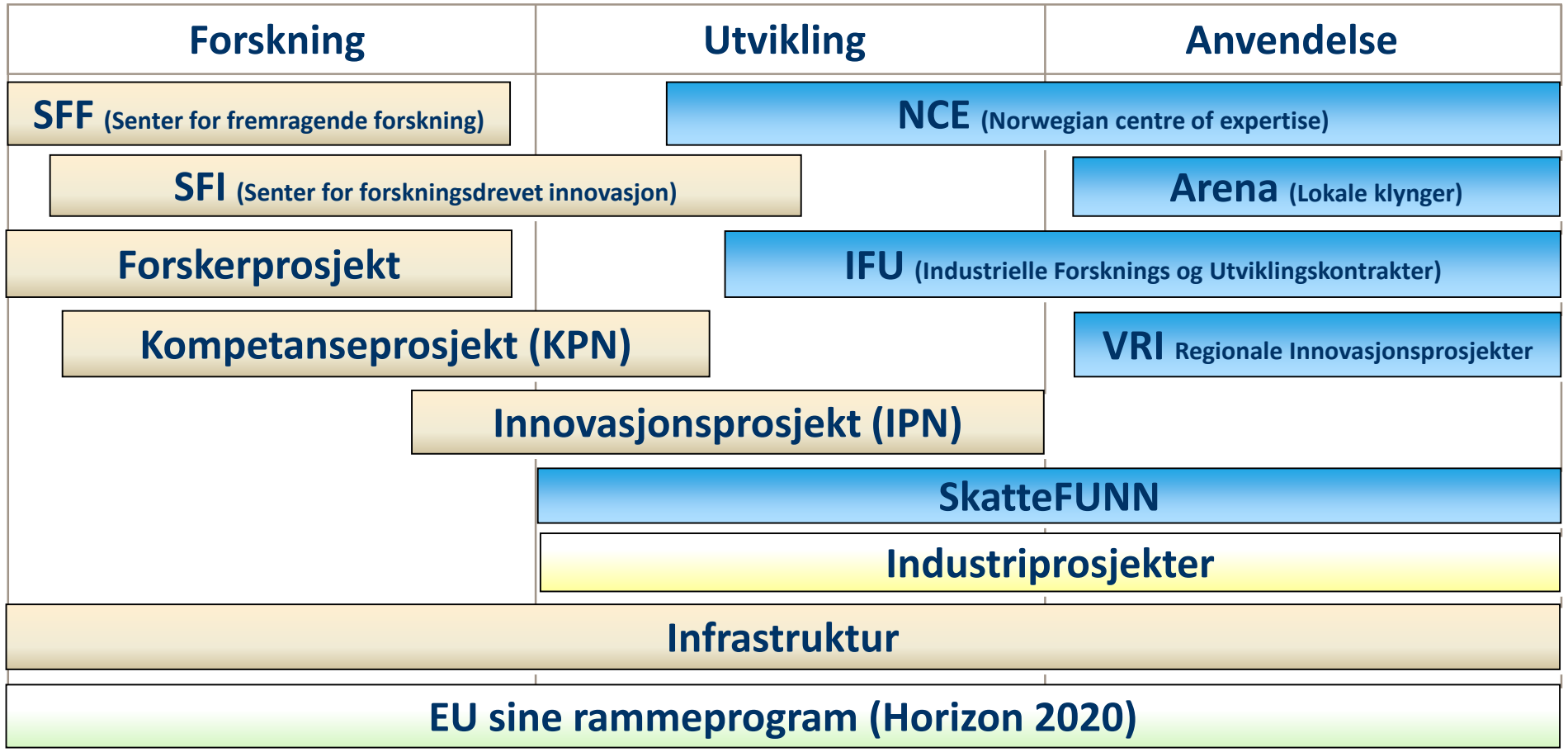
Close working relationships generate innovation and high quality

- Industrial relevance – Industrial involvement – Scientific methods



SINTEF

Det norske virkemiddelapparatet



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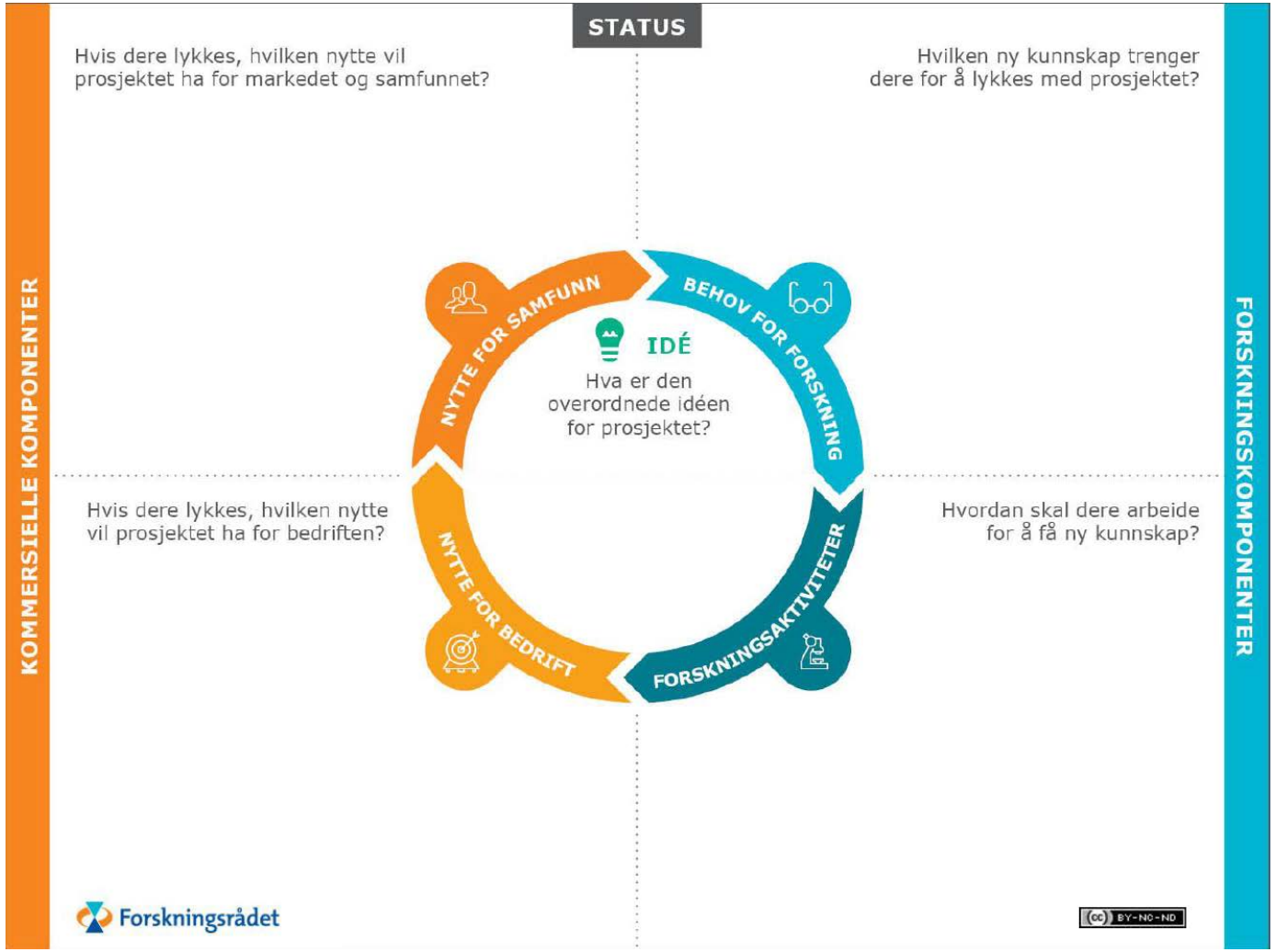
Innovasjonsprosjekter for Næringslivet (IPN)

- Innovasjonsprosjekter er forskning og utviklings(FoU)-prosjekter som skal bidra til verdiskaping og innovasjon hos bedriftene som deltar i prosjektet.
- Søknader til innovasjonsprosjekter vurderes av eksterne paneler etter kriterier som
  - Innovasjonsgrad
  - Forskningshøyde
  - Verdiskapingspotensial
  - Gjennomføringsevne
- Midler til innovasjonsprosjekter kan søkes av bedrifter som samarbeider med andre bedrifter og/eller forskningsmiljøer.
- Bedriften trenger ikke gi kontantbidrag. Dokumentert egen aktivitet utløser midler fra forskningsrådet (in-kind).

Innovasjonsprosjekter for Næringslivet (IPN)



SINTEF

SINTEF

Technology for a better society