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A Modular and Flexible Hyperconnected Assembly Factory Design

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Chapter 1

Introduction of Hyperconnected Assembly Factories
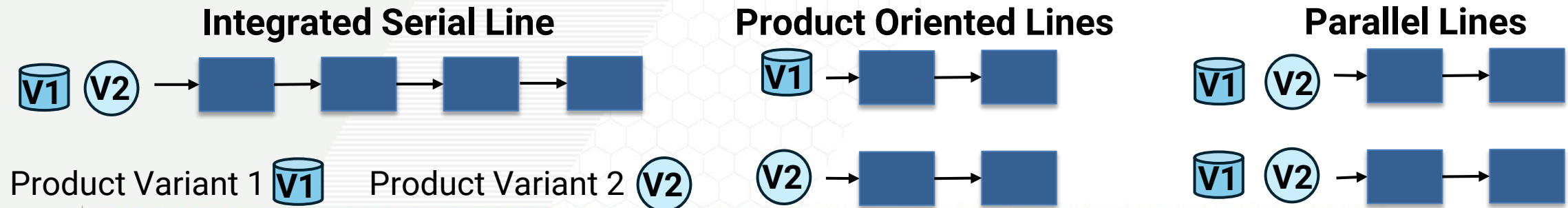
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Introduction: Challenges in Assembly Industry

- **Scalability**
  - maintain good performances (e.g., cost per product, product travel distance in facilities, waiting time) when demand increases and decreases

- **Product Variety**
  - respond to different product variants quickly and cheaply

- **Reconfigurability**
  - add, remove, replace, or redeploy equipment swiftly and inexpensively

- **Environmental Sustainability**
  - include reducing resource waste and decreasing carbon footprint in product transportation

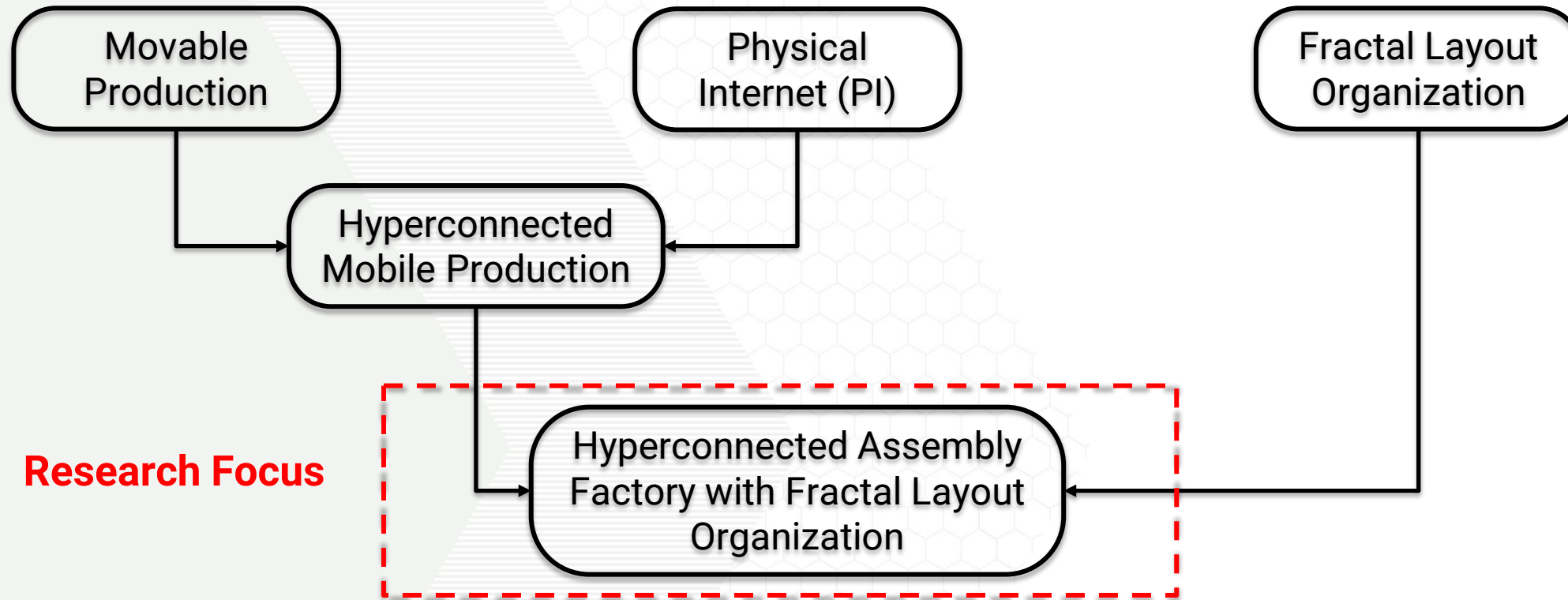Georgia Tech /// CREATING THE NEXT®

Introduction: Assembly and Layout Organization

- **Assembly**
  - a type of manufacturing process that combines components into final products
- **Task**
  - a subdivision of assembly work of products
  - typically, assembly tasks are allocated to a set of workstations
  - workstations are linked by specific product flows
- **Takt Time**
  - the time interval between two consecutive launches of production
  - synchronizes product and material flows among workstations
- **Layout Organization**
  - the pattern of how stations are organized, and how products and materials flow among stations
  - impacts task-station assignment, product/material flows, production schedule, etc.

Examples for Layout Organizations

Integrated Serial Line   **Product Oriented Lines**   **Parallel Lines**

Product Variant 1 V1   Product Variant 2 V2

Related Literature

Hyperconnected Assembly Factory with Fractal Layout Organization:
- **Movable production** ([1],[4]) realized by flexible production systems ([2],[3],[9],[10],[12],[16])
- **Physical Internet** ([5],[6],[7],[8],[14]) promotes sharing equipment in the open and certified assembly factory network
- **Fractal Layout Organization** ([6],[13],[15],[17],[18],[19]), **or "mini-factories within factory":** each modular production center (fractal center) can perform almost all processes for all product variants by itself

A Use Case

- large and heavy products with variants having similar production requirements.
  - similarity measured by process types required (bolting, screwing, welding, etc.), precedence diagrams, and task durations.

- transportation and storage of materials require much less time and cost than in-process or finished products.

- customers are geographically dispersed, and demand fluctuates over time

- "plug and produce" core equipment.
  - core equipment is defined by its necessity and cost.

- all business participants are PI-certified

- Example: wind turbines, prefabricated construction. ([1], [4])
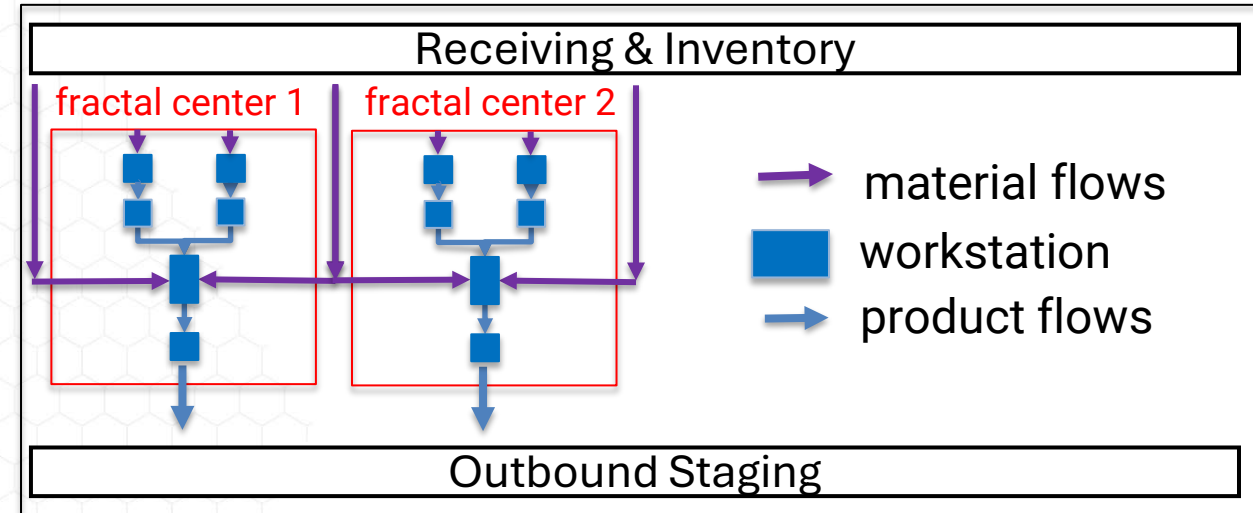
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Example Layout Organization In A Hyperconnected Assembly Factory

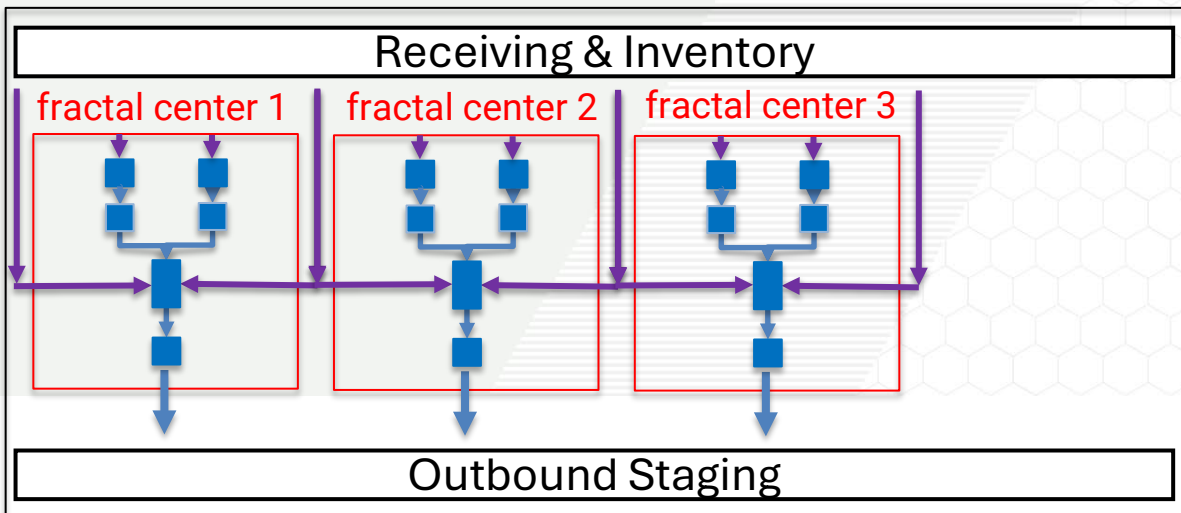each fractal center has independent product flows with other fractal centers

Factory Throughput: x units/day

- *factory throughput: x / $2x$ / $3x$ / $4x$ units/day (dynamic)*
- *fractal center throughput : x units/day (fixed)*
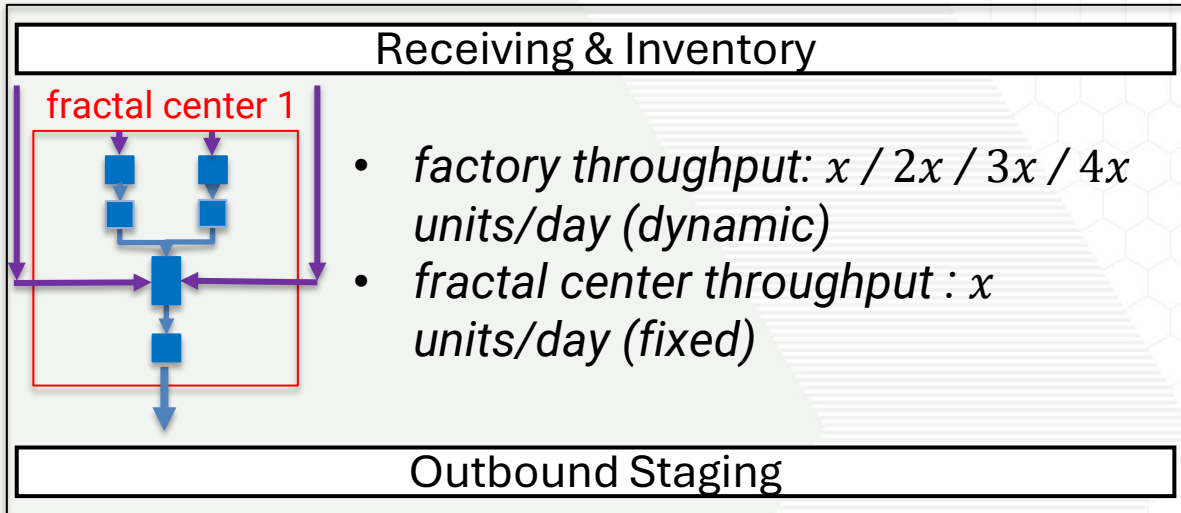
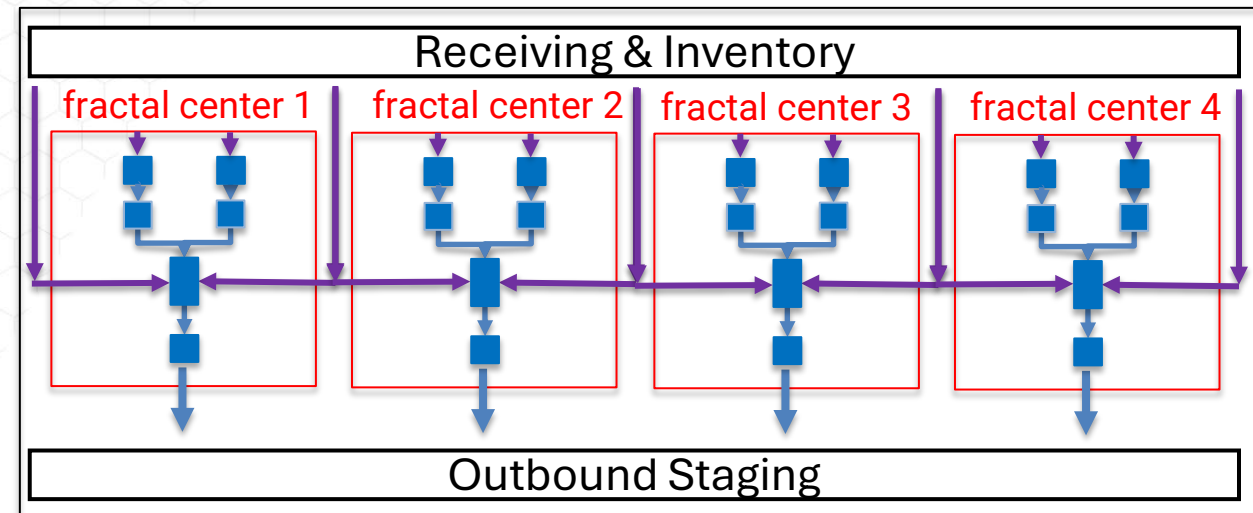**Factory Throughput: $2x$ units/day**
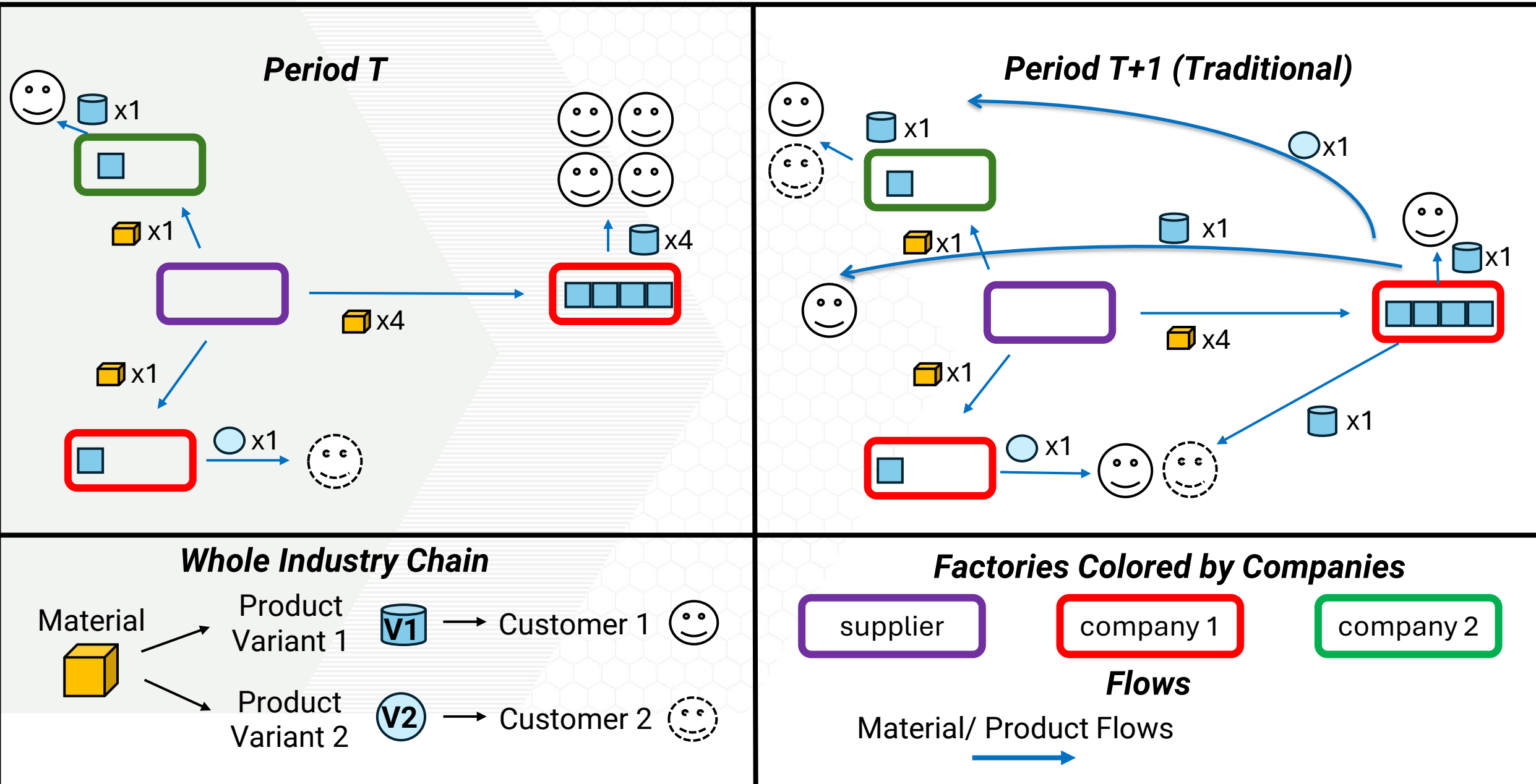
- → material flows
- ■ workstation
- → product flows

Factory Throughput: $3x$ units/day

Factory Throughput: $4x$ units/day

Example for FC Sharing in the PI Assembly Factory Network (1/2)

Period T

Period T+1 (Traditional)

Whole Industry Chain

Material → Product Variant 1 — V1 → Customer 1 ☺

Material → Product Variant 2 — V2 → Customer 2

Factories Colored by Companies

supplier | company 1 | company 2

Flows

Material/ Product Flows →

Example for FC Sharing in the PI Assembly Factory Network (2/2)

trade-off between equipment sharing versus product transportation

Period T

Period T+1 (Sharing fractal centers)

Flows

Material/ Product Flows

Fractal Center Flows

Fractal Centers

Factories Colored by Companies

supplier

company 1

company 2

vertical collaboration

horizontal collaboration
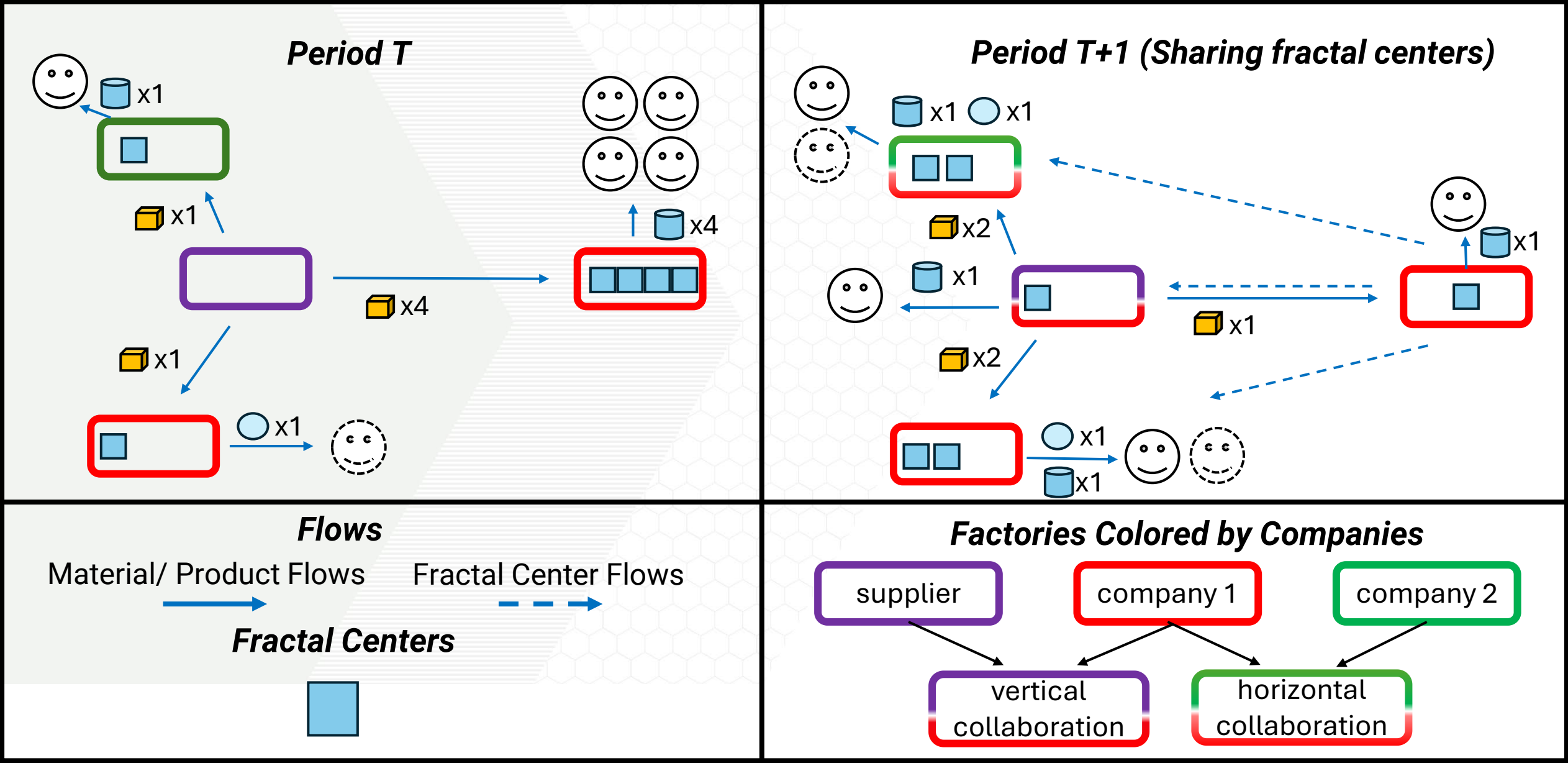
Conclusion and Future Work

- **Scalability** achieved by de/activation of fractal centers
- **Product Variety** and **reconfigurability** realized by flexible production system.
- **Environmental sustainability** enhanced by minimizing final product delivery distance and carbon footage in the overall supply chain
- Still, the proposed hyperconnected assembly factory design may incur **duplicated equipment** and bring more **risks** during FC sharing.

Research avenues remain:

1. **multi-standard fractal centers**
   - FCs may have different workstations or the same number of workstations but different product flows
   - every FC could still produce any variant of product, but is more efficient for a subset of products.
   - e.g., in automotive factories, some FCs more suitable for sedans, whereas others suitable for vans and trucks
2. **rigorous comparison** with other assembly factory designs is also essential.
   - fixed factories versus movable factories, shareable equipment versus unshareable equipment
   - other layout organizations
3. **optimization, AI and other decision-making models** are in need for coordinating and scheduling FC sharing
4. **pilot tests**

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Chapter 1

Introduction of Hyperconnected Assembly Factories

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Thank you!

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