Evolution of Logistic Center Conceptualization
Meeting the Physical Internet Challenges

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of Warehouse Systems

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Macroscopic Positioning

CLAIM

The way **physical objects** are
moved, handled, stored, realized, supplied and used
throughout the world is **not sustainable**
economically, environmentally and socially

GOAL

Enabling the global **sustainability**
of physical object movement, handling, storage,
realization, supply and usage

VISION

Evolving towards a worldwide **Physical Internet**

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Supporting the claim

CLAIM

The way **physical objects** are
moved, handled, stored, realized, supplied and used
throughout the world is **not sustainable**
economically, environmentally and socially

Symptoms that our current way is not sustainable
Leading Us Toward Hitting the Wall Real Hard

- **We are shipping air and packaging**
  - Trucks and containers are often half empty at departure, with a large chunk of the non-emptyness being filled by packaging
- **Empty travel is the norm rather than the exception**
  - Vehicles and containers often return empty, or travel extra routes to find return shipments
  - Vehicles leaving loaded get emptier and emptier as their route unfolds from delivery point to delivery point
- **Truckers have become the modern cowboys**
  - So many are always on the road, so often away form home for long durations
  - Their family and social life is precarious, as well as their personal health

Symptoms that our current way is not sustainable
Leading Us Toward Hitting the Wall Real Hard

- **Products mostly sit idle, stored where unneeded, yet so often unavailable fast where needed**
  - Manufacturers, distributors, retailers and users are all storing products, often in vast quantities through their networks of warehouses and distribution centers, yet service levels and response times to local users are constraining and unreliable
- **So many products are never sold, never used**
  - A significant portion of consumer products that are made never reach the right market on time, ending up unsold and unused while there would have been taken elsewhere
- **Products do not reach those who need them the most**
  - This is specially true in less developed countries and disaster-crisis zones

Symptoms that our current way is not sustainable
Leading Us Toward Hitting the Wall Real Hard

- **Products unnecessarily move, crisscrossing the world**
  - Products commonly travel thousands of miles-kilometers which could have been avoided by making or assembling it much nearer to point of use
- **Getting products in and out of cities is a nightmare**
  - Most cities are not designed and equipped for easing freight transportation, handling and storage, making the feeding of businesses and users in cities a nightmare
- **Fast & reliable multimodal transport is a dream or a joke**
  - Synchronization is so poor, interfaces so badly designed, that multimodal routes are most often cost inefficient and risky

Symptoms that our current way is not sustainable
Leading Us Toward Hitting the Wall Real Hard

- **Production and storage facilities are poorly used**
  - Most businesses invest in storage and/or production facilities which are lowly used most of the times, or yet badly used, dealing with products which would better be dealt elsewhere, forcing a lot of unnecessary travel
- **Networks are neither secure nor robust**
  - There is extreme concentration of operations in a limited number of centralized production and distribution facilities, with travel along a narrow set of high-traffic routes
  - This makes the logistic networks and supply chains of so many businesses, unsecure in face of robbery and terrorism acts, and not robust in face of natural disasters and demand crises

Symptoms that our current way is not sustainable
Leading Us Toward Hitting the Wall Real Hard

- **Smart technology and automation are hard to justify**
  - Vehicles, handling systems and operational facilities have to deal with so many types of materials, shapes and unit loads, with each player independently and locally deciding on his piece of the pie
  - This makes it very hard to justify smart connective technologies such as RFID, systemic handling and transport automation, as well as smart collaborative piloting software
- **Innovation is strangled**
  - Innovation is bottlenecked, notably by lack of generic standards and protocols, transparency, modularity and systemic open infrastructure
  - This makes breakthrough innovation so tough, justifying a focus on marginal epsilon innovation

Readdressing the Goal

GOAL

Enabling the global **sustainability**
of physical object movement, handling, storage,
realization, supply and usage

Expliciting the Overall Goal

Economic goal

Unlock highly significant gains
in global logistic, production, transportation
and business productivity

Environmental goal

Reduce by an order of magnitude
global energy consumption and greenhouse gas emission associated
with logistic, production and transportation

Societal goal

Increase the quality of life
of both the logistic, production and transportation workers
and the overall population by making valuable objects
much more accessible across the world

Restating the Overall Goal

Enabling the global sustainability
of bringing to users from around the world
the physical objects they need and value,
through a triple synergistic gain
in terms of economy, environment and society

The Inspiration for the Vision

VISION

Evolving towards a worldwide **Physical Internet**

The Digital Internet
Building Upon and Expanding Beyond the Information Highway Metaphor

- When the digital world was looking for a way to conceptualize how it should transform itself, it relied on a physically inspired metaphor: building the information highway
- Well, they have done that and went farther, reshaping completely the way digital computing and communication is now performed
- They have invented the Internet, leading the way to the World-Wide Web
- They have enabled the building of an open distributed networked infrastructure that is currently revolutionizing so many facets of our societal and economic reality

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The Essence of the Digital Internet

The Digital Internet is about
the interconnection between networks
in a way transparent for the user,
so allowing the transmission of
formatted data packets
in a standard way
permitting them to transit through
heterogeneous equipment
respecting the TCP/IP protocol

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Toward a Physical Internet

Digital Internet as a Metaphor for the Physical World

Even though there are fundamental differences between the physical world and the information world, the Physical Internet initiative aims to exploit the Internet metaphor so as to propose a vision for a sustainable and progressively deployable breakthrough solution to global problems associated with the way we move, handle, store, realize, supply and use physical objects all around the world

Exposing 12 Key Features of the Physical Internet Vision

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Evolving towards a worldwide **Physical Internet**

Digital Internet:
From information to packets

- The digital Internet does not transmit information, it transmits packets embedding information
- The information packets are designed for ease of use in the Virtual Internet
- The information within the packet is encapsulated and is not dealt with explicitly by the Internet
- The packet header contains all information required for identifying the packet and routing it corrrectly from source to destination
- A packet is constructed for a specific transmission and it is dismantled once it has reached its destination

Digital Internet:
From information to packets

- The Digital Internet is based on a protocol structuring data packets independently from equipment
- In this way, data packets can be processed by different systems and through various networks
  - Modems, copper wires, fiber optic wires, routers, etc.
  - Local area networks, wide area networks, etc.
  - Intranet, Extranet, Internet, Virtual Private Network, etc.

Physical Internet
1. From merchandise to containers

- The Physical Internet should not transmit materials, it should transmit containers

- These containers should be conceived as logistic modules standardized so as to be:
  - Easily transported through various transport means;
  - Easily handled by the hubs having to transit or stock them

  According to the offered service:
  - Local intracity door-to-door level
  - Intercity and intercontinental levels

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Physical Internet
1. From merchandise to containers

- The Physical Internet should not transmit materials, it should transmit containers
- The containers should be designed for ease of use in the Physical Internet
- The merchandise within a container is unitized as content of the container, and is not dealt with explicitly by the Physical Internet
- The containers have smart tags, and sensors if necessary, to allow their proper identification and routing through the Physical Internet
- The container should have minimal footprint when off service, even allowing its easy dismantling and construction upon request

Physical Internet Containers: Physical and functional characteristics

- They should be functionally standardized worldwide, as is the current cargo container
- They should be easy to handle, store, transport, interlock, load, unload, construct and dismantle
- They should have modular dimensions, including the cargo-size containers down to smaller size containers
  - Two 1X1X1 containers should interlock to become a 2X1X1
  - Two interlocked 2X1X1 become a 2X2X1, and so on
  - The resulting composite container should be functionally equivalent to a native container, here a 2X1X1 or a 2X2X2 container
- They may come in various structural grades, adapting to the needs, with their smart tags aware of their structural limits
- They should be sealable for security purposes
- They may have conditioning capabilities, such as temperature control

Physical Internet
1. From merchandise to containers

The definition of containers
is a key element
for defining the interoperability necessary
to the adequate functioning of the Physical Internet

In particular, the containers
can make the network indifferent
to the various contents
and to the modes
of handling, storage and transportation

Physical Internet
2. Universal Interconnectivity

High-performance logistic centers and systems,
making it fast, cheap, easy and reliable
to interconnect containers through modes and routes,
with an overarching aim toward universal interconnectivity

Physical Internet
2. Universal Interconnectivity

- The nodes of the Physical Internet will concurrently be routing and accumulation sites within the networks, as well as interfaces with the exterior, such as inbound-outbound ports
- As currently conceived, sorting, storage and handling physical objects are brakes to interconnection
  - Be it in train sorting yards or in crossdocking platforms
- However there exist exceptions:
  - Such as the recently implemented container port terminals
- There is a need to generalize unloading, orientation, storage and loading operations, widely applying them the modular containers of the Physical Internet in a smart automated way
- The objective is to make load breaking almost negligible temporally and economically

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Physical Internet
3. Container Handling and Storage Systems

Container handling and storage systems,
with innovative technologies and processes
exploiting the characteristics of the modular containers
to offer fast, cheap, easy and reliable
input, storage, composing, decomposing,
monitoring, protection and output
of these containers

The aim is for Physical Internet driven systems innovation
to concurrently target the sustainable enabling
of smart automation and smart human handling

Physical Internet
3. Container Handling and Storage Systems

- Container handling and storage systems are expected to:
  - Enable fast and reliable input and output performance
  - Have seamless interfacing with vehicles and systems moving products in and out, as well as client software systems for tracking and interfacing with the containers
  - Monitor and protect the integrity of containers
  - Secure the containers to the desired level
  - Provide a open live documentation of their specified performance and capabilities and of their demonstrated performance and capabilities, updated through ongoing operations
- This applies in currently-labeled distribution centers, crossdocking centers, train stations, multimodal hubs, seaports, airports, and so on

Physical Internet
4. Distributed Multi-Segment Travel

Distributed multi-segment travel
from A to B through the network,
with distinct carriers and/or modes
taking charge of inter-node segments,
with transit nodes enabling
synchronized transfer of carriers between segments,
and with web software platform
enabling an open market
of transport requesters and transport providers

Digital Internet:
Distributed Multi-Segment Travel

- In the Digital Internet, the packets that constitute an overall transmission, such as an e-mail, do not travel directly from source node A to destination node B
- The packets travel through a series of routers and cables (copper or optical, dynamically moved from origin to destination in as best a way as possible provided the routing algorithms and the congestion through the network
  - An email from Québec to Lausanne may go through tens of routers across the world, from New York to Beijing
- Furthermore, the packets are not restricted to travel together
  - Each may end up traveling its distinct route
  - The overall message is reconstituted upon packet arrival at final destination

Physical Internet:
4. Distributed Multi-Segment Travel

- Currently, if a full load trailer is requested from Québec to Los Angeles, there is high probability that
  - A driver and truck will be assigned to the multi-day trip,
  - The driver sleeping in his truck and driving to destination,
  - Then moving to some as nearby as possible location to pick up a trailer returning toward as near as possible of Québec, to avoid empty travel

Physical Internet:
4. Distributed Multi-Segment Travel

- In the Physical Internet, such an experience would be exceptional. Most probably:
  - A first driver and truck would be assigned to transport it to a transit point 3 to 6 hours away
  - The trailer would be deposited to a slot in the transit point
  - The first would then pick up another trailer required toward Québec
  - Another driver and truck would rapidly afterward pick up the trailer and move it another segment forward (it could be taken charge of by truck, train, boat or plane as pertinent)
  - Repeating the process all the way to Los Angeles
  - The shipper or its representative would have a priori arranged transportation on each segment and sojourn at each transit point, in his best interest in terms of price, timing and risk

Physical Internet
5. Dynamic Distributed Container Deployment

An open web of distribution centers and warehouses,
enabling producers, distributors and retailers
to dynamically deploy the storage of their product containers
in multiple geographically dispersed centers,
moving and storing them so as to be able
to deliver with fast response
to distributed stochastic demand for their products

Physical Internet
5. Dynamic Distributed Container Deployment

- As products and materials are moved and stored in modular secured containers, it allows:
  - Warehouses and DCs to accept handling and storing containers from a wide variety of clients, embedding an indeterminate and impertinent number of distinct products, as long as they respect their throughput, security, conditioning and dimensioning capability specifications
  - Significant improvement in capacity utilization and facility profitability

Physical Internet
5. Dynamic Distributed Container Deployment

- As products and materials are moved and stored in modular secured containers,
  As an open web of easily and cheaply accessible distribution centers and warehouses become available,
  It allows:
  - Producers, distributors, retailers and users to dynamically deploy the storage of their product containers in multiple geographically dispersed centers, moving and storing them so as to be able to deliver fast response to distributed stochastic demand for their products
  - Significant reduction in asset requirements and significant improvement in logistic costs and delivery service performance

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Physical Internet
6. Smart Containers Embedding Smart Objects

Exploiting as best as possible
the capabilities of smart containers
and of their embedded smart objects,
for improving performance as perceived by the client
and overall performance of the Physical Internet

Physical Internet and the Internet of Things

- The Internet of Things is about enabling ubiquous connection with physical objects equipped with smart connective technology, making the objects ever smarter and enabling distributed self-control of objects through networks
  - It exploits technologies such as Internet, Web, RFID and GPS
- The Physical Internet is to exploit as best as possible the capabilities of smart objects, embedded in smart containers, for improvement performance as perceived by the client and user, and for overall perfomance of the Physical Internet

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Physical Internet
7. Innovative PI Enabled Business Models

Innovative business models
for commercializing
Physical Internet enabled offers by various parties,
including revenue models for the various actors

Physical Internet: Remunerating the Players

- In the Digital Internet, the transmission of information is remunerated mostly though bundle flat fees due to the quasi nil marginal costs
- In the Physical Internet, the transmission of a container generates non negligible costs for each of the operators having taken charge of some part of the transmission
- It is thus necessary to define business models for commercializing offers as well as operator revenue models
  - There currently exist examples paving the way to realize this, notably in the airline industry

Physical Internet:
A Business Model Innovation Catalyst

- The Digital Internet has created a plethorea of new businesses and business models, from service providers to e-retailers
- The advent of the Physical Internet will surely have the same impact, stimulating business model innovation:
  - In the various logistic and transport industries, the technology and solutions providers, third-part operators, physical web software services, and so on
  - In the production, distribution and retailing industries, with business models exploiting the open web capabilities enabled by the Physical Internet

Physical Internet
8. Product Design to Minimize PI load

Products designed
to minimize the load they generate on the Physical Internet,
with dimensions adapted to standard container dimensions,
with maximal volumetric and functional density
while containerized

Physical Internet
9. Knowledge-based Product Dematerialization and Rematerialization

Exploiting extensively
the knowledge-based dematerialization of products
and their rematerialization in physical objects at point of use

As it will gain maturity,
the Physical Internet is expected to have
ever more open distributed flexible production centers
capable of locally realizing for clients
a wide variety of products
from digitally transmitted specifications

Physical Internet
9. Knowledge-based Product Dematerialization and Rematerialization

- As it will gain maturity, the Physical Internet is to have ever more open distributed flexible production centers capable of locally realizing a wide variety of products for clients from digitally transmitted specifications
- Third-party production takes an ever growing share of the overall production market, internal production limited to highly sensitive core objects
- Product realization knowledge should be protected, and authenticity of the materialized products should be legally acknowledged

Physical Internet
10. Multi-Level PI Certification

Multi-level Physical Internet certification
of containers, handling systems, vehicles,
information systems
ports, distribution centers,
roads, cities and regions,
protocols and processes,
and so on

Physical Internet
11. Enabling Open Infrastructural Innovation

Systemic coherence and means interoperability must enable the transparent usage of heavy handling, storage and transport means currently existing or to come in the future, that are currently so hard to use, reducing their potential positive environmental impact

The Physical Internet homogeneity in terms of container modules encapsulating objects should allow a much better utilization of means, thus increasing the capacity of infrastructures by the exploitation of standardizations, rationalizations and automations through currently unreachable innovations.

Physical Internet
12. Webbed Reliability and Resilience

The overall Physical Internet network of networks should warrant its own reliability and that of its containers and shipments.

The webbing of the networks and the multiplication of nodes should allow the Physical Internet to insure its own robustness and resilience to unforeseen events.

For example, If a node or a part of a network fail, the traffic of containers should be easily reroutable, as automatically as possible

Realizing the Vision

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Evolving towards a worldwide **Physical Internet**

The Physical Internet:
Global systemic sustainable vision stimulating and aligning action around the world

- Individual initiatives by businesses, industries and governments are necessary but are not sufficient
- There is a need for a macroscopic, holistic, systemic vision offering a unifying, challenging and stimulating framework
- There is a need for an interlaced set of global and local initiatives towards this vision, building on the shoulders of current assets and projects, to help evolve from the current globally unsustainable state to a desired globally sustainable state

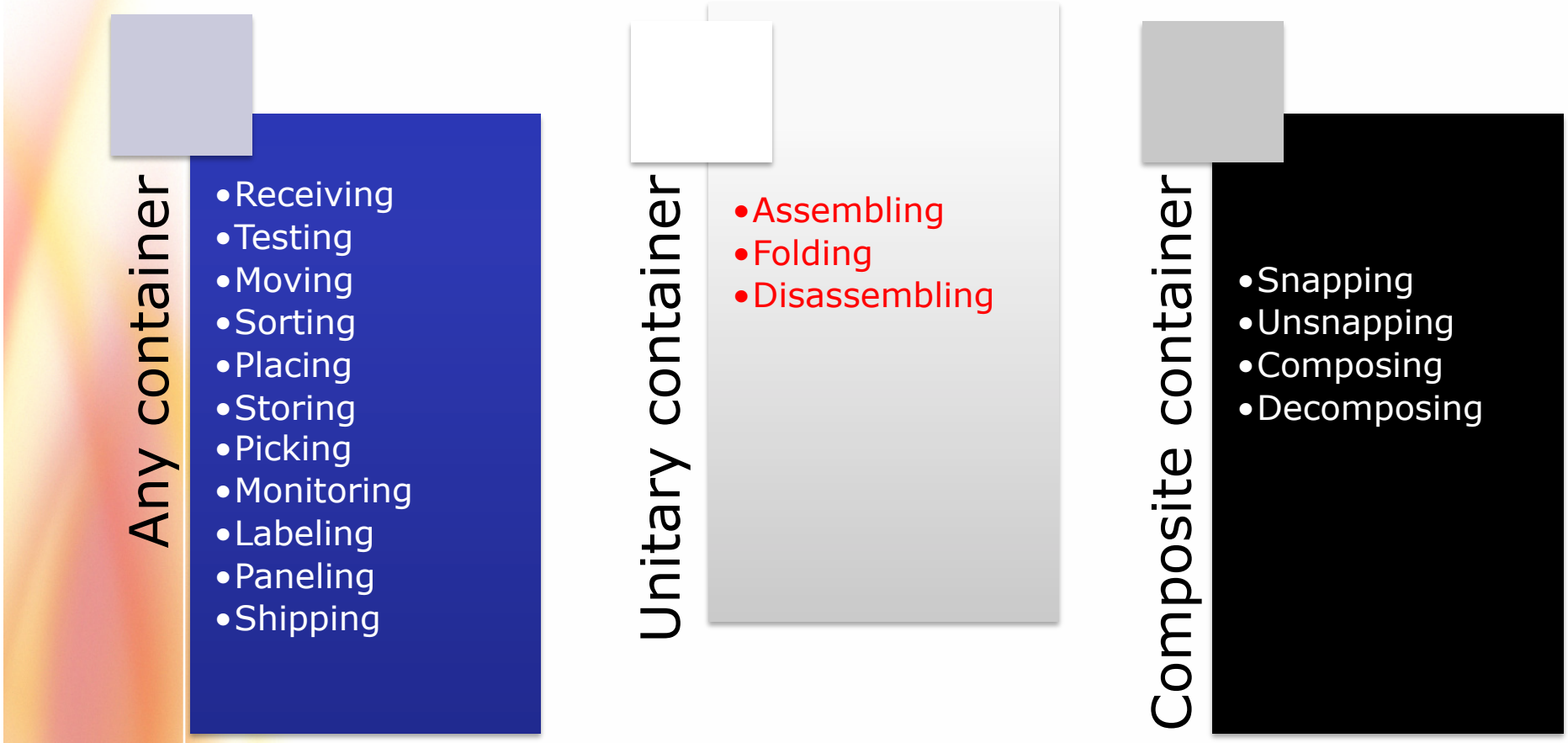
Physical Internet Implementation
Progressive Deployment, Cohabitation and Certification

- The development of such a systemic Physical Internet will not be achieved overnight in a Bing-Bang logic but rather in an ongoing logic of cohabitation and of progressive deployment
  - As long as the actors find value in its usage
  - From the moment they will integrate the Physical Internet norms
- A smooth transition starting with rethinking and retrofitting, then moving toward more transformative phases
- The Physical Internet could therefore constitute itself progressively through the multi-level certification of:
  - Containers
  - Handling and storage technologies, distribution centers, production centers, train stations, ports, multimodal hubs
  - Information systems (e.g. reservation, smart labels, portals)
  - Urban zones and regions, inter-country boundaries

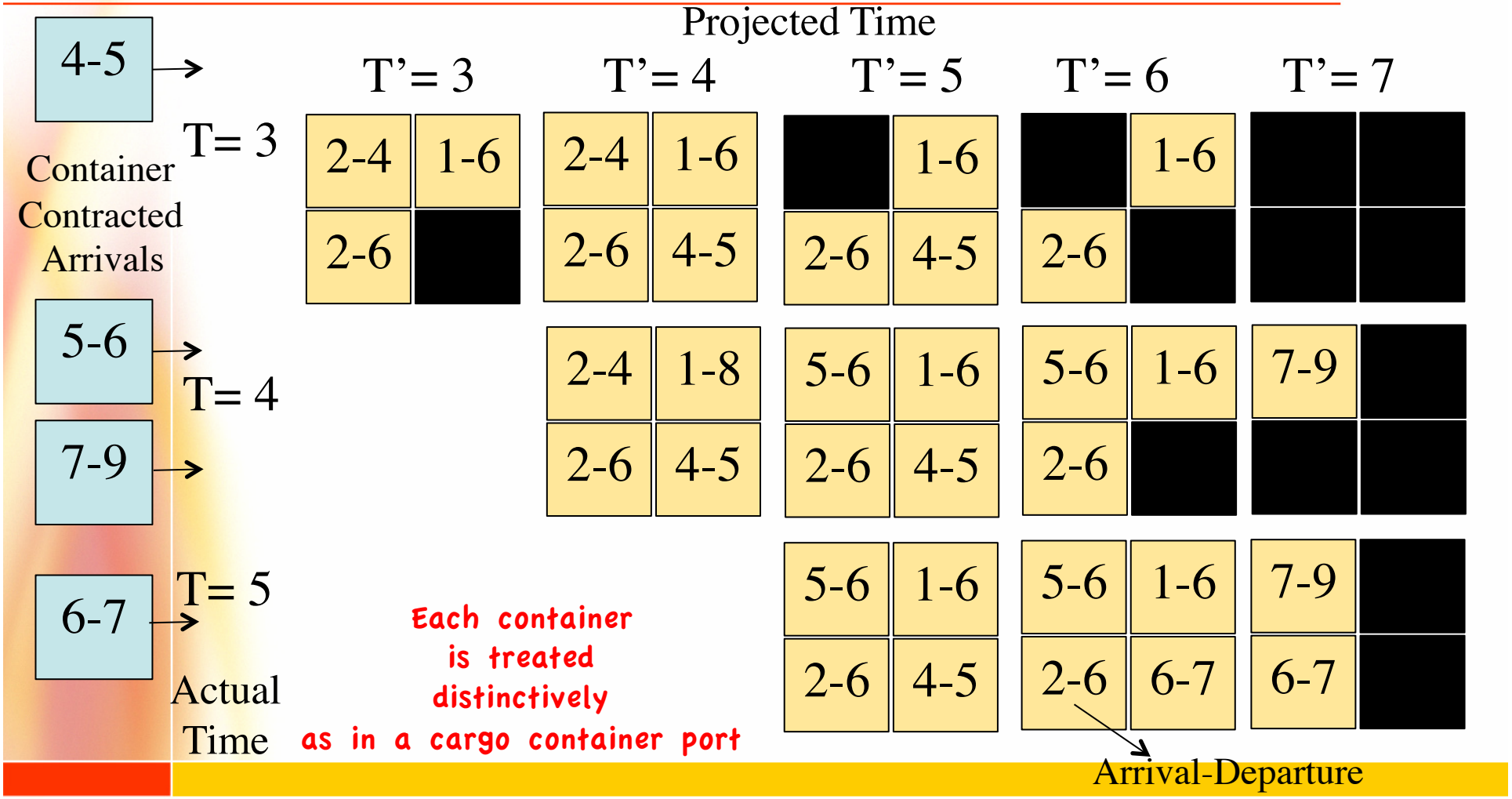
Logistic Centers :
Many conceptualization evolution challenges have been exposed through the presentation until now

- Each of the 12 presented features of the Physical Internet
- has significant impact on the design and operation
- of logistic centers.
- We will not reexpress the features and the links to logistic center design and operation
- We will hereafter focus shortly on key facets that directly relate to the specific theme of the workshop, stochasticity, with emphasis on the evolving nature of such logistic centers.

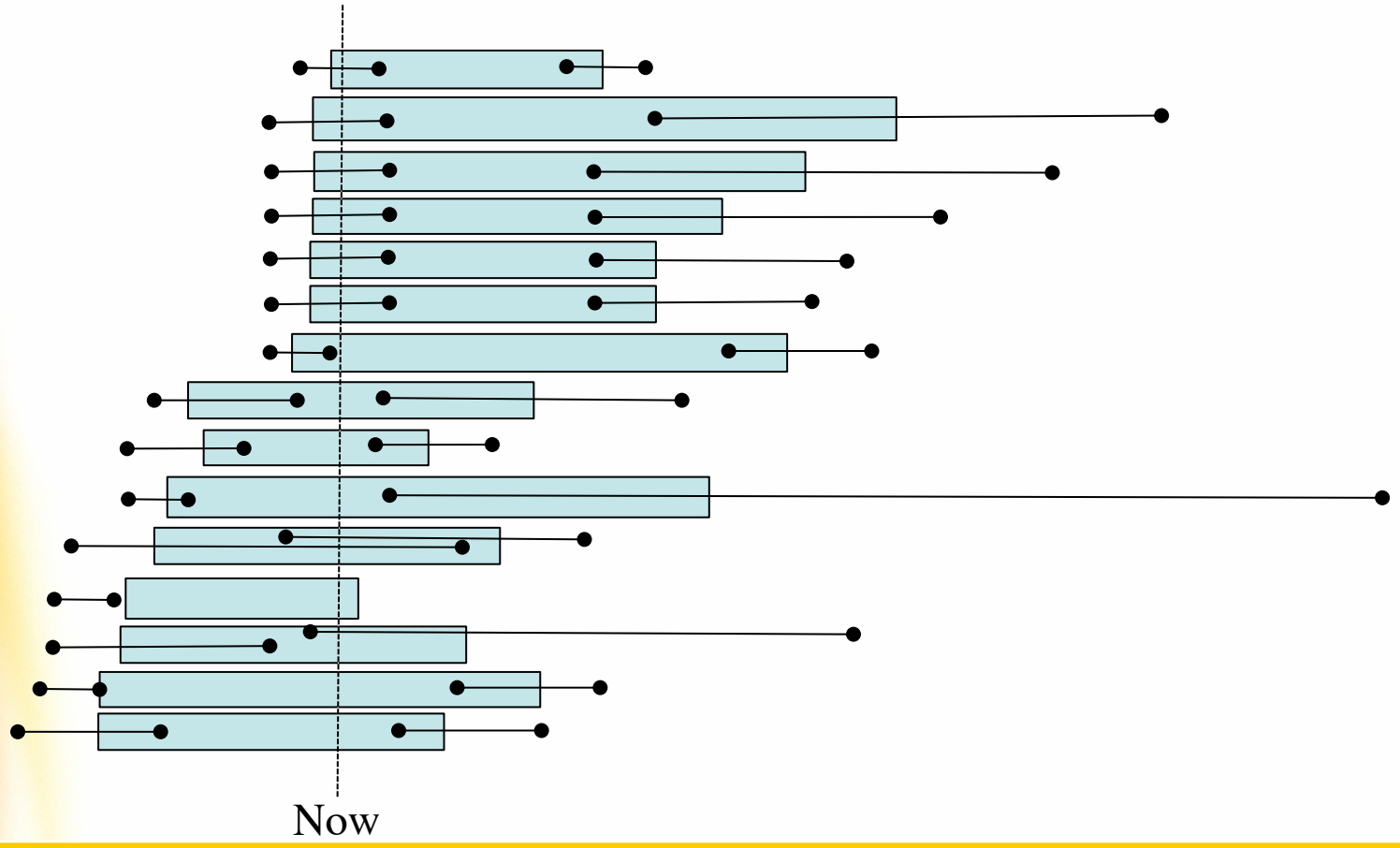
Modular Container Focused Logistic Center Activities



Dynamics of a simple logistic center with deterministic arrivals and departures known at contract time



Occupancy Dynamics of a logistic center when client knowledge about arrivals and departures of containers is stochastic



Dynamic information exchanged between client and center about a container in a more complex stochastic environment

Container:	ID
Client:	ID
Logistician:	ID

Outstore:	OK or Not			
Dimensions:	X	Y	Z	Weight
Support capacity:	Weight			
Handling capabilities:	Feature 1	2	3	...

Conditioning:	Temperature			Humidity			Luminosity			Vibration		
	Min	Target	Max	Min	Target	Max	Min	Target	Max	Min	Target	Max

Arrival:	Inbound Time			Notice Time			Mode probability				
	Earliest	Target	Latest	Earliest	Target	Latest	Cube truck	Tractor-trailer	Train	Boat	Airplane
Departure:	Outbound Time			Notice Time			Mode probability				
	Earliest	Target	Latest	Earliest	Target	Latest	Cube truck	Tractor-trailer	Train	Boat	Airplane

Allowed delay:	Inbound	In-Confirm	Outbound	Out-Confirm
	Max	Max	Max	Max

Contract:	Signature Time	In-Spec Price

Client penalty:	Arrival				Departure			
	Inbound Time		Notice Time		Inbound Time		Notice Time	
	Earlier	Later	Shorter	Longer	Earlier	Later	Shorter	Longer

Center delay penalty:	Inbound	In-Confirm	Outbound	Out-Confirm
	Over	Over	Over	Over

Center penalty:	Temperature		Humidity		Luminosity		Vibration	
	Under	Over	Under	Over	Under	Over	Under	Over

Dealing with Stochasticity

- Explicitly recognize uncertainties and robust engagements at engagement time for each container of each client
- Continuously and openly post of dynamic center performance for its containers in real stochastic environment
- Openly deals with many clients, with containers embedding wide varieties of products, dynamically pooling risks and maximizing capacity usage
- Dynamically deploy containers through the center's network of systems and subcenters so as to constantly be best poised to respond to client inbound and outbound requests.
- Strategically design and capacitize the centers and their systems for fast and easy input, output and redeployment
- Openly post offers that emphasizes the guarranteed throughput and response time performance rates, backed by real data

Conclusion (1/2)

This presentation has outlined a bold paradigm breaking vision for the future of how we handle, store, transport, realize, supply and use physical objects across the world

It proposes to exploit the Internet, which has revolutionized the digital world, as an underlying metaphor for steering innovation in the physical sphere

The outlined Physical Internet does not aim to copy the Digital Internet, but to inspire the creation of a bold systemic wide encompassing vision capable of providing real sustainable solutions to the global problems associated with the way we are currently operating and heading

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Conclusion (2/2)

A small step has been made here,
a lot more are needed to really shape this vision
and, much more important,
to give it flesh through real initiatives and projects
so as to really influence in a positive way
our collective future

A lot of collaboration
between academia, industry and governemnts
will be necessary, across continents, countries and localities

Your help is welcome!

Questions and comments are welcome

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Moving a Container: A Simple Request