Competence Center for Gas Exchange

CC GEx

”Charging for the future”

Energimyndigheten

SCANIA

VOLVO

VOLVO

BorgWarner

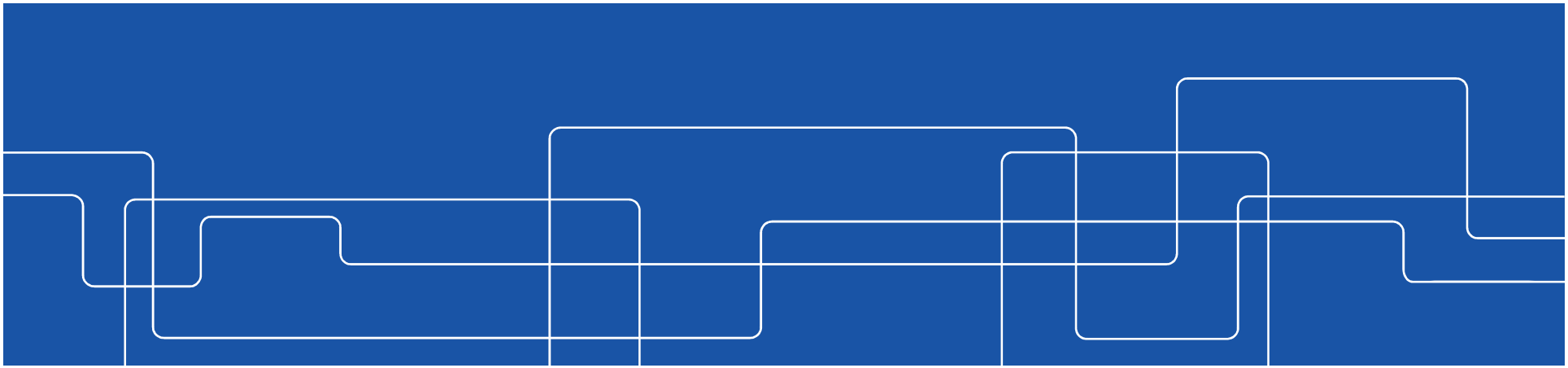
www.ccgex.kth.se

KTH ROYAL INSTITUTE
OF TECHNOLOGY

CCGEx Research Days Program

11th and 12th of October

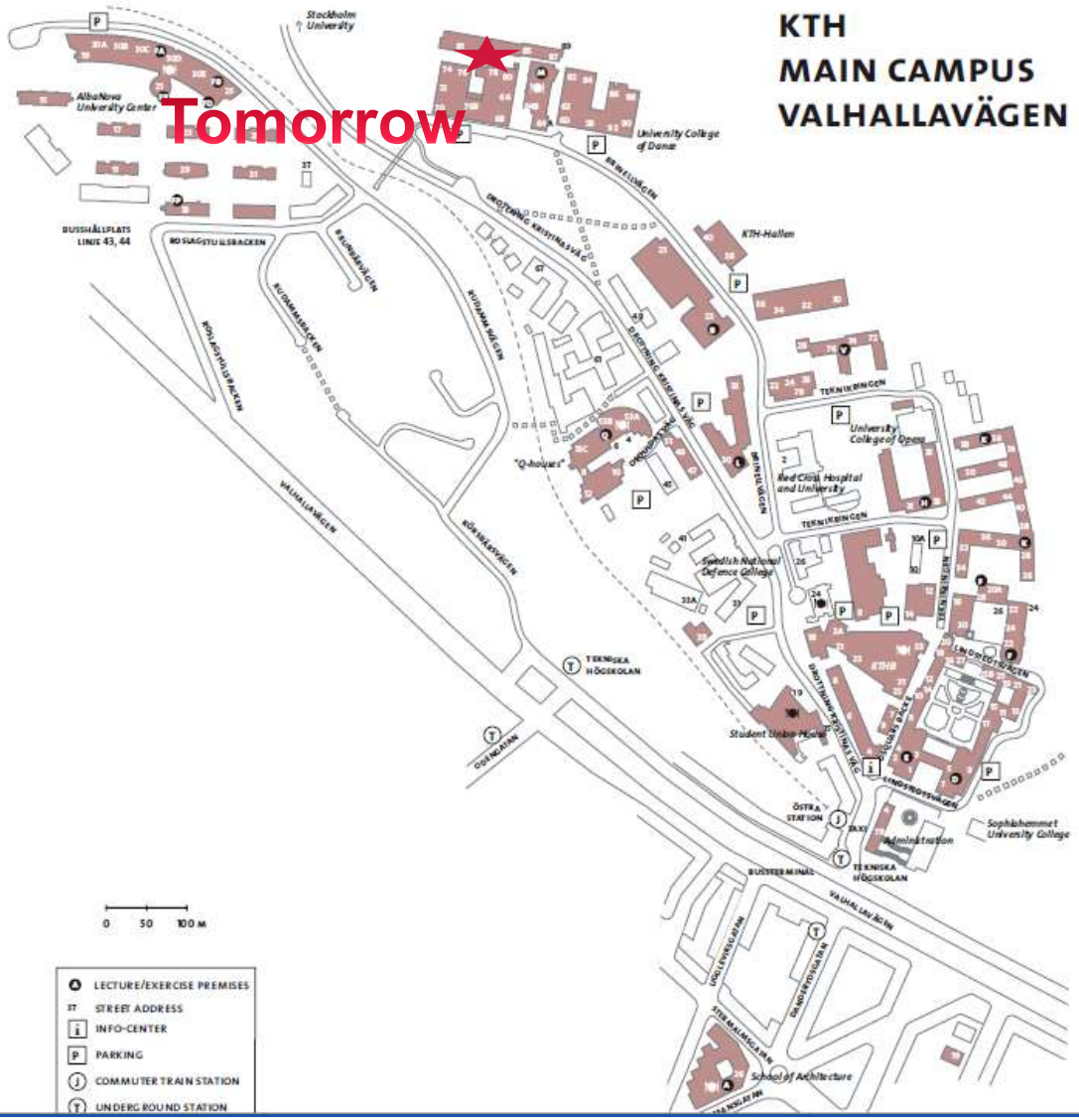
2018 Stockholm KTH



CCGEx Research Days

October 11-12 2018

Welcome to CCGEx and KTH!



Welcome to KTH!
CCGEx Research Days 2018

Introduction of people

NEW - International Advisory Board

Prof. Isabell Trebinjac, École Centrale du Lyon

Prof. Martti Larmi, Aalto University

Partners

KTH academics & staff

CCGEx Research Days 2018

11-12th October, Stockholm

First Hotel Norrtull, S:t Eriksgatan 119 , 113 43 Stockholm, Sverige

Purpose of the days

- ✓ Present CCGEx research and activities
- ✓ Opportunity to meet industry and academic partners
- ✓ Discuss science and technology
- ✓ Launch the 2018-2021 period

Agenda – Morning session 11th October

Norrtull Konferenshotell

09:45-10:00 **Registration & Coffee**

10:00-10:30 **Opening by CCGEx Director**- Anders Christiansen Erlandsson
2014-2017 CCGEx Summary Report on Research Activities

Part 1 **Ongoing Projects**

10:30-11:05 **Research Area: Compressor Off-Design Operation (CoD)**

Mihai Mihaescu: intro + overview (5 minutes)

- Mihai Mihaescu, KTH-Mek (10+5 min). "*Compressor Flow Instabilities at Low Mass Flow Rates: an LES approach.*"
- Asuka G. Pietroniro, Ind. PhD Student, Volvo Cars (10+5 min). "*Computational Aeroacoustics of aerodynamically generated sound in Centrifugal Compressors.*"

11:10-12:15 **Research Area: HOTSIDE**

Mihai Mihaescu: intro + overview (5 minutes)

- Marcus Winroth, KTH-Mek (10+5 min). "*Gas Dynamics of Exhaust Valves.*"
- Ted Holmberg, KTH-ICE (10+5 min). "*Valve Strategies and Exhaust Pulse Utilization."*
- Shyang Maw Lim, KTH-Mek (10+5 min). "*Aerothermodynamics and Exergy Analysis in Turbocharger Radial Turbine."*
- Nicholas Anton, Ind. PhD Student, SCANIA (10+5 min). *"Engine Optimized Engine Turbine."*

12:30-13:30 **LUNCH**

Agenda – Afternoon session 11th October

Norrtull Konferenshotell

13:30-14:20 **Research Area: Engine After Treatment (EAT)**

- Mats Åbom: intro + overview (5 minutes)
  - Zhe Zang, KTH-MWL (10+5 min). "*Agglomeration of Particles in Gas Exhaust Systems by using Acoustics".*
  - Ghulam M. Majal, KTH-MWL/Mek (10+5 min). "Agglomeration of Particles in Exhaust Gases by flow manipulation."
  - Arun Prasath, KTH-ICE (10+5 min). "; *Particulate characterization in the Gas Exchange Systems of DI/SI Engines."*

14:25-15:00 **Research Area: Power Train System Integration (SYSINT)**

- Anders Christiansen Erlandsson: intro + overview (5 minutes)
  - Senthil Krishnan Mahendar, KTH-ICE (10+5 min). "*Heavy Duty DISI Gas Exchange Processes with Alternative Fuels."*
  - Sandhya Thantla, KTH-ICE (10+5 min). "*Low Temperature Waste Heat Recovery (WHR) in IC Engines."*

15:00-15:30 **COFFEE**

Part 2 **Interviews *(two parallel sessions – island configurations)***

15:30-16:10 IAB interviews with PhD Students
15:30-16:10 Interaction between senior researchers /faculty at CCGEx & Industrial Partners

16:10-16:50 IAB interviews with senior researchers and faculty at CCGEx
16:10-16:50 Interaction between industry partners

16:50-17:30 IAB meets industry partners

18:00 **DINNER at Nortull Konferencehotell**

Agenda – 12th October

Room Gladan, Brinellvägen 83

08:30 **Kick-off the new program period by CCGEx Director**- Anders Christiansen Erlandsson

09:00-10:15 **New Research Areas, Projects, and Students**

- i-COLD Mihai Mihaescu:
  - Compressor Response to upstream/downstream installation effects and perturbations – Emelie Trigell, PhD Student
  - Aerodynamically generated noise of centrifugal compressors – Experiments – Post Doc (NN)
  - Non-linear system identification techniques for acoustic characterization of turbochargers under high level of pulsating flow excitation - *Marie Curie student* Niloofar Sayyad Khodashenas (*4:th year) – Associated project*
- i-HOT Mihai Mihaescu:
  - Turbocharger turbine efficiency in steady and pulsating inlet flows – experiments – Yushi Murai, PhD Student
  - Turbine performance optimization with focus on maximizing exergy transfer – Roberto Mosca, PhD Student

10:15-10:45 **COFFEE**

10:45-12:00

- i-SYS Anders Christiansen Erlandsson:
  - Exergy losses in high efficiency charging – Beichuan Hong, PhD Student
  - Engine charging and EAT interaction during transients – Varun Venkataraman, PhD Student
  - Waste Heat Recovery in Pulsating Flows-New techniques – Jianhua Zhou, Post-doc

12:00-13:00 **LUNCH**

13:00-14:00 **IAB meets CCGEx leadership team**

- Summary of impressions

14:00-15:00 **Optional Lab Tour**


GREENPEACE
MEET LISA. AN 8-YEAR-OLD EMISSIONS FILTER!

Eternal Combustion Engines –
the world´s most efficient - > 50% single cycle

CCGEx history in short

- Research center on ICE gas exchange systems and processes for higher efficiency, zero emissions and faster development

- 2014-2017 – third program period
- 2018-2021 – awarded by Swedish Energy Agency

- Three departments at KTH involved ICE; MECH; MWL
  - 11-15 Ph.D students
  - 4 Senior researchers or postdocs
  - 5-7 Professors
- Budget 12-14 mSEK/year cash (+in-kind)

Industry partners

SCANIA, VOLVO; VOLVO CARS, BORG WARNER, WÄRTSILÄ, …

Competence Center for Gas Exchange (CCGEx) at KTH

Vision:
Enable the move from extensive physical testing to innovative virtual development using ***predictive simulation*** *tools developed on physics-based understanding of phenomena*

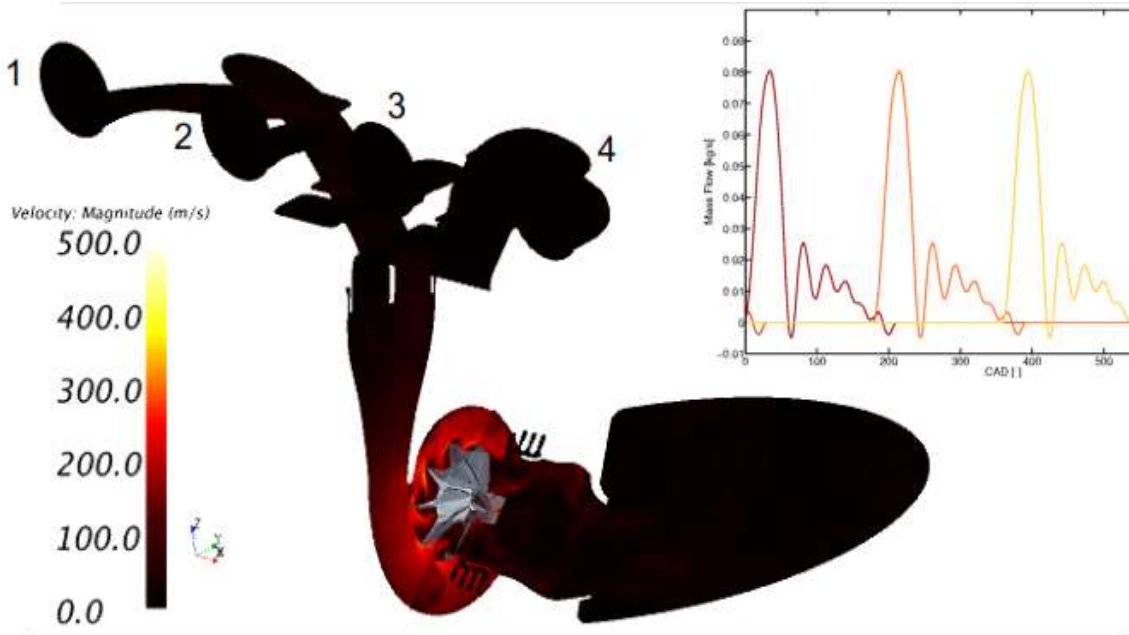
Goal:
Enable knowledge-based and efficient design of next generation clean propulsion systems with focus on advanced Gas Exchange technologies

Tools:
Multidisciplinary & integrated research combining dedicated competences, expertise and facilities in gas dynamics, acoustics, and engine technology

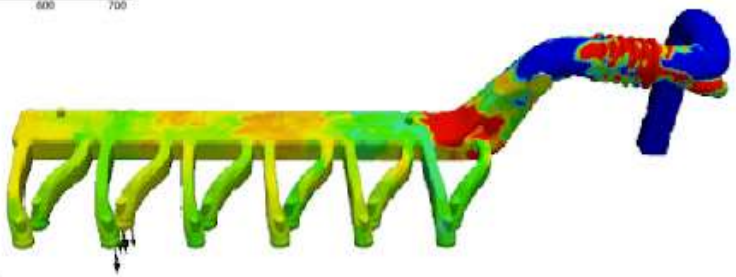
Competence Center for Gas Exchange (CCGEx) at KTH

Challenges with gas exchange system:

- *Physical Level: unsteady & chaotic turbulent flows, heat transfer, flow-acoustic interactions*
- *System Level: complex geometries, multi-component attributes, multi-parameter integration for optimal design*
- *Operation Level: unsteady heat and mass flows, significant impact on engine efficiency & emissions, non-linear control*



Pulsating flow in an exhaust manifold (VOLVO Cars) integrated with turbine for accurate turbo performance assessment



EGR distribution for a SCANIA intake manifold (intensive red: 100%EGR)

CCGEx Reserach areas of relevance to engine industry

Charging
- Increased efficiency, Higher Pressure Ratio, Wider operating range (reduced surge margins), Intercooling integration, packaging, transient response
- Noise, vibration & harshness

EGR & charge air / Exhaust manifold
- Pressure drop; Control /operation
- Efficient / controlled mixing
- Energy recovery – waste hear recovery / Heat transfer

Exhaust aftertreatment
- PMEP influence, Particles, Chemical pollutants, Noise, Thermal management

Engine system
- Thermodynamic cycle, Valve strategy, Miller cycle, Thermal management, Interaction between components

Realistic simulation
- Method development, predictive design, big-data/machine inteligence

CCGEx Expertise

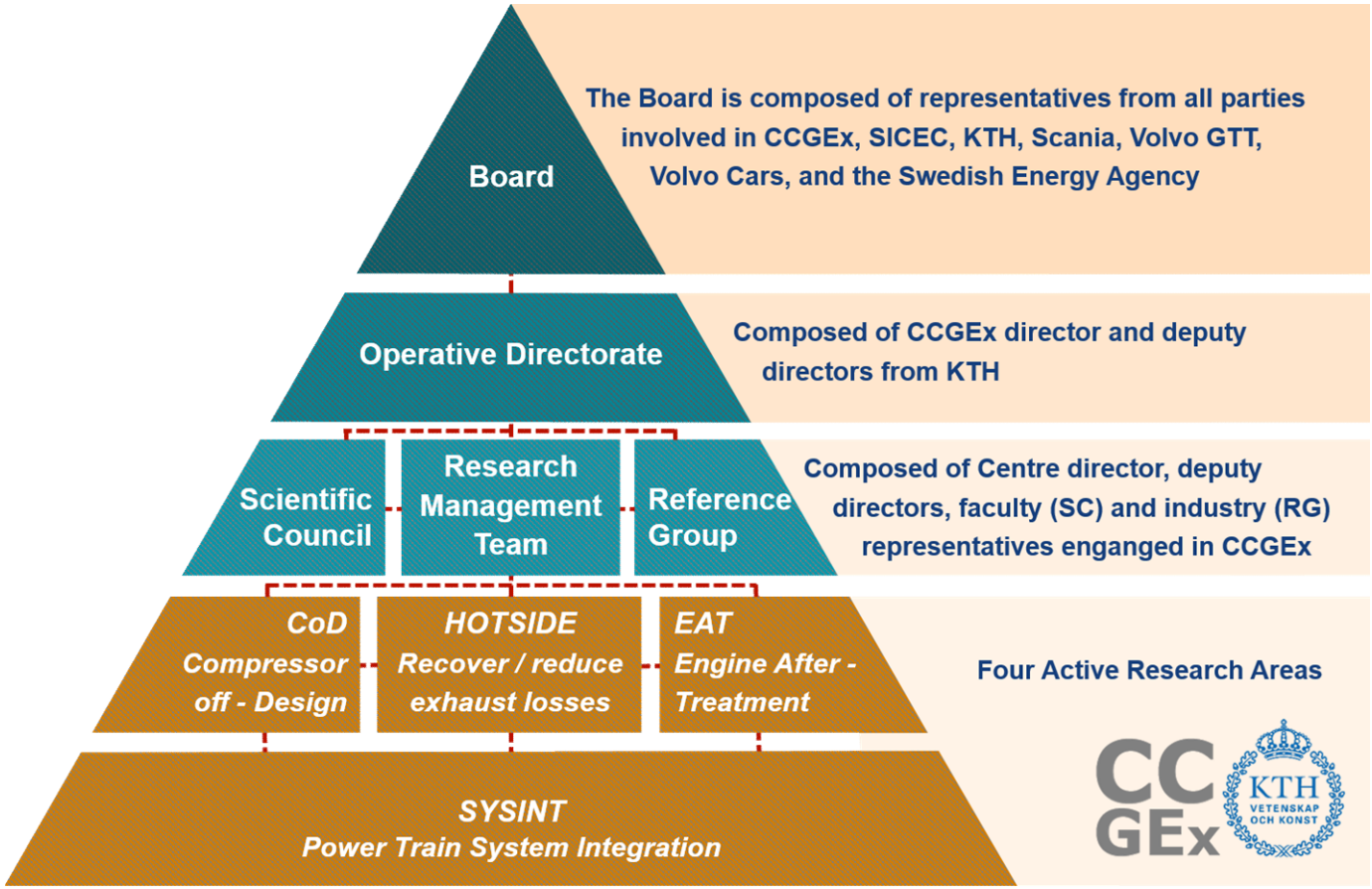
Physics

- Turbulent flows
- Heat-transfer, thermodynamics & compressible flows
- Multiphase flows incl. particles
- Acoustic, noise, vibration & harshness
- Combustion

Methods

- High-fidelity Simulations
- Dynamic System Simulations
- Gas-dynamics & gas-stand experiments
- High resolution flow measurements and laser/optical diagnostics
- Predictive simulations & optimization for virtual design
- Engine testing, rig testing & instrumentation

CCGEx Organization



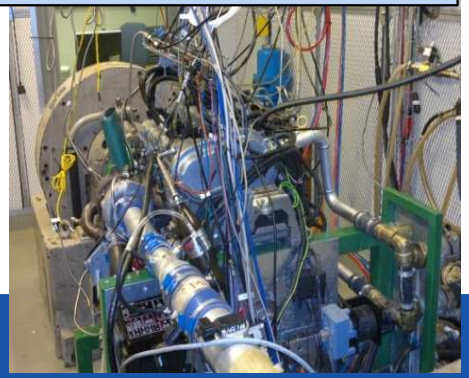
CCGEx Resources: ICE Lab

Focus areas for a **sustainable society**:

- Fuel efficiency
- Renewable fuels
- Low emissions
- Industrial competitiveness

4 test beds + 2 rigs on 400 m^2

- Single-cylinder SCANIA engine
- In-line 13 liter SCANIA engine
- Optical SCANIA research engine
- In-line Volvo Car engine VEP-HP
- High pressure Fuel injection test rig
- Cold test bed -30 degrees C



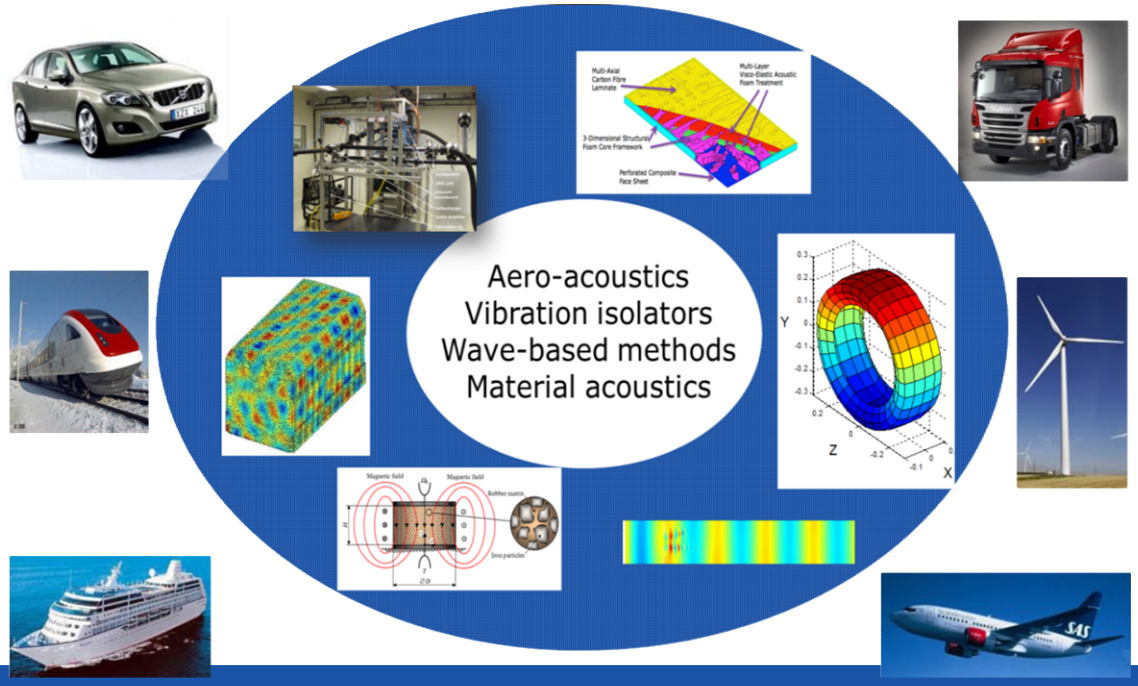
CCGEx Resources: CICERO Lab

- High pressure facility for fundamental and applied research
  - mass flow up to 0.5 kg/s at 5 bar
  - filter and dryer provides clean and dry air to the facility
  - hot air provided by a heater with regulated power up to 18 kW
- Full support from the Fluid Physics Laboratory (KTH Mechanics) with state-of-the-art measurement equipment (pressure, hot-wire, LDV, PIV, PSP etc.)
- Custom-made rigs may be manufactured in the Fluid Physics Laboratory for CCGEx

CCGEx Resources: MWL Lab

Mission: “Understanding the underlying physical mechanisms by means of mathematical modelling and experimental characterization”

Research Areas

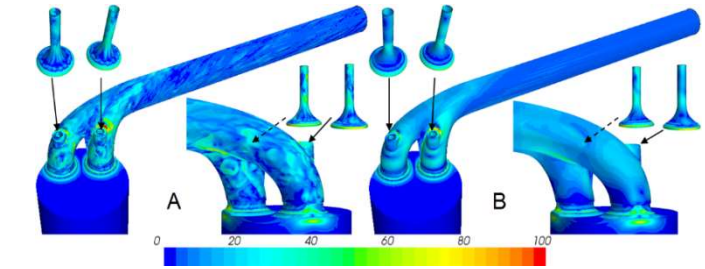


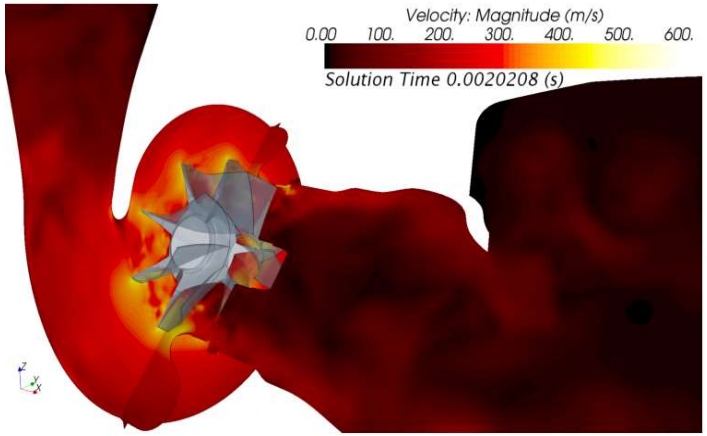
CCGEx Resources: Applied CFD group at KTH-Mechanics

Fluid dynamics research using high-fidelity computational tools with applications to transport phenomena in single/multiphase flows, turbulent mixing & flow mixing control, compressible flows, and heat transfer

Research Areas:

- Unsteady flows in complex geometries
- Gas exchange processes and turbomachinery
- Heat transfer & thermal management
- Multiphase flows & spray modeling
- Compressible flows & aeroacoustics
- Flow control
- Turbulence modeling
- Stability and transition

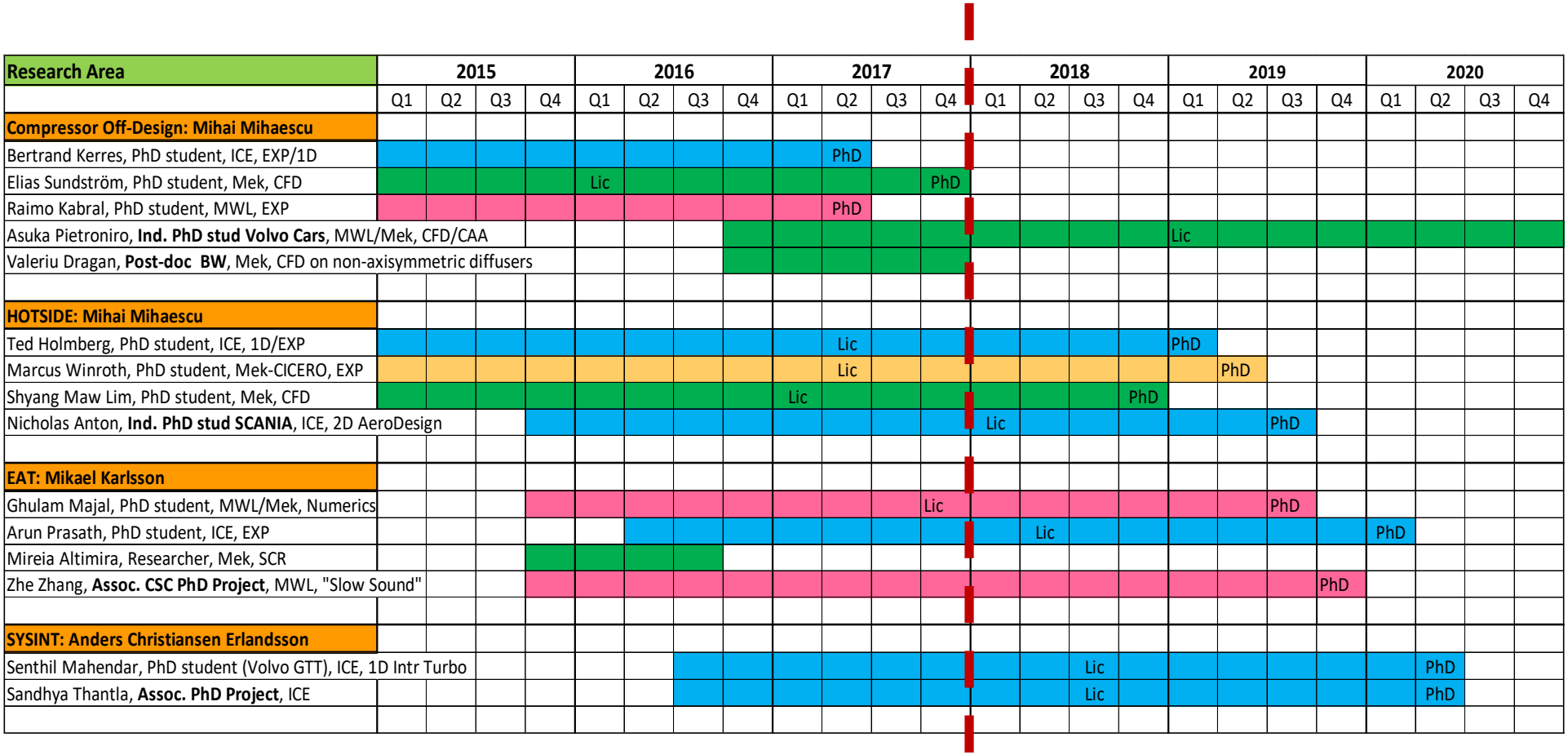




Computational Resources:

- Swedish National Infrastructure for Computing - SNIC, HPC2N
- “In-house” & commercial software programs and post-processing tools

Research areas & projects 2014-2017



2014-2017

Achievements

Ph.D:s

Table 1: Doctoral theses (2014-2017)	11
Sundström, E. (Mek, 2017)	Flow Instabilities in Centrifugal Compressors at Low Mass Flow Rate, PhD thesis, KTH Mechanics, ISBN 978-91-7729-555-6, US-AB, Stockholm, Sweden. http://kth.diva-portal.org/smash/get/diva2:1157882/FULLTEXT02.pdf
Kabral, R. (MWL, 2017)	Turbocharger Aeroacoustics and Optimal Damping of Sound. PhD thesis. KTH MWL, ISBN 978-91-7729-442-9, Stockholm, Sweden. http://kth.diva-portal.org/smash/get/diva2:1096314/FULLTEXT01.pdf
Kerres, B. (MFM/Mek, 2017)	On Stability and Surge in Turbocharger Compressors, PhD thesis, KTH MFM, ISBN 978-91-7729-378-1, US-AB, Stockholm, Sweden. http://kth.diva-portal.org/smash/get/diva2:1093727/FULLTEXT01.pdf
Hynninen, A. (MWL, 2015)	Acoustic In-duct Characterization of Fluid Machines with Applications to Medium Speed IC-engines. PhD thesis, KTH The Marcus Wallenberg Laboratory for Sound and Vibration Research, Stockholm, Sweden. http://kth.diva-portal.org/smash/get/diva2:872313/FULLTEXT01.pdf
Söder, M. (Mek, 2015)	Creation and destruction of in-cylinder flows: Large eddy simulations of the intake and the compression strokes. PhD thesis, KTH Mechanics, Stockholm, Sweden. http://kth.diva-portal.org/smash/get/diva2:806426/FULLTEXT01.pdf
Zhou, L. (MWL, 2015)	Acoustic characterization of orifices and perforated liners with flow and high-level acoustic excitation. PhD thesis, KTH The Marcus Wallenberg Laboratory for Sound and Vibration Research, Stockholm, Sweden. http://kth.diva-portal.org/smash/get/diva2:813073/FULLTEXT01.pdf
Aghaali, H. (MFM, 2014)	Exhaust Heat Utilisation and Losses in Internal Combustion Engines with Focus on the Gas Exchange System, PhD thesis, KTH Machine Design, Stockholm, Sweden. http://kth.diva-portal.org/smash/record.jsf?pid=diva2%3A750114&dswid=-6247
Fjällman, J. (Mek, 2014)	Large Eddy Simulations of Complex Flows in IC-Engine's Exhaust Manifold and Turbine. PhD thesis, KTH Mechanics, Stockholm, Sweden. http://kth.diva-portal.org/smash/get/diva2:748463/FULLTEXT01.pdf
Kalpakli Vester, A. (Mek, 2014)	Vortices in turbulent flows—rocking, rolling and pulsating motions. PhD thesis, KTH Mechanics, Stockholm, Sweden. http://kth.diva-portal.org/smash/get/diva2:717536/FULLTEXT01.pdf
Pastuhoff, M. (Mek, 2014)	Measuring with pressure sensitive paint in time-varying flows. PhD thesis, KTH Mechanics, Stockholm, Sweden. http://kth.diva-portal.org/smash/get/diva2:740366/SUMMARY01.pdf
Reifarth, S. (MFM, 2014)	Efficiency and Mixing Analysis of EGR-Systems for Diesel Engines. PhD thesis, KTH Internal Combustion Engines, Stockholm, Sweden. http://www.diva-portal.org/smash/get/diva2:692865/FULLTEXT01.pdf

Achievements 2014-2017

Table 2: Lic. theses	3
Winroth, M. (Mek, 2017)	On gas dynamics of exhaust valves. Licentiate thesis, KTH Mechanics, Stockholm, Sweden.
Lim, S.M. (Mek, 2017)	Flow and heat transfer in a turbocharger radial turbine. Licentiate thesis, KTH Mechanics, Stockholm, Sweden.
Sundström, E. (Mek, 2016)	Centrifugal compressor flow instabilities at lowmass flow rate. Licentiate thesis, KTH Mechanics, Stockholm, Sweden.

Table 4: Summary on peer-review publications (2014-2017)
https://www.ccgex.kth.se/publications/journal-conference-papers-1.368301

Publication type	CCGEx - all papers -	MFM	MWL	Mek	Collaborations MFM/MWL/Mek	Collaborations with industry
Conference publications	41	8	17	16	(7)	(5)
Int. Journal publications	37	5	14	18	(3)	(5)
Total	**78**	**13**	**31**	**34**	**(10) out of 78**	**(10) out of 78**

Financial report 2014-2017

CCGEx 2014-2017	Budget 2014-2017	Cash 2014 - 2017	Inkind 2014-2017	Totalt 2014 -2017
Lönekostnader	51 150 000	27 546 269	27 596 495	55 142 763
Köpta tjänster		841 916	1 183 693	2 025 609
Utrustning	4 040 000	725 908	2 970 600	3 696 508
Material	1 410 000	439 765	389 000	828 765
Laboratoriekostnader	13 300 000	2 597 683	9 341 639	11 939 322
Resor	490 000	1 275 022		1 275 022
Övriga kostnader		425 099	46 800	471 899
Indirekta kostnader	25 610 000	19 012 653	4 096 070	23 108 723
SUMMA	**96 000 000**	52 864 316	45 624 297	98 488 612

Partner Development 2014-2017

- BorgWarner Turbo Systems Engineering GmbH, Kirchheimbolanden, Germany as partner in the Center (2016-2017)
- Industry PhD student with Volvo Cars (Asuka G.Pietroniro) stared during 2017.
- Industry PhD student with Scania (Nicholas Anton) started during 2015.
- GE Oil & Gas, Italy as collaborator (2016)
- University of Cincinnati, USA as collaborator
- Wärtsilä collaboration development 2017

Acknowledgements

For financial support & in-kind contibutions:
SWEDISH Energy Agency (STEM)
KTH
SCANIA CV
VOLVO GTT
Volvo Cars
BORG WARNER

THANK YOU!

SNIC
PDC @ KTH
Cray XC40 system 53632 cores
(1676 nodes with 32 cores/node)

Students
Faculty
Staff & Administaration
Industry Experts & Managers

Competence Center for Gas Exchange

CC GEx

”Charging for the future”

Energimyndigheten SCANIA VOLVO VOLVO BorgWarner