Computer Graphics

- Introduction -

Philipp Slusallek

Overview

- **Today**
  - Administrative stuff
  - History of Computer Graphics (CG)
- **Next lecture**
  - Overview of Ray Tracing

General Information

- **Core Lecture (Stammvorlesung)**
  - Applied Computer Science (Praktische Informatik)
  - Lectures in English
- **Time and Location**
  - Mon 10:00-12:00h, HS 01, E1.3
  - Thu 8:00-10:00h, HS 01, E1.3 (suggestion: 8:30-10:00h)
- **ECTS:**
  - 9 credit points
- **Web-Page**
  - http://graphics.cg.uni-saarland.de/courses/
  - Schedule, slides as PDF, etc.
  - Literature, assignments, other information
- **Sign up for the course on our Web page now**
  - [Do not forget to sign-out in time before the exams, if you need to]

People

- **Lecturers**
  - Philipp Slusallek
    - E1.1, Room E18, Tel. 3830, Email: slusallek@cs.uni-saarland.de
- **Assistants**
  - Arsène Pérard-Gayot
  - E1.1, Room E13, Tel. 3837, Email: perard@cg.uni-saarland.de
- **Tutors**
  - Julius Kilger (juliuskilger@posteo.de)
  - Joschua Loth (s8joloth@stud.uni-saarland.de)
  - Henrik Philippi (s8hephil@stud.uni-saarland.de)

Exercise Groups

- **Will be announced through the email list**
- **Please register on the course web page**

Weekly Assignments

- **Weekly assignment sheets**
  - Theoretical & programming assignments
  - You will incrementally build your own ray tracing system
  - This will be the basis for the Rendering Competition
- **Grading**
  - Results of the exercises will contribute to the final grade
  - Bonus points (towards the exam) are possible
- **Handing in assignments**
  - Theoretical: In paper form (beginning of lecture) or PDF per email
  - Code: See exercise sheet or Web page (usually by email to tutor)
- **Exercise meetings**
  - Discuss lectures and any issues you might have with TAs
- **Groups of max. 2 students allowed**
  - Each one must be able to present and explain his/her results!
  - Please state who did what!!!

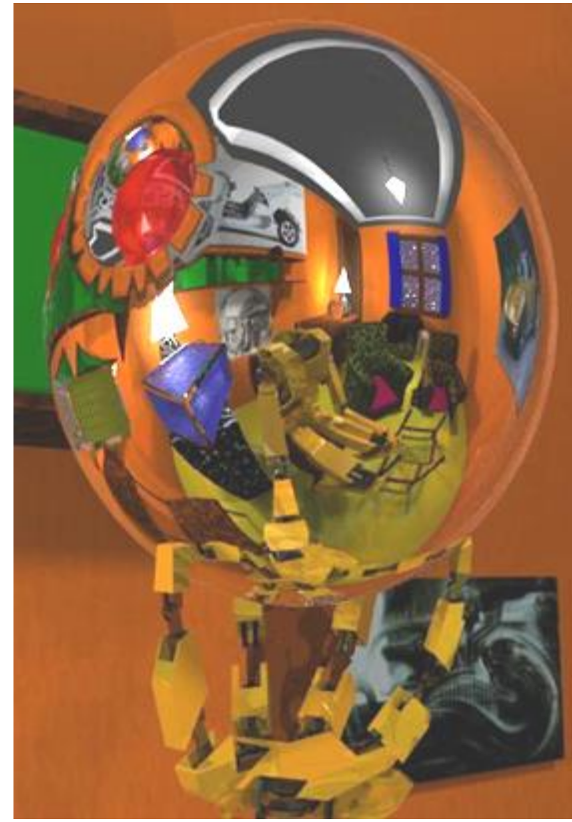
Grading

- **Weekly Assignments**
  - Counts 30% towards final grade (with +20% bonus points)
- **Rendering Competition (exam prereq.)**
  - Counts 10% towards final grade
  - Grading: Artistic quality (jury)
  - Groups of max. 2 students (but higher requirements then)
- **Exams**
  - Mid-term (exam prereq.), counts 20% towards final grade
  - Final exam counts 40% towards final grade
  - Minimum: 50% to pass (in each of the above)
- **Cheating**
  - 0% of assignment grade on first attempt
  - Possibility to fail the entire course if repeated
- **Chance for Repeated Exam**
  - Oral exam (if possible) at the end of the semester break

Rendering Competition

- **Task**
  - Create a realistic image of a virtual environment
  - Incorporate additional technical features into your ray tracer
  - Bonus points count towards exam
  - Creative design of a realistic and/or aesthetic 3D scene
  - Modeling and shading
- **Hand-out in early in course**
  - You can work on it during the entire course
  - Deadline will be announced (see Web page)
- **Results:**
  - One rendered image
  - Web page with technical detail info

Rendering Competition



Rendering Competition 2017/18

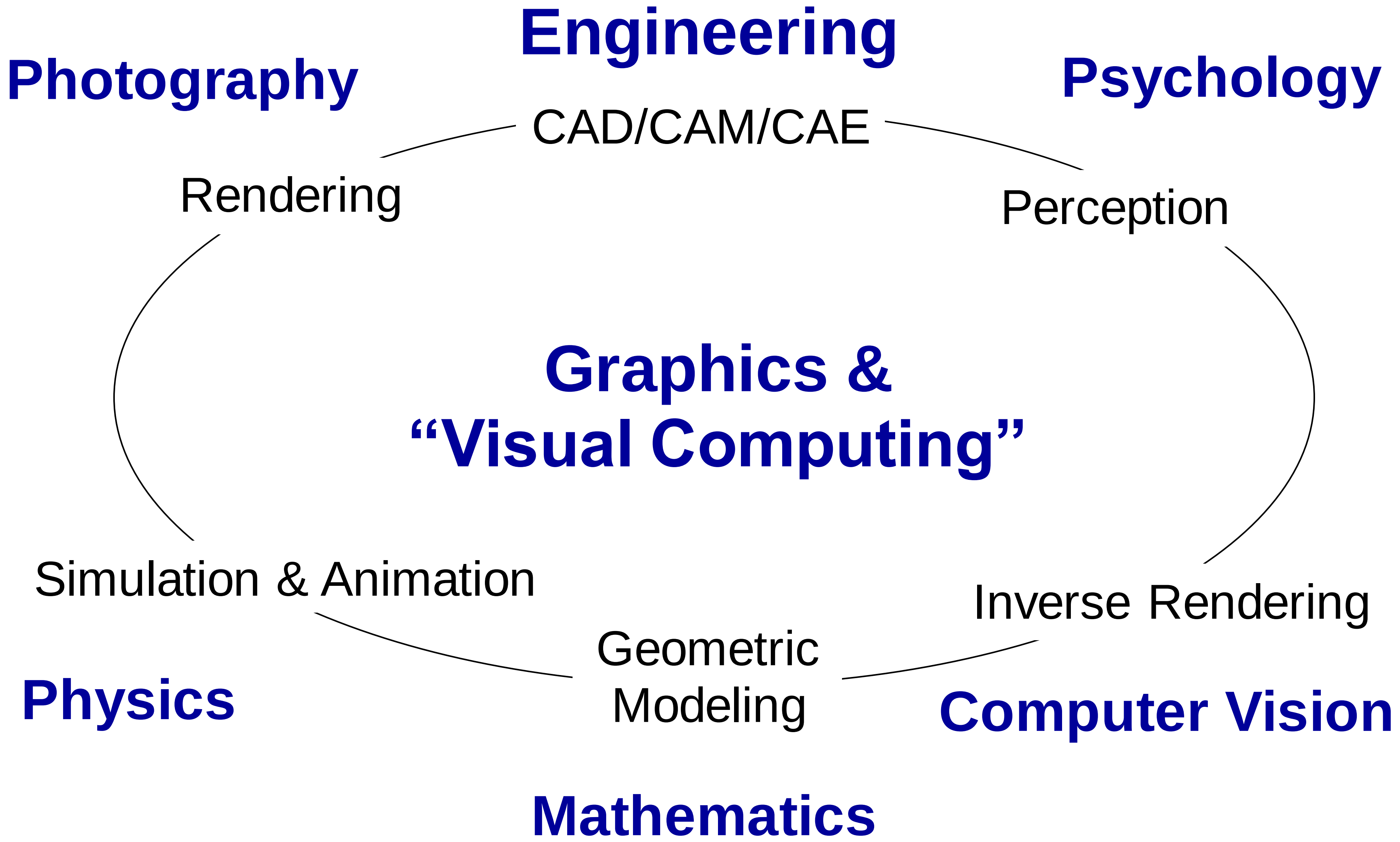
Text Books

- **Suggested Readings:**
  - John Hughes, et al.: **Computer Graphics – Principles and Practice**, Addison-Wesley, 3. Ed, 2013
  - Peter Shirley: **Fundamentals in CG**, 4. Ed, AK Peters, 2016
  - Matt Pharr, Wenzel Jakob, Greg Humphreys: **Physically Based Rendering : From Theory to Implementation**, Morgan Kaufmann Series, 3. Ed., 2016, now freely available: http://www.pbr-book.org/
- **Older**
  - Andrew Glassner: **An Introduction to Ray-Tracing**, Academic Press, 1989
  - David Ebert: **Texturing and Modeling – A procedural approach**, Morgan Kaufmann, 2003
  - Tony Apodaca, Larry Gritz: **Advanced RenderMan: Beyond the Companion**, Morgan Kaufmann, 2000
- **More specific**
  - Thomas Akenine-Möller, Eric Haines, **Real-Time Rendering**, AK Peters, 2nd Ed., 2002
  - John M. Kessenich, et al., **OpenGL Programming Guide**, Addison-Wesley, 9. Ed., 2016

Course Syllabus (Tentative)

- Overview of Ray Tracing
- Geometry Intersections
- Spatial Index / Acceleration Structures
- Vector Algebra Review
- Geometric Transformations
- Light Transport / Rendering Equation
- Material Models
- Shading
- Texturing
- Spectral Analysis / Sampling Theory
- Anti-Aliasing
- Distribution Ray Tracing
- Human Vision
- Color
- Splines
- Clipping
- Rasterization
- OpenGL

What is Computer Graphics ?



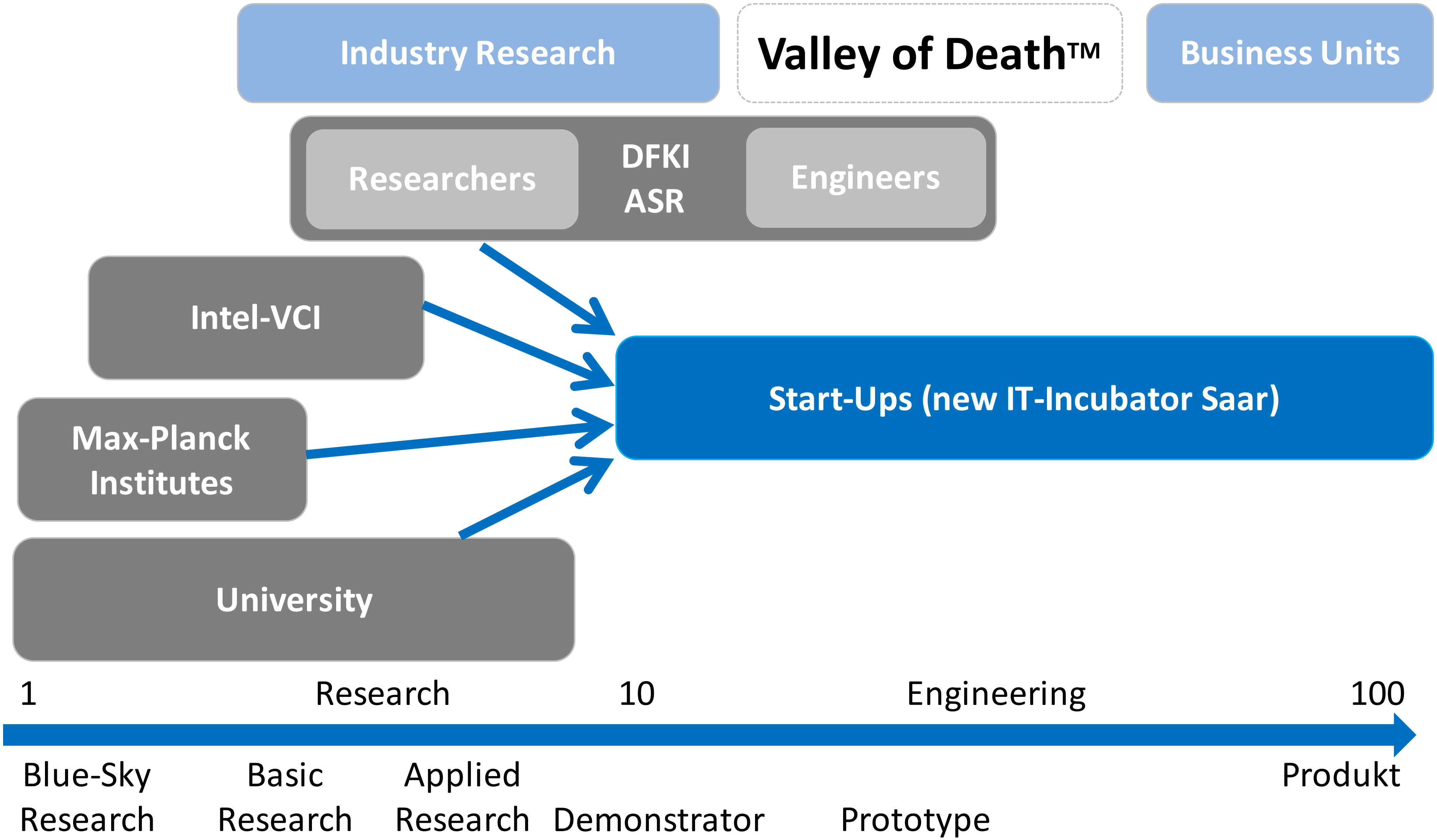
What is Computer Graphics?

Computer Games
Color Management
VR/AR
Languages
Systems
Modeling
Animation
Rendering
Imaging
Visualization
GUI
Plotting
Digital Media
Printer
Computer Architecture
Compression
Computer Vision
Mathematical Modeling

And, and, and, ...

Saarland Informatics Campus

Research & Innovation in SB



German Research Center for Artificial Intelligence (DFKI)

- **Motto**
  - „Computer with Eyes, Ears, and Common Sense“
- **Overview**
  - Largest AI research center worldwide (founded in 1988)
  - Germany’s leading research center for innovative SW technologies
  - 6 sites in Germany
    - Saarbrücken, Bremen, Kaiserslautern; Berlin, Osnabrück, Oldenburg
  - 18 research areas, 10 competence centers, 7 living labs
  - More than 575 core research staff (>1050 total)
  - Revenues of ~50 M€ (2018)
  - More than 90 spin-offs

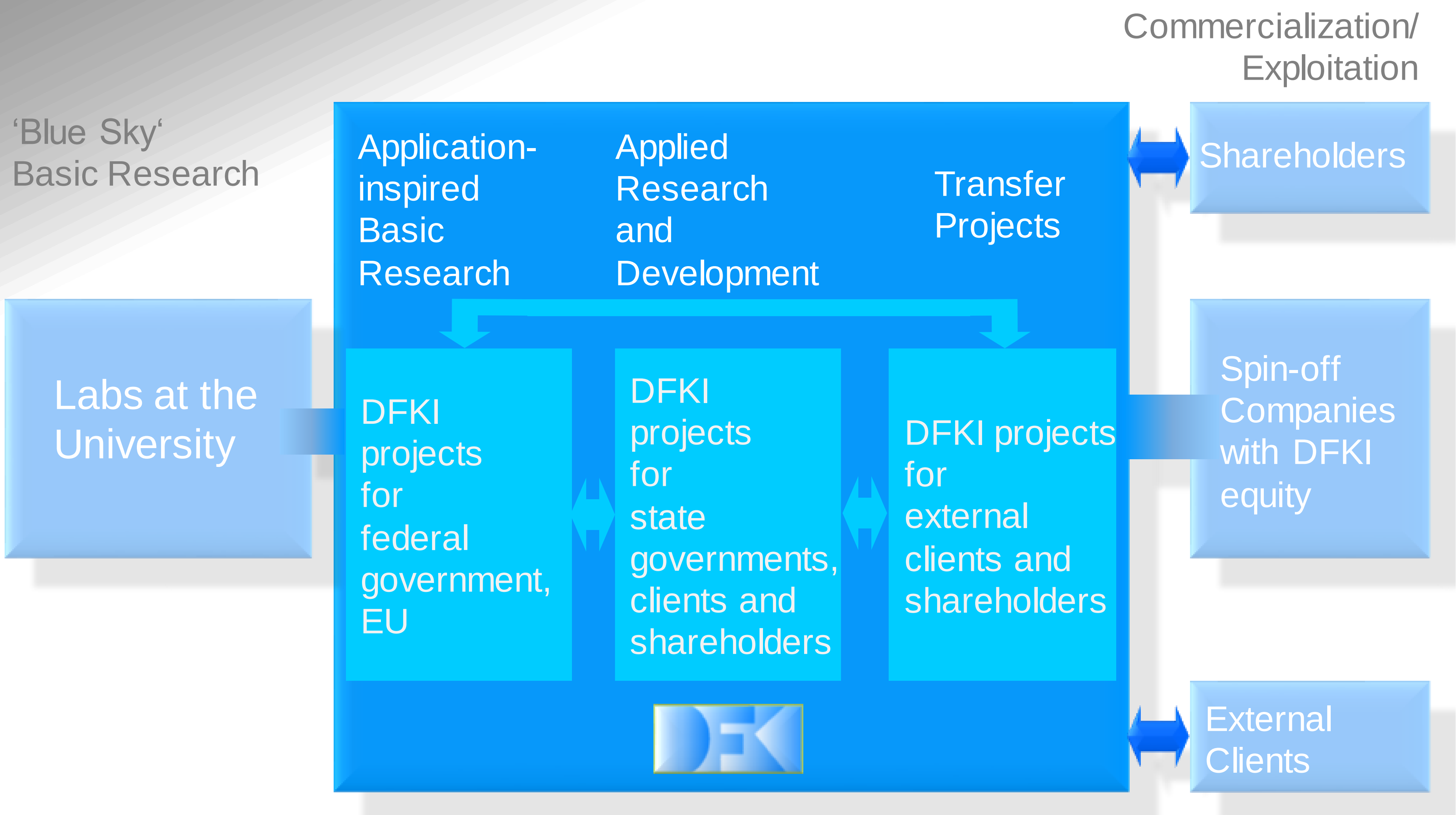
Germany Has a Head-Start

DFKI: The World´s Largest Center for Research & Application in AI

SAP
intel
Google
HARTING
ZF
John Deere
Deutsche Telekom
software AG
Microsoft Deutschland GmbH
Deutsche Börse Group
accenture
EMPOLIS Information Management
Deutsche Messe
KIBG
Volkswagen Aktiengesellschaft
Daimler
BMW Group
Bosch
Ricoh
Claas
Airbus Group
VSE
cerence

Fraunhofer
Universität des Saarlandes
Universität Bremen
Technische Universität Kaiserslautern
Munich RE
DFKI

DFKI Covers the Complete Innovation Cycle



DFKI-Portfolio: Deep Expertise in AI for a Broad Innovation Spectrum

Max Planck Society	Fraunhofer	Helmholtz Society
Application-Oriented Basic Research	**Applied R&D and Transfer**	Large Test- and Demonstration Centers

The entire innovation chain in the horizontal spectrum of DFKI

The vertical specialisation of DFKI on methods and application of Artificial Intelligence

Deep knowledge and excellence in one important section of Computer Science

DFKI Employees

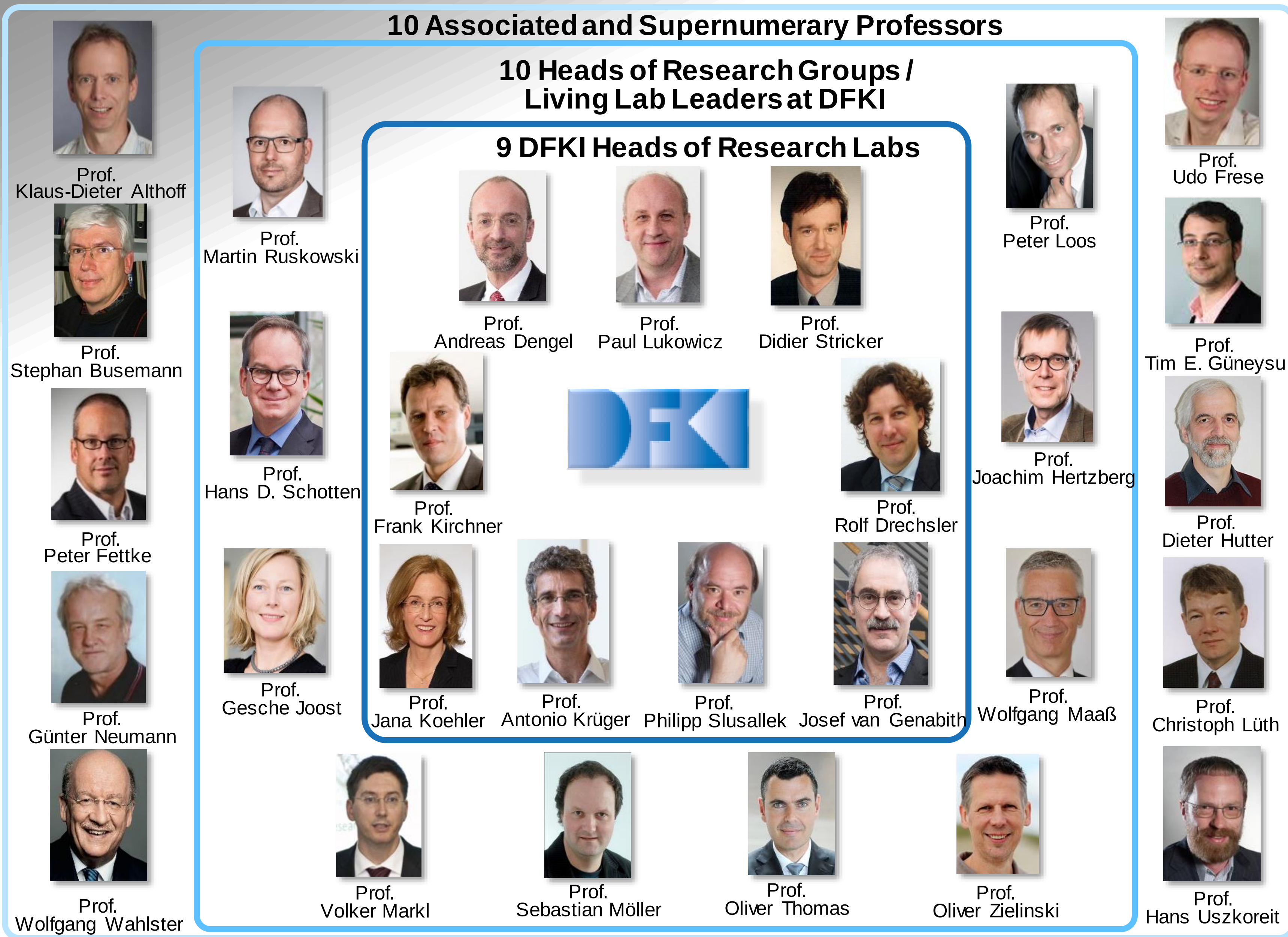
Broad Methodological and Systems Competence in Artificial Intelligence

Deep Scientific Expertise in AI Technology

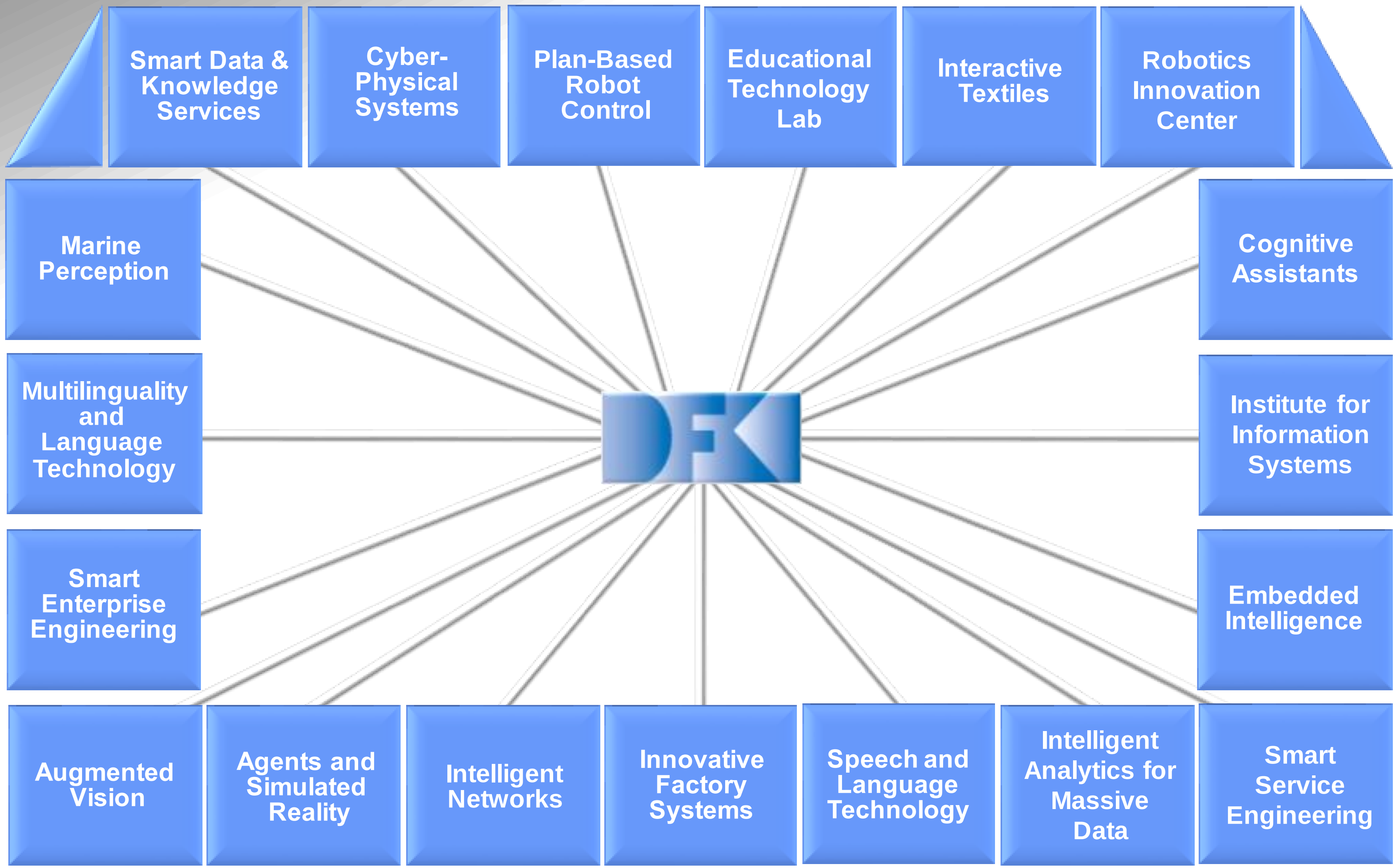
Deep Domain Knowledge in an Area of Application

DFKI

Currently 29 Professors are Working for DFKI



DFKI: R&D Departments & Groups



A Selection of Important Clients in Germany

- BSI – Bundesamt für Sicherheit in der Informationstechnik
- CCI – Competence Center Informatik
- SEMA GROUP
- IBM
- Dresdner Bank
- Trinkaus & Burkhardt Bank seit 1785
- Deutsche Bahn DB
- DAIMLER
- OTTO
- SIEMENS
- Condor
- DEKRA
- Deutsche Post
- T Deutsche Telekom
- SAP
- DATEV
- Verlagsgruppe Georg von Holtzbrinck
- CAP debis KSP
- Bundesministerium für Bildung und Forschung
- PHILIPS
- BASF Aktiengesellschaft
- accenture
- European Media Lab
- TECMATH
- SAARBERG
- faircar
- PORSCHE
- BMW Group
- SEMANTICEDGE
- Bundesministerium für Wirtschaft und Arbeit
- T-Online
- net-linx AG
- Schindler
- BOSCH
- software AG
- Bundesagentur für Arbeit
- Audi
- T-Mobile
- POLIZEI – Saarländische Polizei
- VW
- saarstahl

DFKI

DFKI Recruits Worldwide:
303 Researchers, 64 Countries

Agents and Simulated Reality

AI, Graphics/Simulation, High-Performance Computing

Scientific Director
Philipp Slusallek

Christian Müller (Deputy)

Silke Balzert-Walter (Consulting)

Application Domains

Strategy Board

- **Autonomous Driving** – Christian Müller
- **Computational Sciences** – Tim Dahmen
- **Smart Living** – Hilko Hoffmann
- **Industrie 4.0** – Ingo Zinnikus
- **High-Performance Computing** – Richard Membarth

Research Teams

Hybrid & Symbolic AI
- **Multi-Agent Systems** – Klaus Fischer
- **Intelligent Information Systems** – Matthias Klusch

ML / DL
- **Computational 3D Imaging** – Tim Dahmen

AI Platform
- **Distributed & Web-Based Systems** – René Schubotz
- **High-Performance Graphics & Computing** – Richard Membarth

Application-Driven Teams
- **Autonomous Driving** – Christian Müller
- **Smart Living** – Hilko Hoffmann

Important German, European & International Cooperations:

CLAIRE

HUMANE AI

Philipp Slusallek (Co-Initiator), Silke Balzert-Walter

Lernende Systeme – Die Plattform für Künstliche Intelligenz

Philipp Slusallek, Christian Müller

NPM – Nationale Plattform Zukunft der Mobilität

Philipp Slusallek

SMART LIVING – MADE IN GERMANY

Hilko Hoffmann

National Institute of Advanced Industrial Science and Technology AIST – AIRC

Philipp Slusallek, Christian Müller

DFKI: Agents & Simulated Reality

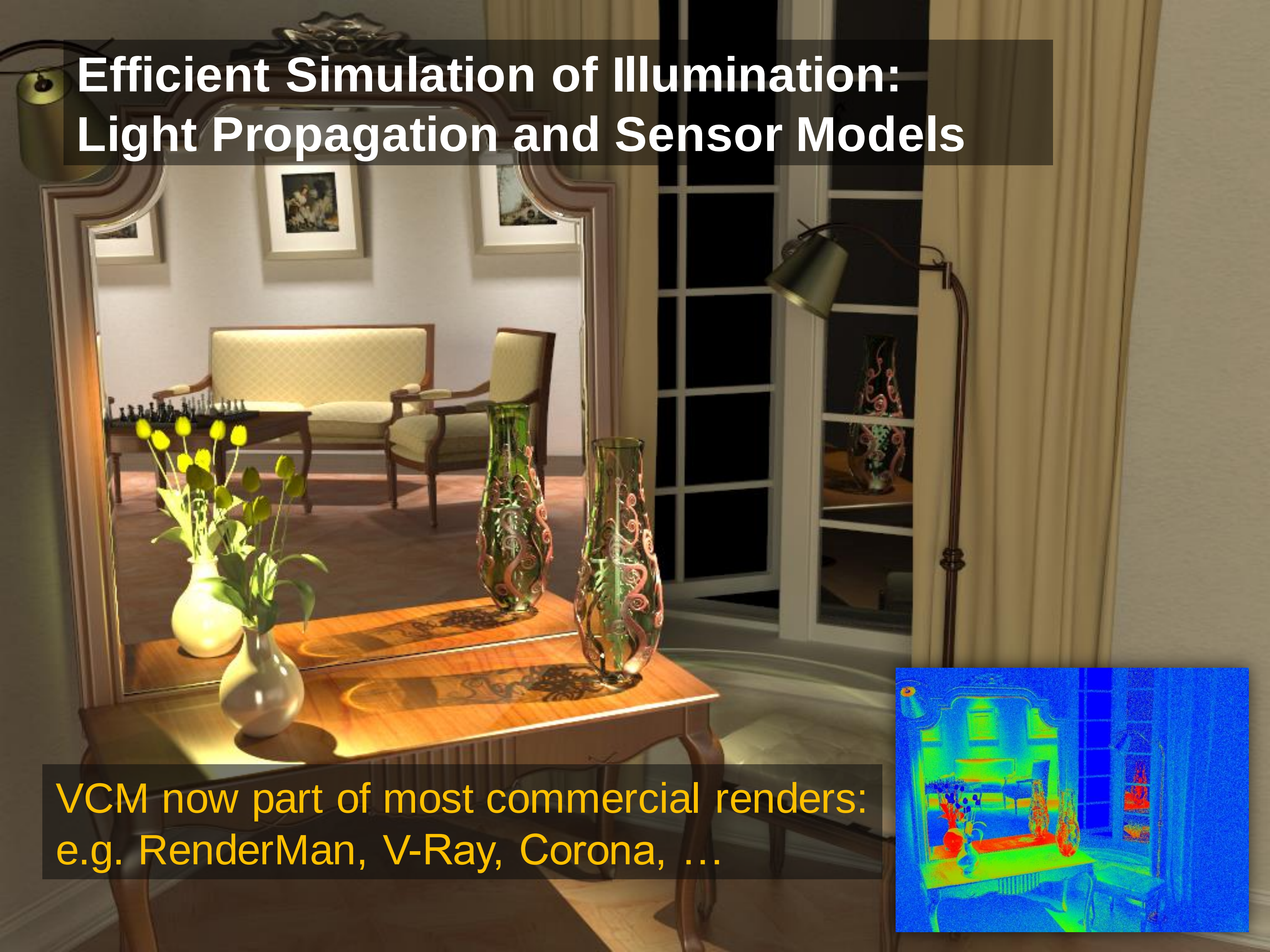
- Bringing together AI, Graphics, HPC, and Security
  - Simulated/Digital Reality (graphics, interaction, simulation)
  - Multi-agent Systems (AI: perception, learning, reasoning, planning)
  - HPC (compiler, parallel/vector computing: CPU/GPU/FPGA)
  - Visualization Center (presentation, teaching/training, consulting)
- Application-Oriented Research
  - >40 PhDs and researchers (plus many HiWis, BS, MS)
  - Many publicly funded projects
    - **EU:** FIWARE, CREMA, DISTRO, …
    - **National:** Hybr-iT, Metacca, ProThOS, HP-DLF, SmartMaaS, …
    - **Industry:** BMW, VW, Intel, Audi, Airbus, Pilz, Siemens, …
- Benefits
  - **Researcher and engineer positions**
    - Plus many HiWi, Bachelor, Master, PhDs
  - Extremely broad industry network (Contacts & Jobs, etc.)

ASR Research Topics

Physically-Based Image Synthesis with Real-Time Ray Tracing

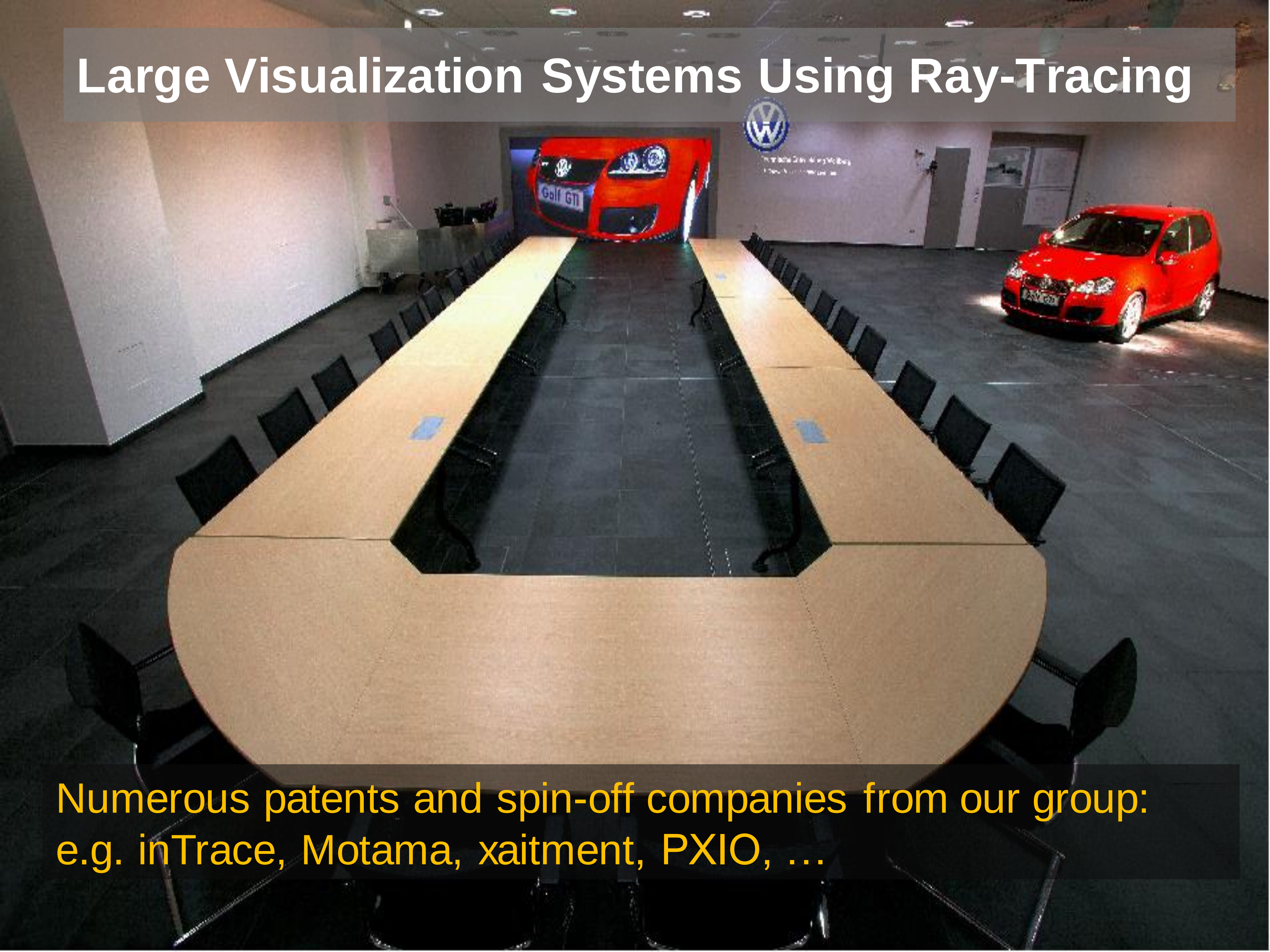
Key product offered now by all major HW vendors:
e.g. Intel (Embree), Nvidia (OptiX), AMD (Radeon Rays) , …

Efficient Simulation of Illumination: Light Propagation and Sensor Models



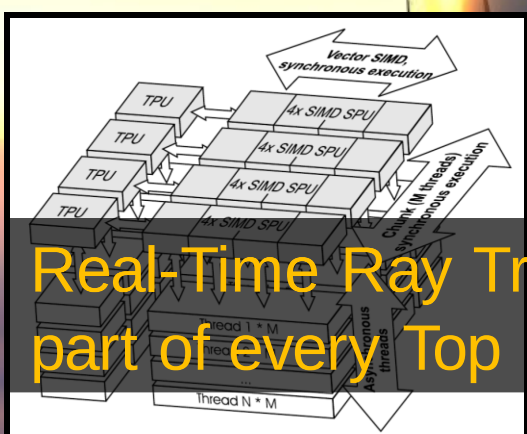
VCM now part of most commercial renders:
e.g. RenderMan, V-Ray, Corona, …

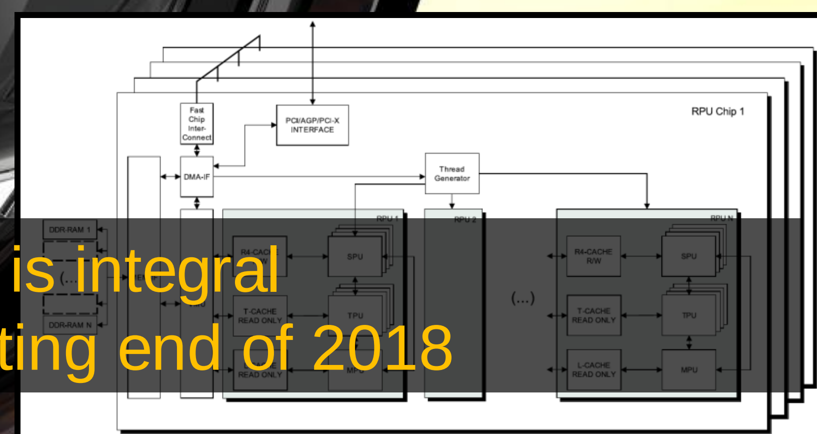
Large Visualization Systems Using Ray-Tracing



Numerous patents and spin-off companies from our group:
e.g. inTrace, Motama, xaitment, PXIO, …

Custom Ray Tracing Processor [Siggraph'05]

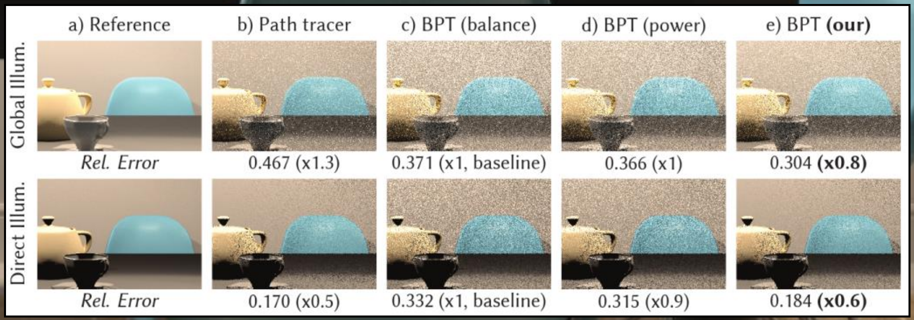




Real-Time Ray Tracing Hardware is integral part of every Top Nvidia GPU starting end of 2018

Fundamental Research in Computer Graphics, High-Performance Computing/Graphics, and AI

Three Siggraph papers
in 2019 alone!



AnyDSL Compiler Framework

Computer Vision DSL | Physics DSL | Ray Tracing DSL | Parallel Runtime DSL | …

Layered DSLs

Developer

Impala Language & Unified Program Representation

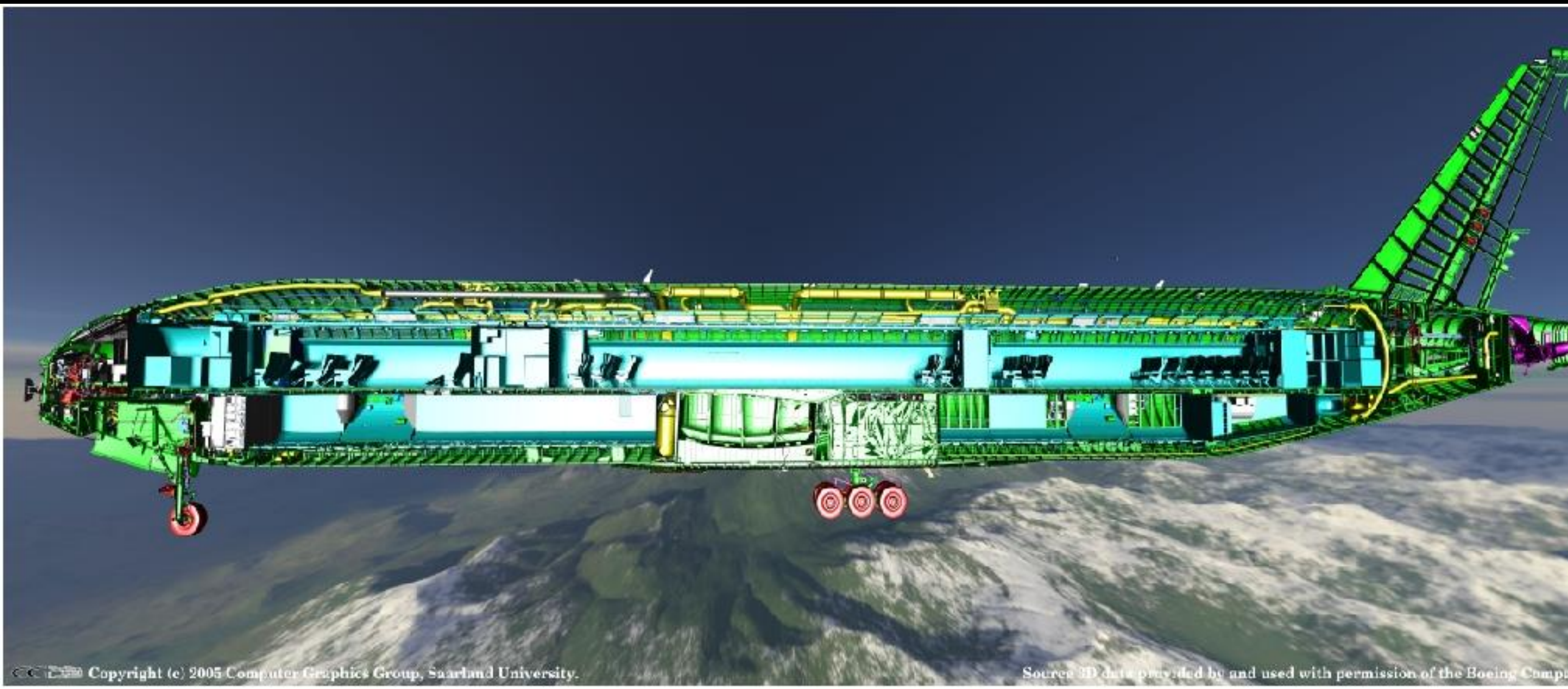
AnyDSL Compiler Framework (Thorin)

Various Backends (via LLVM)

CPUs | GPUs | FPGAs | Accels

GIS and Geo Visualization

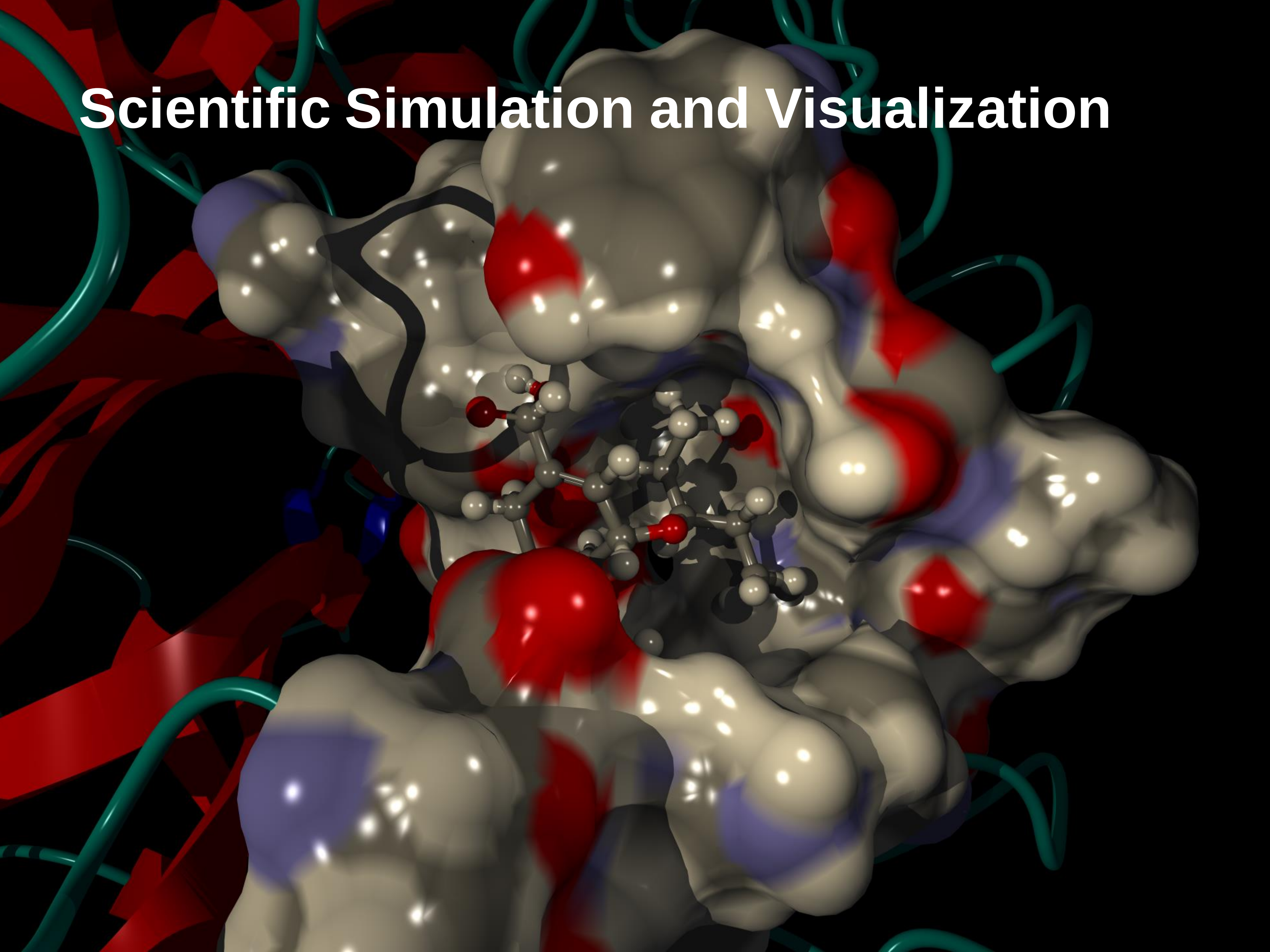
Visualization of Large CAD Models



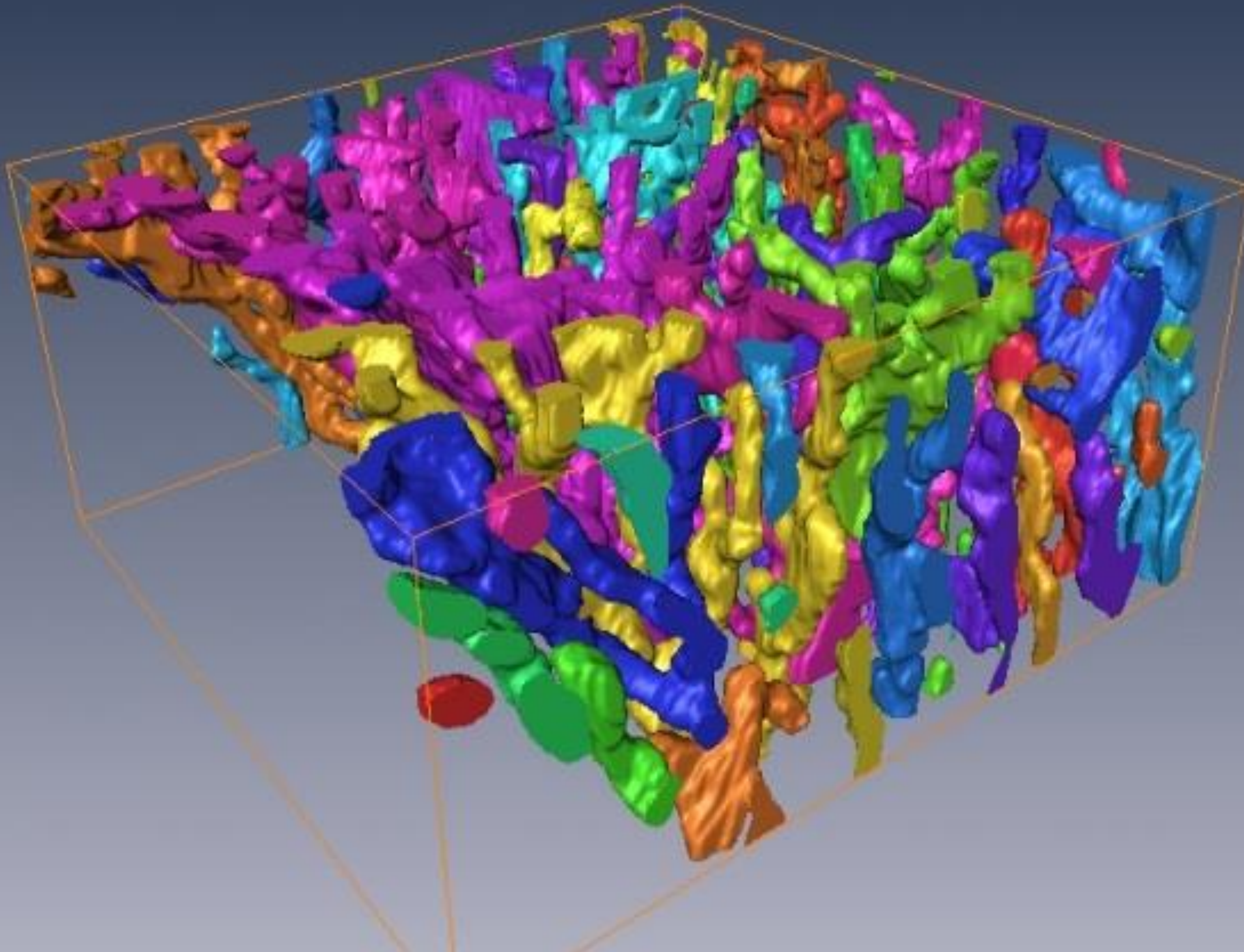
Real-Time Photorealistic Rendering on Film Sets

Display as a Service (DaaS, now Pxio GmbH): Distributed Visualization on the Internet

Scientific Simulation and Visualization



Material Science: Understanding & Predicting Effects of 3D Structures Across Scales



Flexible Production Control Using Multiagent Systems at Saarstahl, Völklingen

DFKI multi-agent technology is running the steelworks, 24/7 for >12 years, 5 researchers transferred

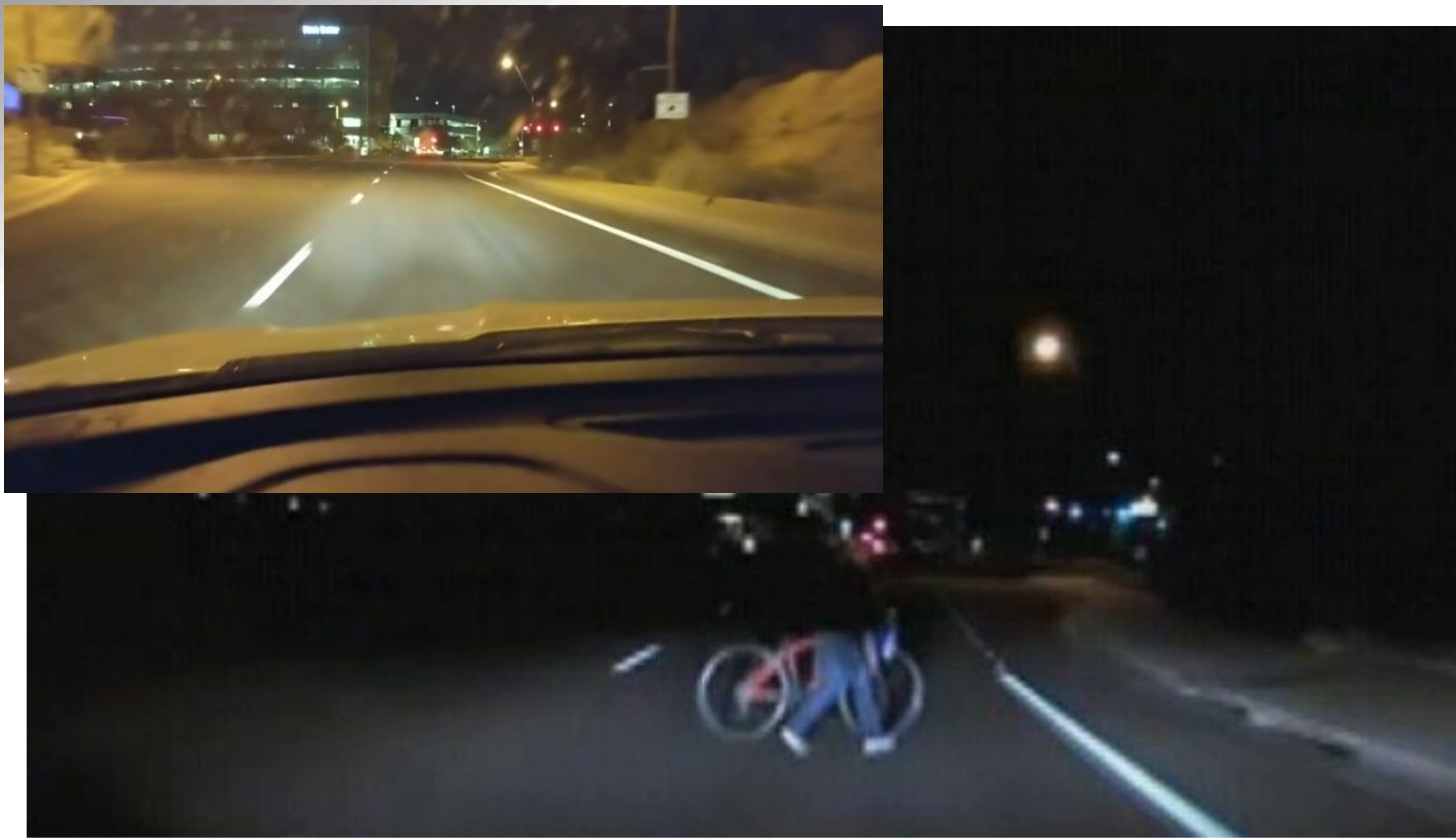
Intelligent Human Simulation, e.g. in Production Environments (Daimler, …)

Collaborative Robotics and Simulated Reality (VW, Airbus, …)

Autonomous Driving: Training using Synthetic Sensor Data (TÜV, …)

Digital Reality:
Using Synthetic Data to Train & Validate Autonomous Systems
(using autonomous driving as an example)

Why Do We Need Training and Validation via Synthetic Data?



Autonomous Systems: The Problem

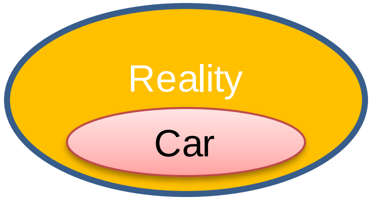
- **Our World is extremely complex**
  - Geometry, Appearance, Motion, Weather, Environment, …
- **Systems must make accurate and reliable decisions**
  - Especially in ***Critical Situations***
  - Increasingly making use of (deep) machine learning
- **Learning of critical situations is essentially impossible**
  - Often little (good) data even for "normal" situations
  - Critical situations rarely happen in reality – per definition!
  - Extremely high-dimensional models

➔Goal: Scalable Learning from *synthetic* input data

- Continuous benchmarking & validation ("Virtual Crash-Test")

Reality

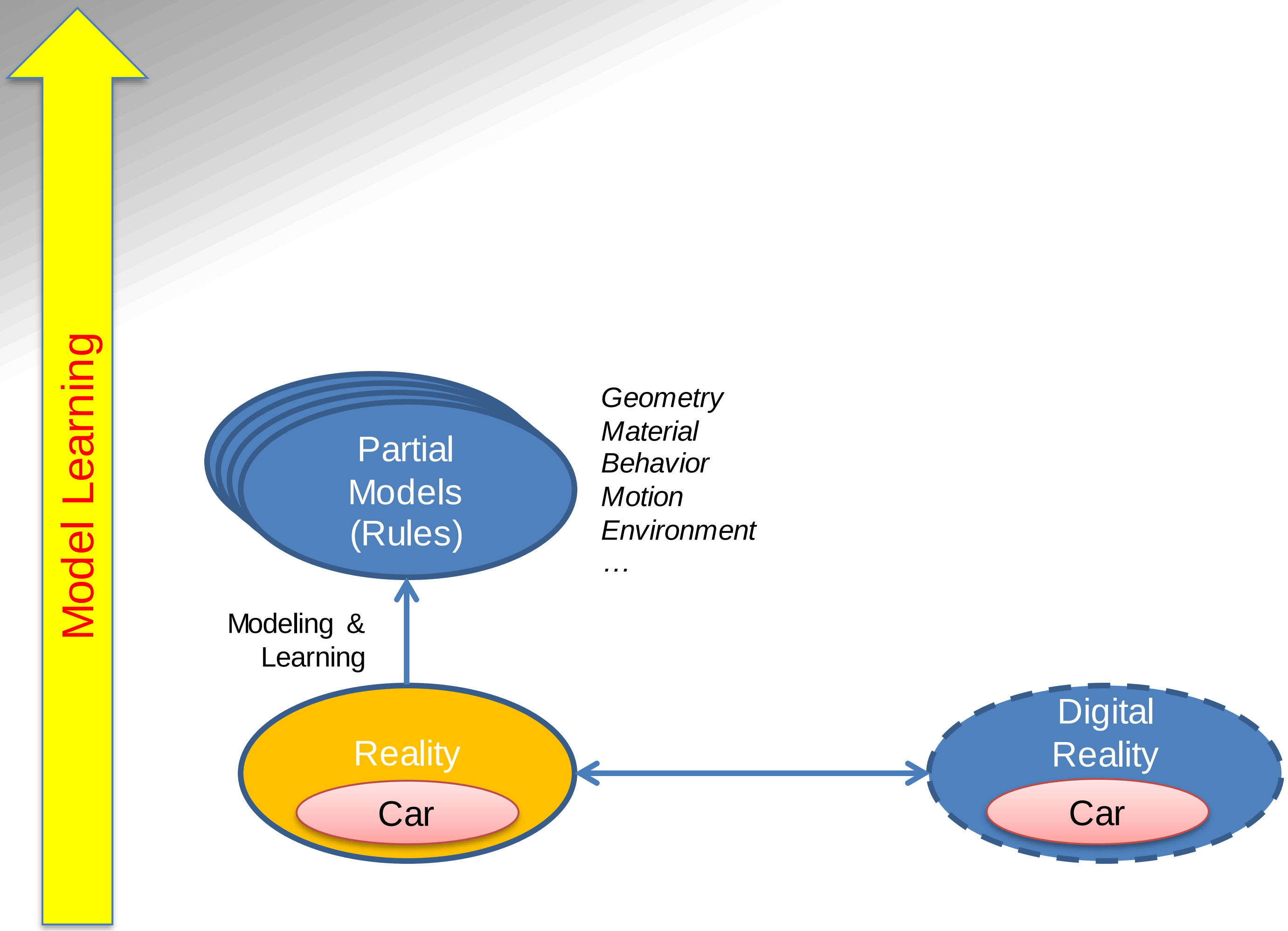
- **Training and Validation in Reality**
  - E.g. driving millions of miles to gather data
  - Difficult, costly, and non-scalable



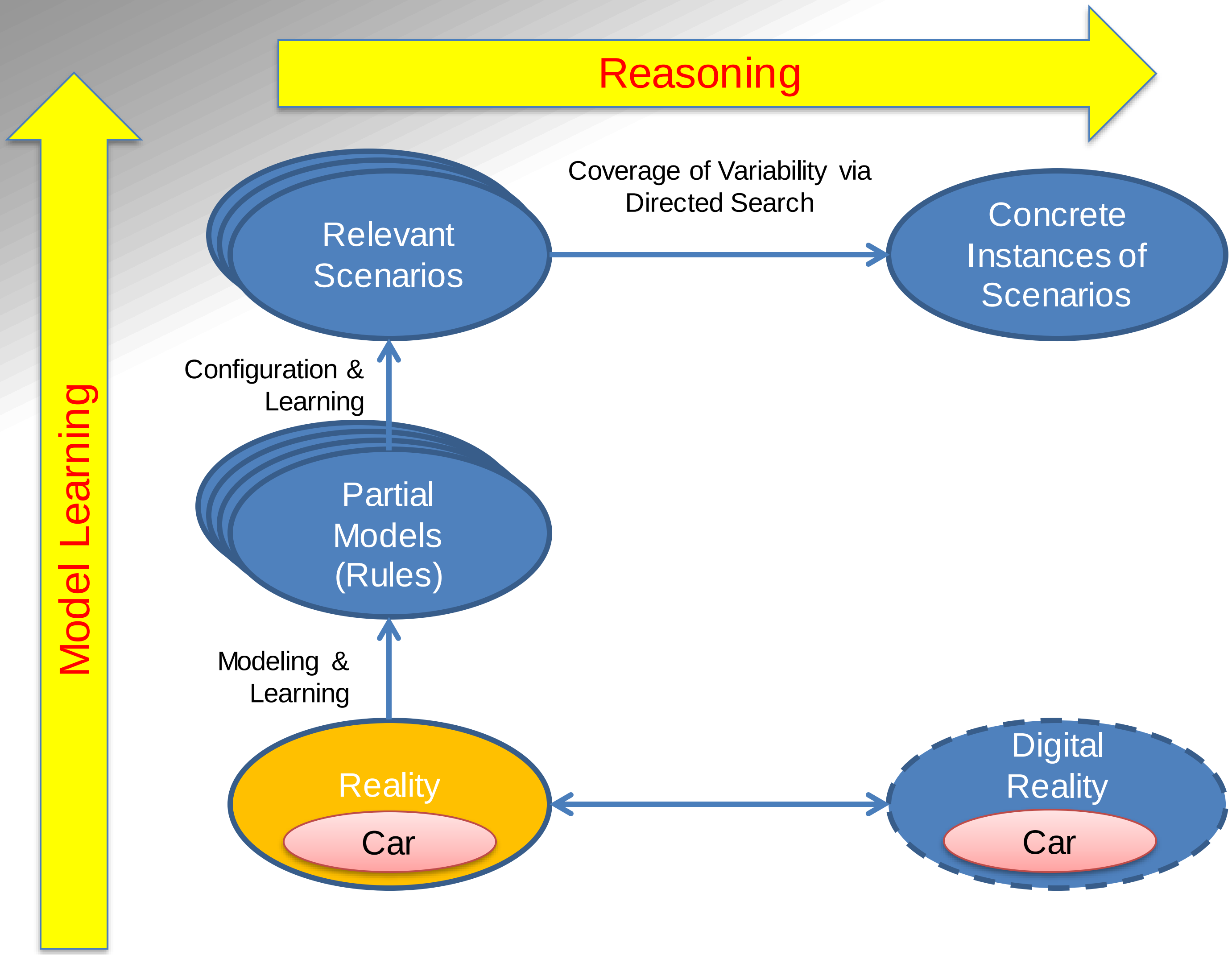
Digital Reality

- **Training and Validation in the *Digital Reality***
  - Arbitrarily scalable (given the right platform)
  - But: Where to get the models and the training data from?

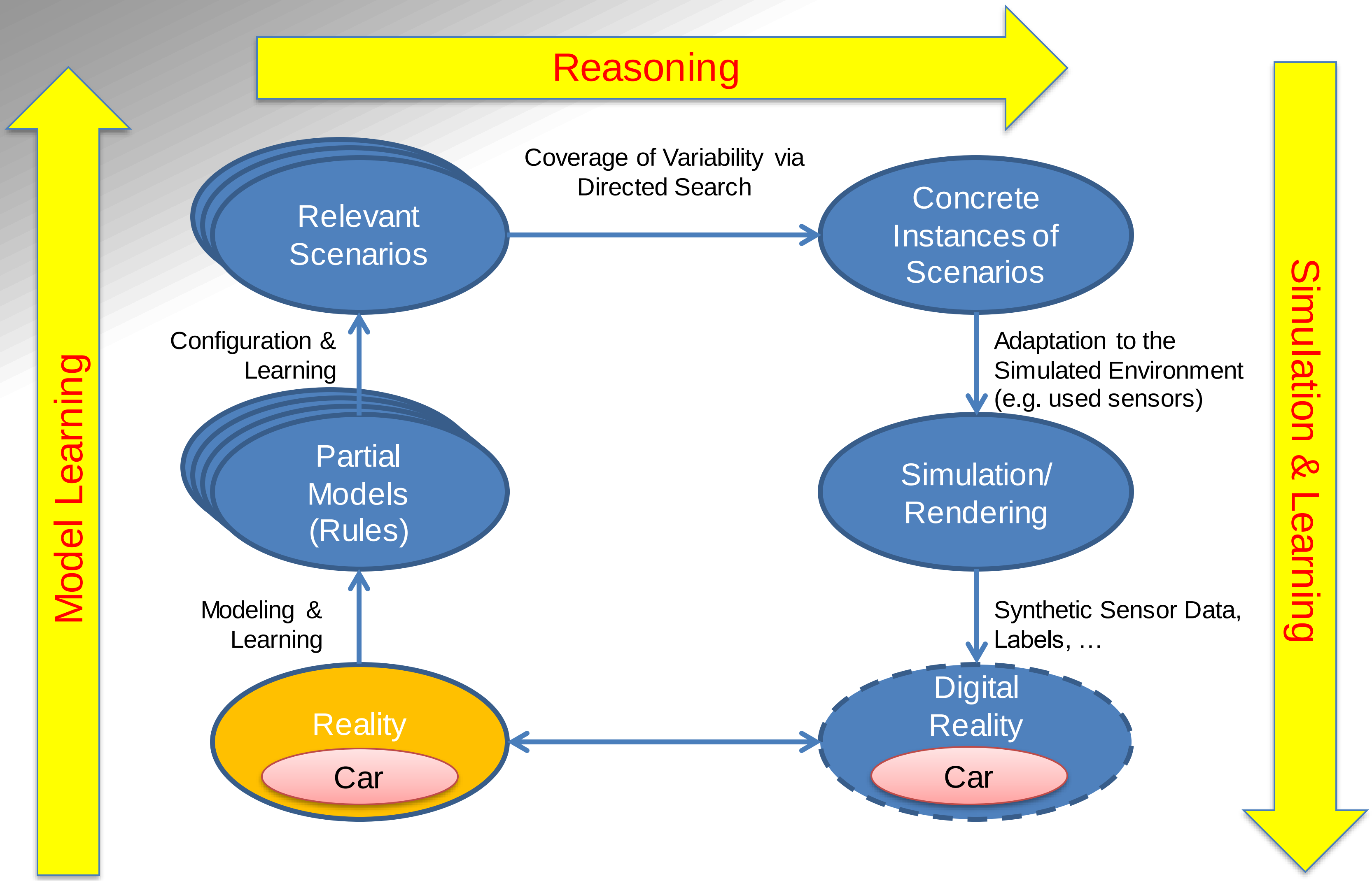
Digital Reality: Learning



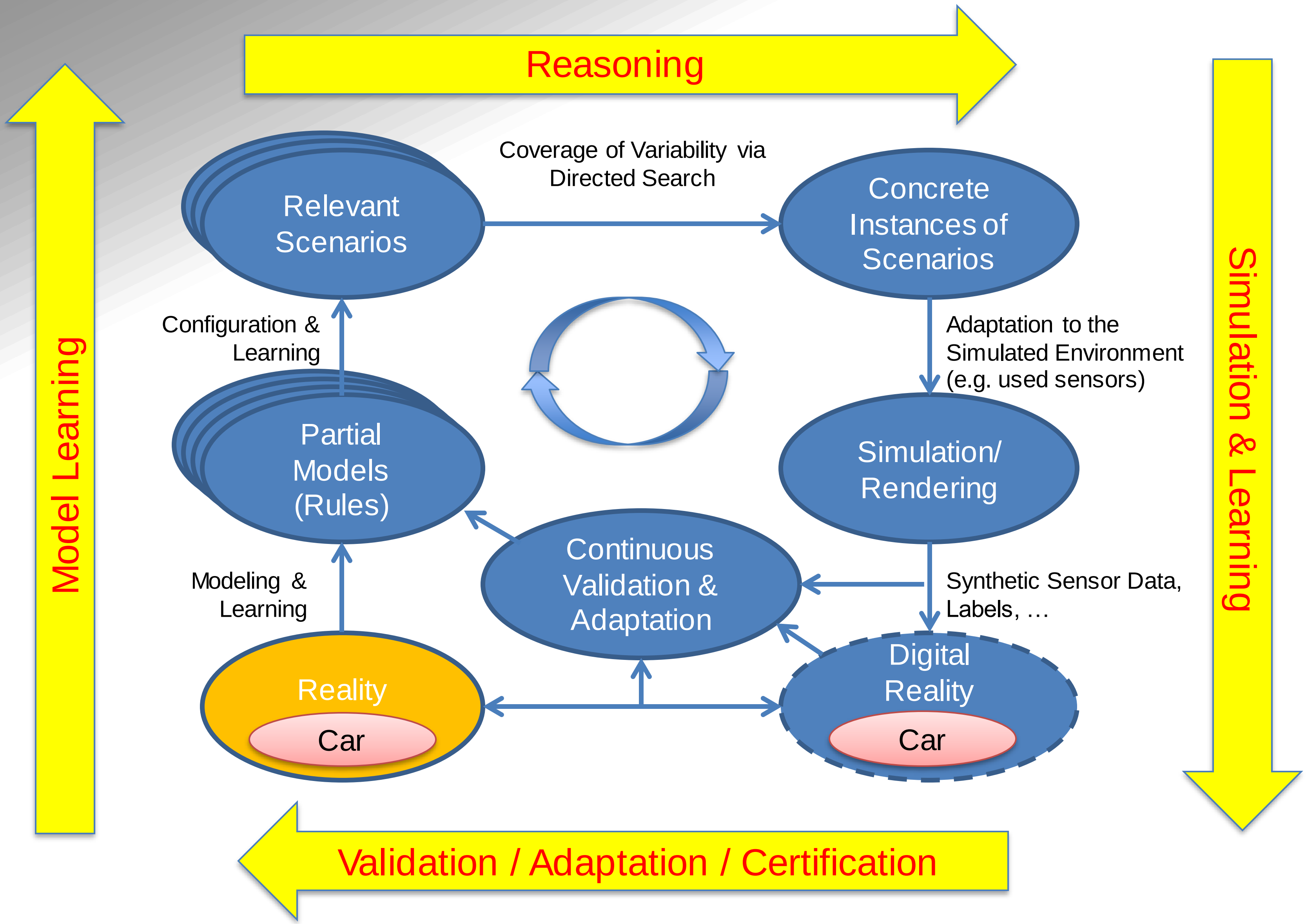
Digital Reality: Reasoning



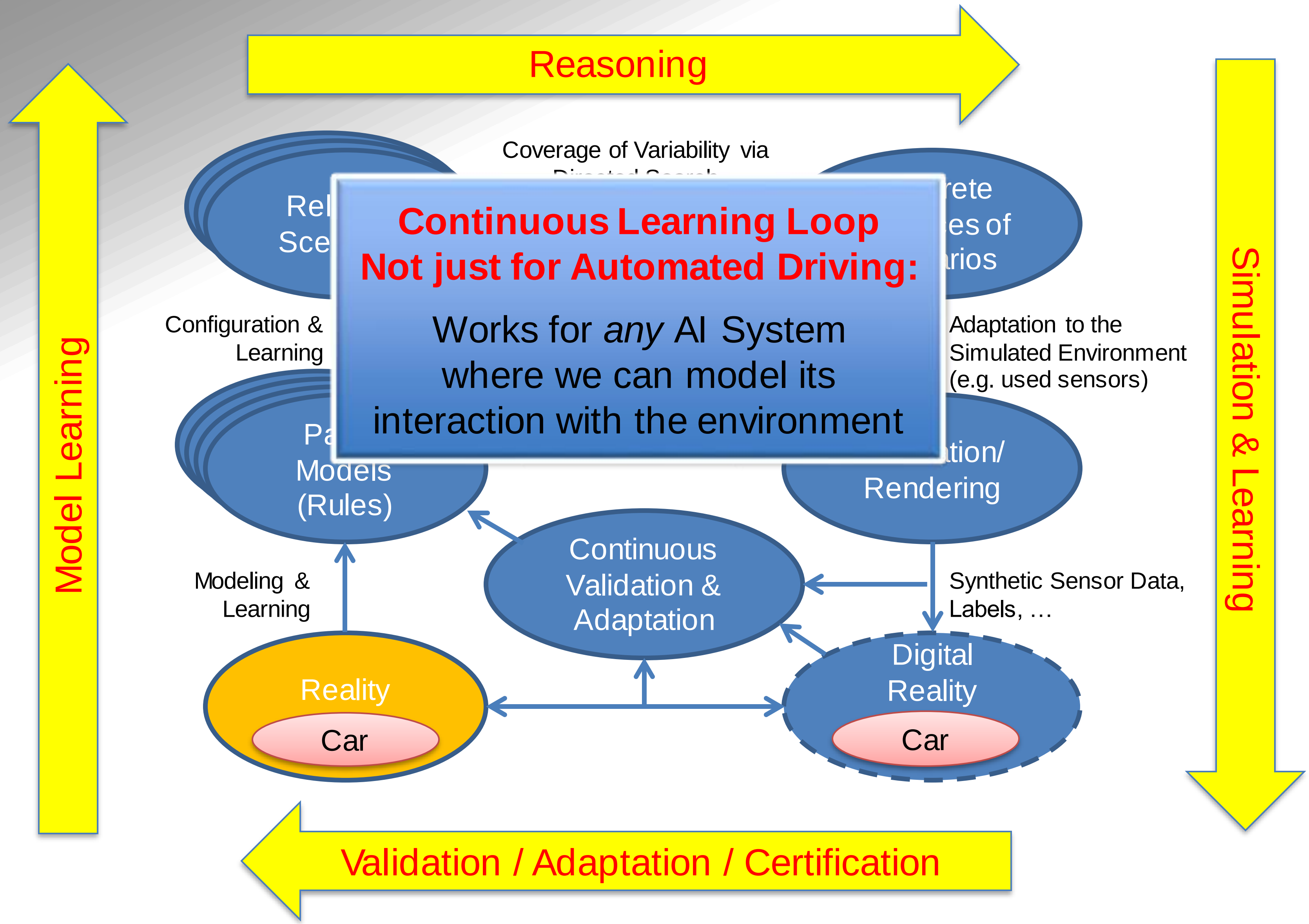
Digital Reality: Simulation



Digital Reality: Validation/Adaptation

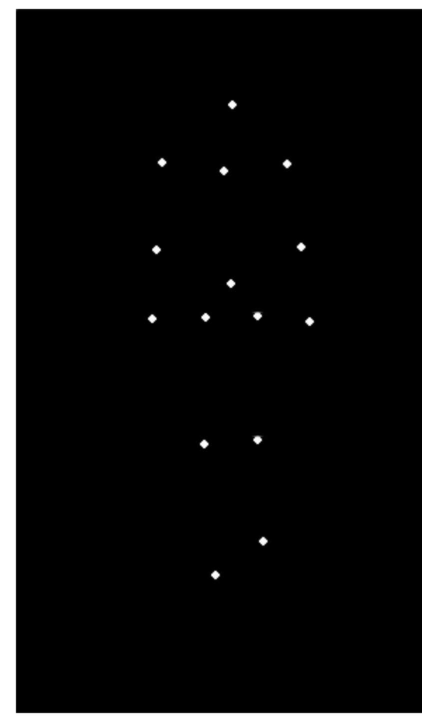


Digital Reality: Continuous Learning



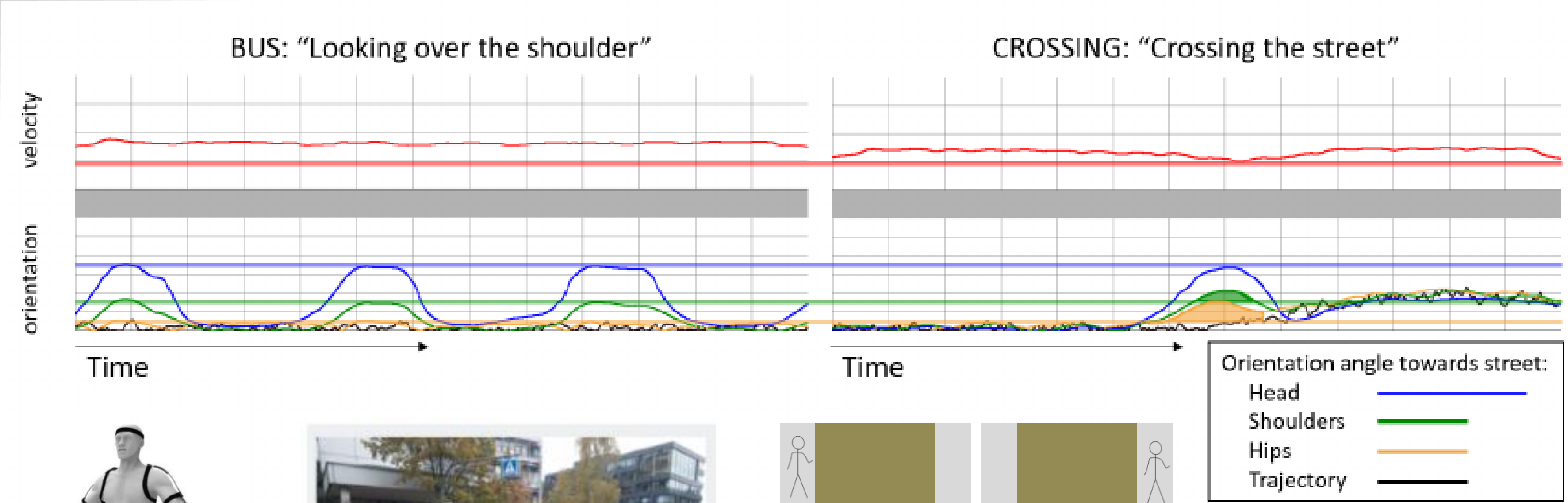
Challenge: Better Models of the World (e.g. Pedestrians)

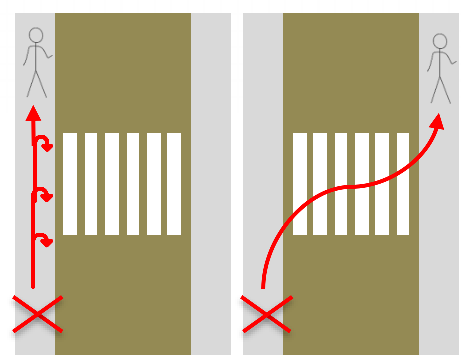
- **Long history in motion research (>40 years)**
  - E.g. Gunnar Johansson's Point Light Walkers (1974)
  - Significant interdisciplinary research (e.g. psychology)
- **Humans can easily discriminate different styles**
  - E.g. gender, age, weight, mood, ...
  - Based on minimal information
- **Can we teach machines the same?**
  - Detect if pedestrian will cross the street
  - Parameterized motion model & style transfer
  - Predictive models & physical limits



Challenge: Pedestrian Motion

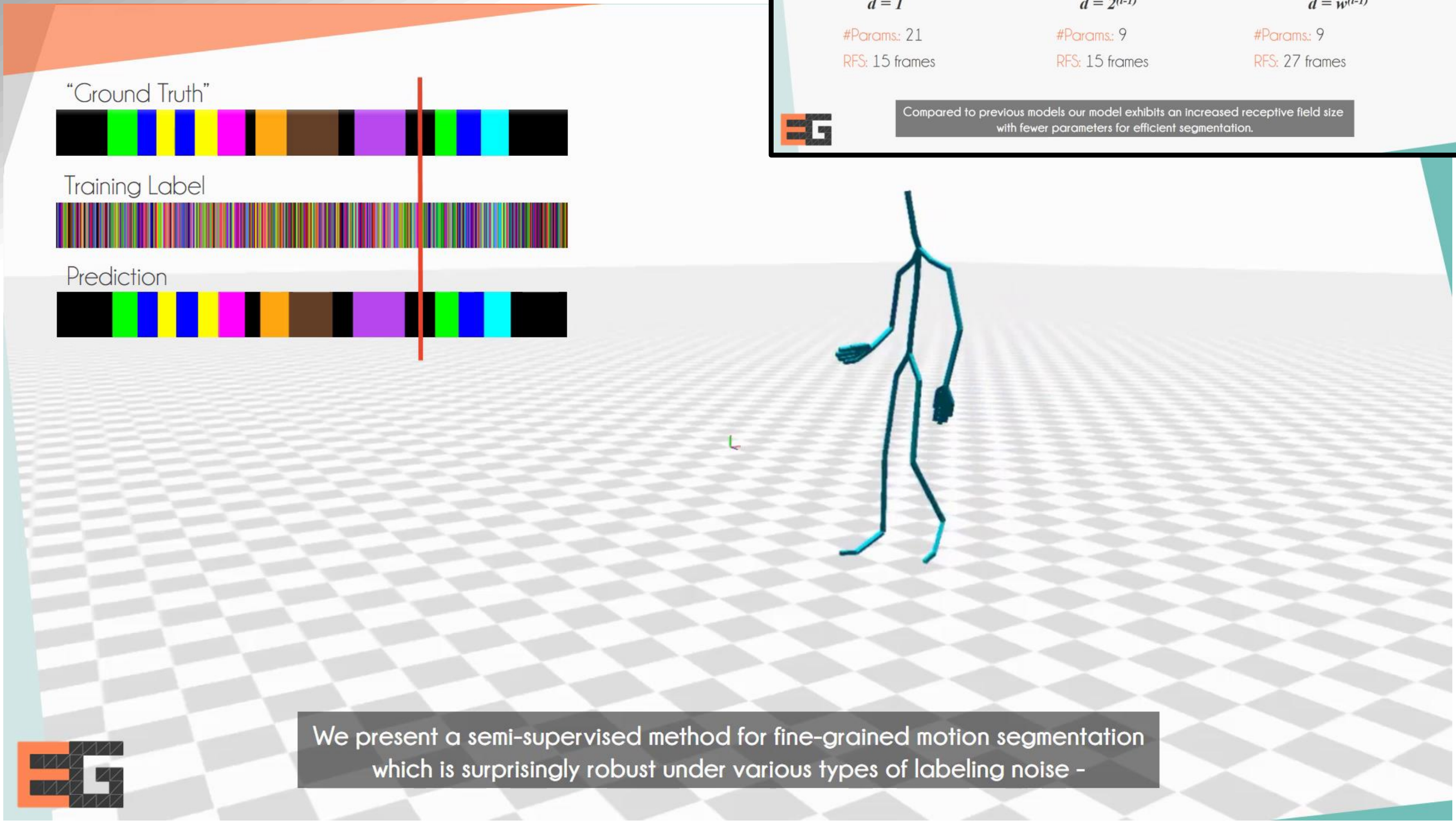
- **Characterizing Pedestrian Motion**
  - Clear motion differences when crossing the street

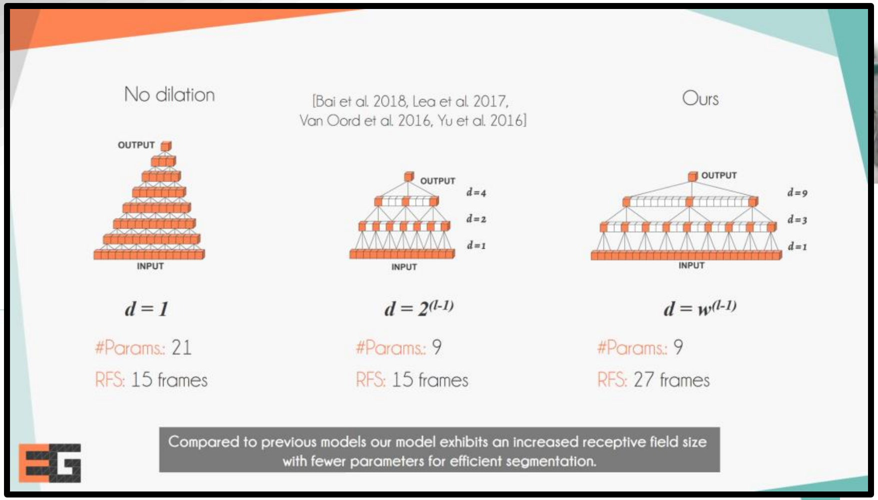




Bus Crossing

New DL Approaches





Challenge: Better Simulation (e.g. Radar Rendering)

- **Key Differences**
  - Longer wavelength: Geometric optics (rays) not sufficient
  - Need for *some* wave optics
    - Diffraction at rough surfaces and edges
    - Need for polarization & resonance
  - Highly different goals
    - Optical: Focus on *diffuse* effects (+ some highlights, reflections, etc.)
    - Radar: Focus on *specular* transport only (i.e. caustic paths)
- **Recent Work on Caustics [Grittmann et al., EGSR’18]**
  - Identifying “useful” specular paths (using VCM)
  - Guides samples to *visible specular effects (e.g. indirect radar echos)*
- **Combining research on rendering and radar technology**

Challenge: Do we Need a Better Basis for our Simulation?

- **In the past: Two big markets, focused on nice images**
  - *Gaming*: Very nice images (at 60+ Hz)
    - Must compromise realism for frame rate
  - *Film & Marketing*: Even nicer images (at hours per image)
    - Will compromise realism for the story and artistic expression
  - Both are being used for simulations for Autonomous Driving
- **But: Strong need for *correct* images**
  - Lidar, radar, multi-spectral, polarization, measured materials, …
  - Need for “error bar per pixel” & validation
  - Existing engines unlikely to adapt to these fundamental changes
- **Towards “Predictive Rendering” engine**
  - Focused on physical accuracy & high throughput
  - Based on latest graphics research results (and GPU-HW)

Wrap-Up

- **Computer Graphics**
  - Rendering, Modeling, Visualization, Animation, Imaging, …
- **Young, dynamic area**
  - “Everything is possible” mentality
  - Progress driven by research & technology
  - Flexible transfer between research and industry
- **Big industry !**
  - Intel, Nvidia, AMD, Imagination, ARM, …
  - Automotive, aerospace, engineering, …
  - Entertainment: games, film, TV, animations, …
- **Innovation areas**
  - Digital Reality, Visualization, Industrie-4.0, Big Data, Smart Cities, …
- **Interdisciplinary field**
  - Relations to mathematics, physics, engineering, psychology, art, entertainment, …