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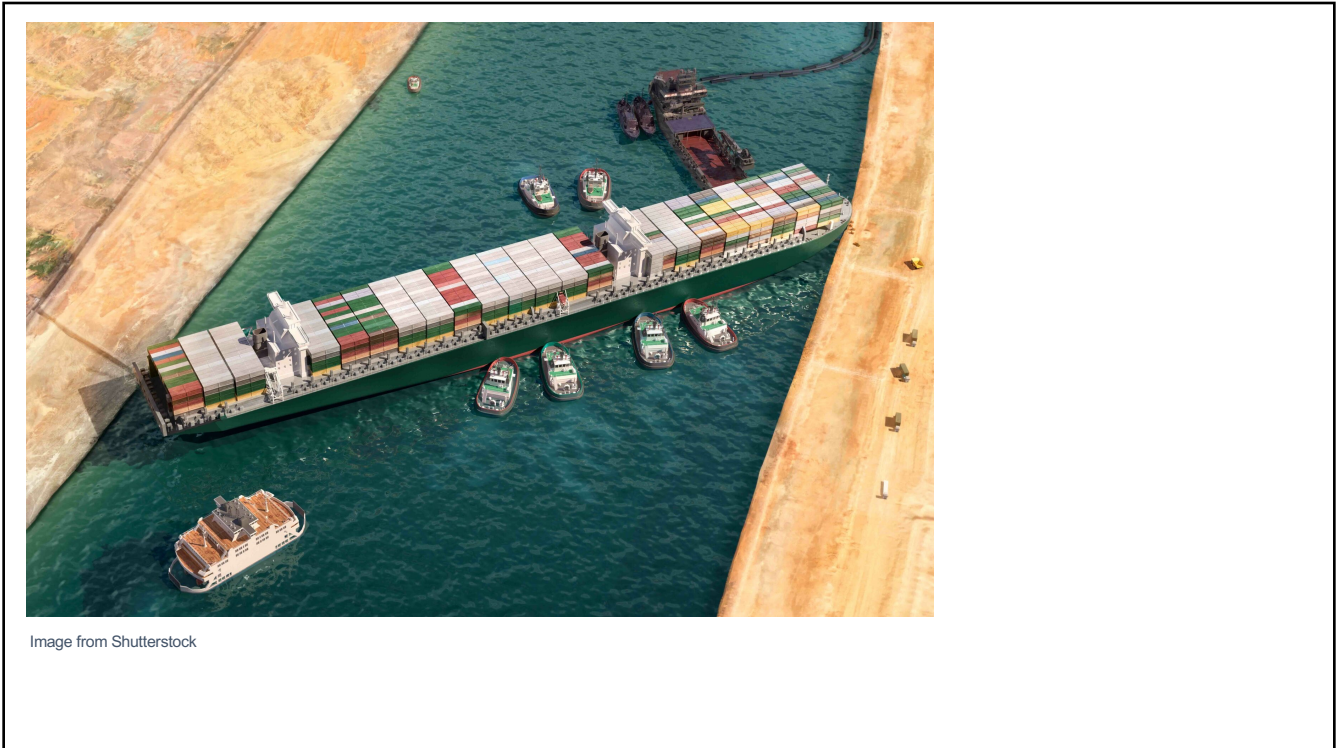
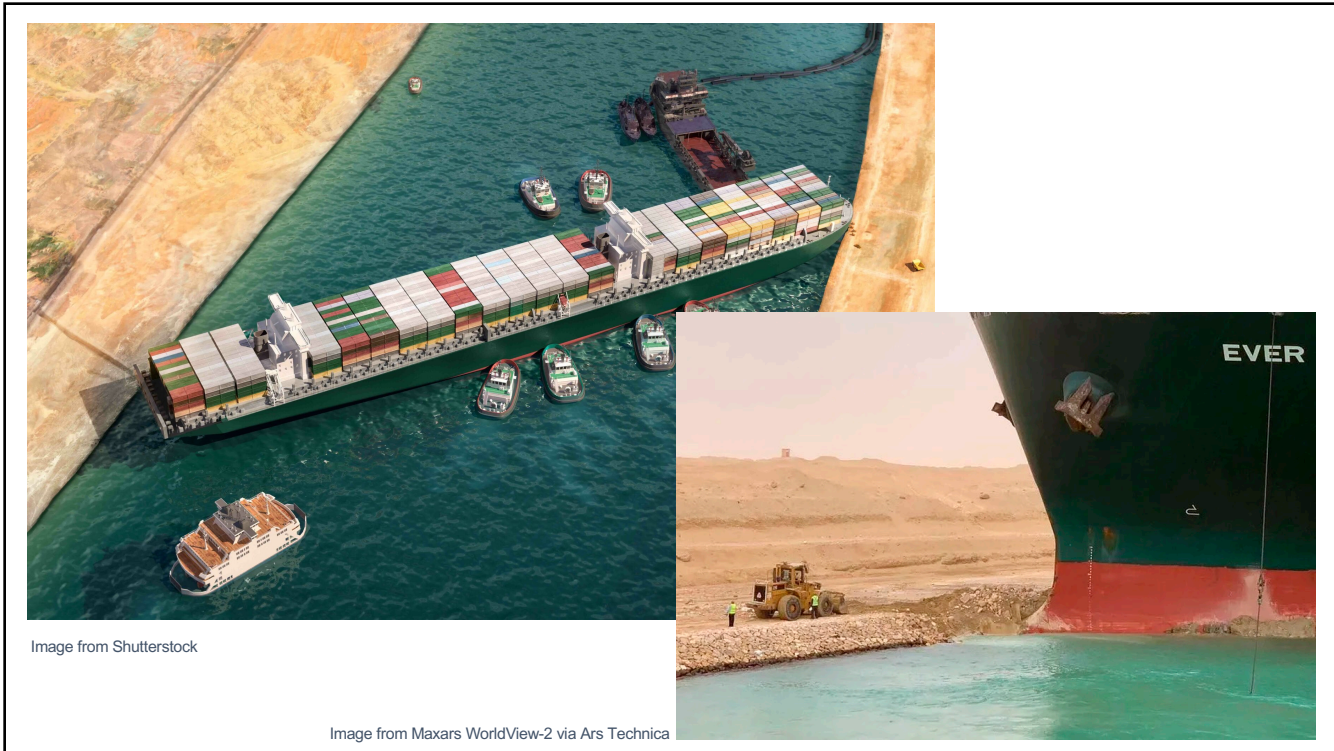


Image from Shutterstock

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## “World’s most costly traffic jam”



370 ships were stacked for ~ 1 week in 2021

- Thousands of containers delayed ~ 2 weeks
- Inbound / outbound raw materials, finished goods, equipment
- Delays, shortages, and inventory imbalances



What options did producers have?

- ST: shift/halt production, beg for extensions, ...
- LT: near-shoring, scale back JIT, ...



Shock was massive and rippled to the consumer

- Cost as much as \$400 million/HOUR in lost trade (CNBC), which is passed on to buyers



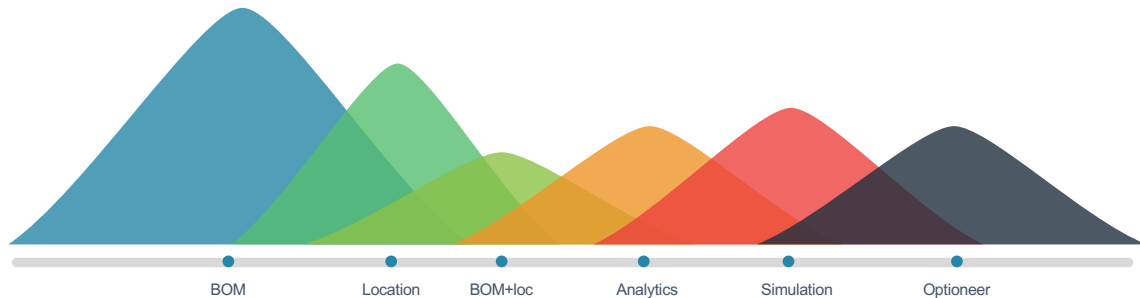
How can we prepare? It WILL happen again



Image from MyShipTraffic app via news.com.au

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## It starts with data, ends with action



● Do we have a BOM?  
Is it accurate? Current?

● Where are the inputs?  
Where are the components? Who has them? How do we get them?

● BOM + current location  
BOM management & visibility into part location via GPS / RFID are key

● Analyze the chain  
Where are the weak spots?

● Simulate impacts  
Which products are most affected? Customers?

● Optioneer  
Game out economic, technical, reputational impacts

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That could also be called a digital thread. A digital thread is ...

A **system** model that includes whatever the user needs: drawings, CAD models, CAM tool paths, assembly instructions, physics, inspection data, sensor data, repair history, physical parts added/subtracted, **BOM**, **supplier risk assessment**, **parts locations**, trade availability, equipment state ... updated as needed.

Does this all have to be in a **single** digital thread? Hmmmm.....

- Monica Schnitger

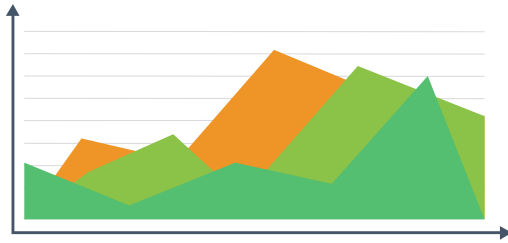
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## This is hard; why bother?

### Digital Threads for organizational change

Create a more data-focused organization; greater cohesion around data for purpose; customer focus from design through service



### For supply chains, specifically

- | Better visibility: monitor/track status and performance of supply chain in near-real time
- | Assess risk: detect/respond to disruptions faster and more effectively
- | Test supply chain design before implementation. Identify capacity constraints, demand fluctuations, inventory imbalances
- | Test contingencies: assess uncertainties and plan response and recovery
- | Create new types of innovation: new suppliers; better collaboration with partners and stakeholders, new modes of shipment

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## Digital threads enable new business opportunities



### Cooling-as-a-service, $\$/\Delta^{\circ}\text{F}$

- Changes relationship from one-time sale to continuous
- Changes economics from large, upfront to longer, periodic, smaller sale
- Goal: meet KPIs, max uptime with min OPEX, min CAPEX

### Move maintenance from reactive to predictive

How? Lots of sensors, remote monitoring, analytics

Edge maintenance using executable ROMs

Thread = as-installed/as-maintained per unit; connectivity/data gather

### Then from AC to connected building services

Cooling =  $f(\text{occupancy, weather, interior use, ...})$

What else relies on those same inputs? Escalators/elevators, lighting, ...

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## Wind turbine, on or off?

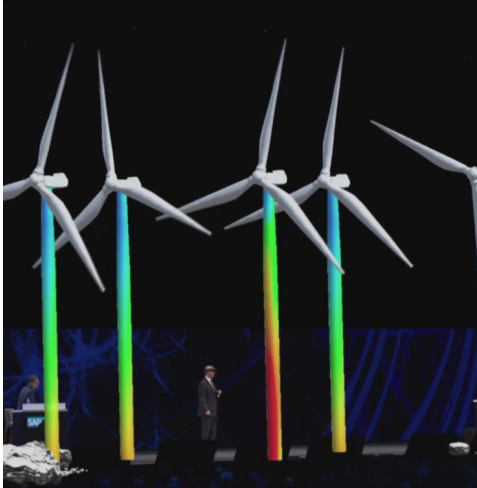


Image from SAPPHIRE keynote, May 2017

### Constant trade off between profit and cost

- Cost of wear + maintenance  $\gg$  profit?
- Remote; risky, expensive maintenance

### Create CAE-driven digital threads of as-is pylon

Detailed digital thread of each individual system, accurate as-is data  
Sensors (real or virtual) + structural simulation signals system health  
Start with 1 turbine/pylon, prove fidelity

### Then entire field ... then all assets

Optimize 1 pylon, realize it affects all others; model field, prove fidelity  
Then all assets under management

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## “Digital Twins are in the WSJ; make me one!”



### Airports have many (aging) assets

- What do we have? Physical? Digital? As-is / as-built / as-designed?
- Regulated / unregulated, security-driven, old/new

### Map physical, then create digital

- Laser scanning, photogrammetry into automatic model creation
- Also GIS, AEC, MCAD, electronics
- From contractors, municipality, airlines ... Many formats, fidelities, states

### To do ... what, exactly?

- CFO wanted to put own stamp on organization
- Create cohesion, focus on data as a deliverable
- Ultimately, get better control over all assets — for infrastructure planning, project execution; coordinated analytics for people/plane/goods movement; security using image recognition, etc.

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## Optimizing refinery profit with AI/ML — on a digital thread



### Constant trade off between profit and cost

- Need to optimize capacity, maintenance timing, staff availability
- Produce/don't = f(Order book/due dates, inventory levels, market forecasts for inputs, delay, penalties)
- Goal is to create a predictable, optimal schedule to maximize profit

### Requires a LOT of data

- Accurate model of chemical processes
- Current as-is state of maintained equipment
- Quality level of inputs (for pre-processing or additive decisions)
- Costs of all inputs (power, raw materials, catalysts, etc.)
- While operating, sensor data streams in —all monitored, most archived

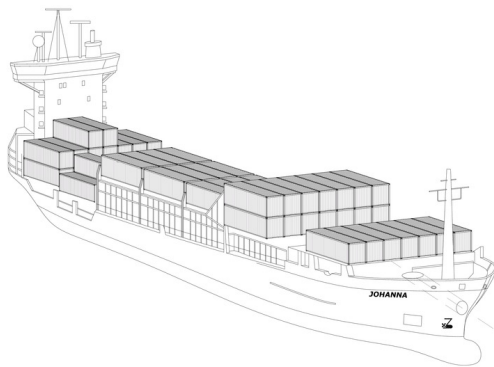
### Petrochem may be ahead on operating digital threads

- Process flow diagram is core thread — it's a drawing, not a CAD model
- Facility constantly adjusting to inputs so automation is essential, not extra
- Focus of plant designers/builders as service offering to operators

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## Technology is only a part of the digital thread story

The Ever Given would probably have run aground even if there was a digital thread — litigation continues. But it might have changed the situation enough to prevent it ...



*The key here is **as-is**; start with 1 or 2 key systems*

#### ● CAE-enabled load/transit

Dynamics/statics ROM, sensor inputs; simple operator output

#### ● Advanced route planning

Using software, f(weather, traffic, fuel use, sensor inputs ...)

#### ● Local control, with help

Remote, on-land master/pilot available

#### ● Look for engagement

Most potential crew inexperienced; train on digital assets, AR/VR, gamification

#### ● Autonomous at sea

Autonomous in open seas, using on sensor data to optimize fuel use v transit time

#### ● Update Update Update

Model as-is hull, simulate integrity; fed back into thread; update ROMs, training , etc.

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## Digital threads can interconnect, model, serve in context



+ As-designed  
CAD, CAE, PLM, etc.



+ Supply chain  
BOMs, SCM, ERP, etc.



+ As-built  
CAM, IT/OT, Edge, etc.



+ As-operated  
CAD,  
IoT/sensors/connectivity,  
etc.

*Technology is only a part of the digital thread story — it is, essentially, an organizational-change story much like PLM was/is*

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## Figuring out what's next

Shocks will keep coming

Digital threads help us be ready, forcing us to gather data, perhaps change to a more data-centric culture

- How can digital threads be used to optimize performance, efficiency and innovation?
- Should they be integrated with/created for IoT, AI and cloud computing?
- What processes need real-time / near real-time / static data?
- Who interacts with the thread, what format do they want/need? Where do we need 3D, visualization, simulation? When is 2D enough?
- It's got to be current or identified as static — can't be both!**



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Stay in touch!

Monica Schnitger  
Schnitger Corp

[www.schnitgercorp.com](http://www.schnitgercorp.com)

[monica@schnitgercorp.com](mailto:monica@schnitgercorp.com)

<https://www.linkedin.com/in/monicaschnitger/>

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## Whatever happened to the Ever Given?

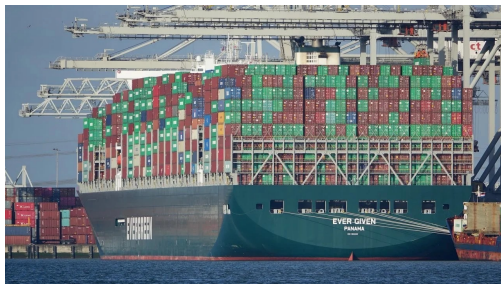






Image: <https://www.flickr.com/photos/68359921@N08/49643352087/>

- 

**Back plying her route**  
Asia to Europe — but should she be?  
Shipping has too much idle capacity for a vessel this big, IMHO
- 

**Probably typical with respect to crewing**  
Shipping still assumes a 1950s-era stereotype: white, male, middling education. Today's crews are far more diverse and less experienced
- 

**Technology use likely lags other industries**  
Shipping experimenting with autonomy, remote ops  
Training must be gamified, connected; tech is often under-utilized  
Sensor data is gathered and archived but rarely used; sound familiar?
- 

**Litigation continues**  
No one has admitted responsibility for the grounding, though hundreds of millions have already been paid in compensation

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## Naval building is constrained — commercial is different



### Integrated design/build

Leads to manufacturing and supply chain efficiencies; designed for manufacturability; possibly for maintenance



### Closer coupling for innovation

Energy saving hull forms, new materials to reduce weight, alt energy propulsion systems, waste heat recovery ...



### Supply chain innovation

Some captive elements but in any case, massive leverage because of volume



### MARAD was (kinda) right!

Imabari Employs modern versions of all the techniques MARAD wanted us to learn in the 1980s — but harder to implement without captive supply chains



Image of Saijo Shipyard, courtesy of Imabari Shipbuilding Co.

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## Ever Given is a Suezmax container ship



### Huge!

400m x 60m x 33m  
(Empire State Building x  
20 story building x  
3 school buses)



### Complicated

Leased to technical  
operator: staffing,  
chartering her capacity



### KPI 1: On time

Synchronizes transit  
schedule to supply  
chains, meaning  
predictability is key



Image: Wikipedia. [https://en.wikipedia.org/wiki/Ever\\_Given](https://en.wikipedia.org/wiki/Ever_Given)



### Huge!

Carries 20K containers



### Complicated

Probably no digital thread  
of most systems and likely  
not of the entire vessel



### New-ish!

Newer than the average  
fleet, so has more  
sensors and electronics

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