Digital Twins: A Key to Sustainable Stewardship of Urban Sea Systems?

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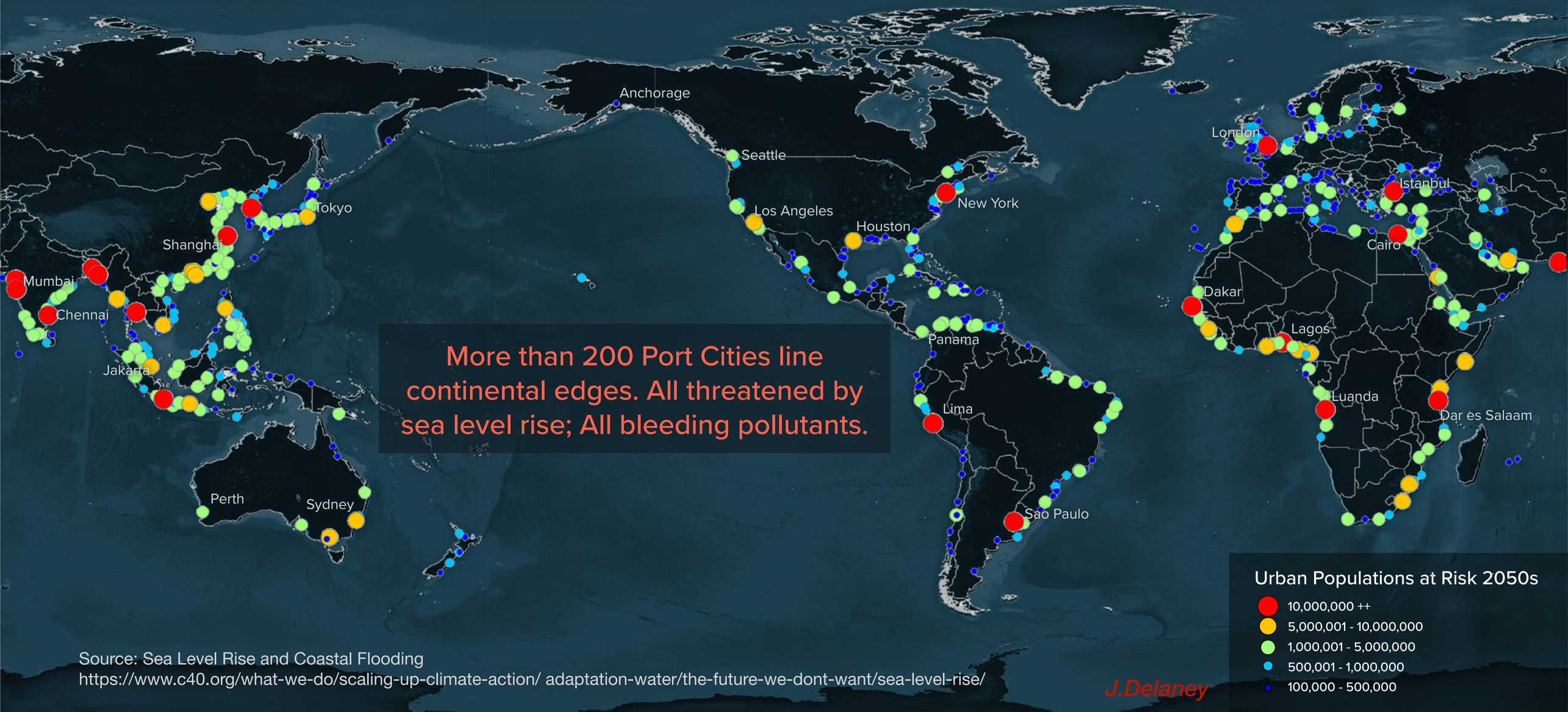
WHAT IS AN URBAN SEA SYSTEM?

Urban Sea Systems *are interactive networks of all natural and anthropogenic activities within coastal watersheds harboring one, or more, major port cities.* They are "Systems of Systems".

WHERE ARE URBAN SEAS LOCATED?

Port Cities Define Urban Sea System Locations forming a "Global Trade Network"



Source: Sea Level Rise and Coastal Flooding
https://www.c40.org/what-we-do/scaling-up-climate-action/ adaptation-water/the-future-we-dont-want/sea-level-rise/

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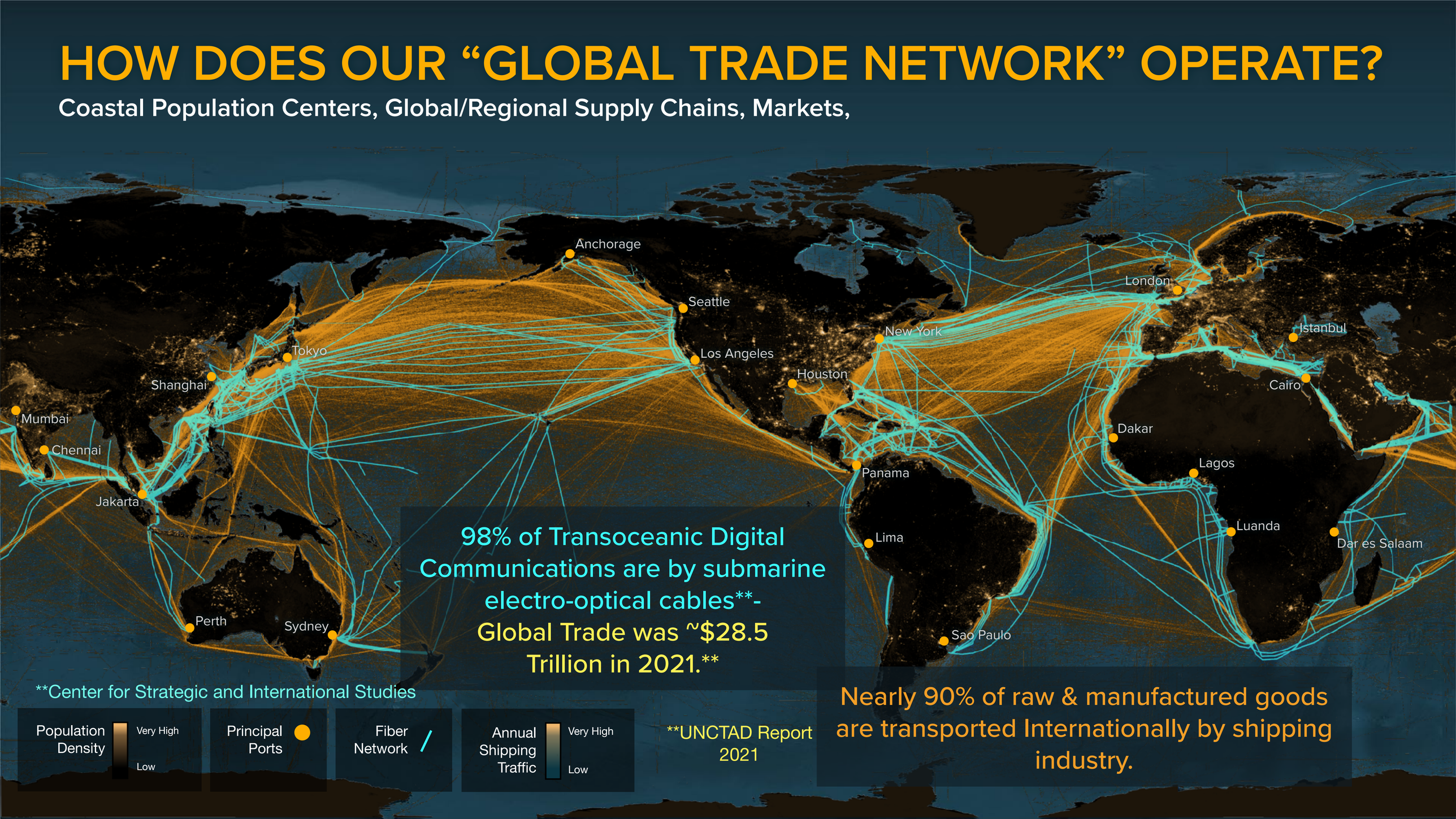
HOW DOES OUR “GLOBAL TRADE NETWORK” OPERATE?

Coastal Population Centers, Global/Regional Supply Chains, Markets,



98% of Transoceanic Digital Communications are by submarine electro-optical cables**- Global Trade was ~$28.5 Trillion in 2021.**

**Center for Strategic and International Studies

Population Density: Very High – Low

Principal Ports

Fiber Network

Annual Shipping Traffic: Very High – Low

**UNCTAD Report 2021

Nearly 90% of raw & manufactured goods are transported Internationally by shipping industry.

AN URBAN SEA SYSTEM IS A “SYSTEM OF SYSTEMS”

Globally Distributed, Locally-Regionally Managed

THEY ARE:

Global/Regional supply chain hubs → $$$;

→ “Hot Spots” of ocean-atmosphere pollution;

→ Vulnerable to natural disaster and attack;

→ Hosts to entrenched inequality.

WE MUST FIND A WAY TO:

Preserve-enhance **Economic Vitality**,

Mitigate-reverse **Ecological Decline**,

Address-protect **National Security**,

Optimize **Social Justice** & **Population Health**

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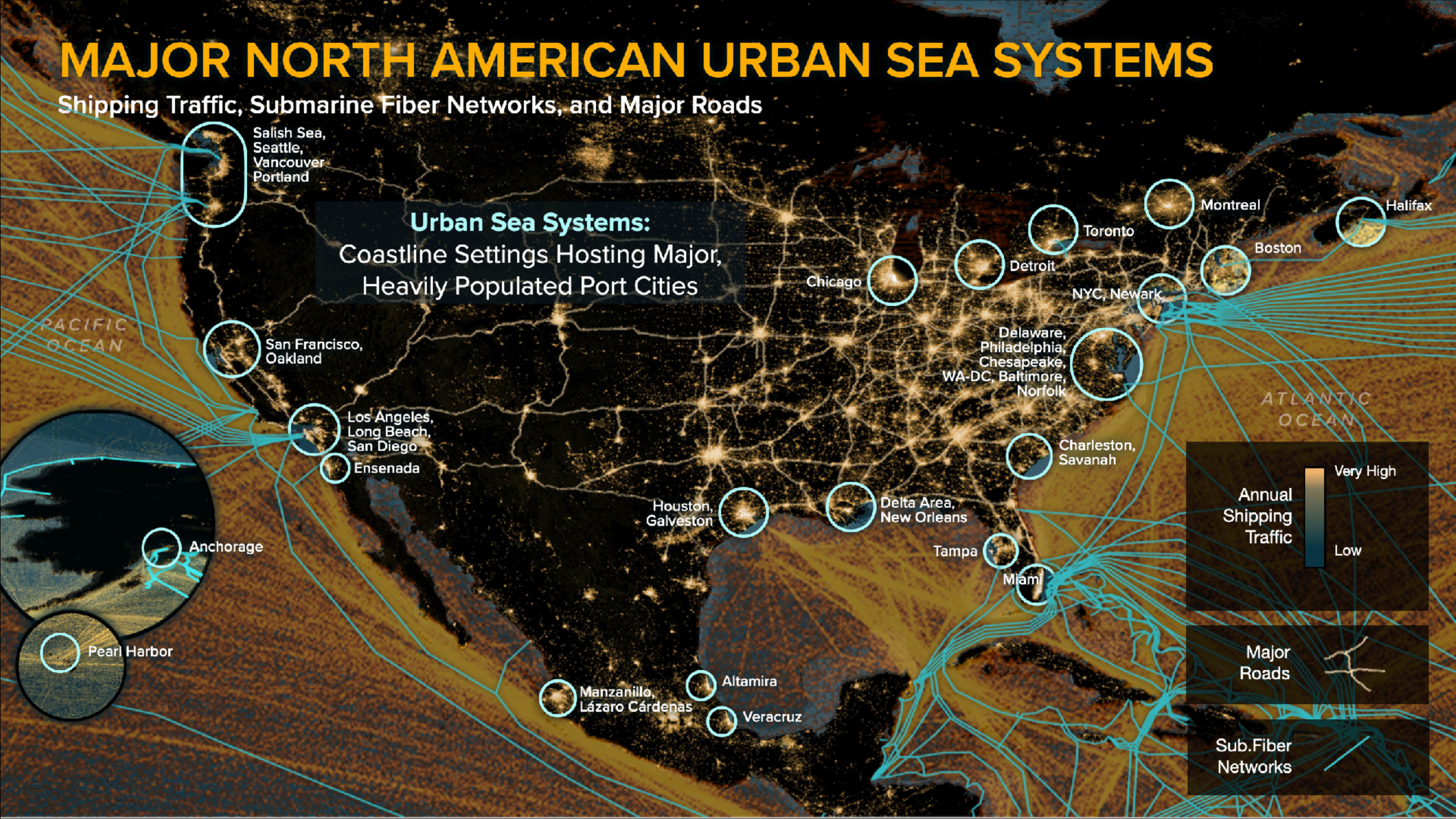

MAJOR NORTH AMERICAN URBAN SEA SYSTEMS
Shipping Traffic, Submarine Fiber Networks, and Major Roads
Urban Sea Systems:
Coastline Settings Hosting Major, Heavily Populated Port Cities
Salish Sea, Seattle, Vancouver Portland
San Francisco, Oakland
Los Angeles, Long Beach, San Diego
Ensenada
Anchorage
Pearl Harbor
Manzanillo, Lázaro Cárdenas
Altamira
Veracruz
Houston, Galveston
Delta Area, New Orleans
Tampa
Miami
Charleston, Savanah
Delaware, Philadelphia, Chesapeake, WA-DC, Baltimore, Norfolk
NYC, Newark
Chicago
Detroit
Toronto
Montreal
Boston
Halifax
PACIFIC OCEAN
ATLANTIC OCEAN
Annual Shipping Traffic
Very High
Low
Major Roads
Sub.Fiber Networks

“OCEAN POLLUTION”

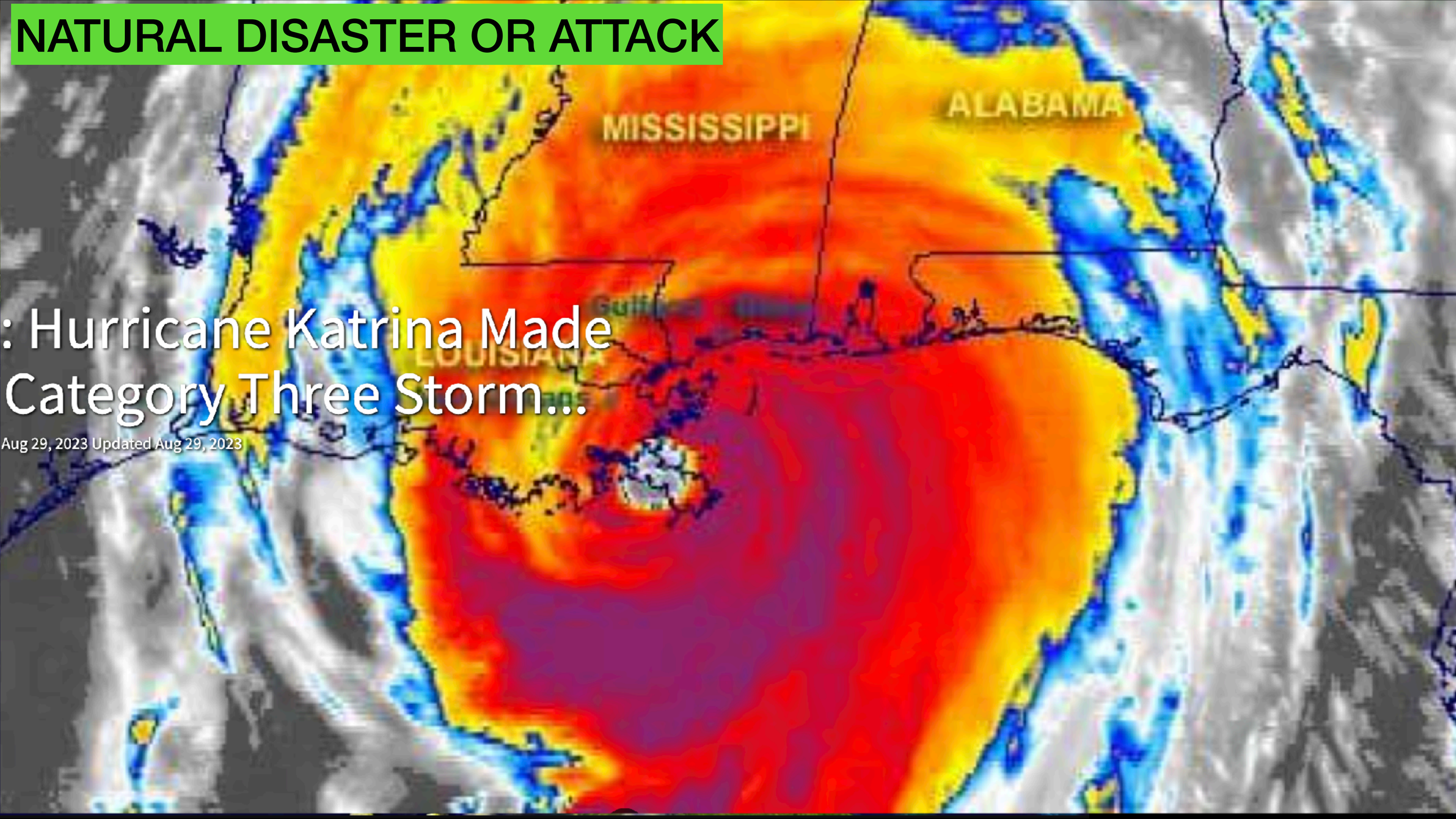
What else is accumulating in addition to all that plastic?

Trace elements, Pharmaceuticals, Heat, Pathogens, Sound, Wrecks…

Can the environmental impacts of Urban Sea Systems be Quantified?

Great Pacific Garbage Patch
Photo credit:
https://www.infrastructurenews.co.nz/great-pacific-garbage-patch-cleanup-take-two/

NATURAL DISASTER OR ATTACK



: Hurricane Katrina Made
Category Three Storm...

Aug 29, 2023 Updated Aug 29, 2023

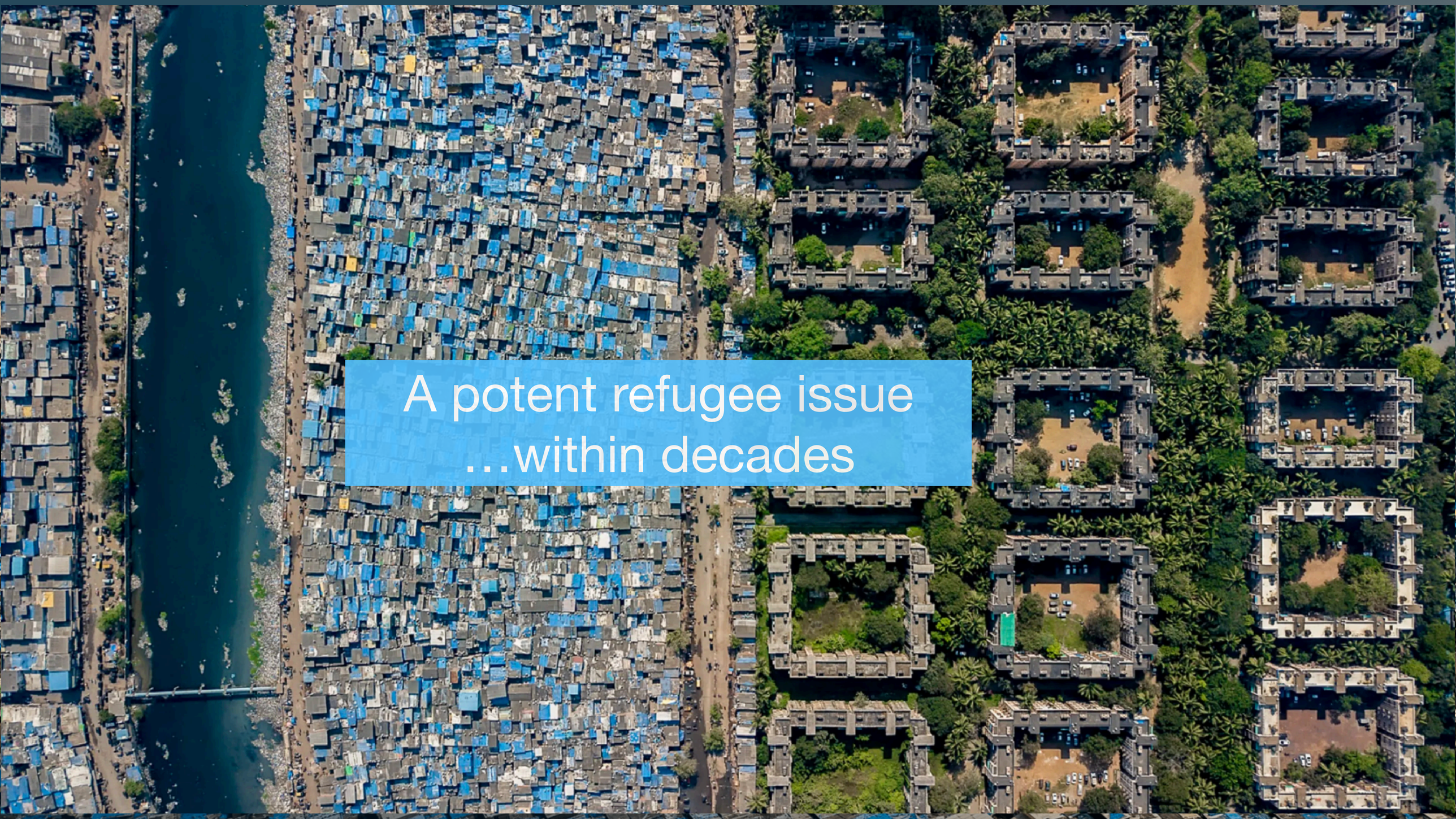
NATURAL DISASTER OR ATTACK

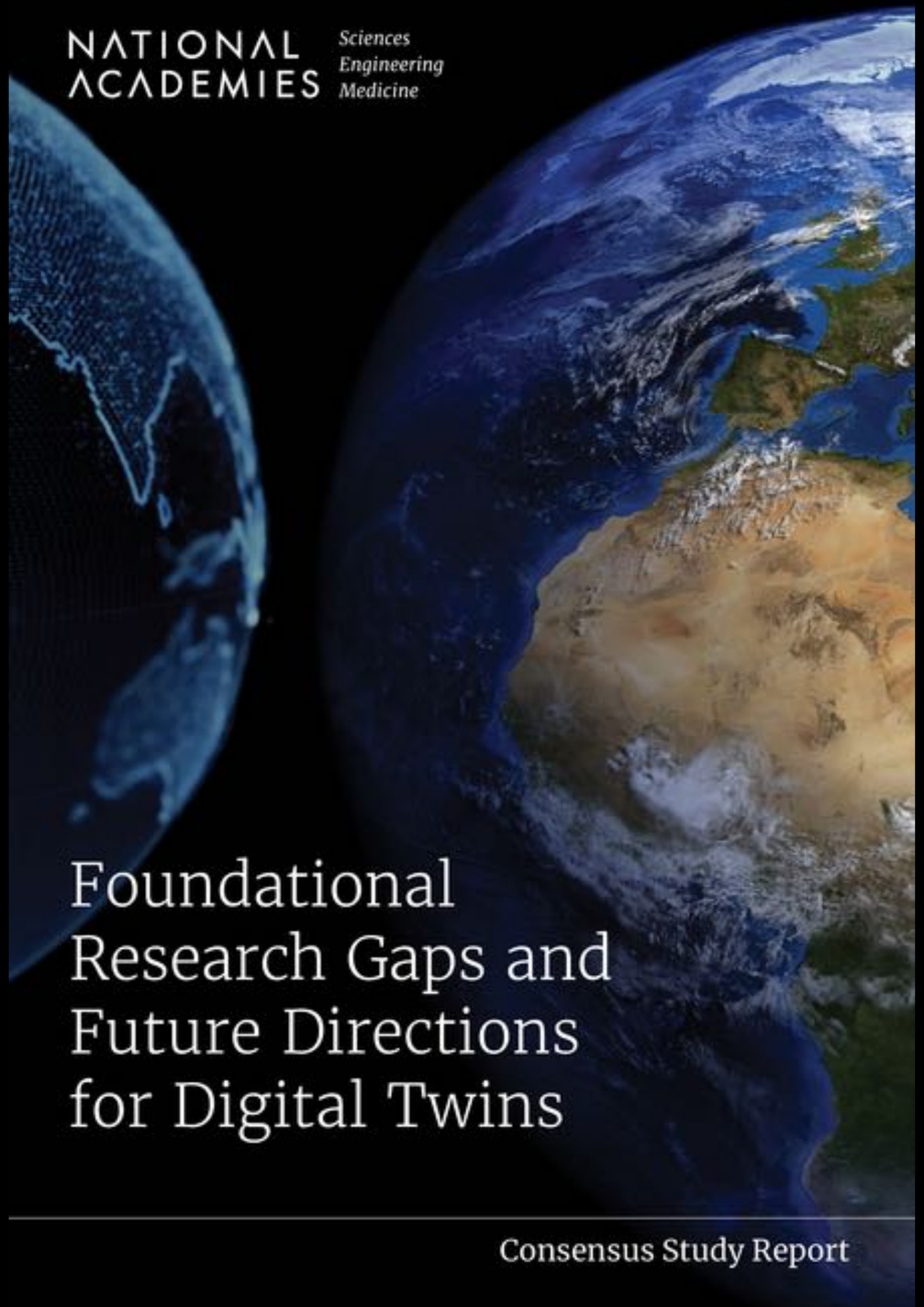
Hurricane Sandy 2012

Deepwater Horizon
Gulf of Mexico
2010

Eleven people died when BP's Deepwater Horizon rig exploded and it caused the worst accidental oil spill in US history. Photograph: AFP/Getty Images

UNFORSEEN EVENTS IMPACT OPERATIONS, COMMUNITY, ECOLOGY

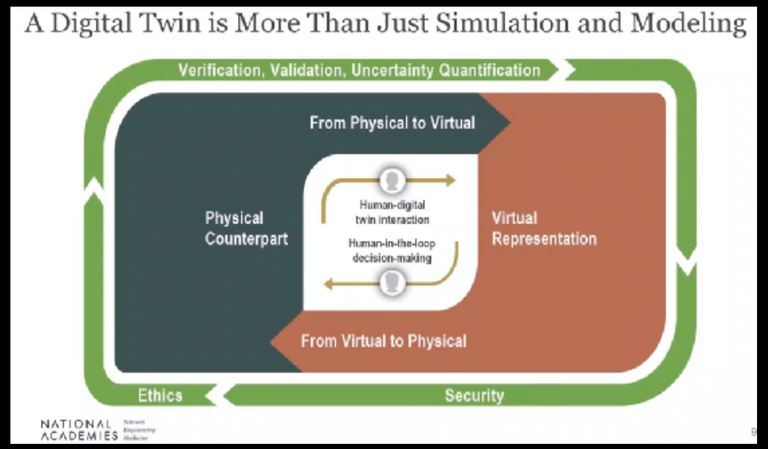

A potent refugee issue
…within decades



"A digital twin is a set of virtual information constructs that mimics the structure, context, and behavior of a natural, engineered, or social system (or system-of-systems)".

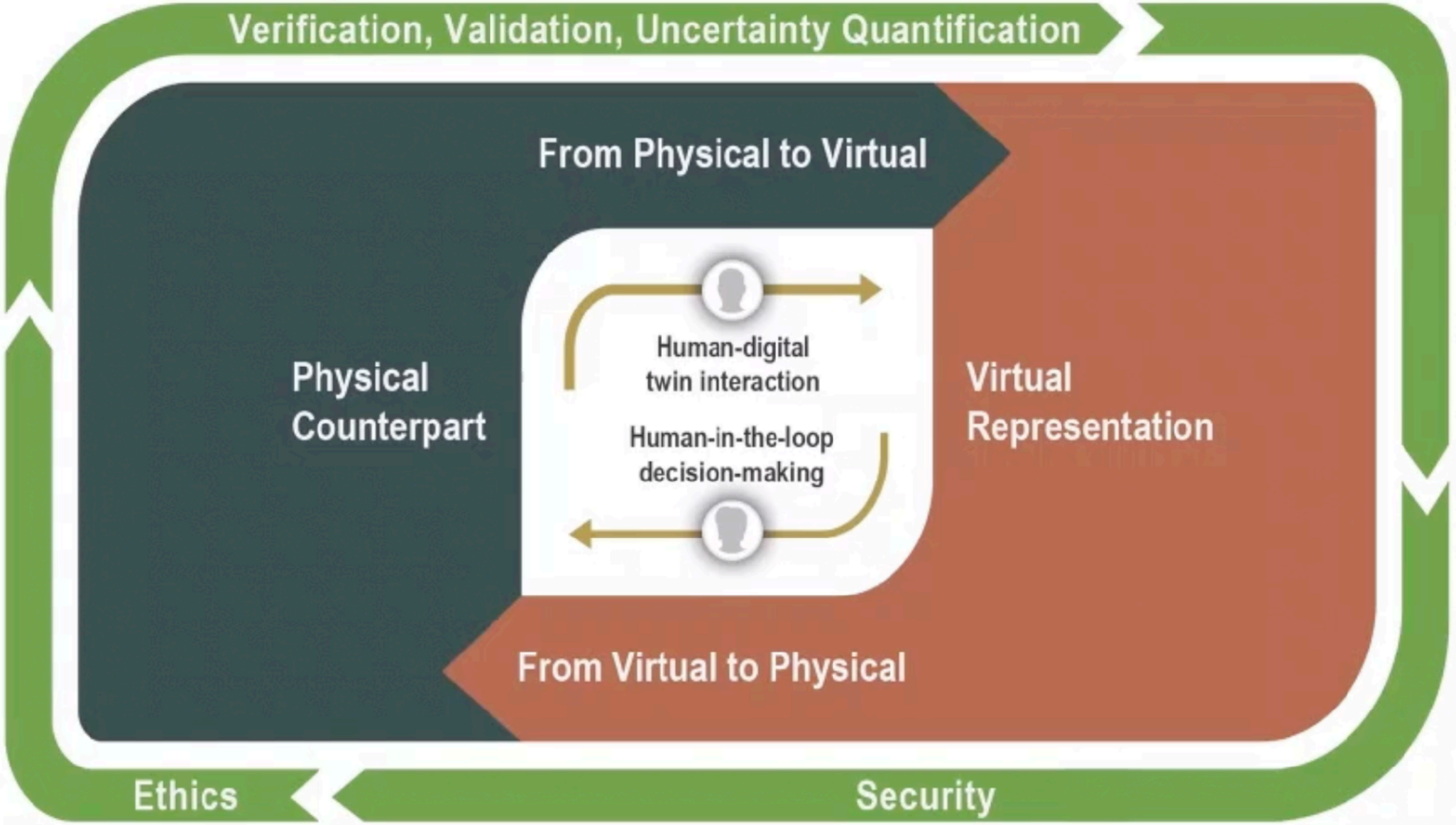
"It is dynamically updated with data from its physical twin, and its predictive capability, informs decisions that realize value".

"The bidirectional interaction between the virtual and the physical is central to the digital twin".



National Academies of Sciences, Engineering, and Medicine. 2024. Foundational Research Gaps and Future Directions for Digital Twins. Washington, DC: The National Academies Press. https://doi.org/10.17226/26894.

A Digital Twin is More Than Just Simulation and Modeling



NATIONAL ACADEMIES Sciences Engineering Medicine

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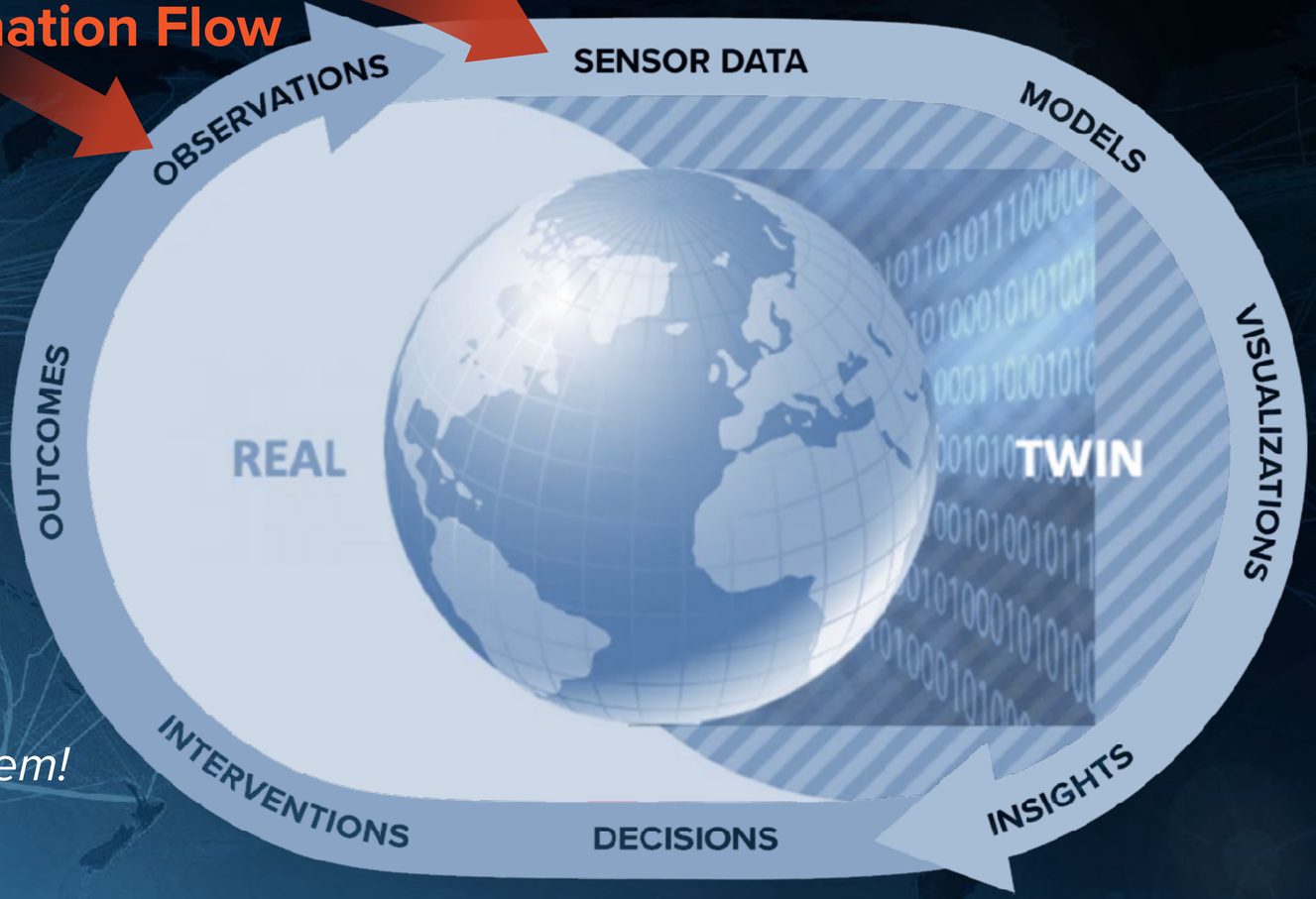
DIGITAL TWINS OF THE OCEAN - *"MORE THAN MODELS"*

DITTO
Digital Twins of the Ocean

Historical & Real-time Information Flow



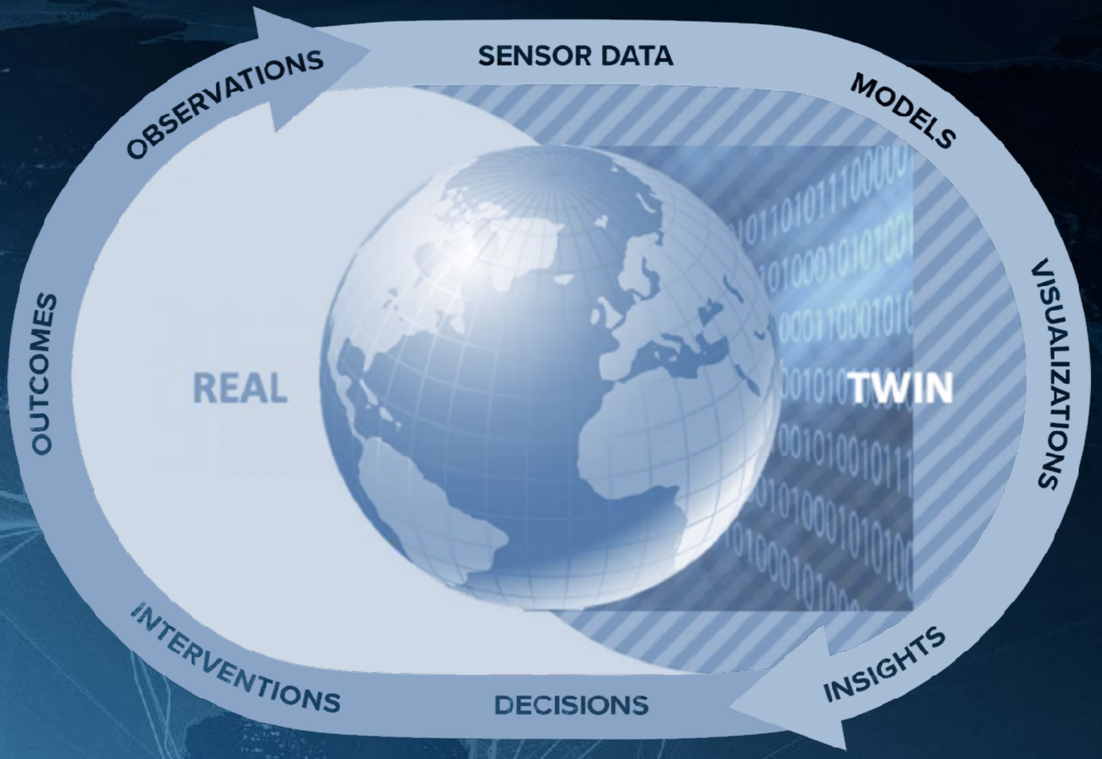
Can "play" with the time domain

"What-if" Scenarios
How will the ocean change if humans act?
A Boundary Value Problem!

DTs improve with with usage

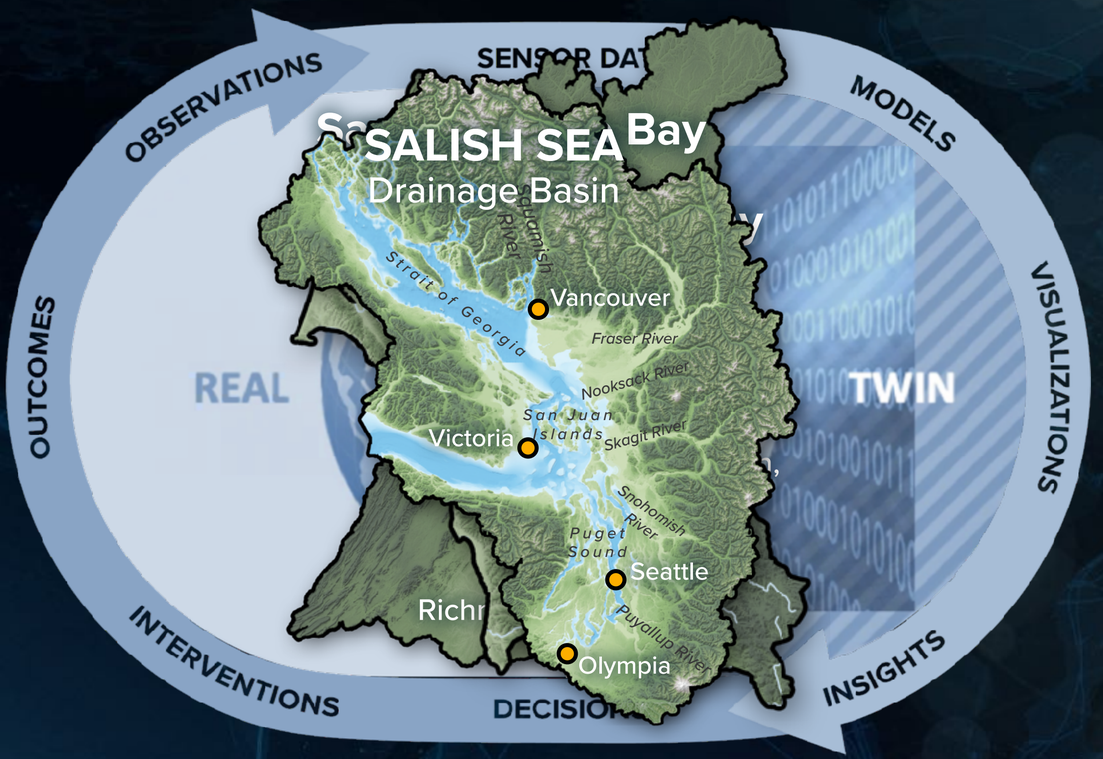
(Slide from Martin Visbeck: a Vision for Creating Digital Twins of our Global Ocean)

Digital Twins of Ocean



...An aggregate of many Subsystems.

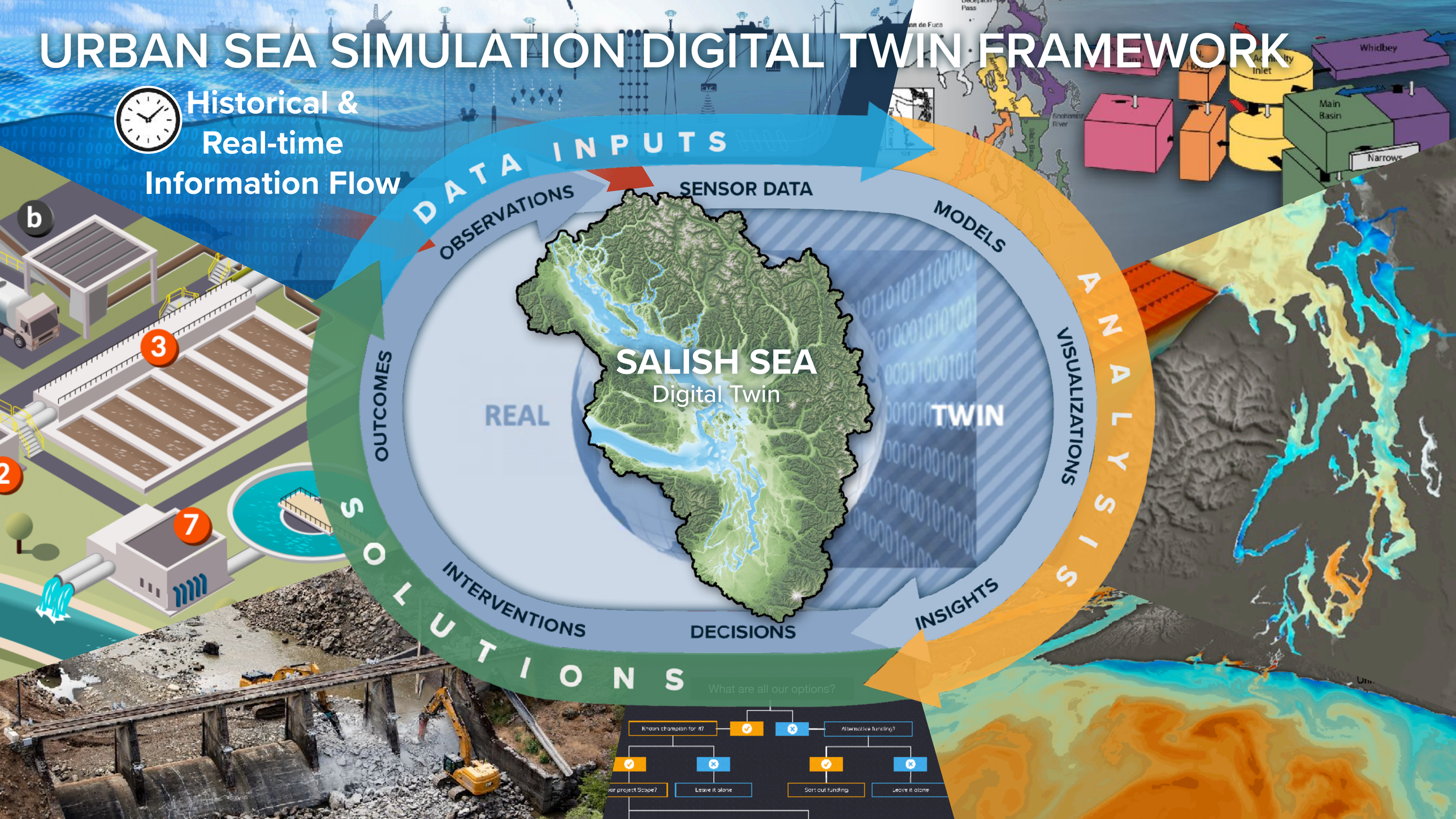
Digital Twins of Urban Sea Systems...



- **Watershed** Processes
- **Urban-Suburban** Activities
- **Marine-Terrestrial** Waters

URBAN SEA SIMULATION DIGITAL TWIN FRAMEWORK

Historical &
Real-time
Information Flow



HOW MIGHT ONE BEGIN CONSTRUCTING A DIGITAL TWIN OF AN URBAN SEA SYSTEM?

Watershed,
Port City,
& Marine Sector

Each process can be rendered as a sub-component “digital twin module”.

EACH PROCESS CAN BE CHARACTERIZED

Weather Climate

Sea Level Storm Flooding

Storm & Waste H2O' Management

Port Operations Supply Chain

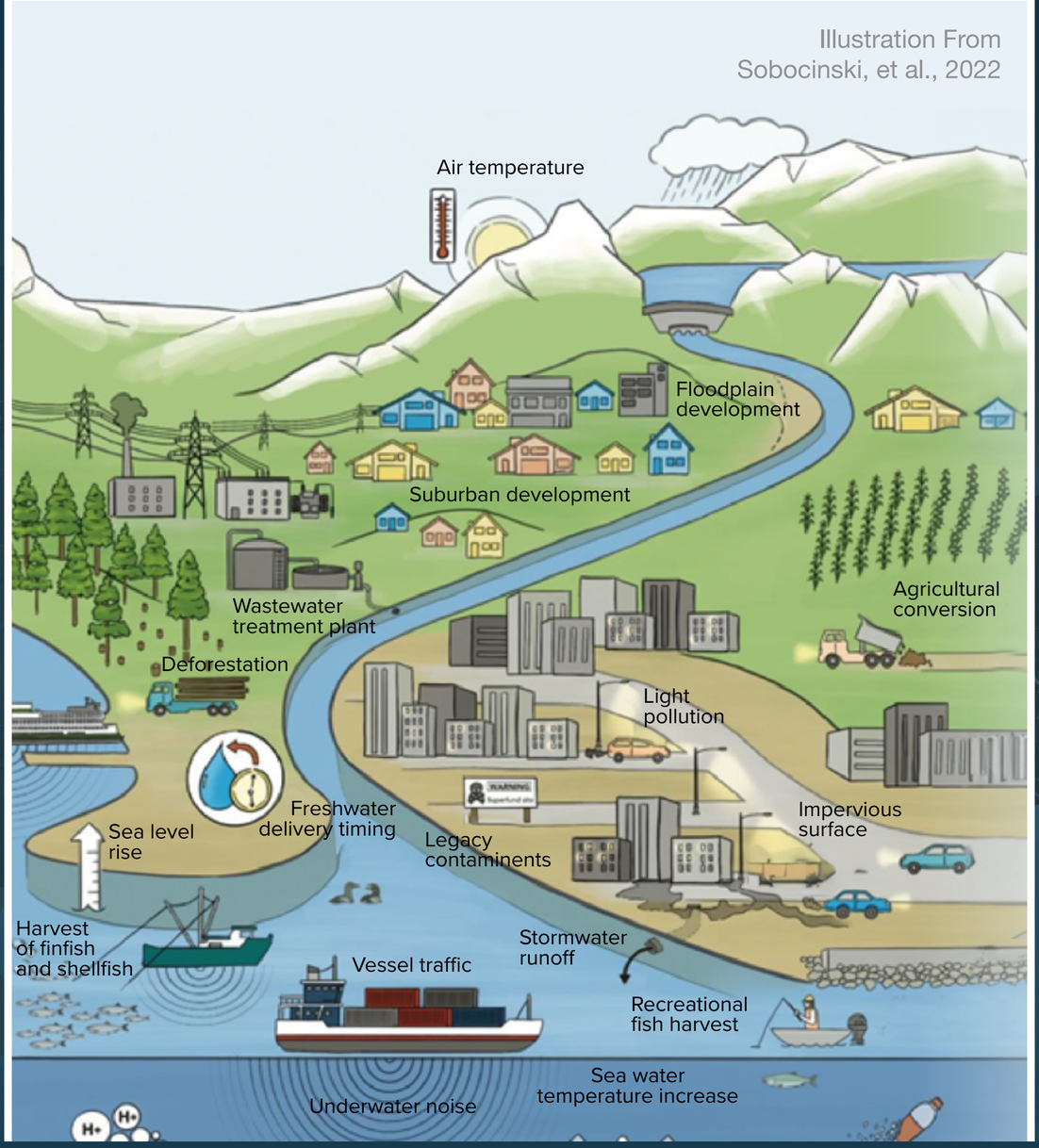
Pollution All Forms

Real-time Data Flow

Circulation of Marine Sector

Education Outreach

Illustration from K. Sobocinski, et al 2022



BY A DIGITAL TWIN MODULE

Hazards Natural Man Made

Power Generation: C-Neutral

Fishing Industry & Recreation

Manufacturing Input Output

Agriculture Aquaculture

Built Environment Smart City

Community Ownership Population Health

Forest Management

Full Urban Sea System Digital Twins will comprise **ALL** interacting modules

Many Domain Experts Are Essential; - but some work in Silos

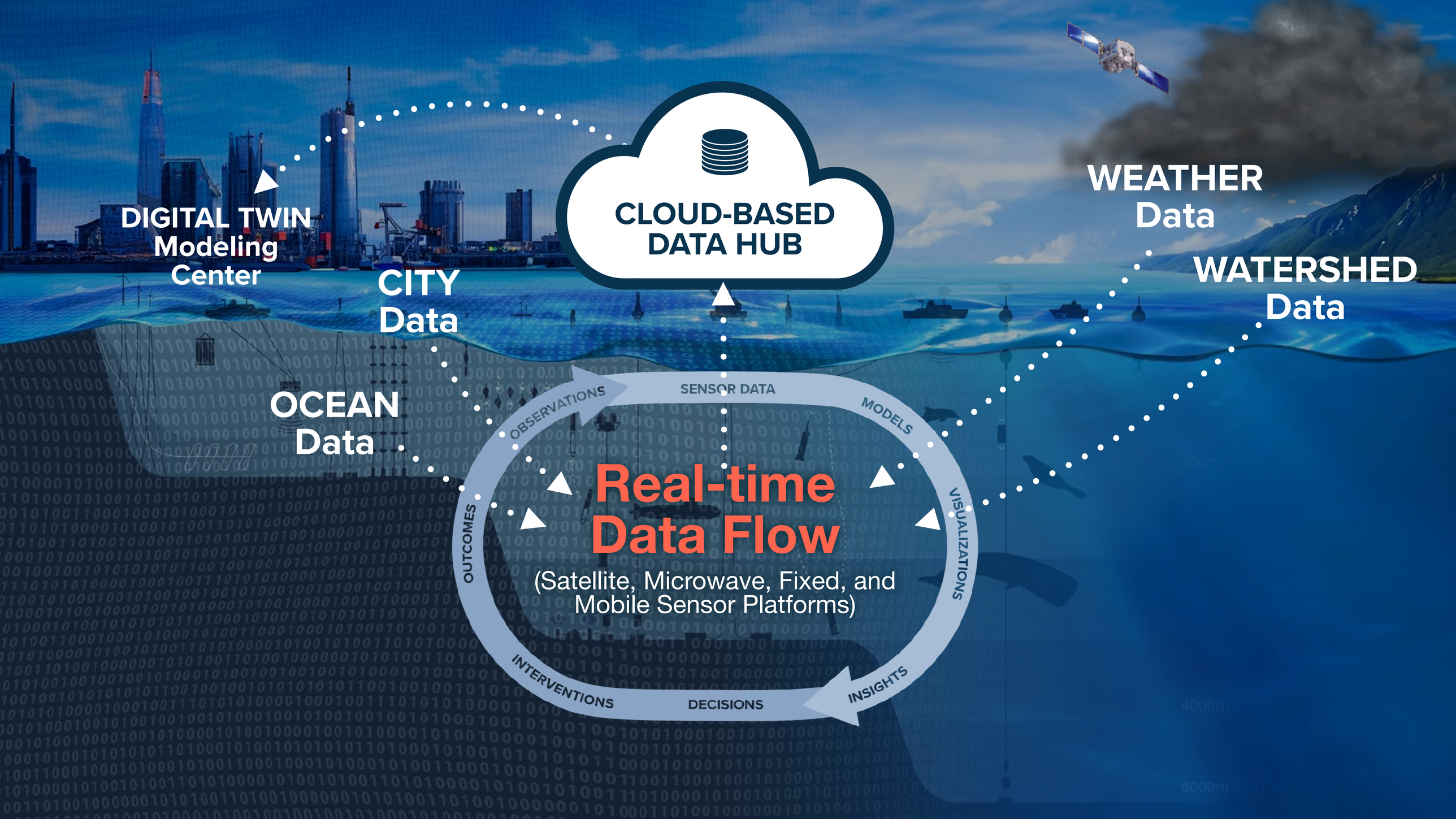
Across-the-board collaboration is crucial for success

It is unlikely that any single group has the expertise to optimally manage **ENTIRE Urban Sea Systems**

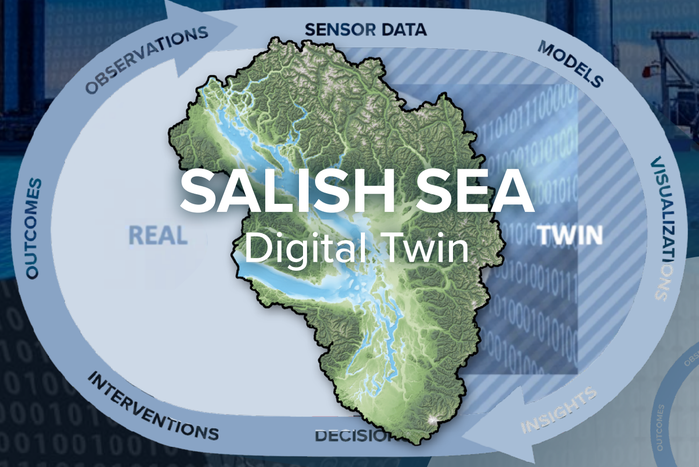
Expertise Silo

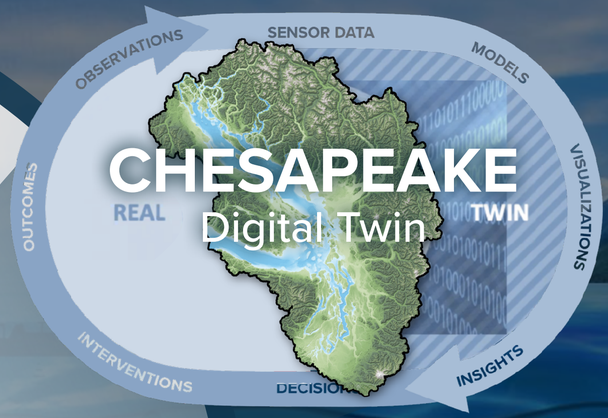
Interactive Digital Twin Subcomponents

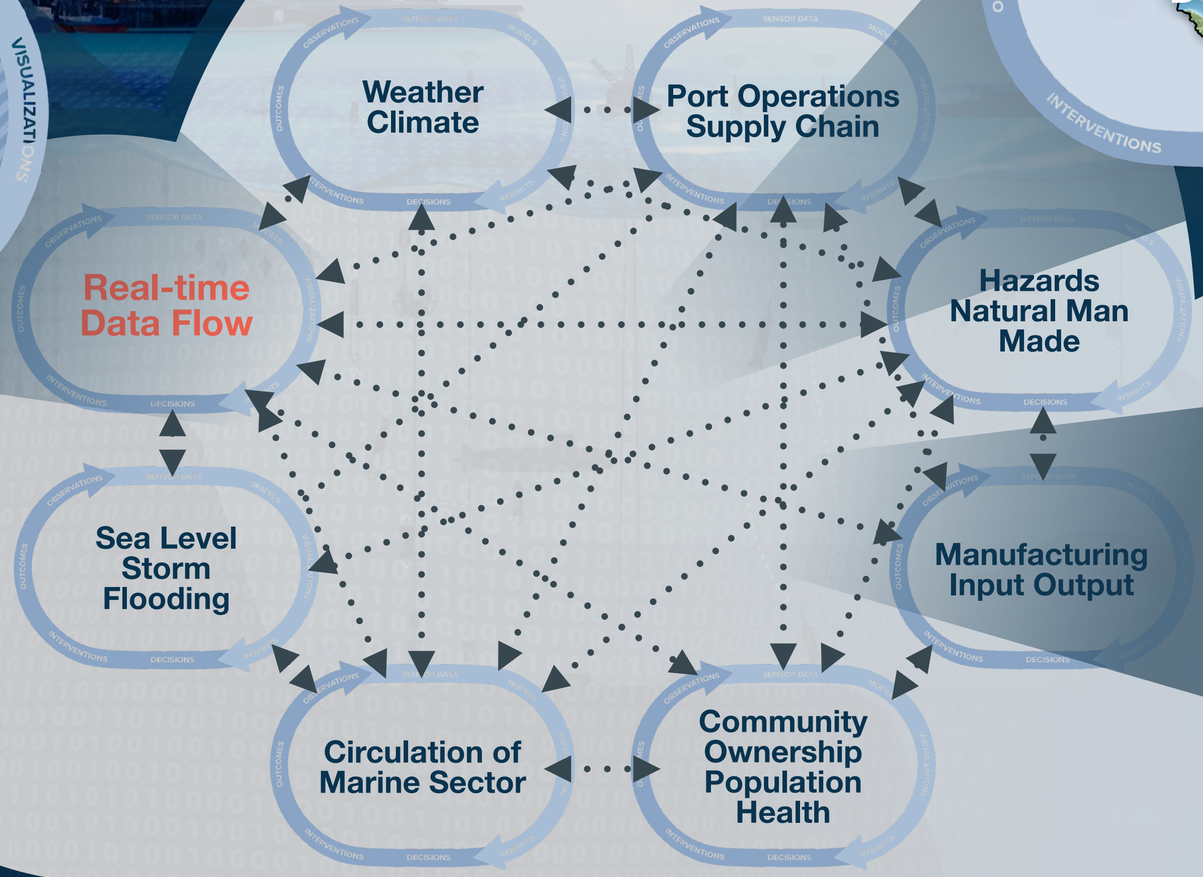
Cloud Storage & Interaction


DIGITAL TWIN
Modeling
Center
CLOUD-BASED
DATA HUB
WEATHER
Data
WATERSHED
Data
CITY
Data
OCEAN
Data
SENSOR DATA
OBSERVATIONS
MODELS
VISUALIZATIONS
INSIGHTS
DECISIONS
INTERVENTIONS
OUTCOMES
Real-time
Data Flow
(Satellite, Microwave, Fixed, and
Mobile Sensor Platforms)

MODULE INTERACTIONS WOULD BE A CONSTANT RESPONSE TO CONTINUOUS REAL-TIME DATA FLOW







Standardization and interoperability are essential for data collected, formatting, archiving, and model development

EVERY URBAN SEA SYSTEM IS UNIQUE & COMPLEX

But all face many similar issues and stresses.

On a Decadal Scale:

A comprehensive, interactive, international effort to optimize stewardship of all Urban Sea Systems would benefit most of humanity.

And,

Progress in addressing Urban Sea System Issues would also serve as progress toward alleviating many causes & impacts of climate change.

JRD RECOMMENDATIONS to NSF-DSOS Committee

- Identify Test-bed “UrbSea Trouble Spots”; Design Solution Paths: *Choose small number of Urban Sea Systems for Testing Integrated Digital Twin (DT) approaches to evolve capability of addressing more than 200 such systems on the Periphery of our Ocean*;
- Implement technical, legal, & economc sustainability of Real-Time data flow;
- Consider parallel development of Gaming Approaches to Urban Sea Systems: *These could underpin all levels of Education about complex interplay among stakeholders, as well as provide training grounds for UrbSea DT users and decision makers;*
- Foster Preparation of Generalists in addition to Specialists: *Interdisciplinary Degrees spanning computational, data, mathematical, and domain sciences are foundational to creating a workforce to advance development and use of Digital Twins;*
- Aggressively Pursue Multi-level Partnering: Agencies,Tribes, Industry, NGO’s;
- Expand “STEM” to “STE**A**M” (**A**rts) - Cast broader net>>more creativity/innovation.

''The Future Ain't What It Used To Be…”

Yogi Berra

Thank You!