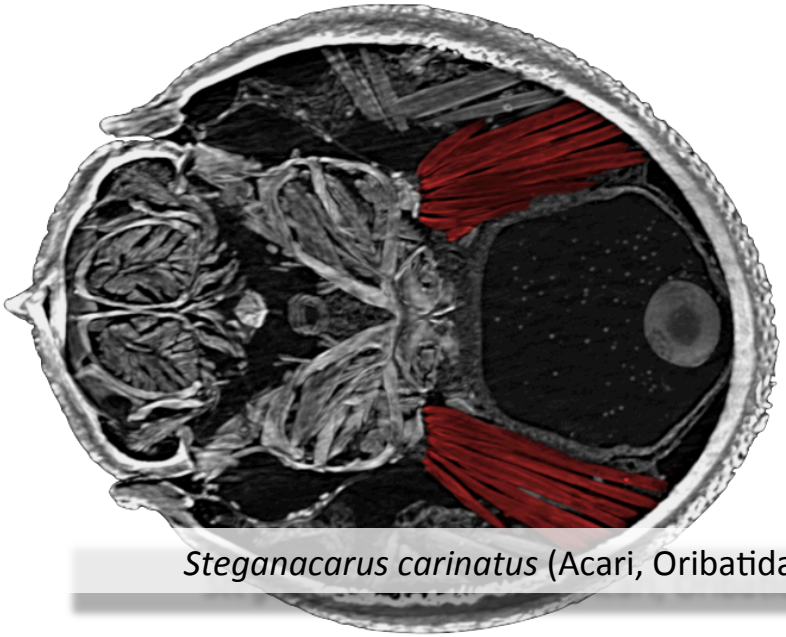
Arthropod Structure revealed by ultra-fast Tomography and Online Reconstruction

Arthropod Structure revealed by ultra-fast Tomography and Online Reconstruction

A new method for ultra-fast X-ray tomography (2013-2016)

Science-driven development of

- Management of large datasets
- Cloud-based analysis environment
- Advanced segmentation of 4D X-ray images



Steganacarus carinatus (Acari, Oribatida)

Network for functional morphology and systematics:

TECHNISCHE UNIVERSITÄT DARMSTADT

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386

KIT Karlsruhe Institute of Technology

ANKA

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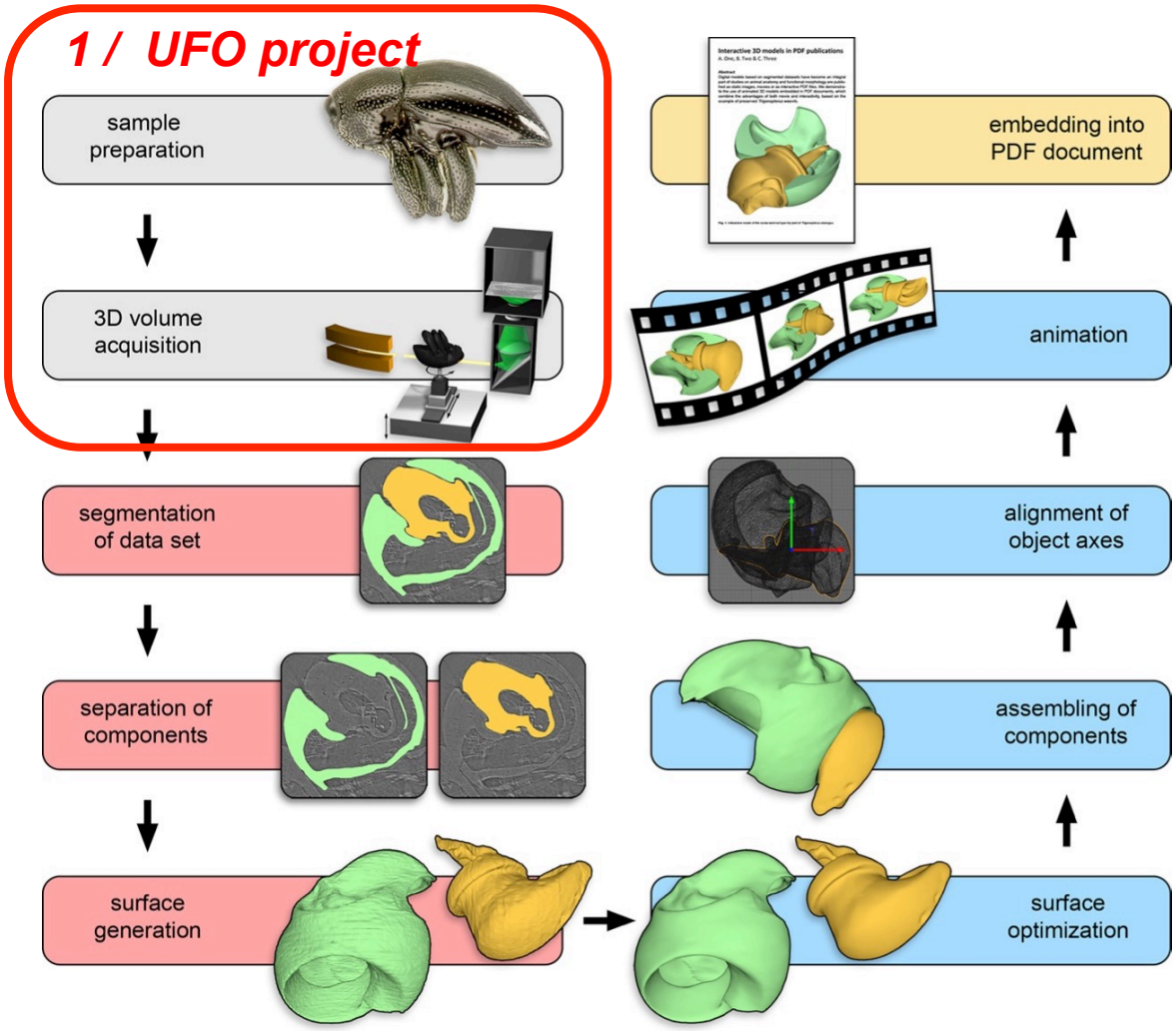
Synchrotron X-ray Microtomography

- **X-ray tomography** is an indispensable tool for biology
- In-vivo experiments are desirable
- Datasets and resolutions are increasing
- **Experiment and analysis is time consuming**



courtesy T v d Kamp, KIT

Ultrafast Tomography = the “UFO Project”

- *Technologies:*
  - High-speed detector system for short exposure times
  - Automation for high sample throughput
    - Sample changer
    - “Concert” – a new control system
  - Fast reconstruction by GPU computing
    - UFO computing framework

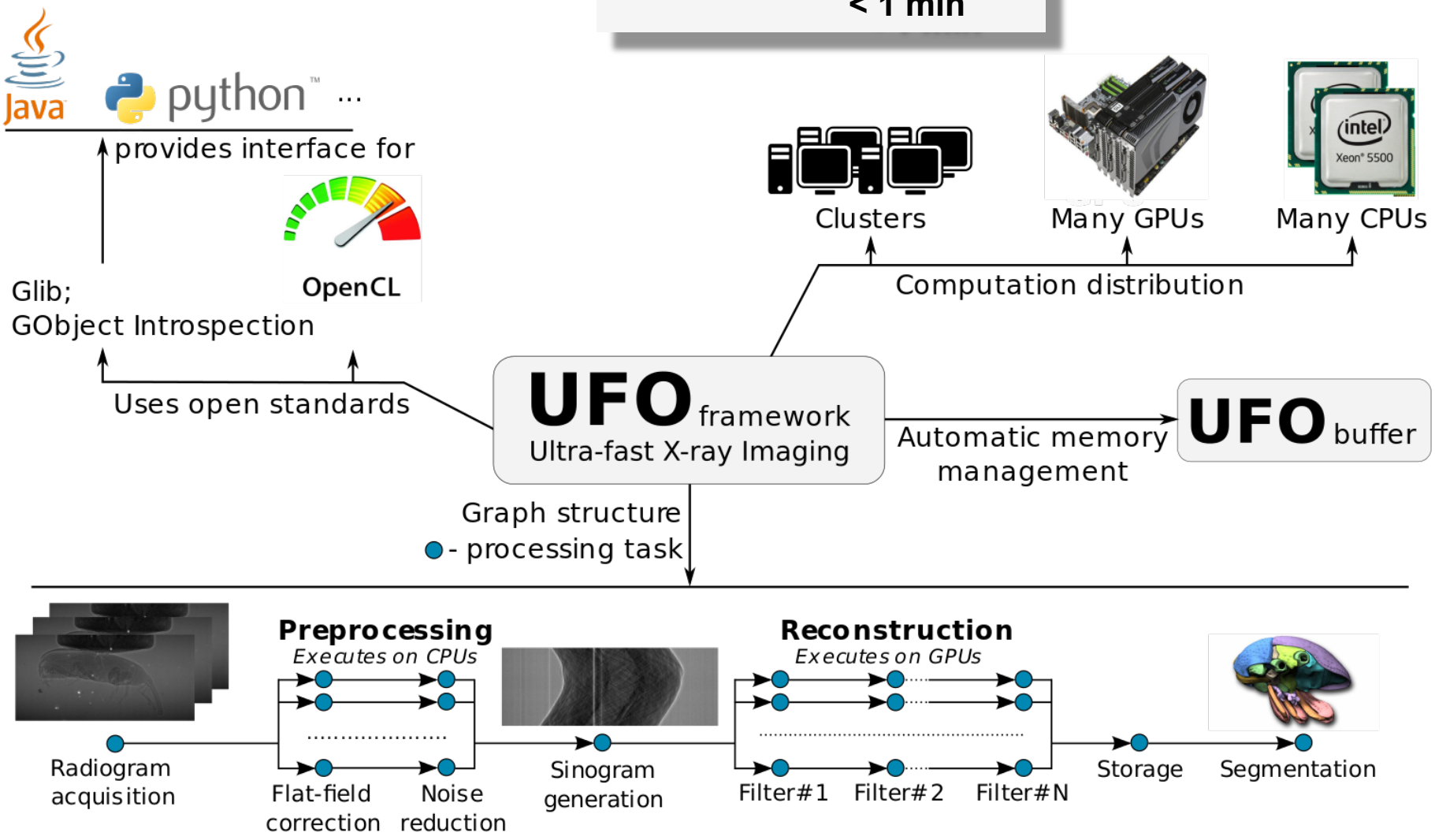
“… pushing tomography from hours to the seconds level …”

- *Results:*
  - In-vivo tomography – called 3D-Cinemography
  - Tomography with hundreds of samples

- *“One thing more”:*
  - Smart camera framework
    (used at HZG and for beam monitoring, …)

Parallel Computing

Reconstruction performance **> 1 GB/sec**
< 1 min



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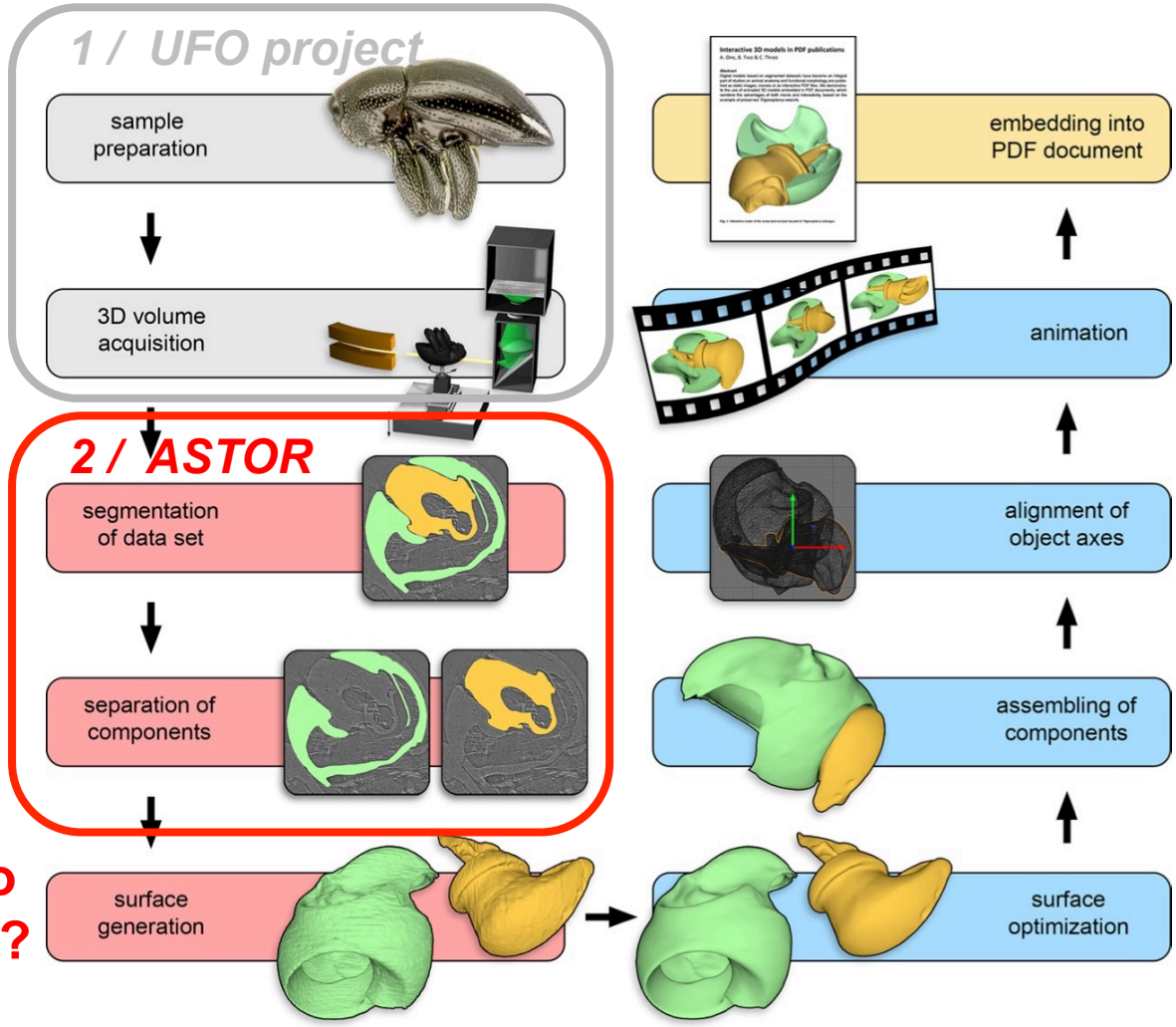
How to simplify access to synchrotron tomography?



courtesy T v d Kamp, KIT

Virtual Analysis Environments = ASTOR

- *Technologies:*
  - Automatic workflows for large datasets
  - Virtualization + remote Access
  - Improved algorithms for segmentation
- *Results:*
  - Analysis-as-a-service is possible (via Vmware)
  - Significant acceleration of segmentation

"… finding alternatives to copying large datasets …"

Virtual Analysis Infrastructure

Cloud technologies enable remote analysis
without data download

4
- Interactive
4D visualization

ASTOR web-portal

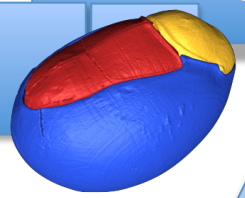
2
- Access via DFN + DSL
- Remote 3D applications

Virtual analysis infrastructure

Long-term archive

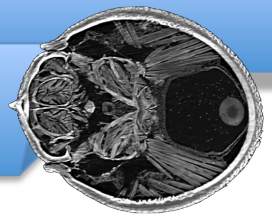
ASTOR processing cache

5



3 - Managing large-scale datasets

ANKA imaging beamline



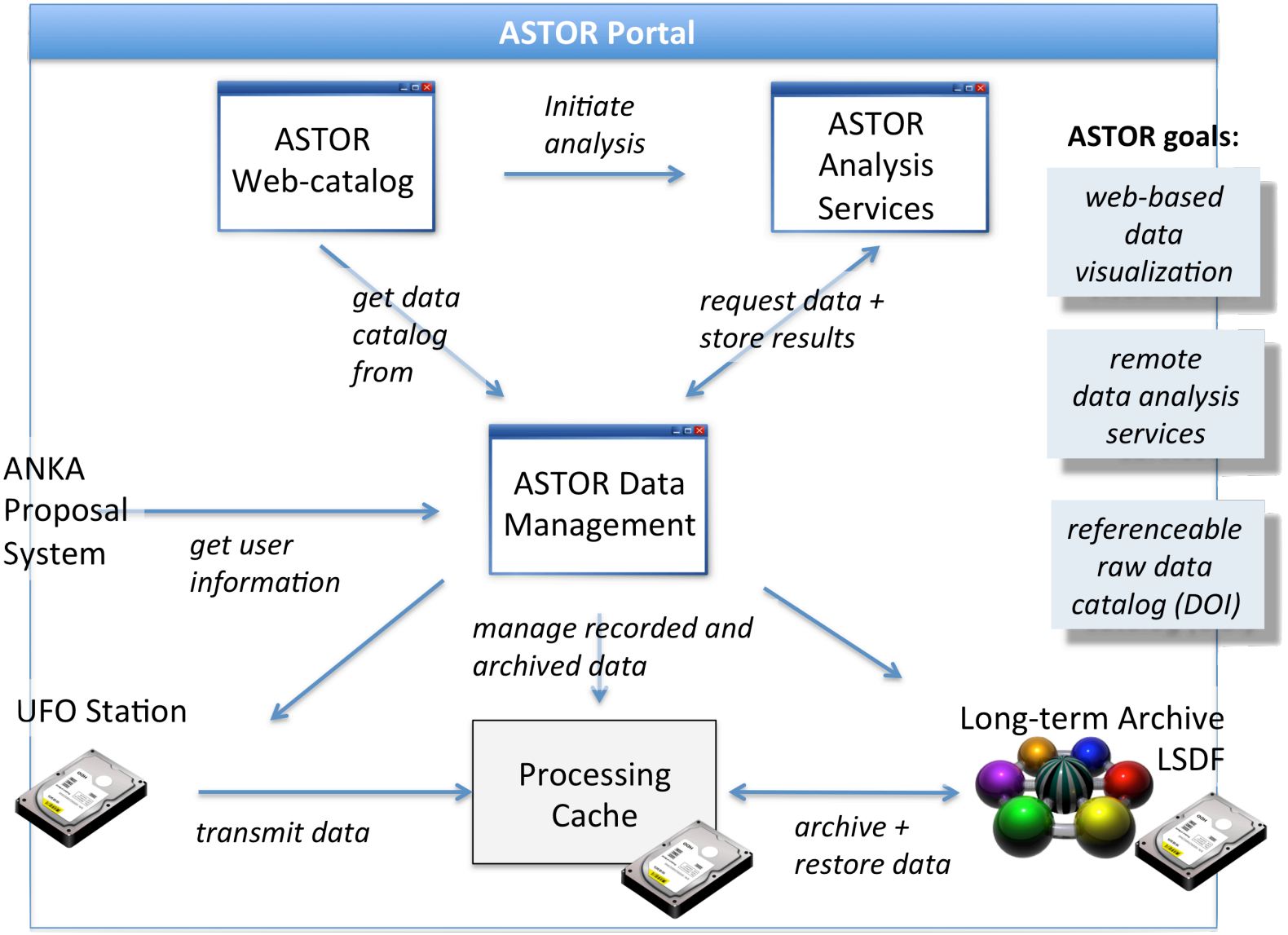
1

Tasks:

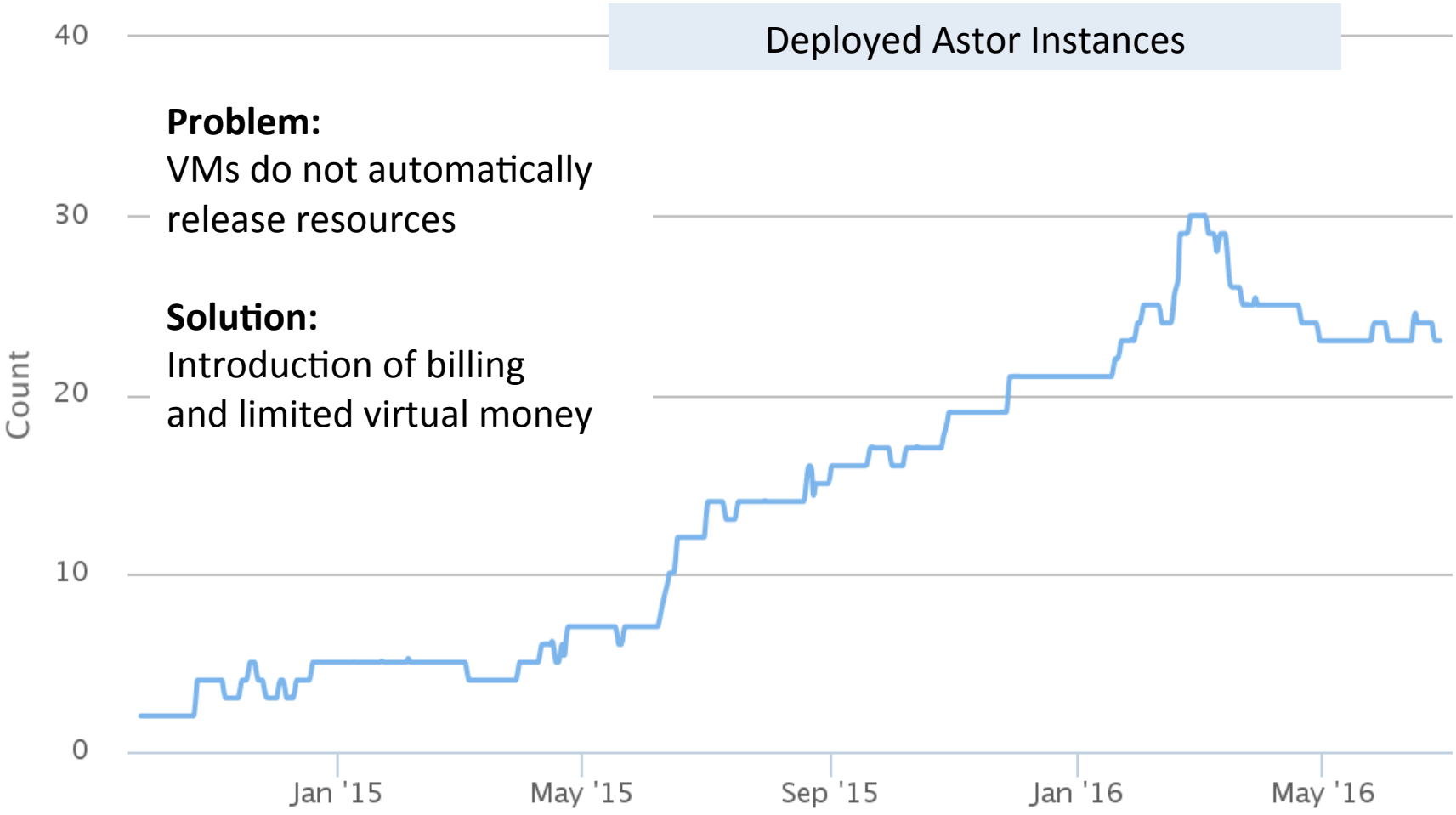
1 - Science-driven
2 - Analysis infrastructure
3 - Work flow
4 - Web portal
5 - 4D analysis
e.g. segmentation

astor is a cooperation of the Universities Darmstadt, Heidelberg and KIT
to develop advanced technologies for the ANKA synchrotron facility in the Helmholtz Association

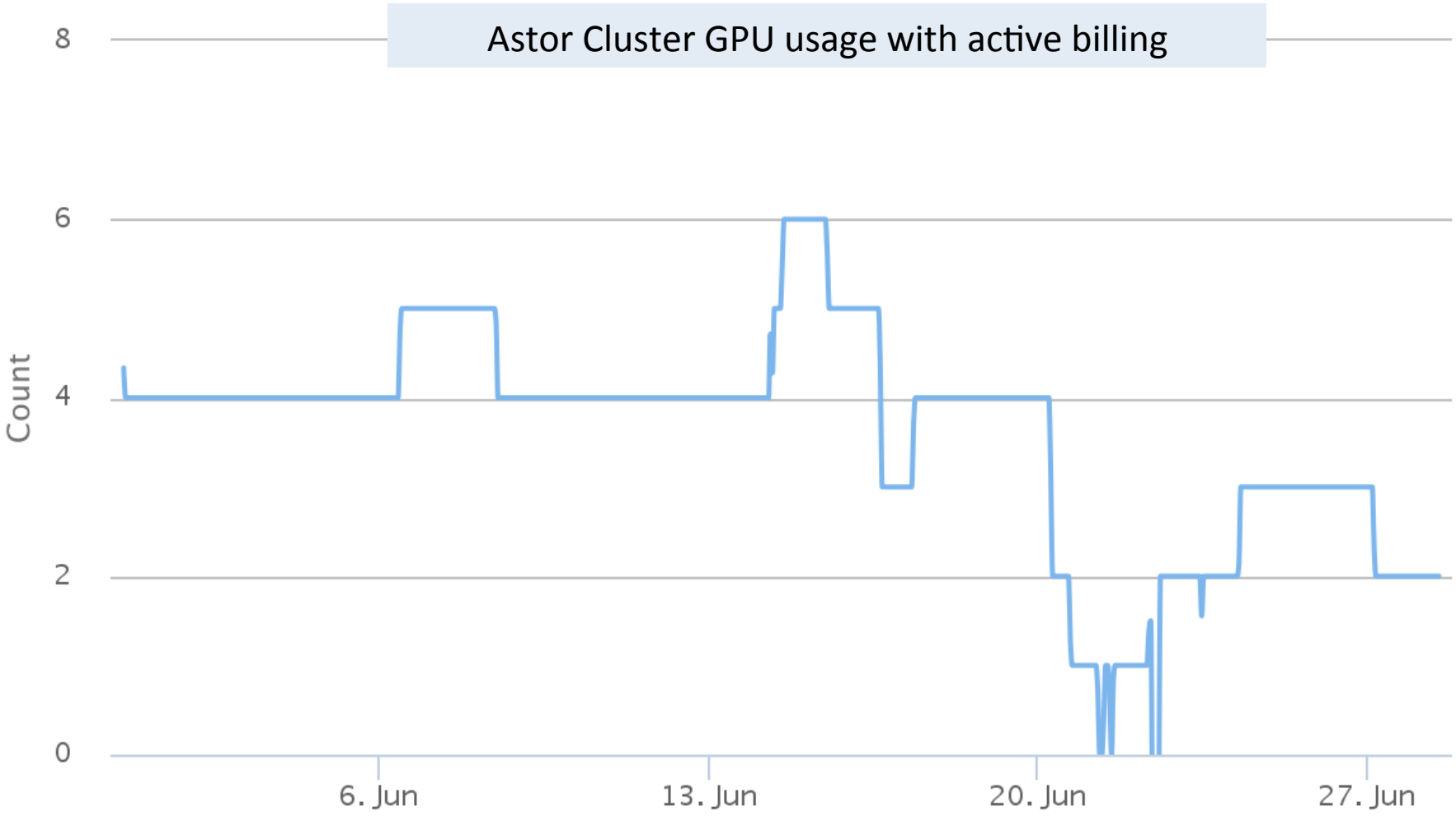
ASTOR Analysis Environment



Analysis Cluster Usage



Analysis Cluster Usage

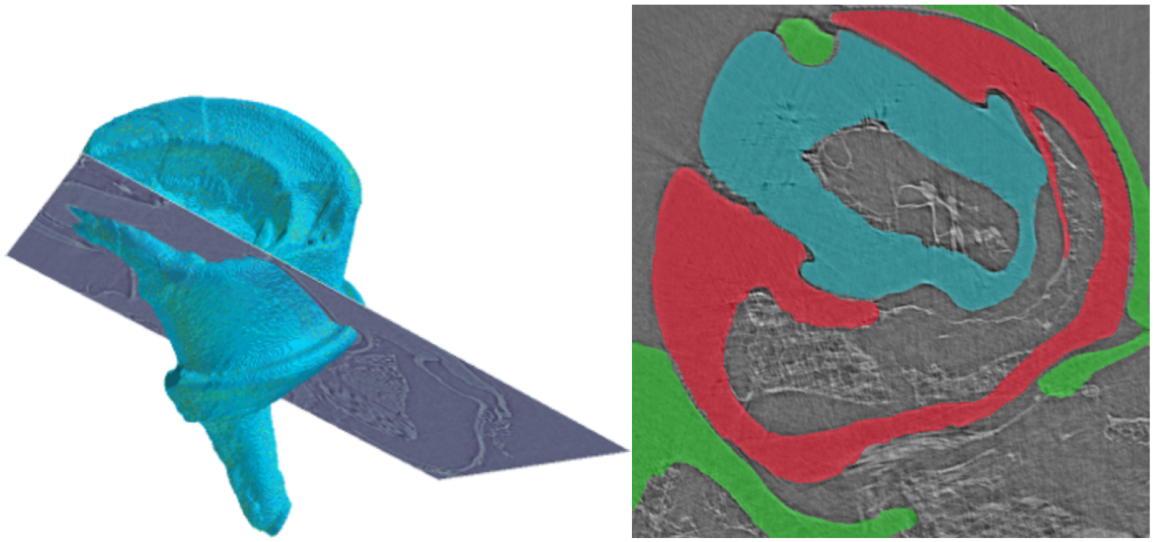


3D Segmentation Algorithms

Algorithm:

1. Preprocess: Label the segments in some well chosen slices.
2. Start a great number of weighted random walks at each labeled pixel.
3. The number of hits by random walks which were started in the same segment leads to the probability that a voxel belongs to this segment.
4. Post-processing using Active Contour Method in 3D.

1



P Lösel, V Heuveline, SPIE 2016, Paper 9784-92

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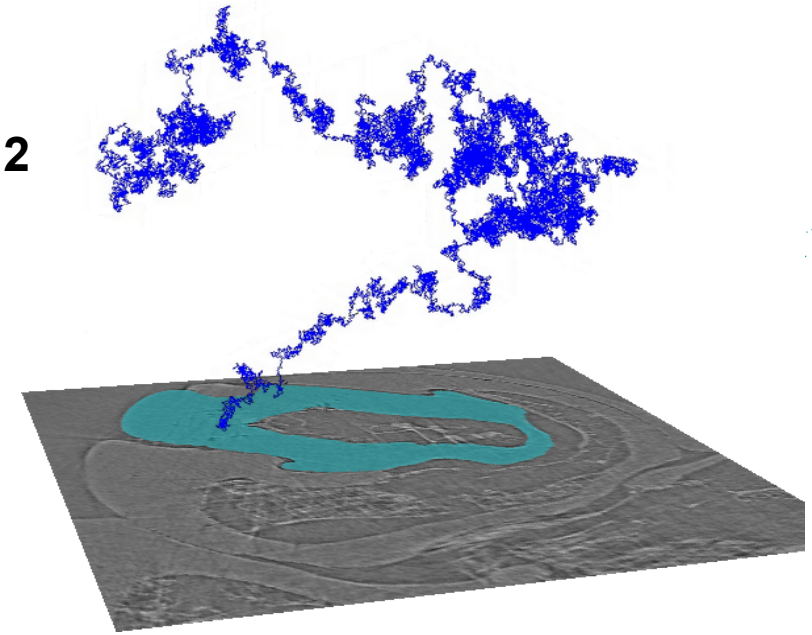

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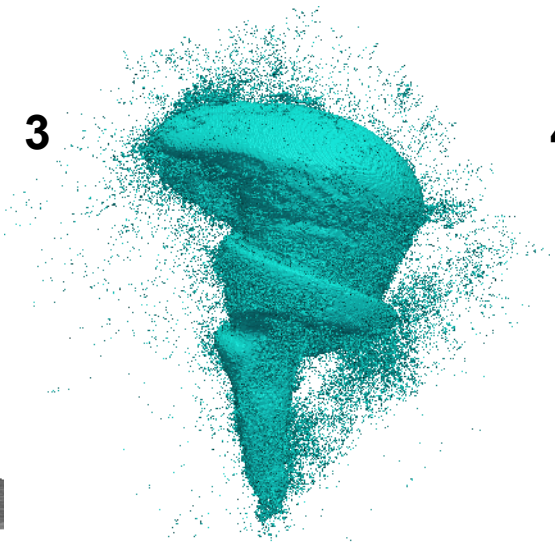

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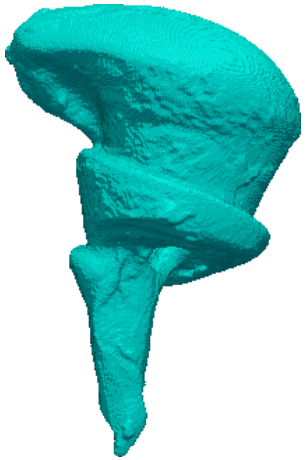

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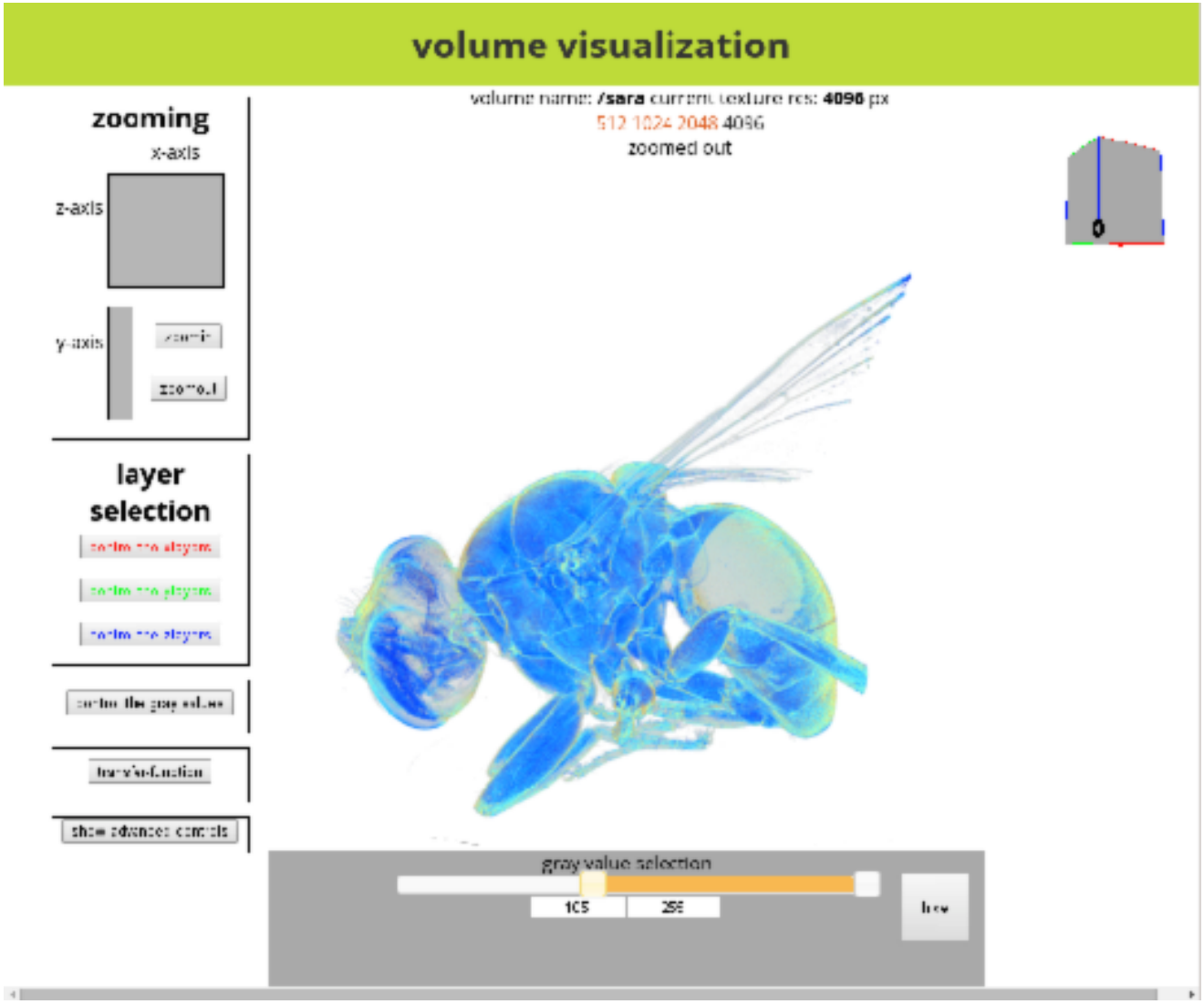
3D Web-Visualization



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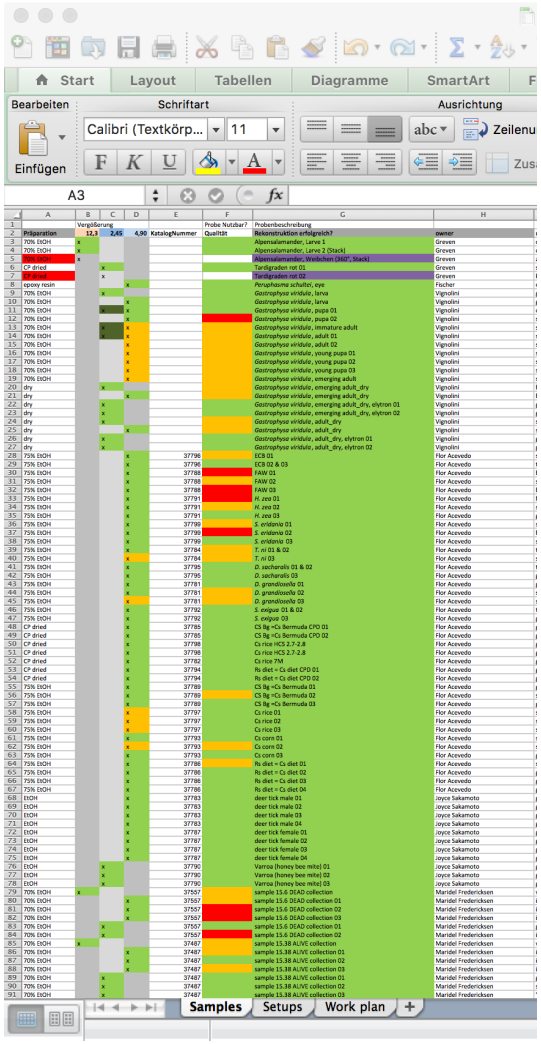
Tomography Service for Morphology

- ANKA domain expert collects samples
  - Check of sample quality
- Measurement at ANKA
  - Beamtime 6 days (e.g. Nov 2015)
  - Up to 300 samples from 14 scientists
  - Methods: Radiology, Tomography, Cine-Tomography
  - Samples: in alcohol, dried, amber, …
  - More than 90% of the samples are usefull
  - Interested scientists might join
- Datasets are automatically transfered to processing storage
  - Analysis by remote access
  - First Non-ASTOR groups use Amira at ASTOR
  - Analysed datasets after ½ a is 10-15%



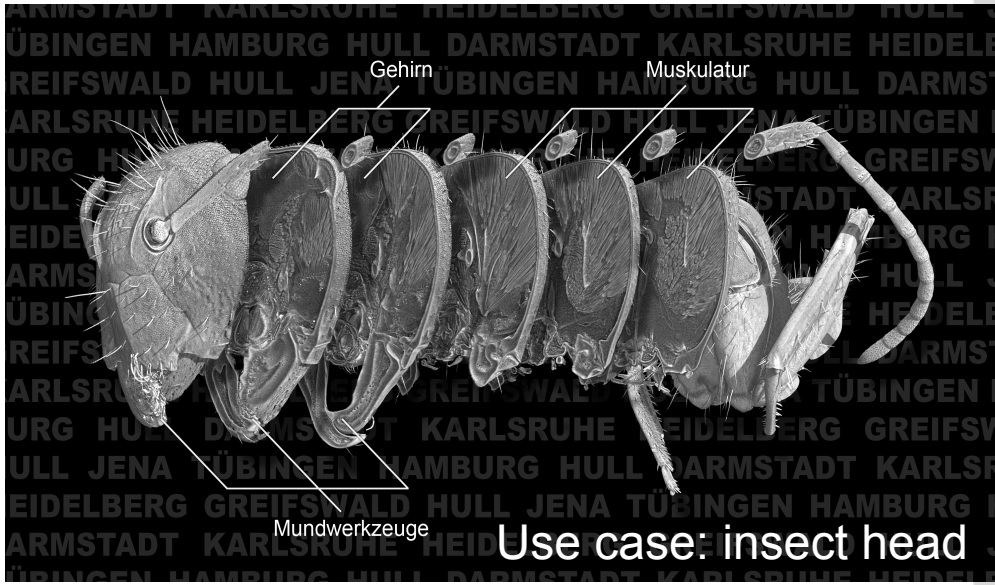
Next Step:

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Karlsruhe Institute of Technology

Network for Online Visualization and Synergistic Analysis of Tomographic Data

- **Goals:**
  - Complete analysis of datasets by complementary groups
  - Development of advanced collaborative analysis tools



- **Partners:**
  - Helmholtz-Zentrum Geesthacht, Zentrum für Materialforschung und Küstenforschung (HZG), Karlsruhe Institute of Technology (KIT)
  - Universities Darmstadt, Heidelberg, Tübingen, Jena, Greifswald, Hull

Collaborative Research = NOVA

*"**A fourth data-intensive science is emerging**. The goal is to have a world in which all of science literature is online, all the science data is online, and they interoperate with each other." (Jim Gray, 2007)*

- *Technologies:*
  - Algorithms for automatic segmentation
  - Data portal
  - Tools for collaborative data analysis
    - Fast remote visualization
    - Quality assurance; merging results; documented workflows
- *Collaborative data analysis*
  - *Prove our tools with a biologically exciting use case !!!*
    - Larger numbers of samples are feasible for statistical research
    - E.g. digitization of museum collections
    - Combination of in-vivo and high-resolution imaging
    - Exploit modalities by phase-contrast methods

"… establish workflows, policies and tools for public data repositories …"

"… start a comprehensive open source data catalog…"

Arbeitsplan

AP 1 Koordination morphologischer Datenaufnahmen und Auswertung

- 1.1 Datenaufnahme
- 1.2 Koordination der (...) Datenauswertung
- 1.3 ~~Workshops und Nachwuchsförderung~~

AP 2 Kollaborative Analysewerkzeuge

- 2.1 Dateninfrastruktur -- *verstärkte Unterstützung HZG/DESY*
- 2.2. „Remote Data Analysis“
- 2.3 Datenportal -- *funktionsreduzierter Prototyp*
- 2.4 Integration der optimierten Segmentierungsmethoden

AP 3 Visualisierungsservices & Computing

- 3.1 Visualisierungsservices
- ~~3.2 Darstellung multimodaler Bilder~~
- ~~3.3 Extraktion von Merkmalen~~

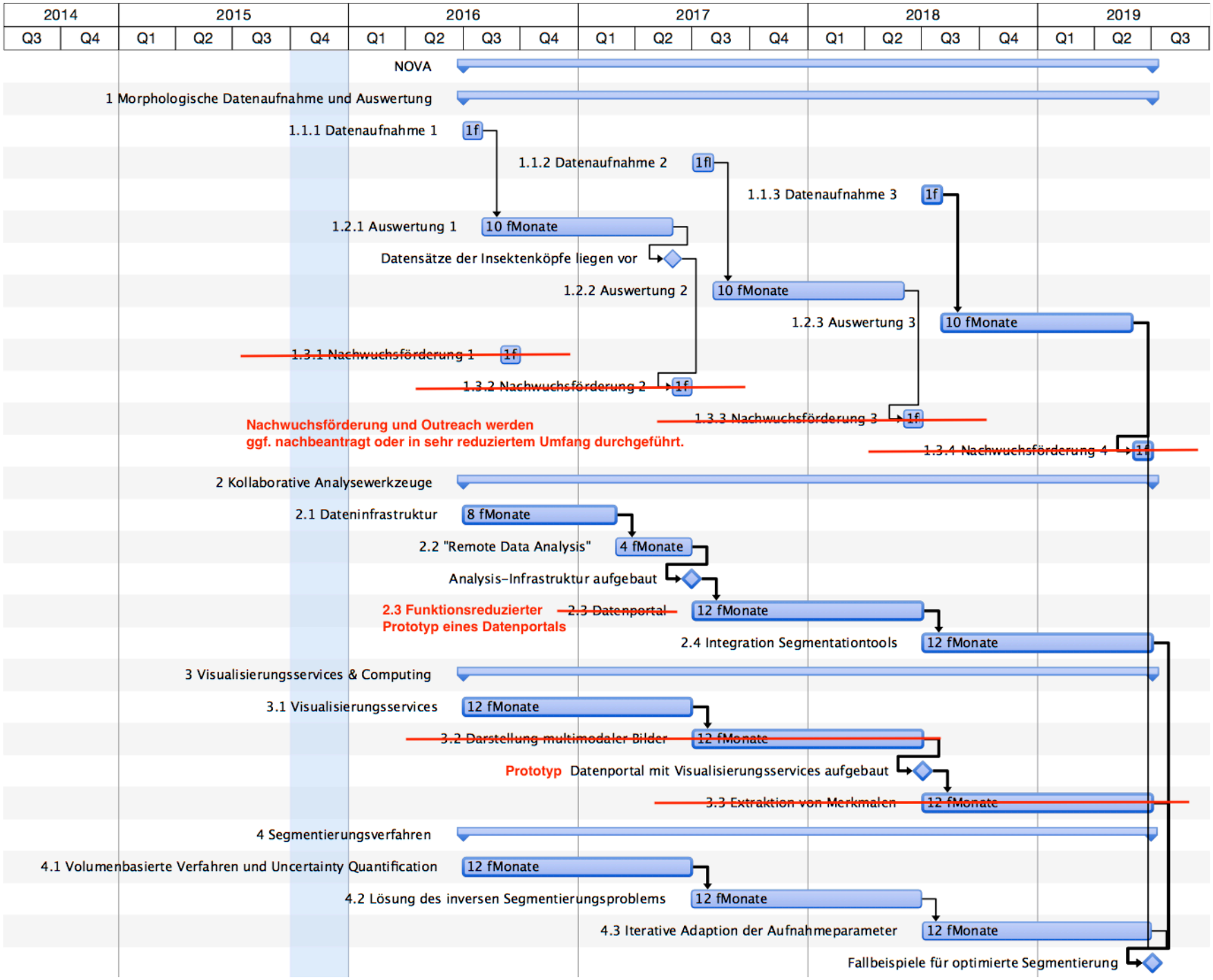
AP 4 Verfahren für eine automatische und teilautomatische Segmentierung

- 4.1 Volumenbasierte Verfahren und Uncert. Quantification
- 4.2 Lösung des inversen Segmentierungsproblems
- 4.3 Iterative Adaption der Aufnahmeparameter

TUD
1 FTE statt 2 FTE
Ausstell. gestrichen

KIT
1 FTE statt 3 FTE
IT-Infr. 100k
statt 160k

UHD
1 FTE
GPU Server


2014
2015
2016
2017
2018
2019
Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3
NOVA
1 Morphologische Datenaufnahme und Auswertung
1.1.1 Datenaufnahme 1
1f
1.1.2 Datenaufnahme 2
1f
1.1.3 Datenaufnahme 3
1f
1.2.1 Auswertung 1
10 fMonate
Datensätze der Insektenköpfe liegen vor
1.2.2 Auswertung 2
10 fMonate
1.2.3 Auswertung 3
10 fMonate
1.3.1 Nachwuchsförderung 1
1f
1.3.2 Nachwuchsförderung 2
1f
1.3.3 Nachwuchsförderung 3
1f
Nachwuchsförderung und Outreach werden
ggf. nachbeantragt oder in sehr reduziertem Umfang durchgeführt.
1.3.4 Nachwuchsförderung 4
1f
2 Kollaborative Analysewerkzeuge
2.1 Dateninfrastruktur
8 fMonate
2.2 "Remote Data Analysis"
4 fMonate
Analysis-Infrastruktur aufgebaut
2.3 Funktionsreduzierter
Prototyp eines Datenportals
2.3 Datenportal
12 fMonate
2.4 Integration Segmentationtools
12 fMonate
3 Visualisierungsservices & Computing
3.1 Visualisierungsservices
12 fMonate
3.2 Darstellung multimodaler Bilder
12 fMonate
Prototyp Datenportal mit Visualisierungsservices aufgebaut
3.3 Extraktion von Merkmalen
12 fMonate
4 Segmentierungsverfahren
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4.2 Lösung des inversen Segmentierungsproblems
12 fMonate
4.3 Iterative Adaption der Aufnahmeparameter
12 fMonate
Fallbeispiele für optimierte Segmentierung

Rückmeldung PT (zur Kürzung)

Großes Interesse der Gutachter am ursprünglichen Arbeitsplan lag im Aufbau von **Datenportalen**

Die Kürzung wurde trotzdem ausgesprochen, weil **Mittel vom Quellenbetreiber DESY** eingefordert werden sollten, denn DESY sollte ja von Ihrem erfolgreich durchgeführten Projekt später profitieren. Eine Einbindung von DESY (bezüglich **Personal oder Kosten von Soft- und Hardware**) schien den Gutachtern sinnvoll und möglich.

Eine Frage war auch, ob eine **Open Access** Möglichkeit geplant sei, wo DESY dann unbedingt teilnehmen sollte. Die Spezifikation der ‚data policy' steht bei DESY derzeit zur Diskussion und das Datenmanagement sollte zum Ende der NOVA Laufzeit 2019 eine konkrete Form angenommen haben, in das sich hoffentlich auch das von Ihnen entwickelte Portal für Tomographiedaten integrieren lässt.

Nachwuchs- und Outreach-Aktivitäten wie Workshops können (oder sollen sogar) separat, also unabhängig von anderen Ausgaben im Projekts, beantragt werden.

Bitte teilen Sie uns vor Mitte November mit, das die **Kooperationsvereinbarung** zustande gekommen ist.

NOVA

Main objectives:

- Development of collaborative analysis tools
- Complete analysis of datasets by complementary groups

Milestones:

- **Tomographic datasets** of insect heads (after 1 year)
  - Workshops and training for students
  - Efficient usage of available beamtime
- **Computer-Infrastructure** with virtual analysis environment (after 1 year)
  - OpenData policy
  - Data portal; segmentation services; scientific value chain
- **Visualization services** for raw data (after 2 years)
  - Pre-processing and data organization for fast preview
  - Multi modalities; merging; measureing
- **Optimized segmentation** for tomography (after 3 years)
  - Volume based methods
  - Uncertainty quantification
  - Consideration of imaging properties

Outreach