CARME

An Open-Source Framework for Multi-User, Interactive Jobs on Distributed GPU-Systems

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Machine Learning in the Wild

Why We Need a Tool for ML/DL on HPC Clusters

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Machine Learning in the Wild

Why We Need a Tool for ML/DL on HPC Clusters

Machine Learning and Data Analytics

- showed **remarkable success** in many distinct fields
  (e.g. image processing, text translation, medical imaging, …)
- rise of **hybrid** and/or **ML/DL** supported **algorithms**
  (e.g. climate forecast, physics informed networks, …)
- **model size increases** drastically
  (needs more memory & compute power)
- generate **large investments** in new **multi-GPU hardware**

Utilize HPC Systems

The Way It Was for Decades

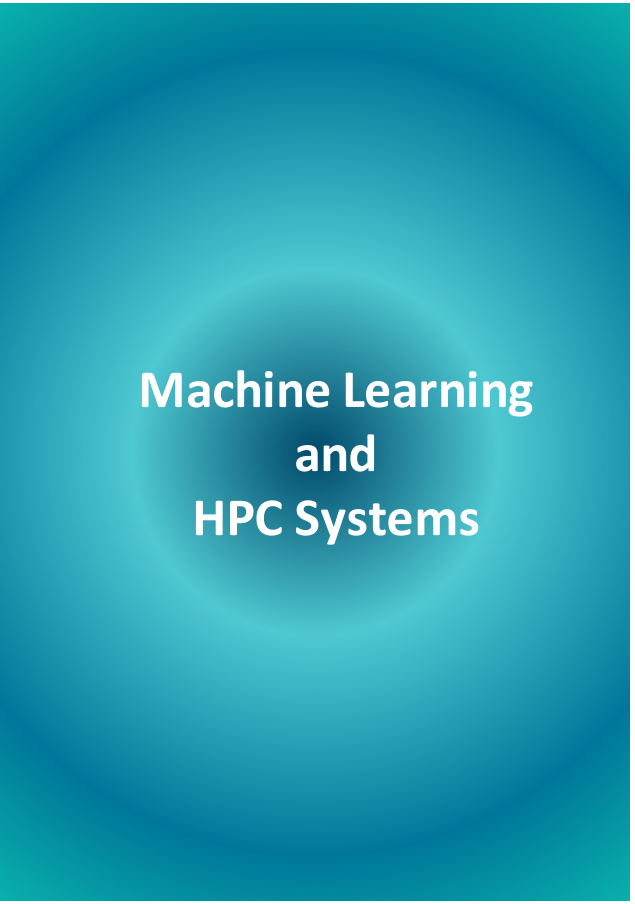
- other fields use **HPC systems for decades**
  (e.g., physics, chemistry, mathematics, …)
- HPC clusters are set up to **make use of** the **hardware** that is installed
  (e.g., multi-node jobs)
- **calculate huge problems**
  (e.g., extreme memory and computationally intensive simulations)
- **command line driven** usage
  (e.g., submit non-interactive batch jobs, jobs do not start directly)

HPC Systems

- huge compute resources
- resources are spread over various nodes
- often focus on parallel usage
- limited runtimes

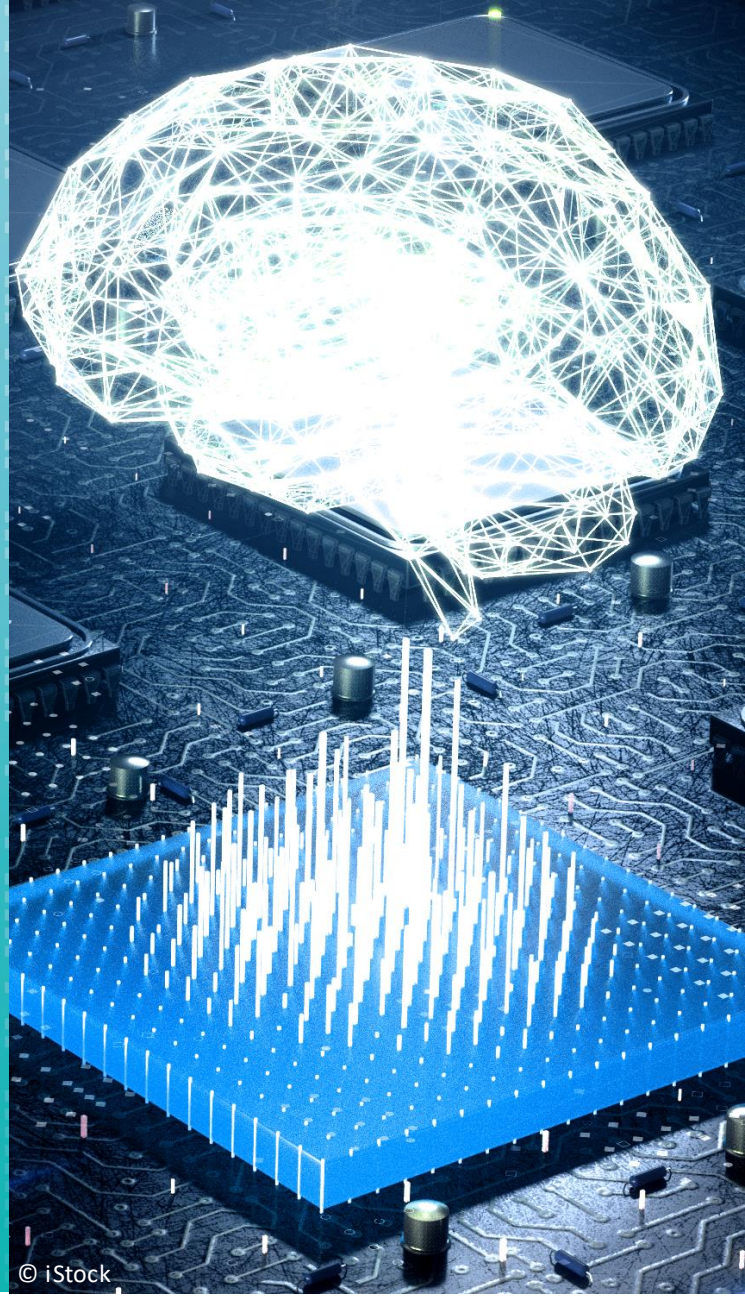
Machine Learning and HPC Systems

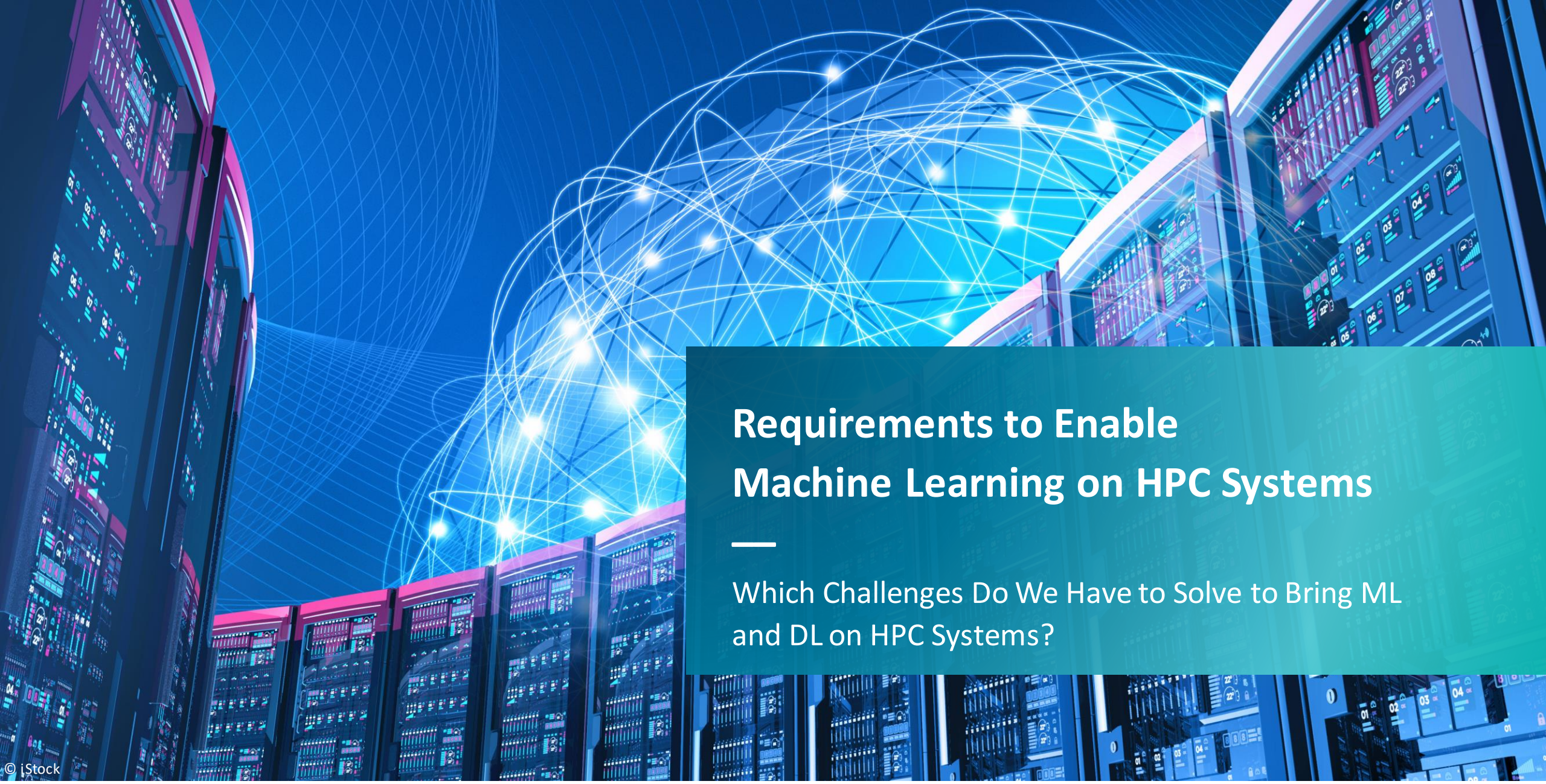
What We Would Expect



- efficiently **manage** and **use** your **resources**
  (how to utilize the full power of multi-GPU systems?)
- **match your workflow** with these resources
  (how can I develop interactively?)
- scale your applications to **use multiple GPUs** and/or **nodes**
  (how do I easily utilize multiple GPUs in various nodes?)
- manage **data I/O** and data **storage**
  (how do I access my data?)

Machine Learning
and
HPC Systems
Two Distinct Worlds?





Requirements to Enable Machine Learning on HPC Systems

Which Challenges Do We Have to Solve to Bring ML and DL on HPC Systems?

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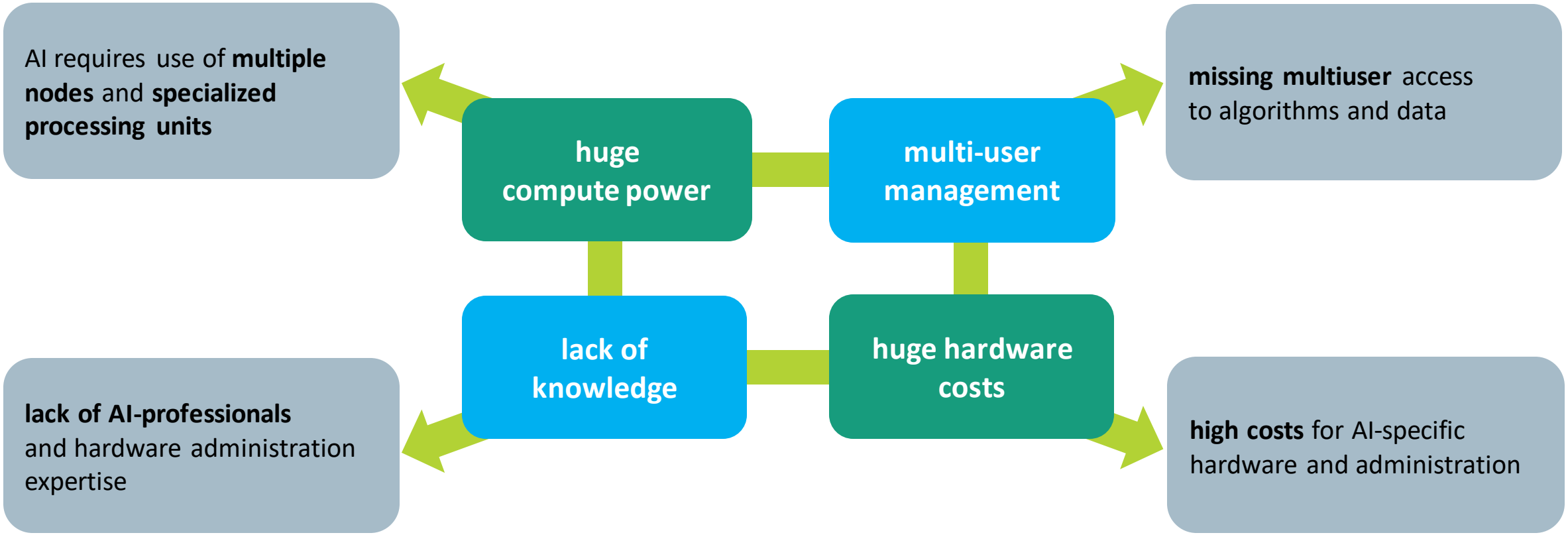
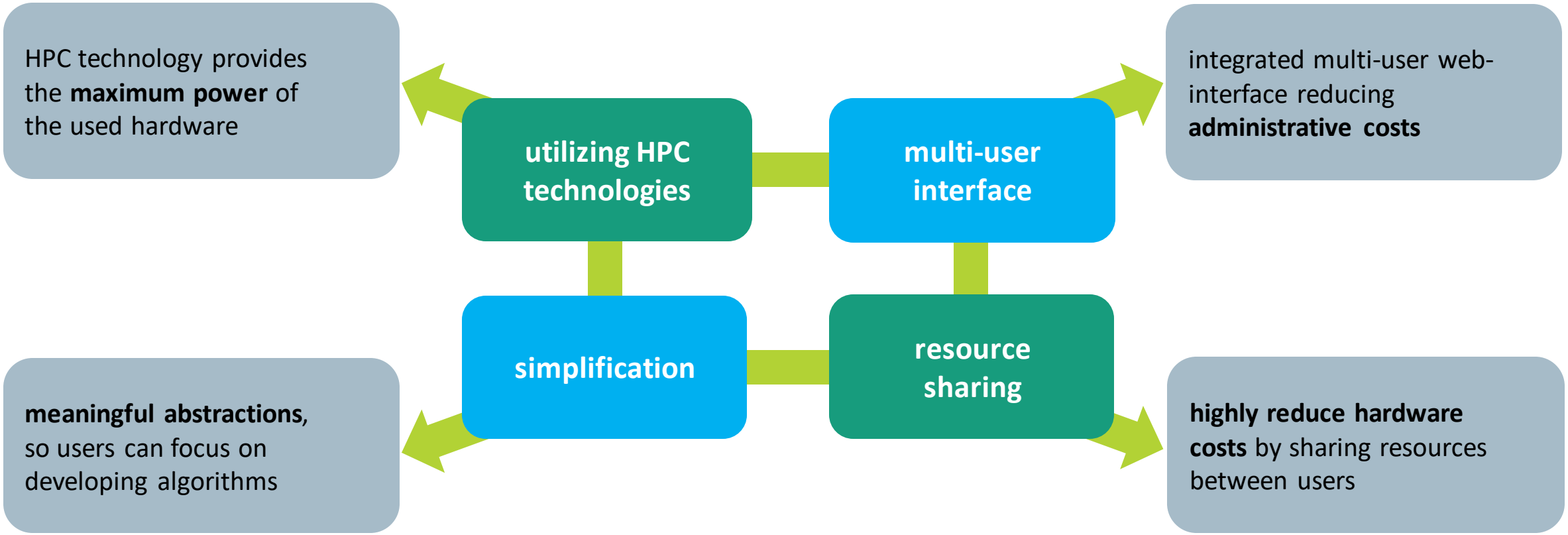
Machine Learning and HPC Systems

Things We Must Take Care of on Hpc Systems



Machine Learning and HPC Systems

Our Proposed Solution: Proven HPC Tools



Combining Open-Source ML Tools with HPC Backends

The CARME Way

Carme – an open-source framework to manage resources for multiple users running interactive jobs on an HPC Clusters

combines

Data Science

- **secure web frontend main GUIs**
  - Code-Server/JupyterLab
  - TensorBoard
- **anaconda environments**
  - miniconda / mambaforge

HPC

- **user and job management**
  - **LDAP** and **SLURM**
- **data I/O technologies** (e.g. **BeeGFS**)
- **using containers** (**Singularity**)
- **monitoring tools** (e.g. **Zabbix**)

Open–Source Tools

https://carmeteam.github.io/Carme/

The Details of Our Solution

What It Is Really About

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Resource Management

How to Assign Resources to Competing Users?

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Resource Management

Proven HPC Tools

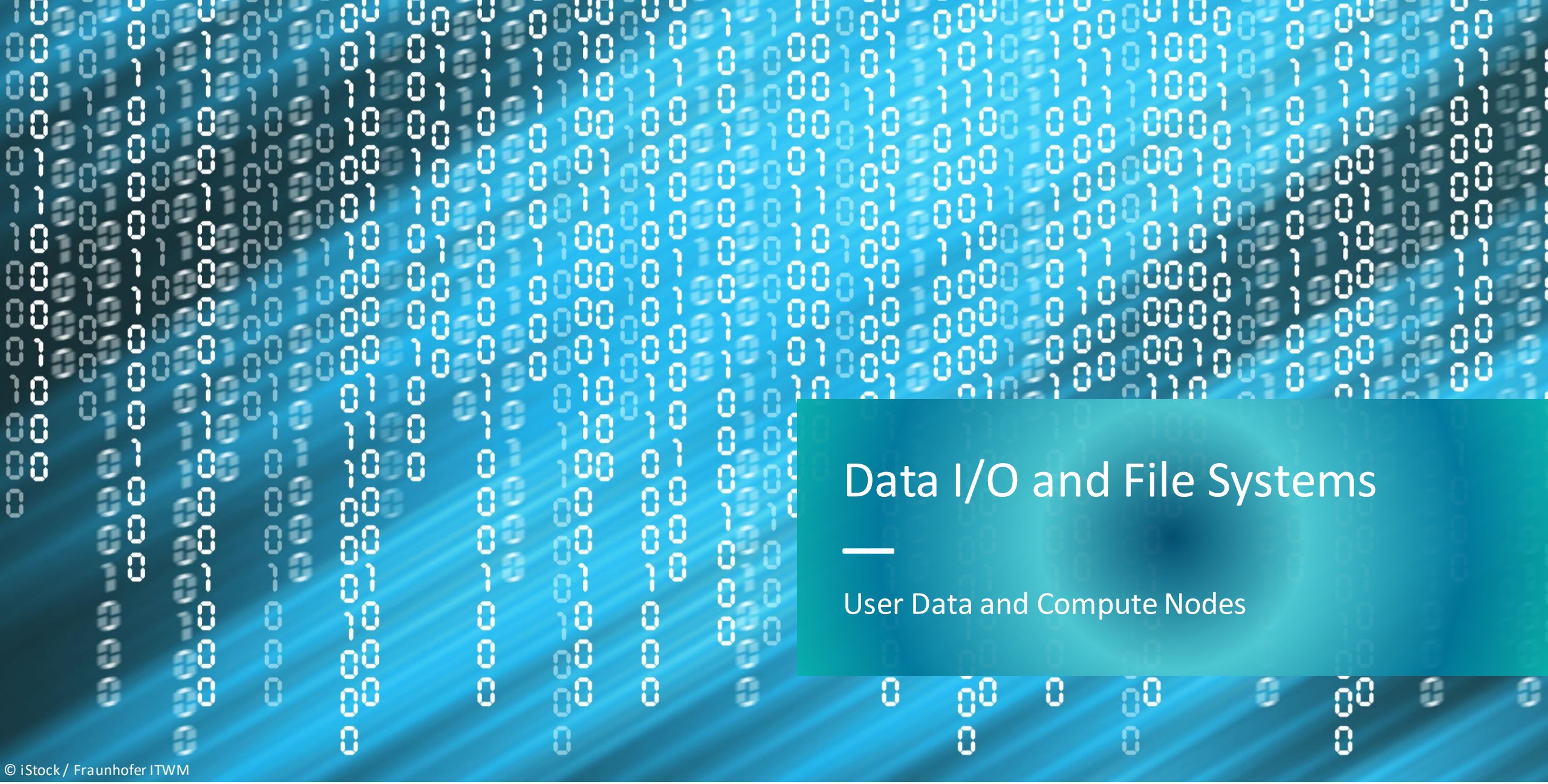
LDAP[1] (user management)

- LDAP = Lightweight Directory Access Protocol
- use your LDAP
- different user roles

SLURM[2] (job scheduler)

- easy integration in existing installations
- make use of cgroups plugins
- using quotas, queues, resource reservation
- many useful extensions available
  (e.g., preemtion, hiberate if idle, …)

[1] https://www.openldap.org
[2] https://slurm.schedmd.com



Data I/O and File Systems

User Data and Compute Nodes

Data I/O and File Systems

BeeGFS[3]

- redundant, parallel file system
- **huge** data **throughput** (via infiniband)
- temporary job FS (BeeOND) on local SSDs between node
- **open-source** (commercial support available)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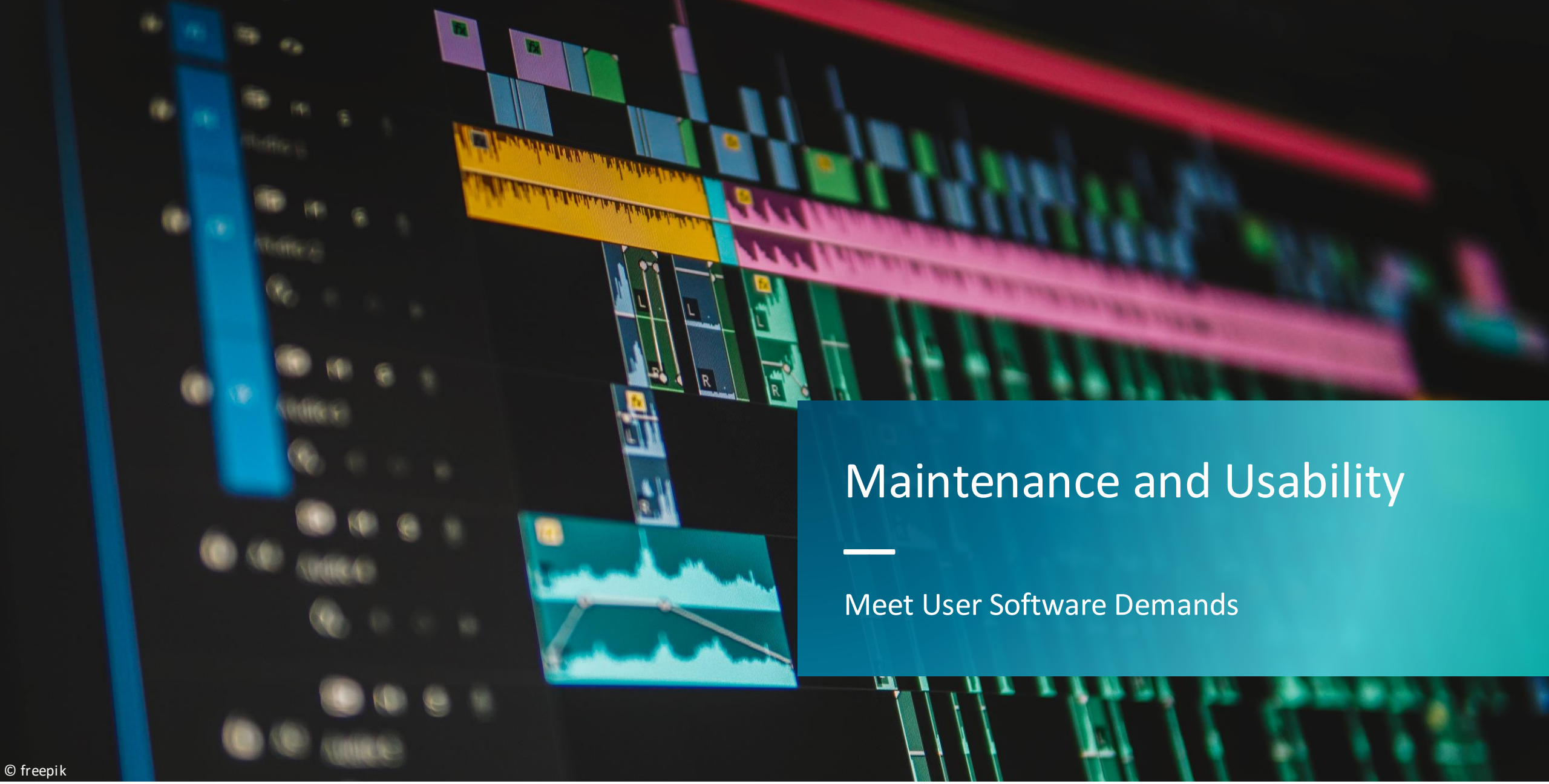
[3] https://www.beegfs.io



Maintenance and Usability

Meet User Software Demands

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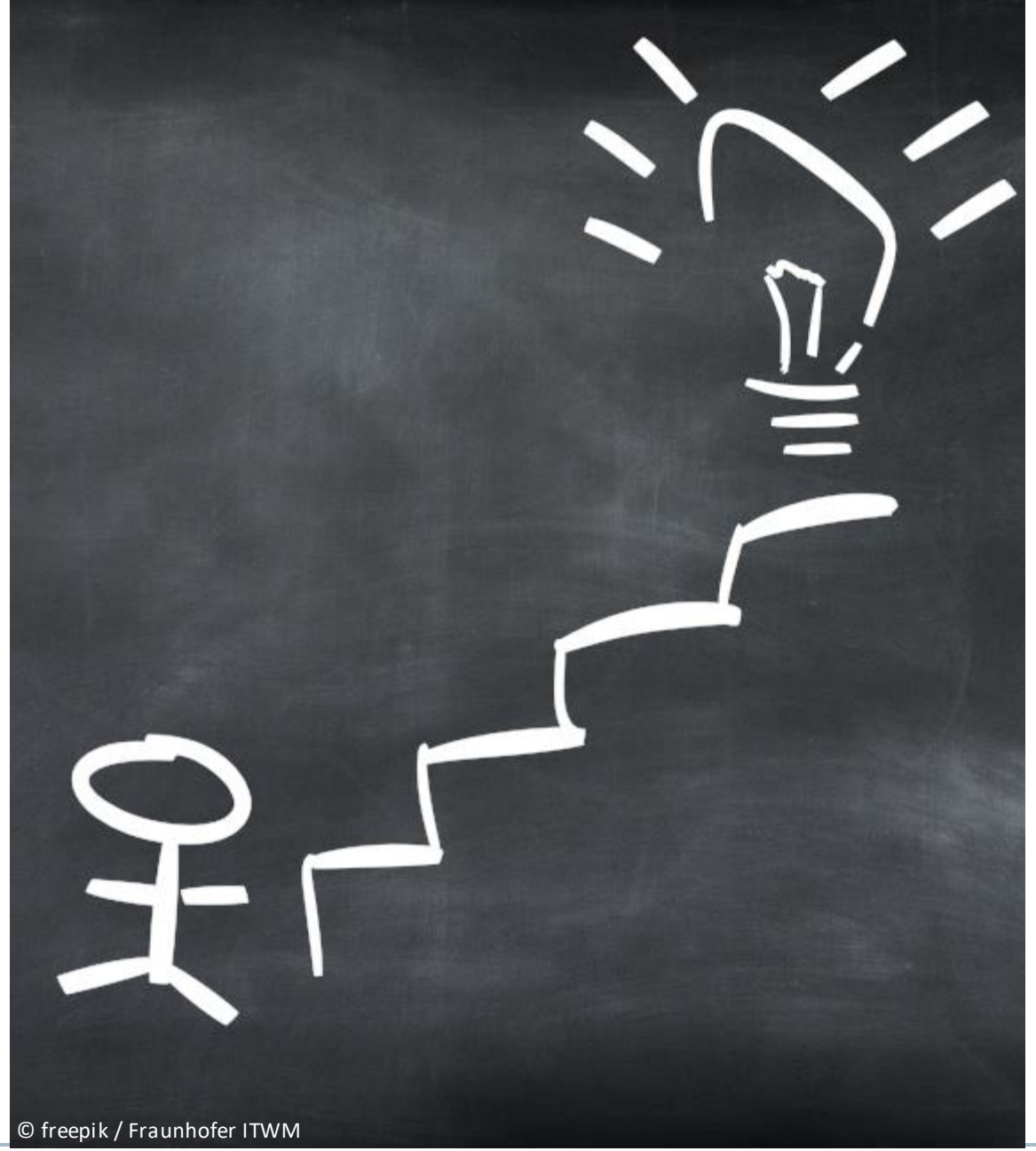
Maintenance and Useability

Demandings, We Have to Care

- **using graphic cards for calculations**
  - install drivers, the corresponding libraries and TensorFlow, PyTorch, …
  - easy GPU access
- **ML/DL algorithms**
  - libraries, programs and dependencies change fast
  - different algorithms need different programs/libraries
- **programs/tools often available as deb-packages**
  - but many HPC clusters are rpm-based
- **HPC clusters have very heterogeneous users**
  - need a lot of different tools and some dependencies may collide
  - users cannot be root



Maintenance and Useability

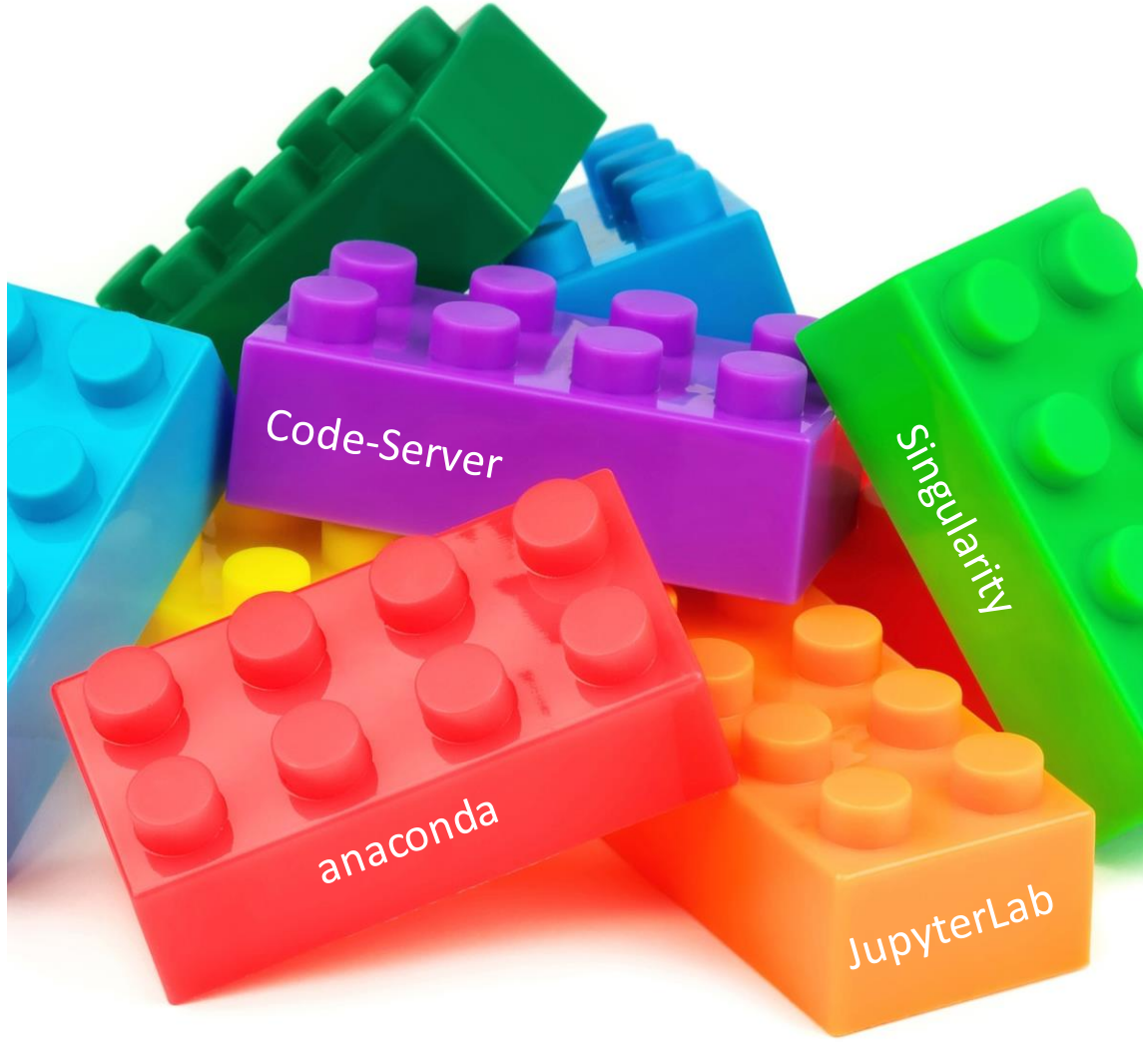
Easy for Users and Admins

easy to use (for users)

- access via web interface
- interactive development tools
  (e.g., Code-Server, TheiaIDE, JupyterLab)
- direct GPU access
- uncomplicated multi-node/-GPU usage

easy maintainable (for administrators)

- provide different libs for specific user groups
- use anaconda environments
- stick to singularity containers



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Maintenance and Usability

Portable Software Environments

singularity[4] containers

- provide the OS that ML/DL users need
- on the host: base OS and graphics drivers
  in the image: all other dependencies
- no root-privileges to start the container
- only needed folders mounted
  (e.g., `/home/USERNAME`, `/scratch/USERNAME`)
- create images from scratch (takes a few minutes)
  or transform an existing (clean) docker image

[4] https://www.sylabs.io/singularity

Maintenance and Useability

The Base Environment CARME Provides

Carme Singularity "Base Image"

- set of **basig software** (e.g. vim, nano, gcc, gdb, …)
- everything **ready to use IB** (using free drivers)
- **MPI** and **GPI** are installed per default (GPISpace installation ready)
- **miniconda** and/or **mambaforge**
- **Python 3.X**
- **Code-Server** and **JupyterLab**
- **headless** or **web-based applications** can run inside the container

Maintenance and Useability

Userspace Package Management

anaconda[5] based environments

- **open-source** (normal and enterprice versions)
- central **miniconda/mambaforge** installation inside the image (people can use it directly)
- users have the freedom to **install** (most) of the **libs and tools** they need (precise version control)
- all **PyTorch** and **TensorFlow** versions possible
- easily **share** and **save** your **environments**
- supporting **cooperation**

[5] https://www.anaconda.com

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Resource Utilization

Who Has Access to Which Resources?

Resource Utilization

Control the Resources You Have

- CARME utilizes the **scheduler resource limits** (fully respects non-carme jobs, cgroups, queues, etc.)
- **additional limits** can be defined **on top** of the scheduler limits (modify #(nodes), #(GPUs), running jobs, etc.)
- **integrates** smoothly **in** your **existing scheduler** (only a CARME feature flag is needed)
- everything **inside a job** runs inside an **isolated namespace** (programs cannot escape a job)
- inside a job you can **only** see the **GPUs associated with** the **job** (no access to information of other GPUs on the node)

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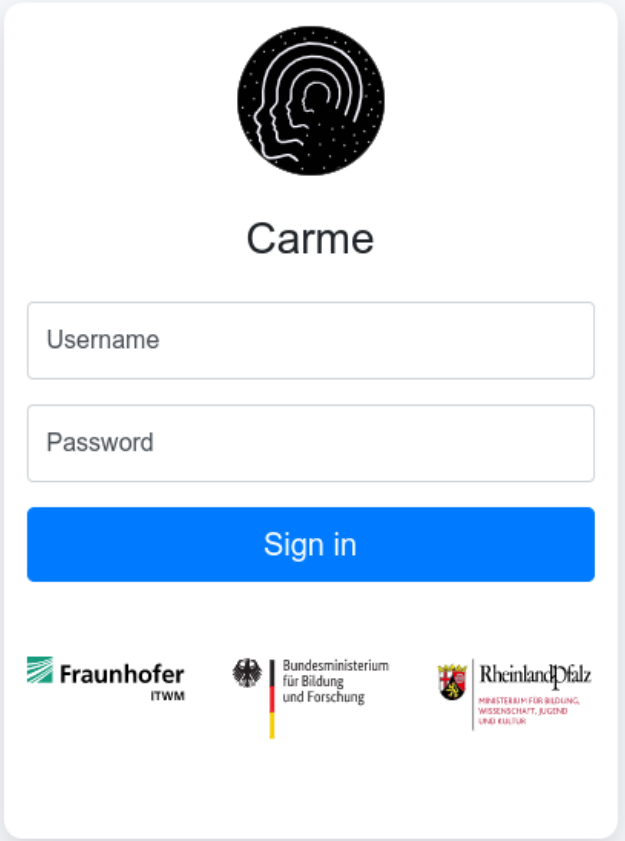
Interactive and Secure Multi-User Environments

ML/DL and Data Science Users Want Interactive Access

Interactive Usage

Secure and Simple Access

- access via **web interface**
- **no additional software** (like ssh or special tool)
- runs **behind your firewall**
- **secure autehntification** (e.g. via our LDAP) and additional **2FA**



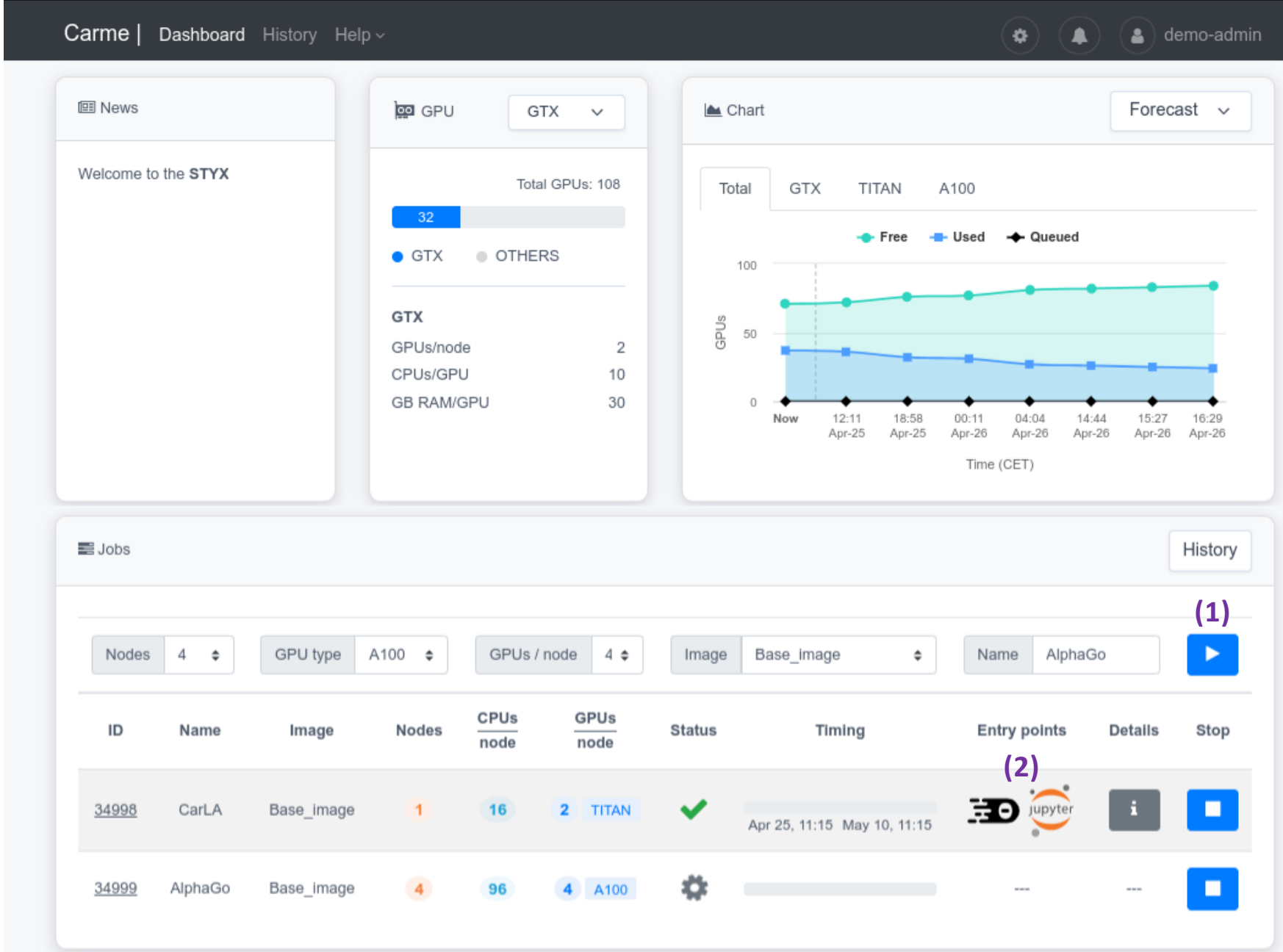
Interactive Usage

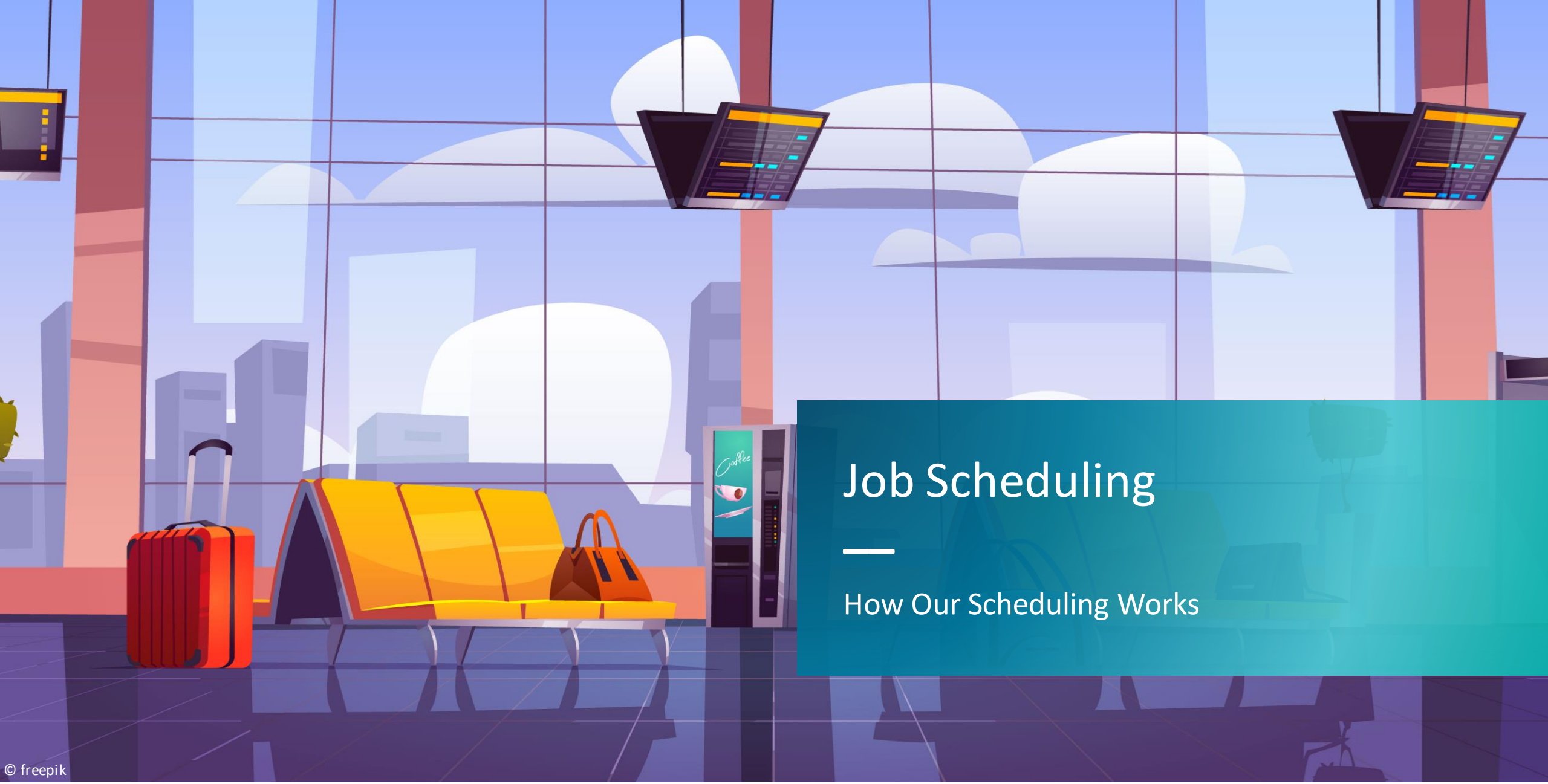
The User Control Center

two clicks to development

(1) start a job

(2) select your preferred development environment





Job Scheduling

How Our Scheduling Works

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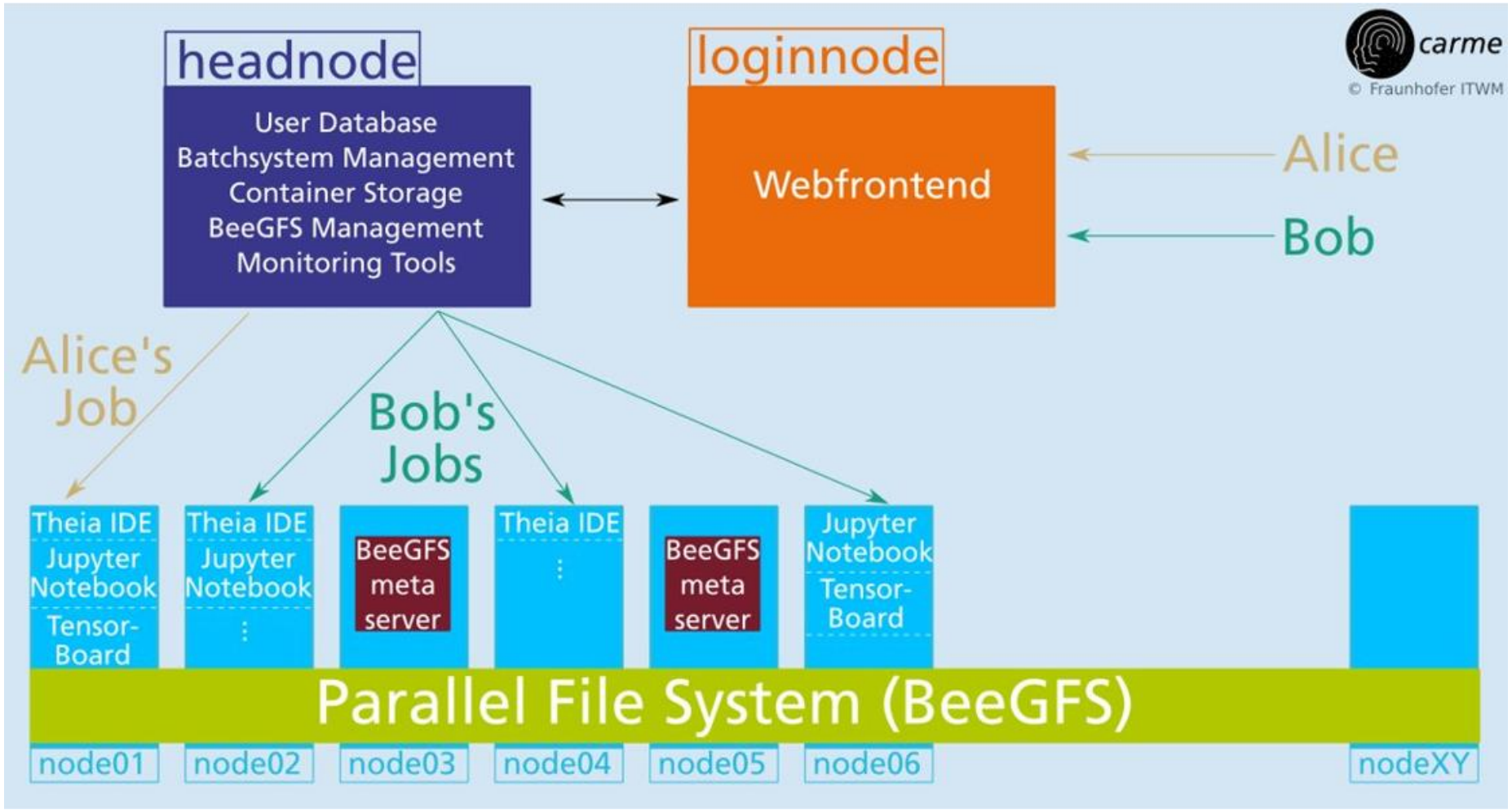
Job Submission Scheme



Job Submission Scheme

- user login to the web interface
- user submits a job
  - request for new job is sent from the frontend to our HPC-backend
  - secure connection via rpyc and special keys
- our HPC-backend
  - gets the job information from the frontend and our data base
  - finally submits the job to the scheduler as original user
- job start script is handed over to the scheduler
  - scheduler checks handed over information (resource limits, user accounts, availability, …)
  - respective CARME prolog scripts run (only if the job belongs to us)
- job starts on the requested node(s)
- user is informed in the frontend that the job has successfully started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Security Concept

Our Security Idea

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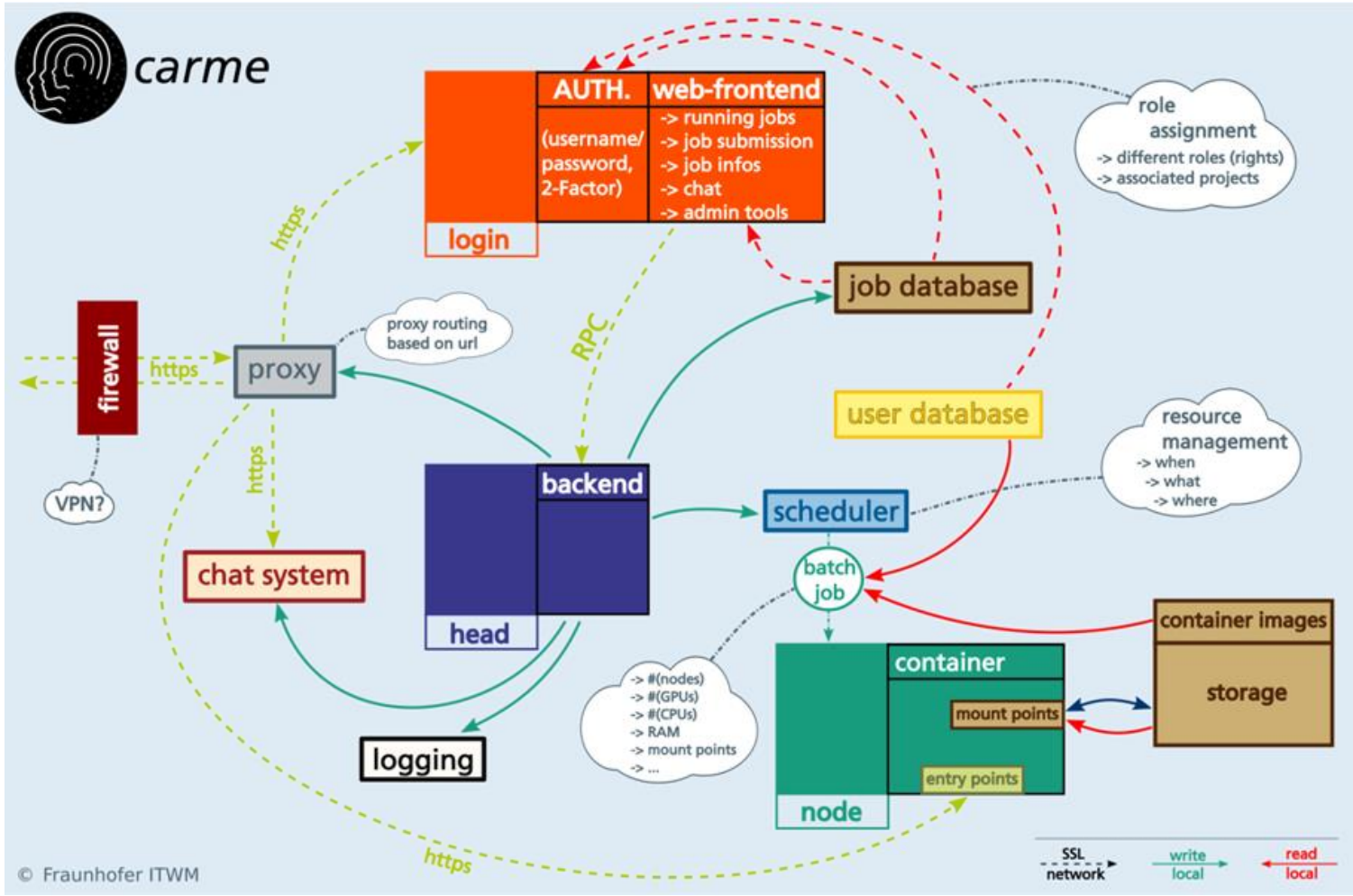
Security Concept

Our Security Idea



Security Concept
Our Security Idea

- everything can run **behind your firewall**
- we utilize our **own proxy** and **frontend**
  (both are separated singularity containers)
- **secure connection** between frontend and backend
- access **requires authentication** and **2FA**
- define what is **mounted inside** a **job**
- fully **integrate** the **limitations** of your **scheduler**
- **additional limitations** in CARME
  (e.g., resource limits, running jobs and singularity images)
- everything **inside** a **job** runs in its **own namespace**
  (no chance to use other resources)

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Our Key Features

What We Have for You

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Our Key Features
In a Nutshell

- **seamless integration** into existing HPC setups
- user-friendly **web-interface** providing **flexible** and **os-independent** access from anywhere in the world
- **interactive jobs** to develop directly **on the cluster** with your favorite **deep learning tools**
- fully **separated jobs** with **custom resources**
- **intuitive abstraction** of complex cluster topologies
- **distributed multi-node/multi-gpu jobs** with direct access to GPI, GPI-Space, MPI, Tarantella and Horovod
- user maintained and **containerized environments** using **singularity** and **anaconda**

Our Key Features
In More Detail

- **seamless integration with available HPC tools**
  - job scheduling via SLURM
  - native LDAP support for user authentication
  - integrate existing distributed file systems like BeeGFS
- **access via web-interface**
  - OS independent (only web browser needed)
  - full user information (running jobs, cluster usage, news, messages)
  - start / stop jobs within the web-interface
- **interactive jobs**
  - flexible access to GPUs
  - access via web driven GUIs (TheiaIDE, JupyterLab)
- **distributed multi-node and/or multi-gpu jobs**
  - easy and intuitive job scheduling
  - directly use GPI, GPI-Space, MPI, Tarantella and Horovod within the jobs
- **full control about accounting and resource management**
  - job scheduling according to user specific roles
  - compute resources are user exclusive
- **user maintained, containerized environments**
  - singularity containers (runs as normal user, GPU, Ethernet and Infiband support)
  - anaconda environments (easy updates, project/user specific environments)
  - built-in matching between GPU driver and ML/DL tools

In Summary

What You get

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In Summary
What You Get

- **interactive development** access to HPC systems
  (keep your workflow with Jupyter Notebooks or full IDE)
- **easy** way to **submit** and **get jobs** on big clusters
  (simpified submission mask, no need to write batch scripts)
- guarantee that **only you** have **access** to **your resources**
  (no need to worry about other users)
- utilize **containers** and **conda environments** to get software
  (keep track with quickly chaning and diverse tool requirements)
- **access** your **HPC cluster** via a **web browser**
  (no need to install special or additional software)

In Summary
What You Get

The Administrator Side

- **easily integrate** CARME in your scheduler set up
  (a feature flag and our prolog/epilog scripts is all you need)
- **control** which **folders** user have access to
  (you can decide per image which folders are mounted or not)
- **provide** the **basic software** that ML/DL users need to do their work
  (keep the host installation small and clean)
- manage our **data base via** a simple **web interface**
- **simplify** the **support** for AI and Data Science users
- get **logs** and **error outputs** for CARME scripts and services

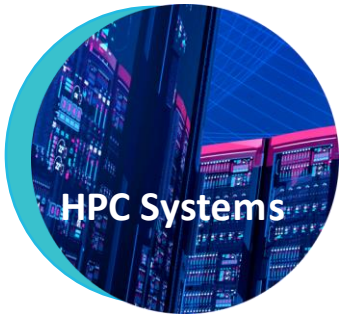
In Summary
What You Get

- CARME was always and will be **developed in Germany**
  (following Fraunhofer standards and respecting data privacy)
- **license** that allows **commercial use**
- giving users a tool to **easily utilize GPU resources**
  (be sure that your investments in hardware pay off)
- **increase** the **productivitiy** of both your AI developers
  and researchers and your system administrators

Bringing AI Development / Education and HPC Systems Together

The CARME Way

Carme – an open-source framework to manage resources for multiple users running interactive jobs on an HPC Clusters



AI and Data Science Tools

- Code-Server
- JupyterLab
- Anaconda Environments (mambaforge/miniconda)

HPC Tools

- SLURM
- LDAP
- Singularity
- BeeGFS
- Zabbix

Open-Source Tools

enables

AI Development

- develop code
- schedule & track experiments
- debug model performance

AI Education

- hands-on sessions
- slides & homework
- easy Q&A

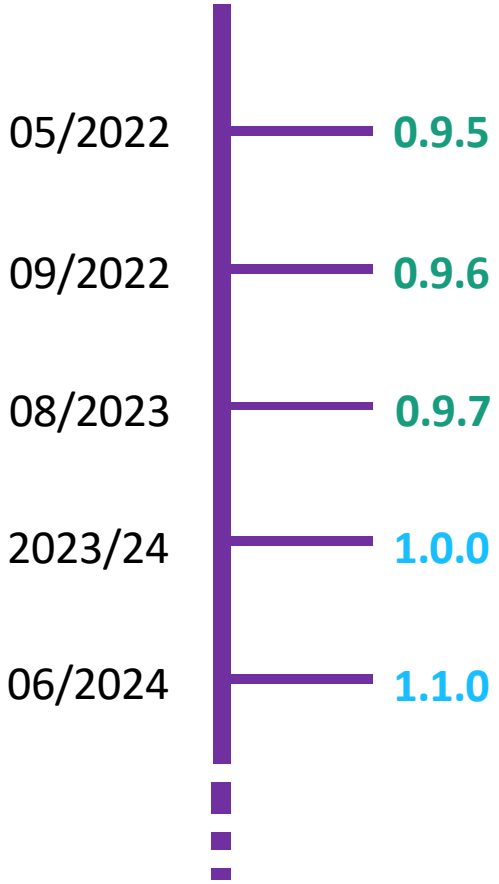
https://carmeteam.github.io/Carme/

Roadmap

Where to Go

Roadmap
Where to Go

- available **on GitHub** (https://carmeteam.github.io/Carme/)
- **installation** on **demand** (including support)
- release cycle: **6–9 months**
- latest release: **r0.9.7** (08/2023)
- next release: **r1.0.0** (2023/24)



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