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   14:00-16:00h, HS 01, E1.3
  - Wed   10:00-12:00h, HS 01, E1.3

- **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**
  - Stefan Lemme
    E1.1, Room E13, Tel. 3792, Email: lemme@cg.uni-saarland.de
  - Arsène Pérard-Gayot
    E1.1, Room E11, Tel. 3837, Email: perard@cs.uni-saarland.de

- **Tutors**
  - Pascal Grittmann
    Email: s9pagrit@stud.uni-saarland.de
  - NN

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 (hand-written)
  - Code: Email to assistant (see exercise sheet or Web page)

- **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 all results!

Grading

- **Weekly Assignments**
  - Counts 30% towards final grade (with +20% bonus points)

- **Rendering Competition (exam prereq.)**
  - Counts 10% towards final grade
  - Grading: Artistic quality only (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
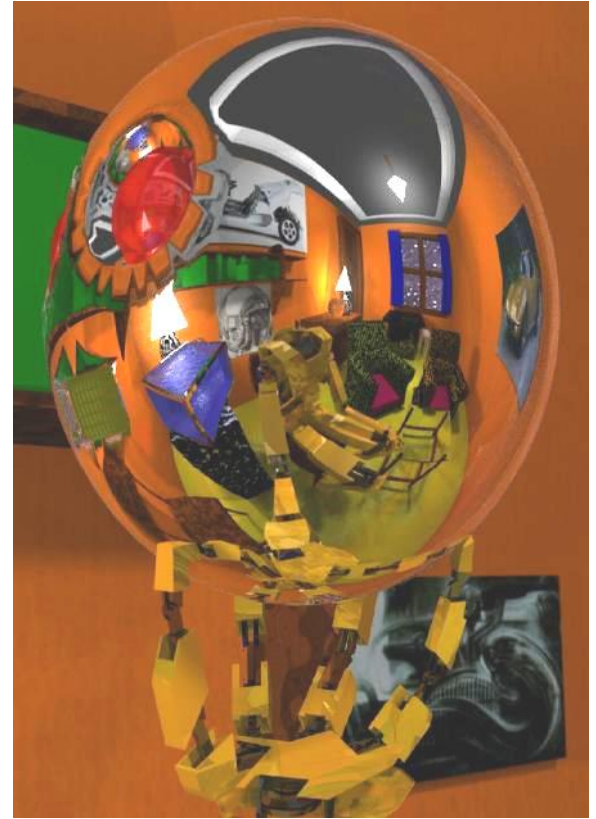
Rendering Competition

- **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

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, Greg Humphreys: **Physically Based Rendering : From Theory to Implementation**, Morgan Kaufmann Series, 3. Ed., 2016
- **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
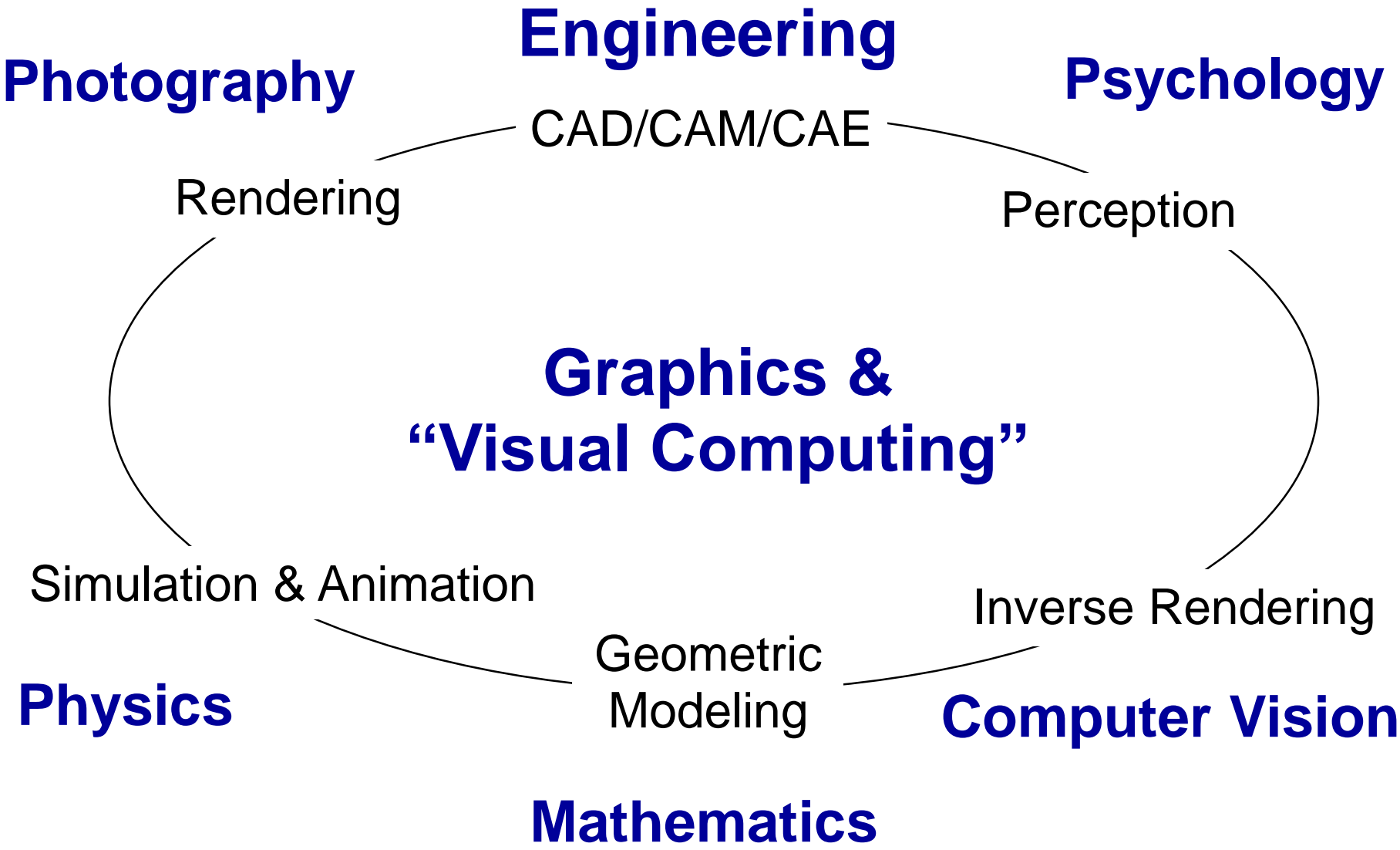- **More specific**
  - Thomas Akenine-Möller, Eric Haines, **Real-Time Rendering**, AK Peters, 2nd Ed., 2002
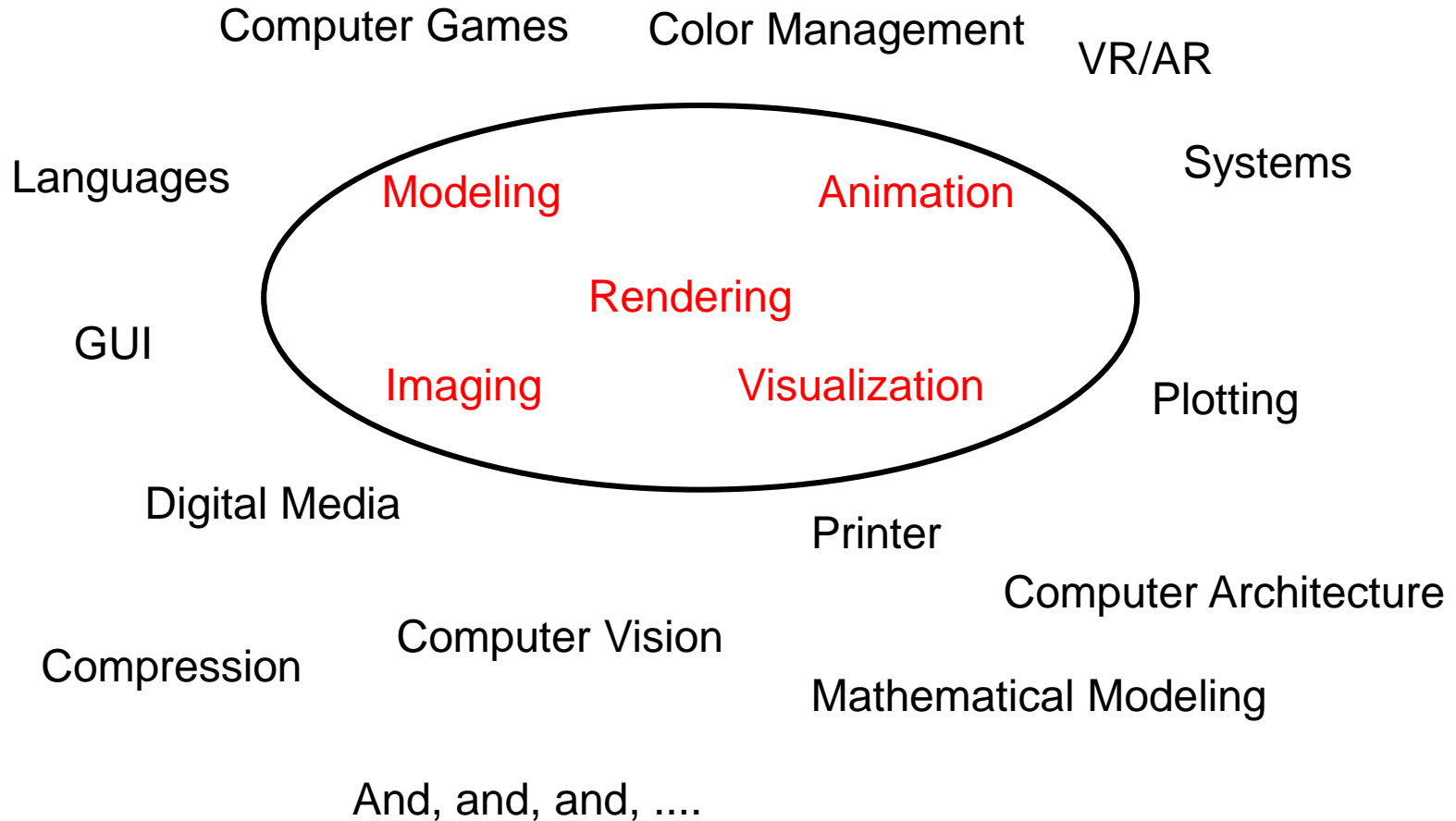 - John M. Kessenich, et al., **OpenGL Programming Guide**, Addison-Wesley, 9. Ed., 2016

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 ?

Engineering

Photography   **Psychology**

CAD/CAM/CAE

Rendering   Perception

**Graphics &
"Visual Computing"**

Simulation & Animation   Inverse Rendering

Geometric
Modeling

Physics   **Computer Vision**

Mathematics

What is Computer Graphics?

Computer Games   Color Management   VR/AR

Systems

Languages   Modeling   Animation

Rendering

GUI   Imaging   Visualization   Plotting

Digital Media   Printer

Computer Architecture

Computer Vision

Compression   Mathematical Modeling

And, and, and, ...

Saarland Informatics Campus

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CS in Saarland: Impact

- #Citations (in 1000) of top-10 computer scientists
- (Google Scholar, 20-Oct-2015)

TU DA	TUM	Saarland	ETHZ	EPFL	Oxford	UW Seattle	Stanford	CMU
60	111	189	186	241	221	216	427	409

D   EU   US
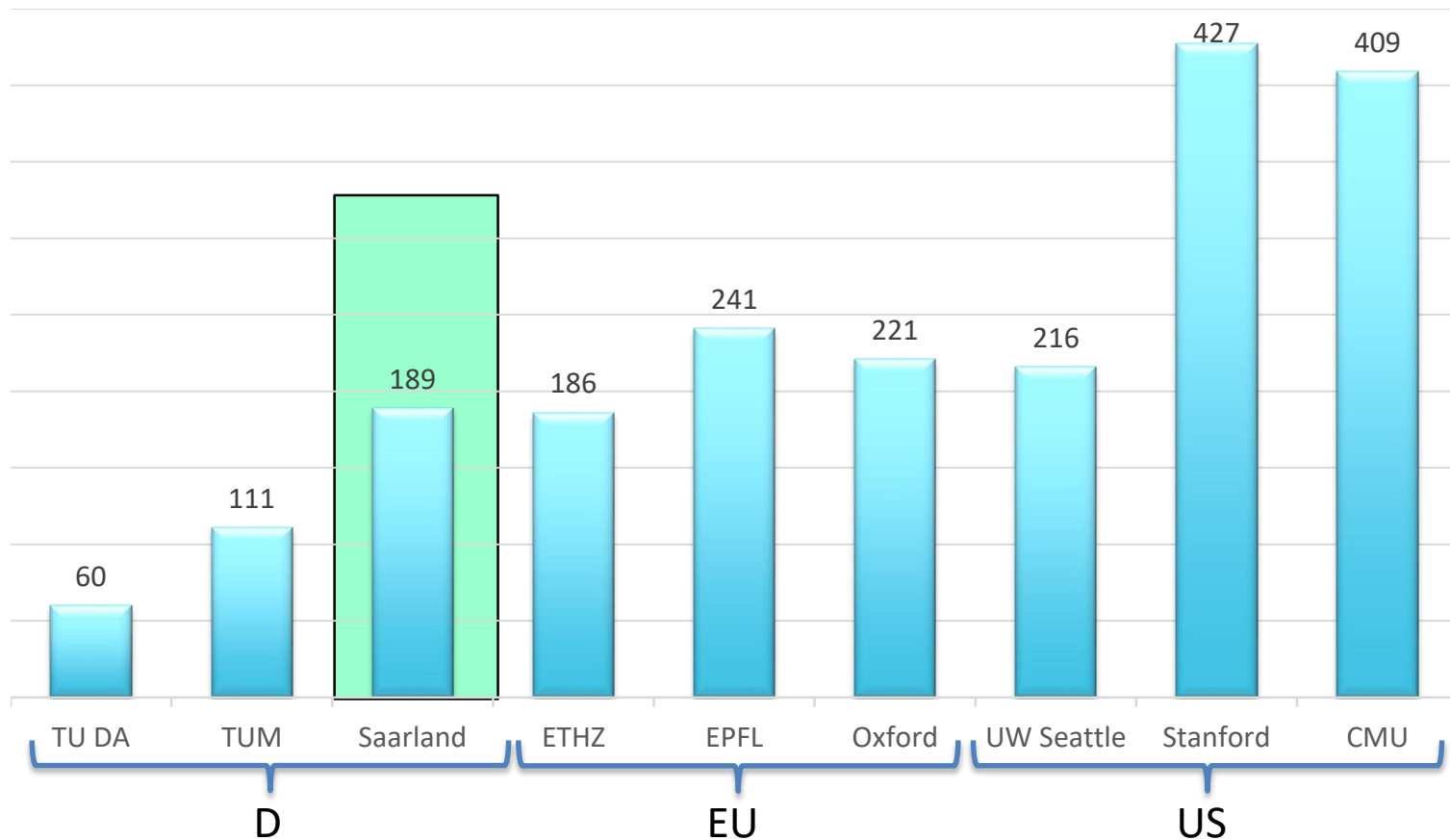
Research & Innovation in SB

Industry Research

Valley of Death™

Business Units

DFKI ASR

Researchers

Engineers

Intel-VCI

Max-Planck Institutes

University

Start-Ups (new IT-Incubator Saar)

| 1 | Research | 10 | Engineering | 100 |

Blue-Sky Research   Basic Research   Applied Research   Demonstrator   Prototype   Produkt
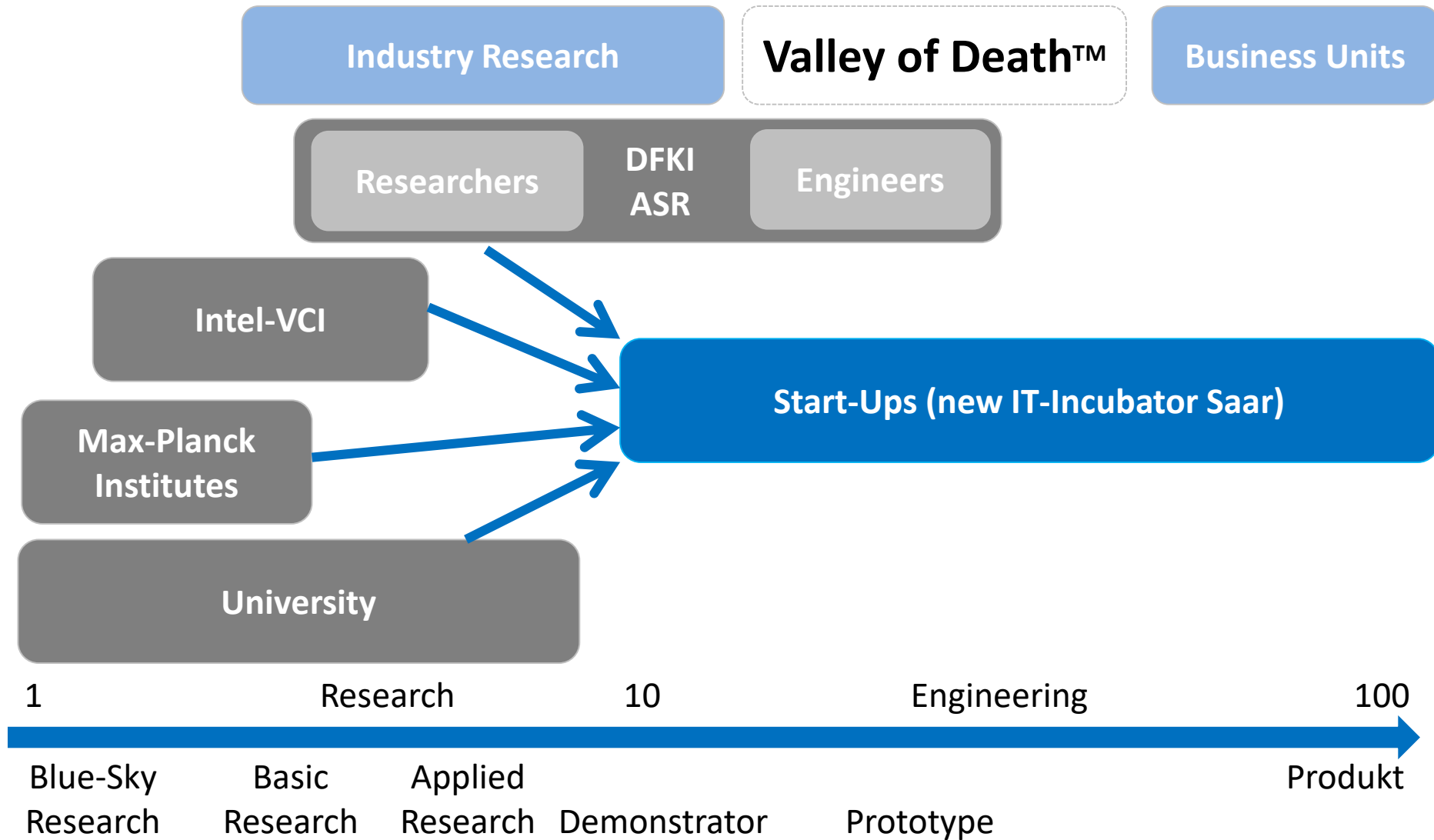
DFKI: German AI Research Center

- Motto
  - Providing Computers with Eyes, Ears and Common Sense"

- Key Facts
  - The world's largest AI research center
  - One of the largest application-oriented CS research institute in Europe
  - PPP: Industry network/shareholders
    - EADS, BMW, Daimler, Intel, Microsoft, …
  - 5 Locations in Germany
    - Saarbrücken, Bremen, Kaiserslautern
    - Berlin & Osnabrück
  - ~500 researchers (~900 with students)
  - ~ 40 M€ revenue per year
  - > 60 spin-offs

DFKI: Agents & Simulated Reality

- Bringing together AI, Graphics, HPC, and Security
  – Simulated 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.)

Agents & Simulated Reality

AI & Graphics & HPC & Security

Scientific Director
Philipp Slusallek

Knowledge- and Technology Transfer

VisCenter Georg Demme	**Strategic Relations** Hilko Hoffmann	**SW-Engineering & Organization** Georg Demme

Application Domains

Autonomous Driving Christian Müller	**Industrie 4.0** Ingo Zinnikus	**Computational Sciences** Tim Dahmen	**Smart Environments** Hilko Hoffmann

Research: Topics & Teams

Multi-agent Systems Klaus Fischer	**Intelligent Information Systems** Matthias Klusch	**Linked Data Representations** René Schubotz	**Autonomous Driving** Christian Müller
Computational 3D Imaging Tim Dahmen	**High-Performance Graphics & Computing** Richard Membarth	**Smart System Security** Stefan Nürnberger	**Behavior, Interaction & Visualization** Georg Demme

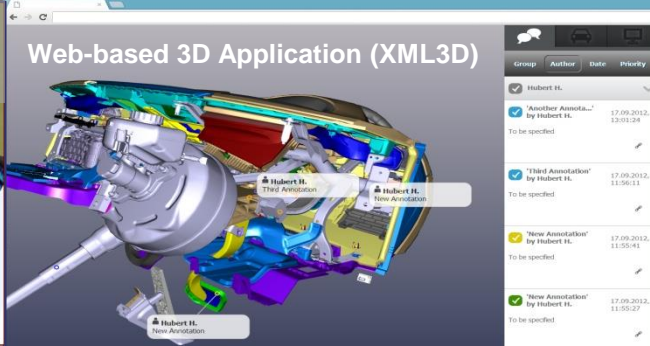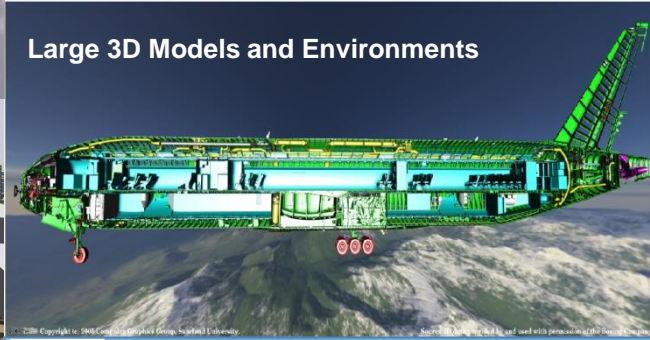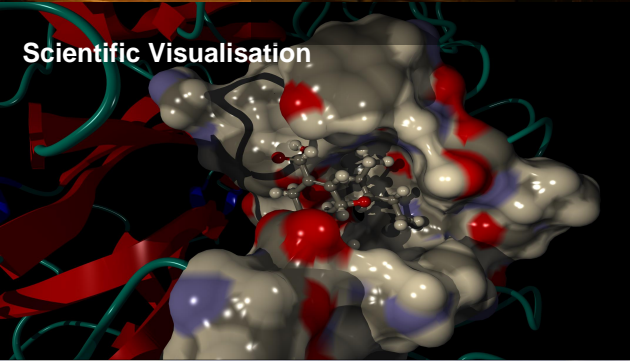| CISPA	UNIVERSITÄT DES SAARLANDES	Multimodal Computing and Interaction	intel VISUAL COMPUTING INSTITUTE
Survivable Systems and Services Philipp Slusallek	**Distributed Realistic Graphics** Philipp Slusallek	**Large-Scale Virtual Environments** Philipp Slusallek	**Visual Computing** Philipp Slusallek
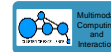
Intel Visual Computing Institute

- Institute of Saarland University in collaboration with
  - Intel Labs, DFKI, MPI for Informatics, and MPI for Software-Systems
    - Plus MMCI Excellence Cluster & CISPA Center for IT Security
  - Project-oriented:
    - ~55 researchers across 18 research projects
  - Funded by Intel (12 Mio)
    - 4 Intel employees co-located
  - Focused on basic research – within application context

- „Open and Collaborative" research
  - Open for other industry and research institutes
  - EU network (Delft, Lund, Karlsruhe, others), growing quickly
  - US sister institute (ISTC-VC, now NSF center)

- Benefits
  - Offers many new HiWi, Bachelor, Master, PhD opportunities
  - Good contacts to Intel and other industry (Jobs, etc.)

Intel-VCI Research Network

ISTC-VC

SCI Institute, Utah, USA

Stanford University,
California, USA

# ASR Research Topics

Flexible Production Control Using Multiagent Systems

Verification and Secure Systems (BSI-certified Evaluation Center)

Physically-Based Image Synthese
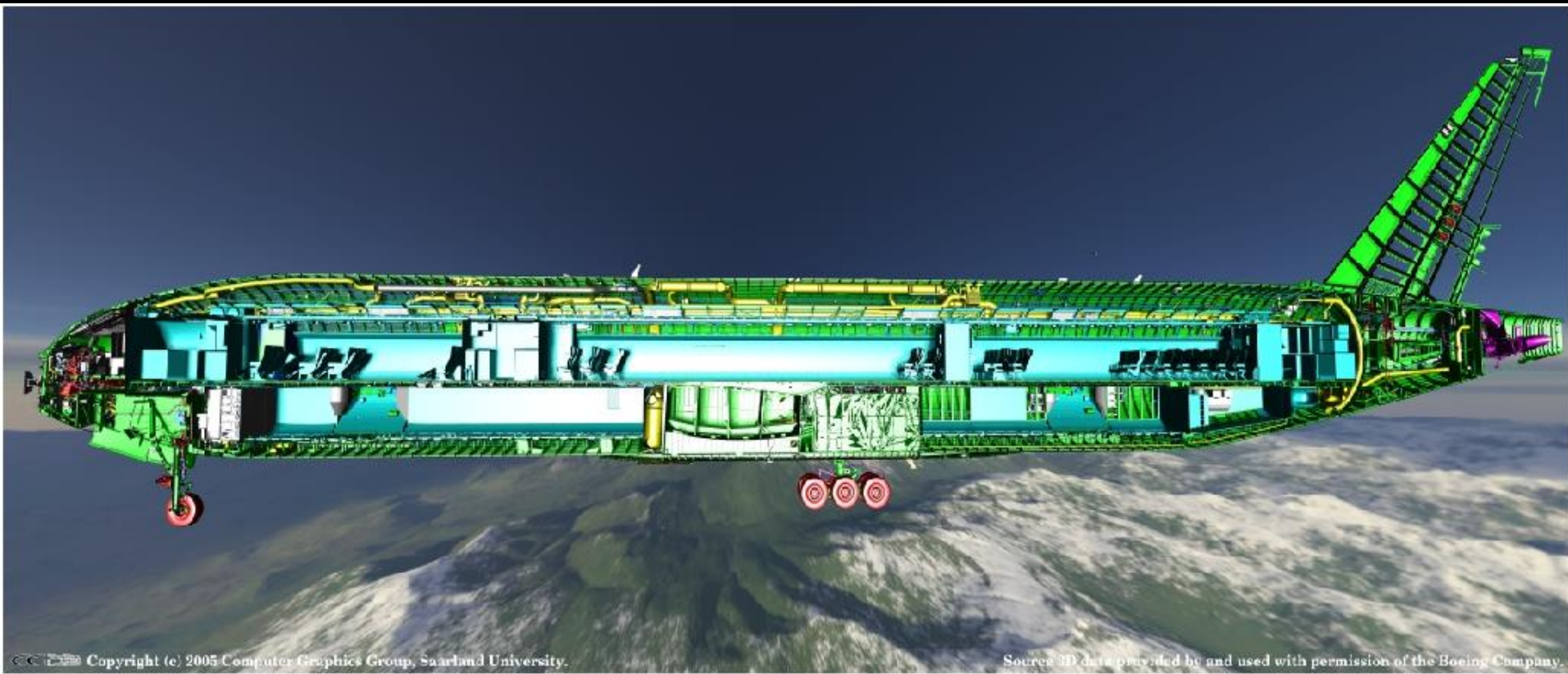
Scientific Visualisation

GIS and Geo Visualization

Reconstruction of Cultural Heritage

Future City Planning and Management

Large 3D Models and Environments

Large Visualization Systems

Intelligent Human Simulation in Production

Web-based 3D Application (XML3D)

Distributed Visualization on the Internet

Flexible Production Control Using Multiagent Systems

Verification and Secure Systems
(BSI-certified Evaluation Center)

Physically-Based Image Synthese

Efficient Simulation of Illumination
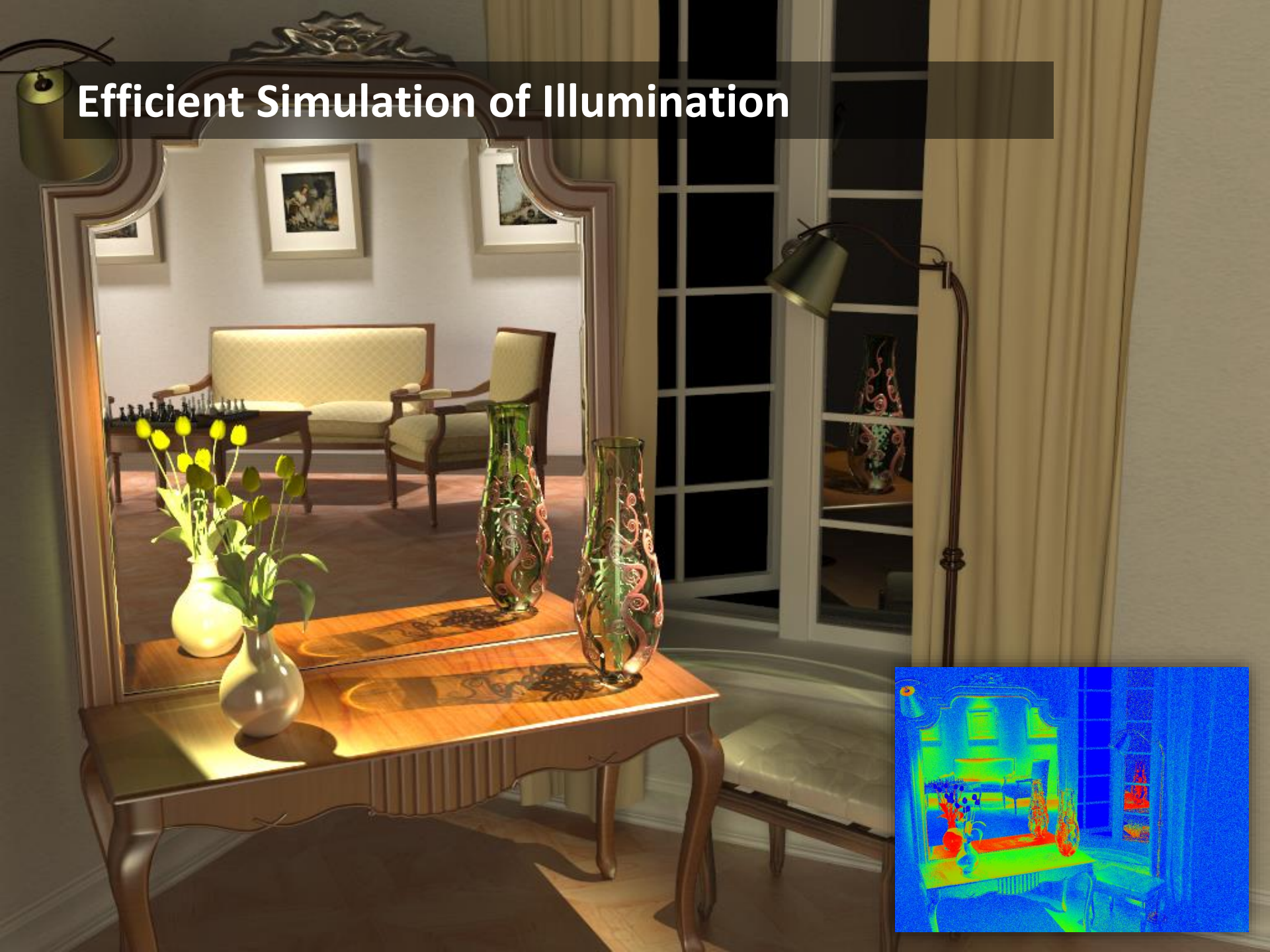
Scientific Simulation and Visualization
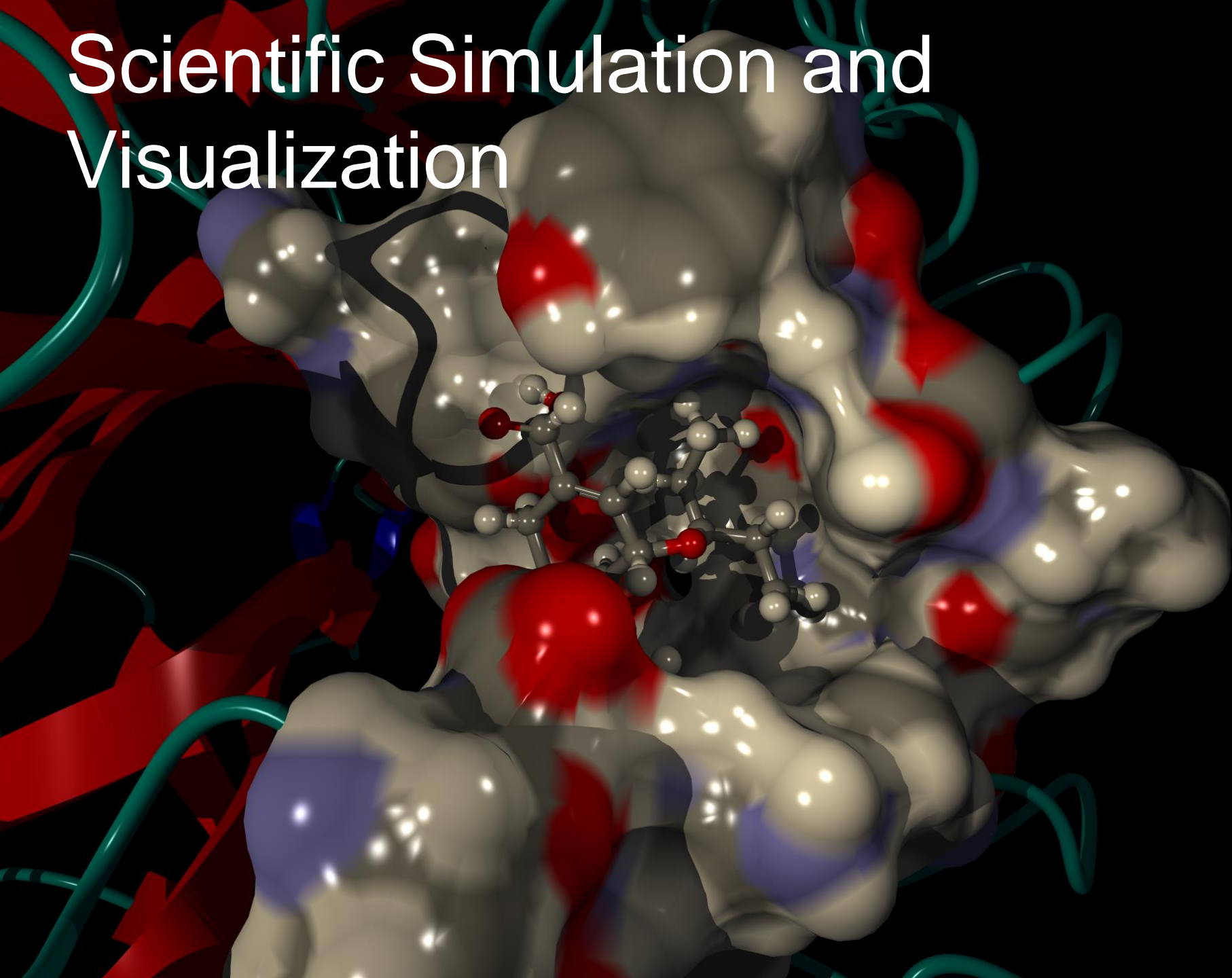
Large CAD Models

Large Visualization Systems
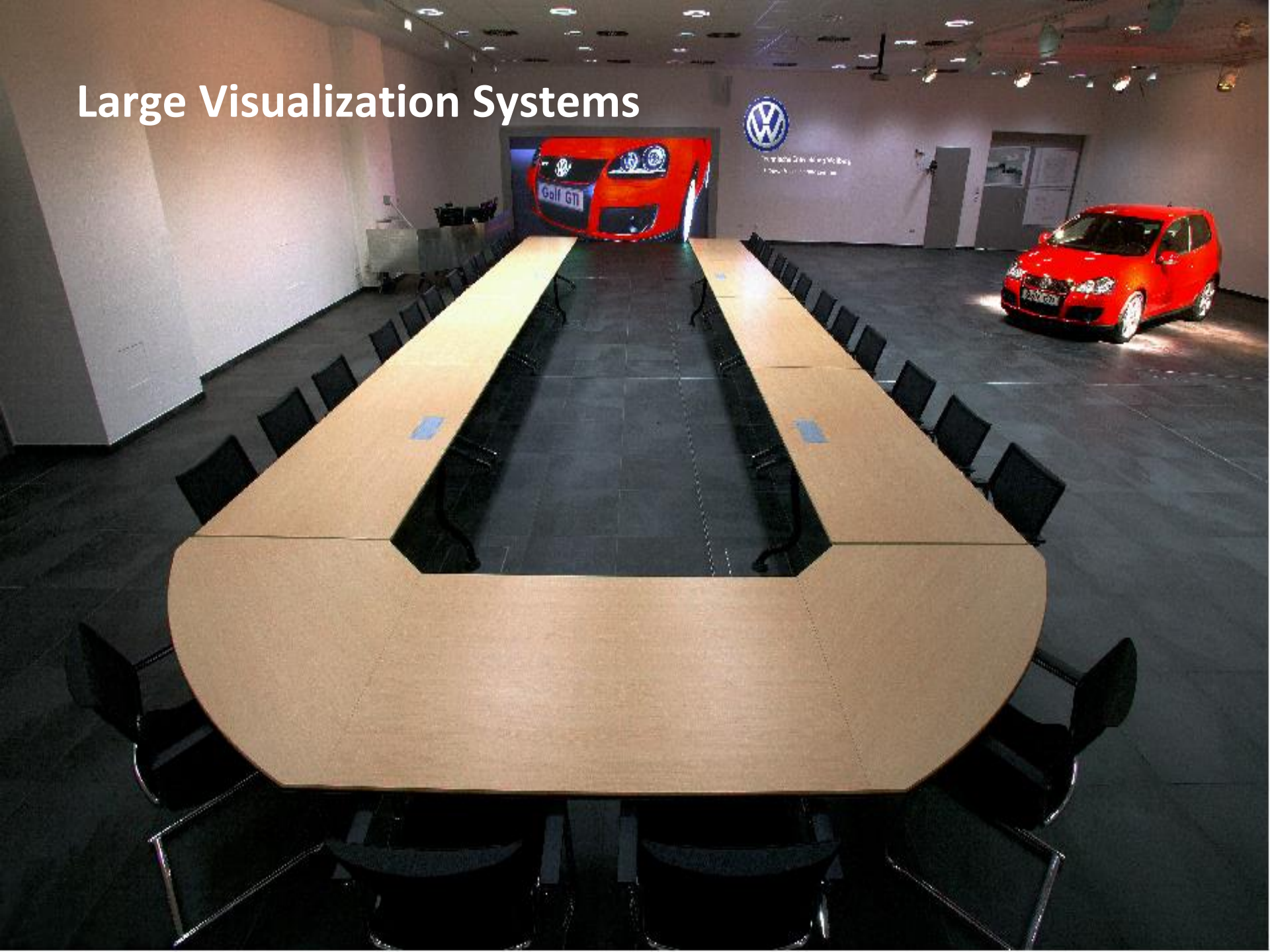
GIS and Geo Visualization
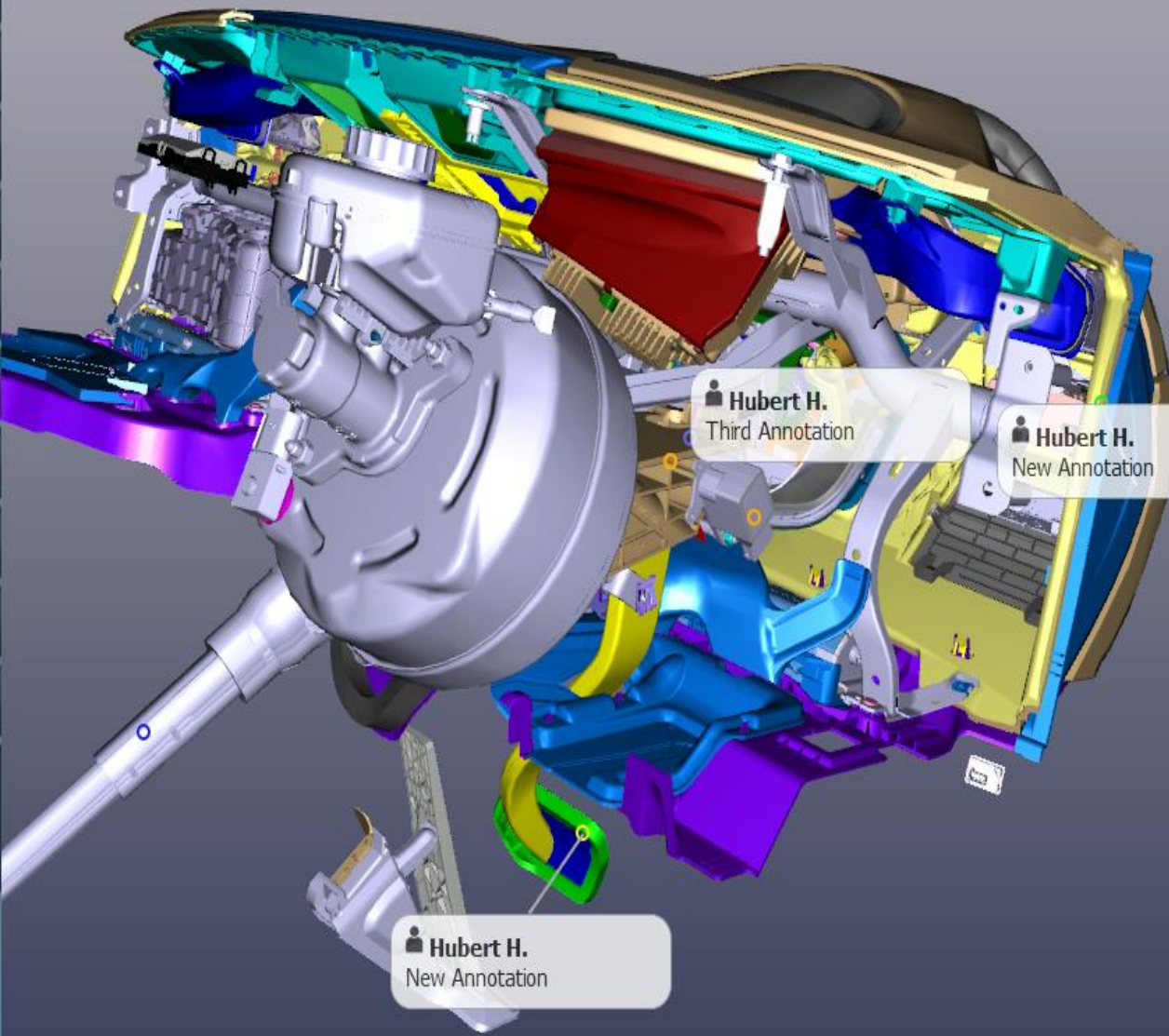
Reconstruction of Cultural Heritage

Future City Planning and Management

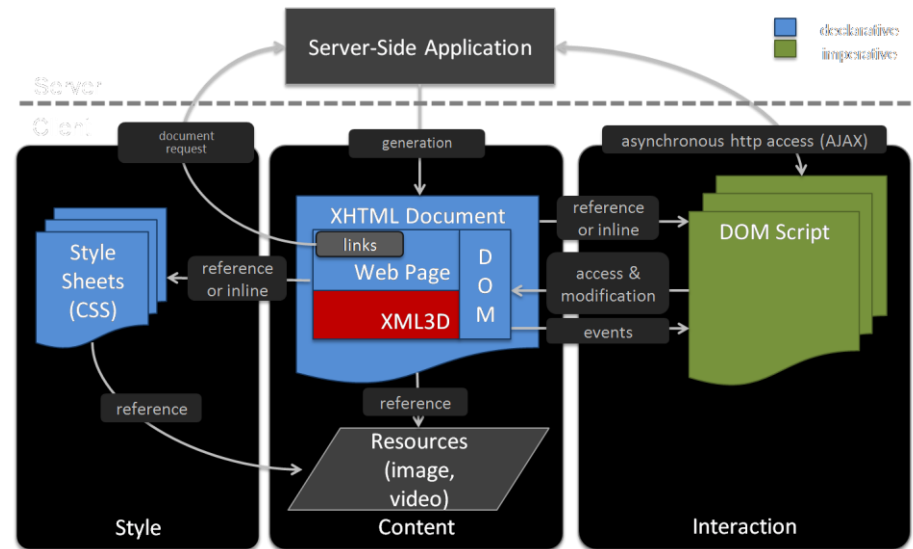**Intelligent Human Simulation in Production**
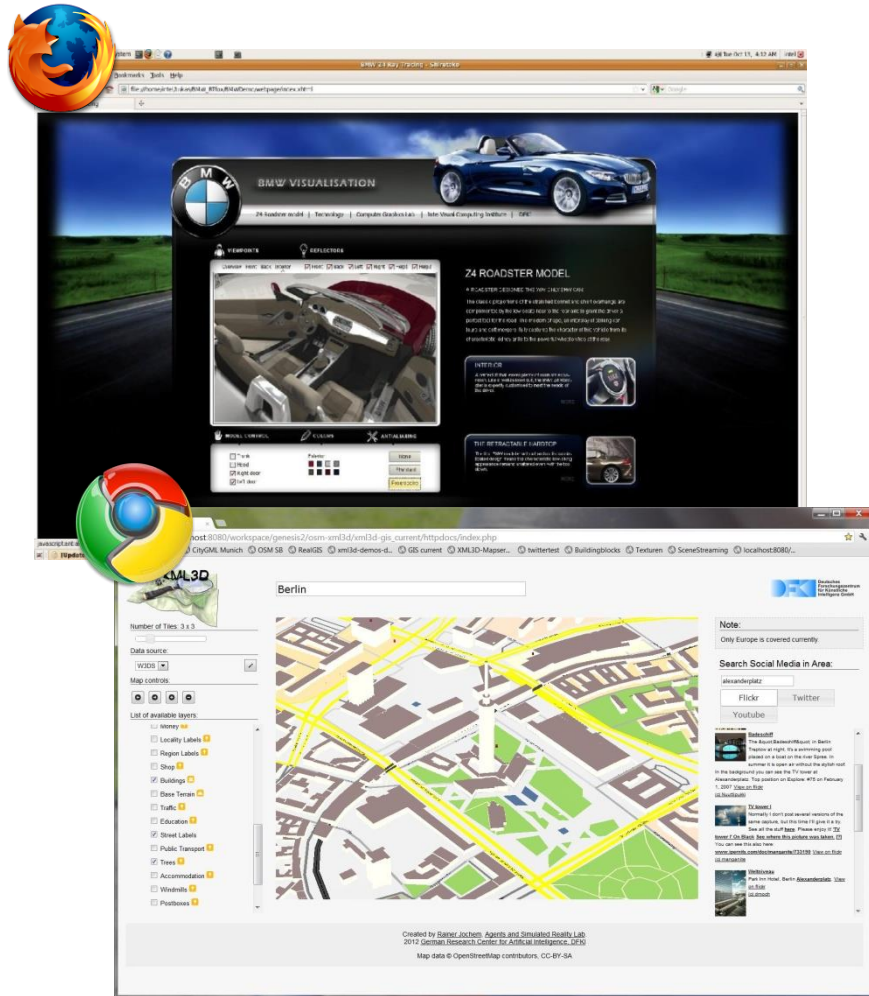
Web-Based 3D Application (XML3D)

Distributed Visualization on the Internet

XML3D:Interactive 3D for the Web
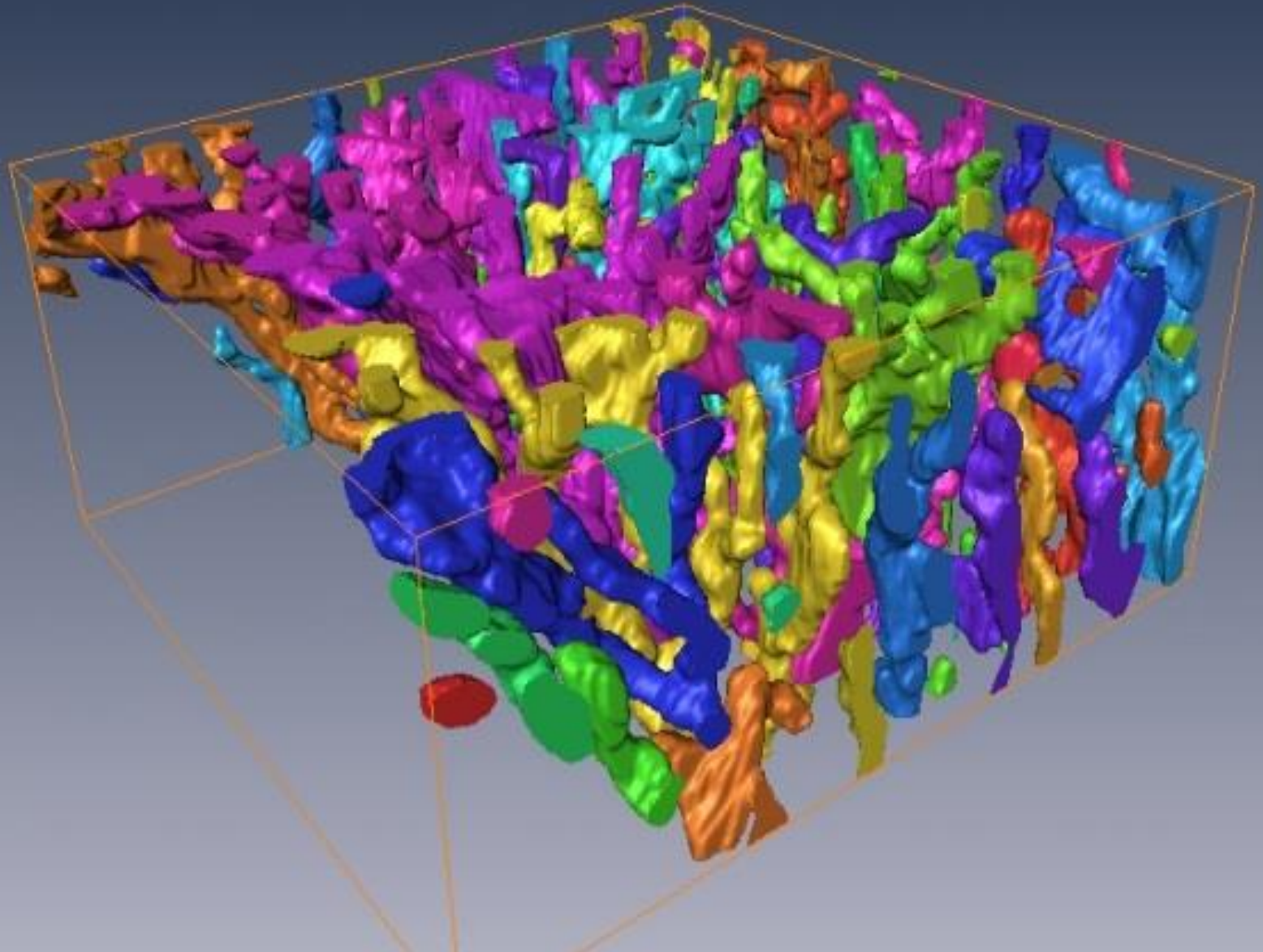


```
<html
<body> …

<xml3d  id = "world1"  style = "width: 1000px; height: 500px;"> …

<group id = "shape_d1"  shader = "#s_d1 "

     ondblclick = "triggerMenu(event); capture_record(event)">

     <mesh type = "triangles" id = "m_mesh" >
          <data> <float3 name= "position"> 1.0 0.0 1.0 1.0 0.0 1.0
…</float3> …

     </mesh>  </group> </xml3d>   ….

</body> </html>
```
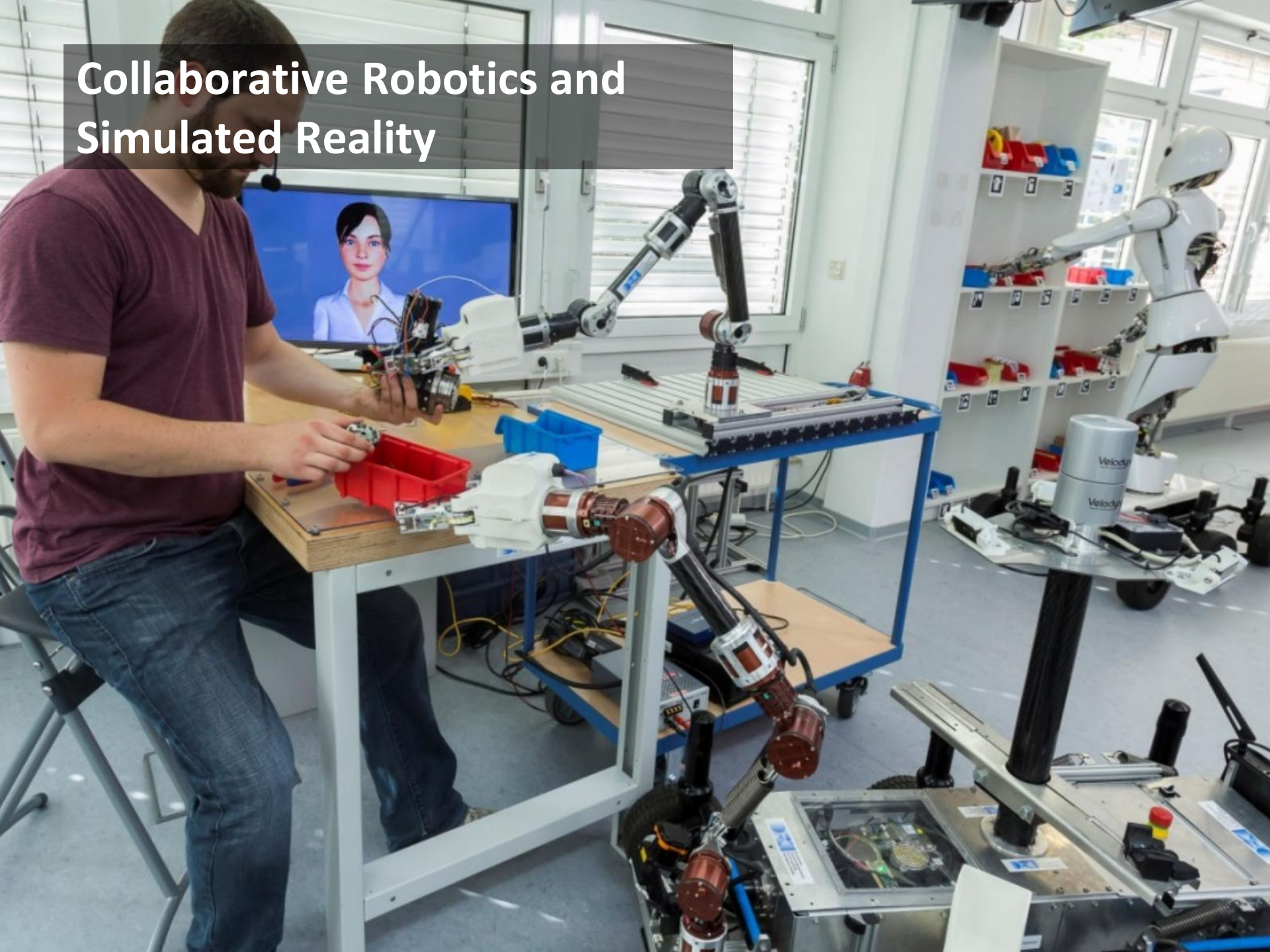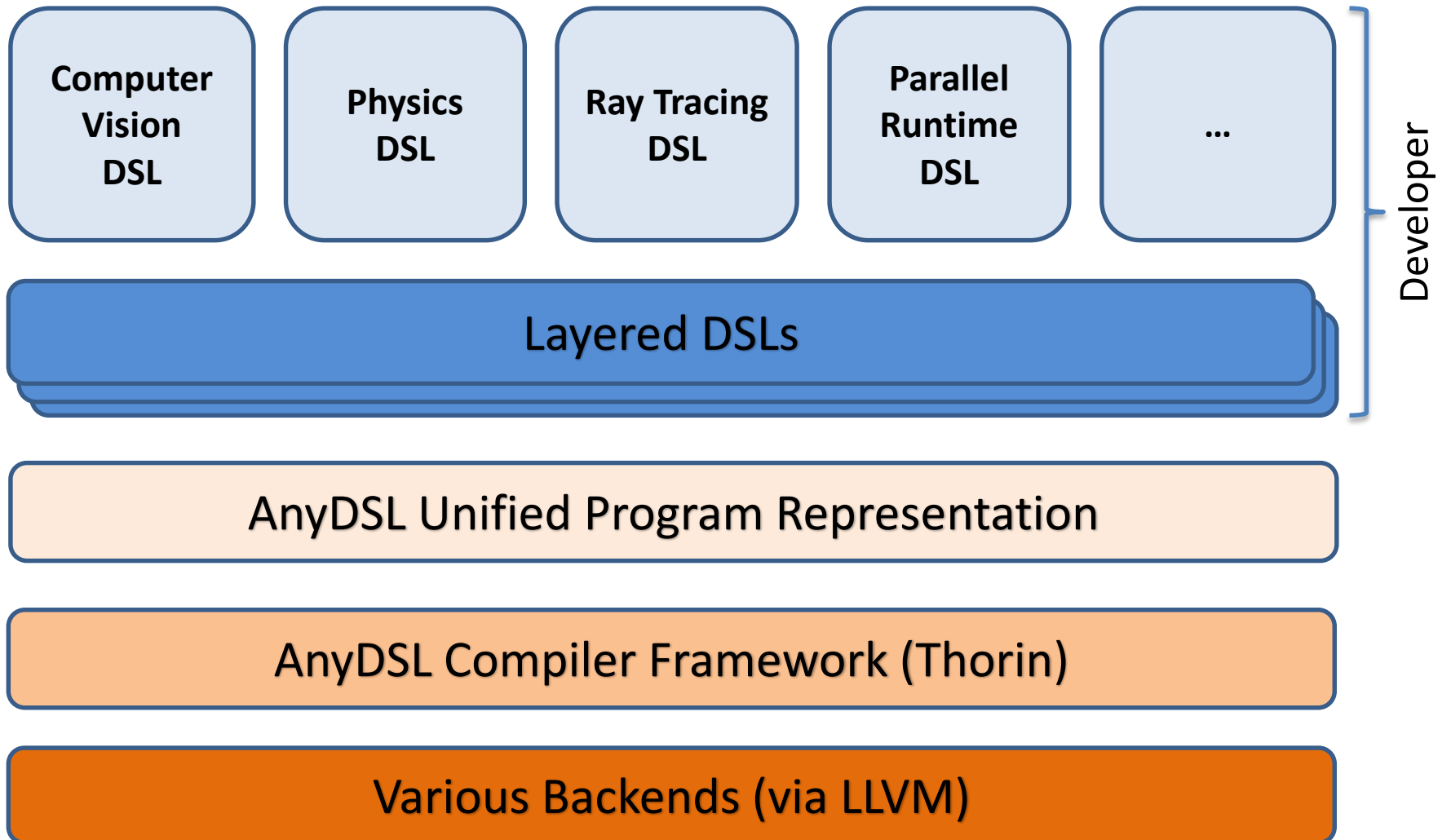
Material Science: Understanding & Predicting Across Scales

Collaborative Robotics and Simulated Reality

Autonomous Driving: Training using Synthetic Sensor Data

AnyDSL Compiler Framework

Computer Vision DSL	Physics DSL	Ray Tracing DSL	Parallel Runtime DSL	...

Developer

Layered DSLs

AnyDSL Unified Program Representation

AnyDSL Compiler Framework (Thorin)

Various Backends (via LLVM)

AnyDSL: The Vision

- Single high-level representation of our algorithms
- Simple transformations to wide range of target hardware architectures

- First step: RTfact for real-Time Ray Tracing [HPG 08]
  - Use of C++ Template Metaprogramming
  - Great performance (-10%)
  - But essentially unusable because of weird syntax

- Now: AnyDSL
  - Pure high-level algorithmic code and simple HW mapping code
  - Simultaneously: Less and simpler code & much faster to write (10x)
  - **Stencil:** +40% on Intel x86, +45% on Nvidia, +50% on AMD GPU
  - **Ray-Tracing:** +20-25% on same compiler (LLVM)

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**
  - Visualization, Industrie-4.0, Big Data, Smart Cities, …
- **Interdisciplinary field**
  - Relations to mathematics, physics, engineering, psychology, art, entertainment, …

  Philipp Slusallek