Beyond Data Handling: Edge computing micro-Datacenters

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EDHPC 2025

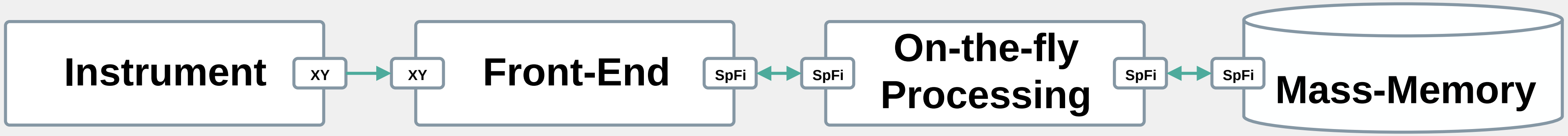
Outline

- Data Handling
- Beyond Data Handling
- The Edge Datacenter

Data Handling (DH)

DH driven by use cases for EO/Remote Sensing/Science

Real-time pre-process



Real-time post-process

Olivier Mourra, David Steenari, Felix Siegle, ADHA, an Agile Platform Enhancing New Satellite On-Board Data Processing Systems, EDHPC 2023

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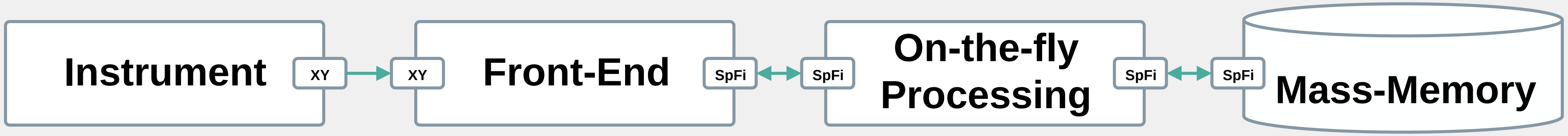

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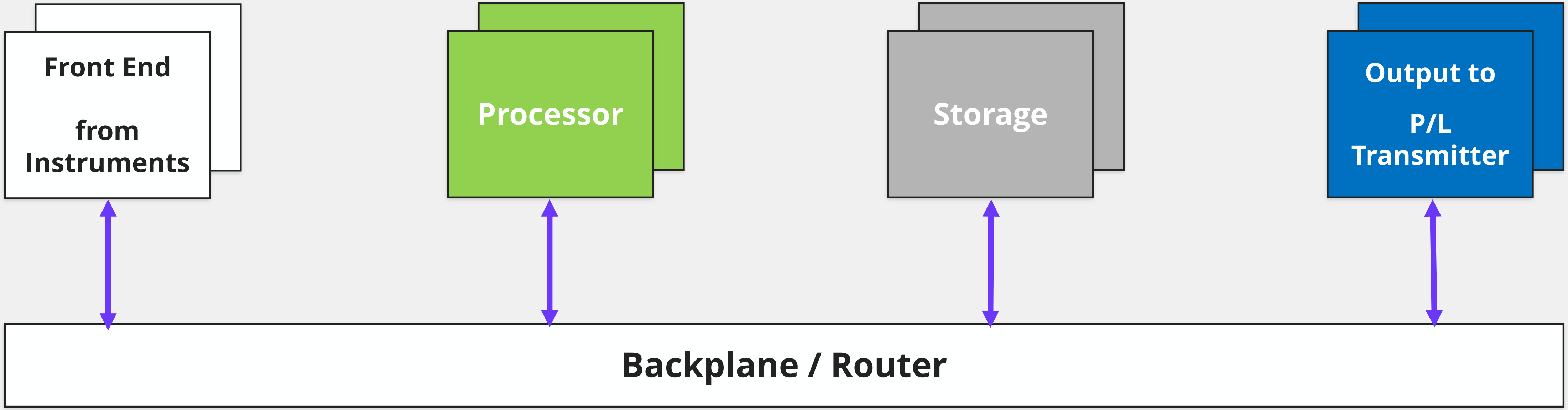
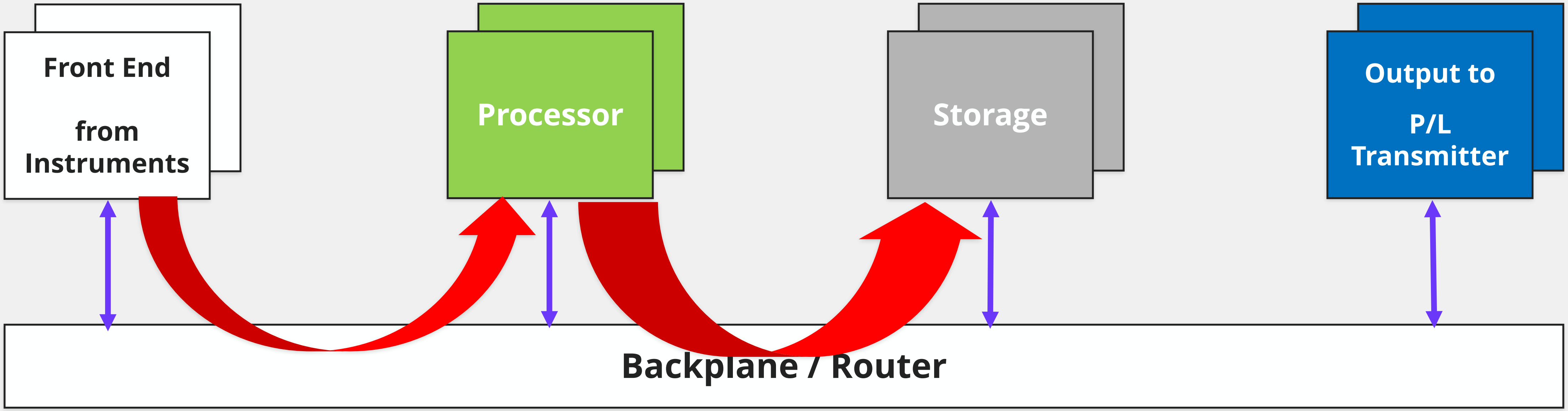


Potential bottlenecks on pre-processing



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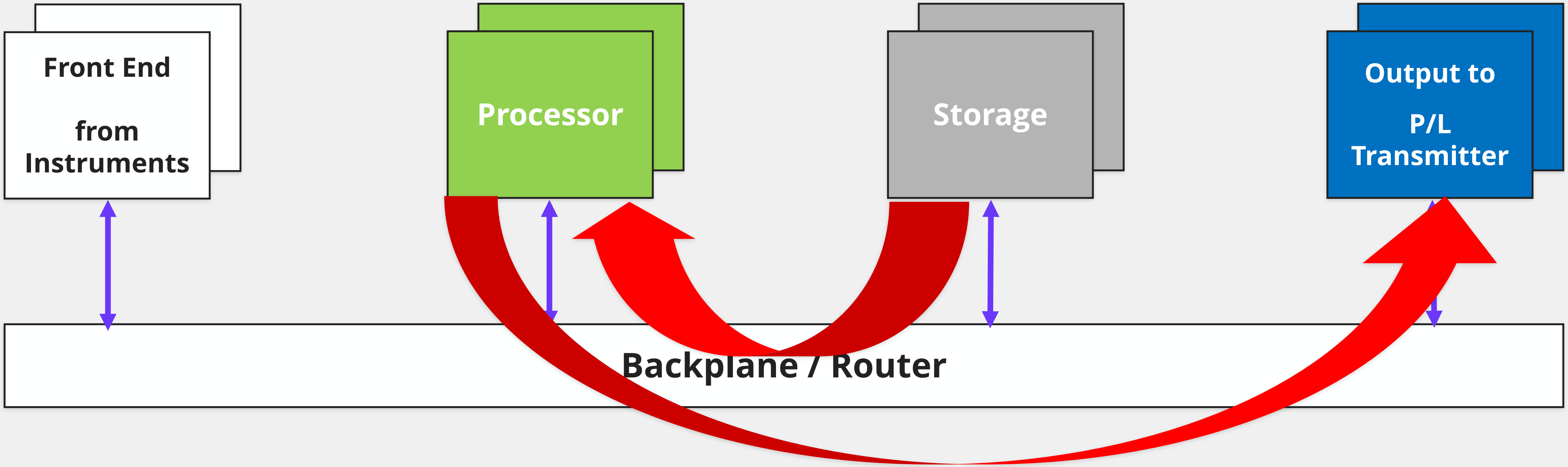

DH architecture challenges

- Potential bottlenecks
- Hard to scale
  - Adding more cards is limited
  - Adding more cards may not eliminate bottlenecks
  - Instead, continuously seeking new technology for components and interconnect
- Inflexible connectivity
  - Not every card fits in every slot
- Limited reconfigurability
  - Designed to perform pre-planned use cases
- Many types of cards / slots / sockets
  - Limited economically

But there is hope!

- Similar issues were encountered in terrestrial edge computing
- Solution:
  - Edge datacenters
  - Inspired by core / large datacenters (“hyper-scalers”)

- Similar evolution can be applied to space computing

Beyond Data Handling

Trends in Space computing (it's the economy, …)

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200 Kg → 2 Ton

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New Space: Commercialization, **cost** pressures	Markets (gov't) shift from buying satellites to services Commrc'l operators sell data services at low cost & hi QoS Need hi-end datacenters incl. terrestrial SW stacks and apps Low-cost datacenters need mass production Mass production requires a standard product

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Technology & security	Smart FDIR enables COTS HW & SW Strong (AI enabled) security enables Terrestrial SW and mitigates adversarial cyber attacks

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Outcome of trend analysis

- Need compute architecture that
  - Addresses the exploding demand
  - Enables distributed, SW-defined, virtualized compute
  - Flexible & scalable
  - Enables lower cost (mass produced) solutions
  - Embraces terrestrial fast-paced progress (AI, SW)

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- Such an architecture already exists: *The Edge Datacenters*
  - Successfully applied and employed on Earth

Disaggregated, network-centric edge datacenter

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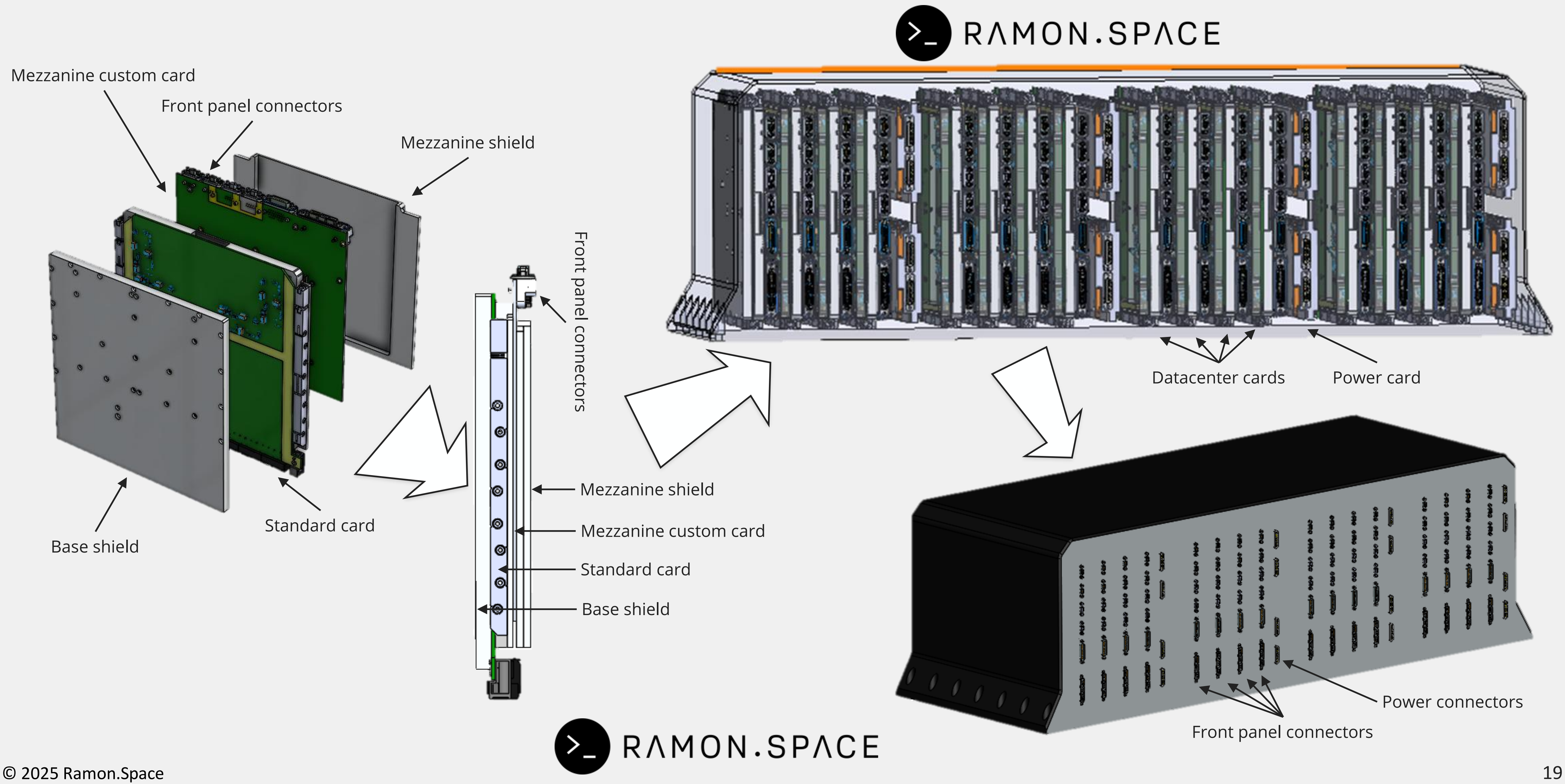
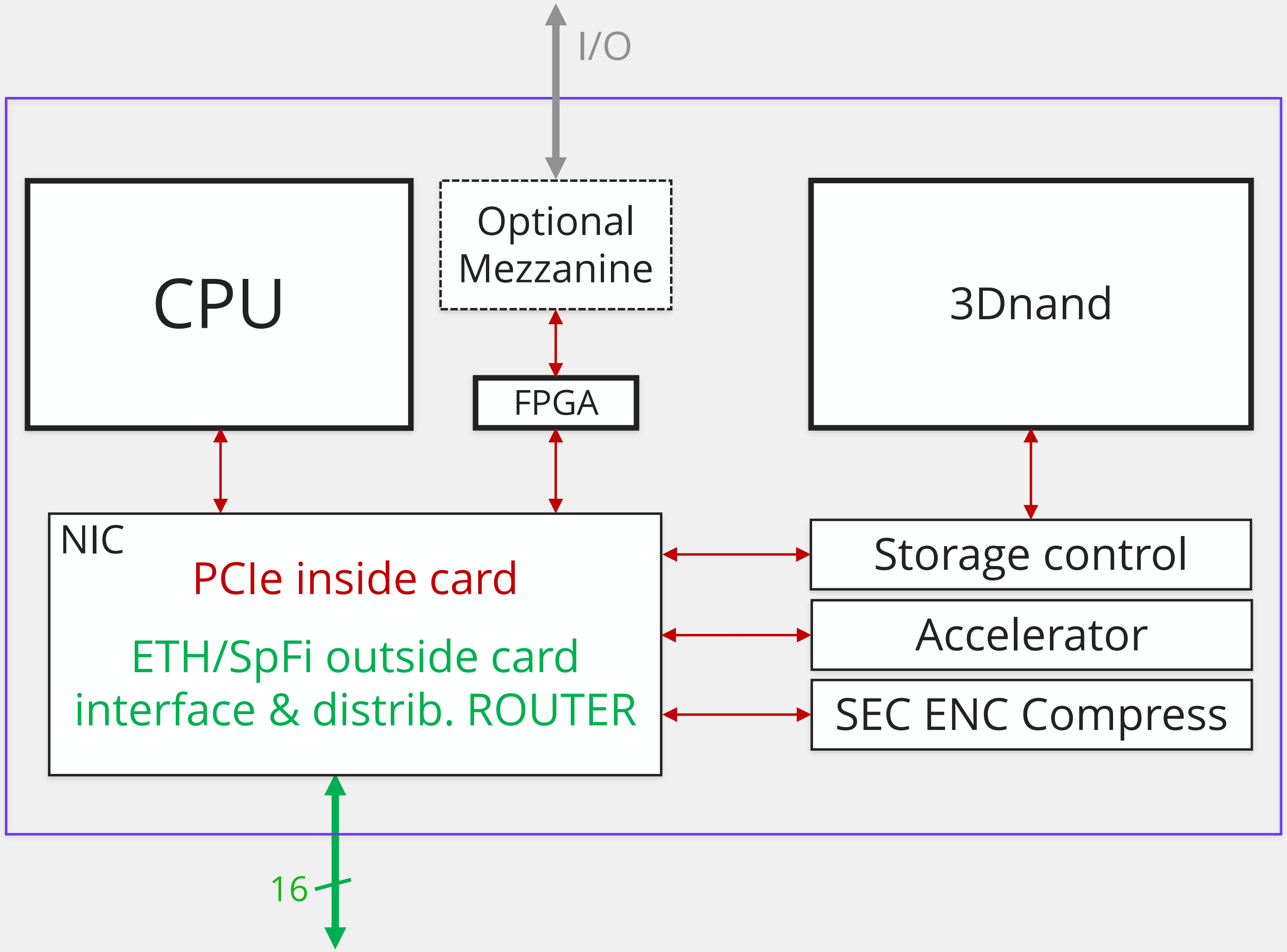
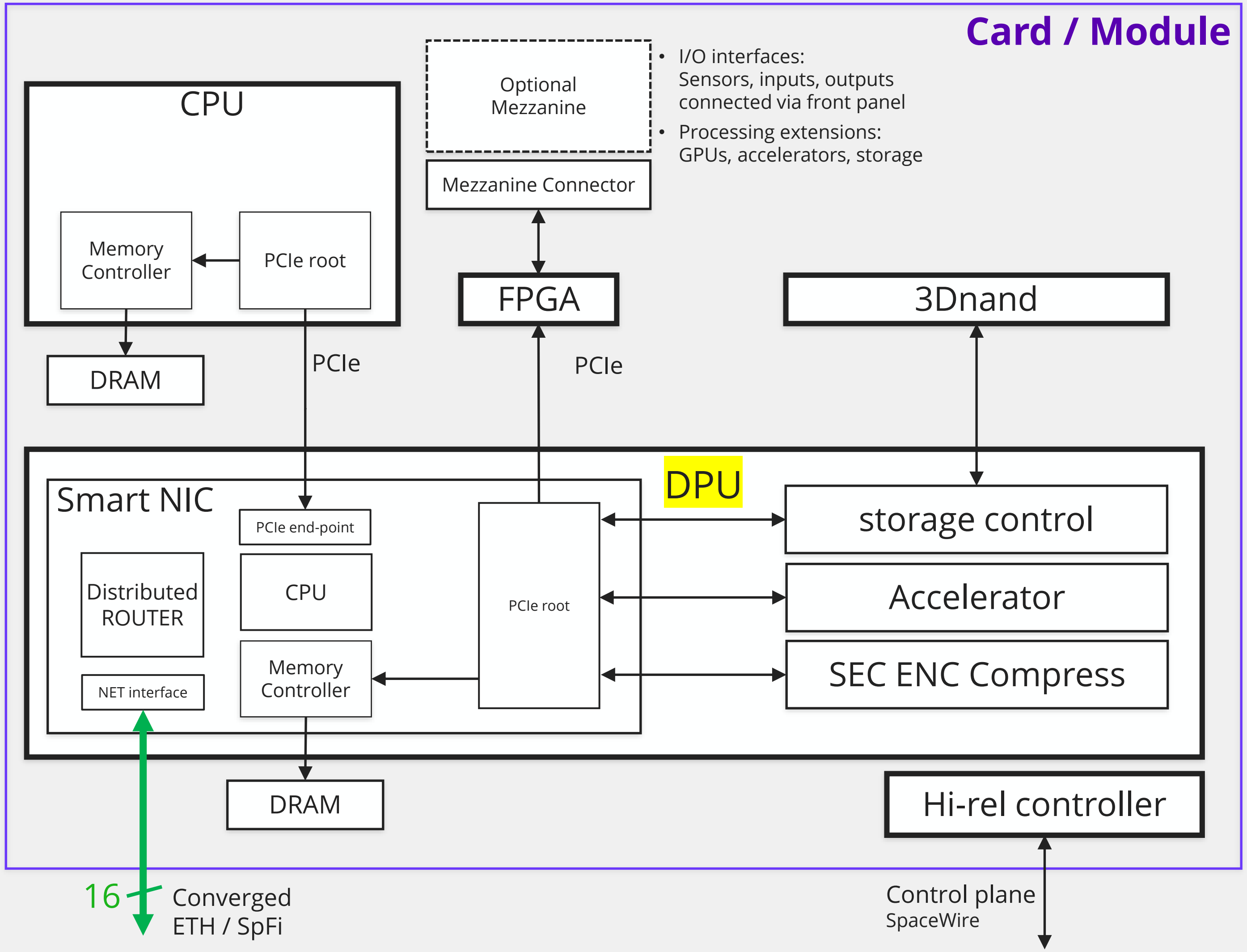


The standard datacenter card



- Each standard card contains everything
- SDN by NIC
- RDMA
(direct card-to-card access)

Deeper dive into the standard card: DPU

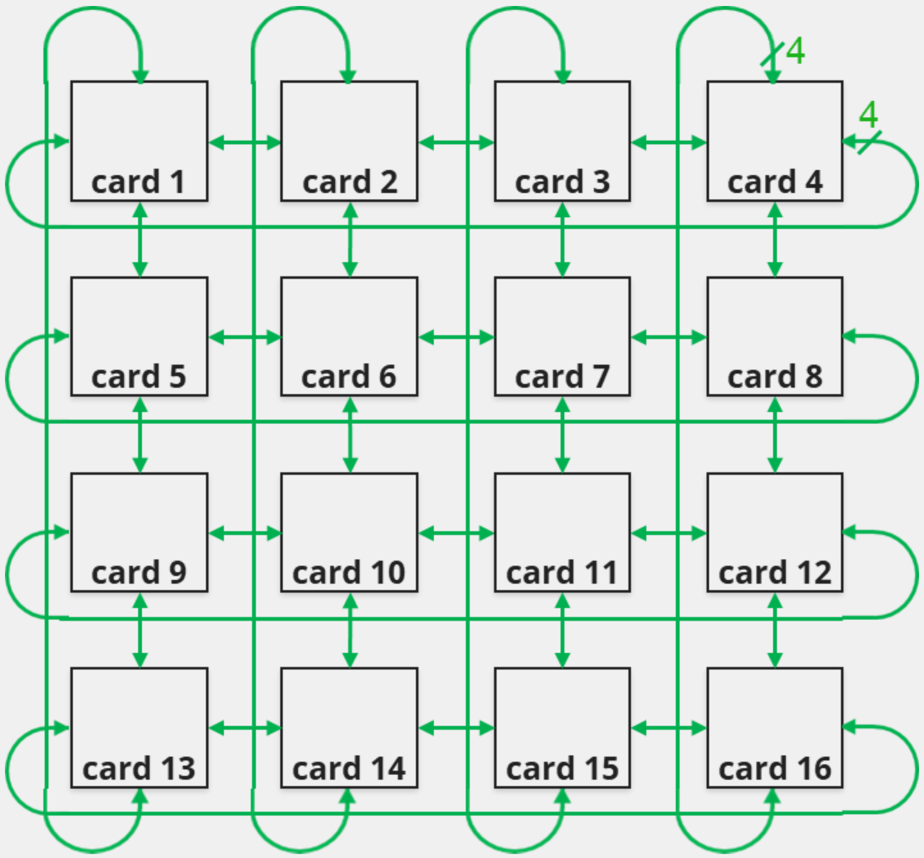


DPU combines:

- Interface to CPU
- Smart-NIC
- PCIe root
- SSD controller
- GPU/accelerator
- Interface to FPGA

Any device on the card can access other devices either on same card or, thru ETH/SpFi, on other cards. Including remote access to memories.

The Physical Network: 4—connected 2D torus



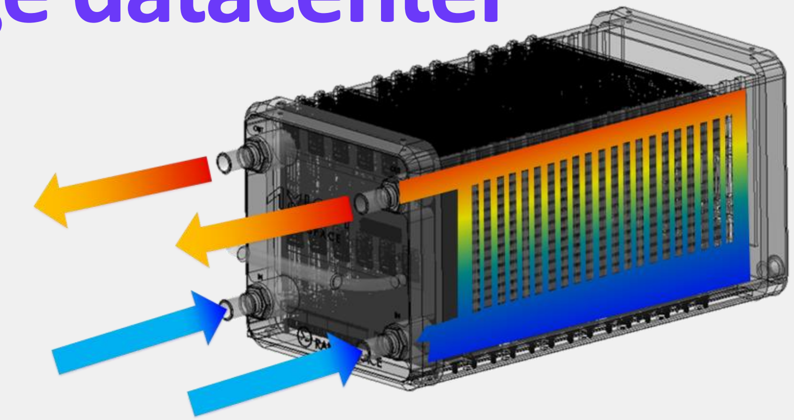
- SDN can implement any topology on top of the physical network
- Extensive redundancy
- Massive parallelism eliminates bottlenecks

Summary

On-board DH → On-board edge datacenter

- Natural evolution of Space computing
- Follows wisdom of terrestrial core & edge computing
- Execution of users' applications
- Mass production → low cost for constellations
- Lower cost & risk, shorter schedule for integrators and users
- Standard architecture → can use standard SW
- Scalable in orbit

Challenges en route to on-board edge datacenter



- Large, high power thermo-mechanical design
- Security
- HiRel controllers, networks, health management & FDIR
- COTS adoption, protocol converters
- New design of a smart network
- Ruggedized Linux & other SW

Thank You

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