FME AI FOR INDUSTRY JAAREVENT

Op weg naar autonome systemen met behulp van AI

7 december 2023

FME POWERED BY DUTCH TECHNOLOGY

AUTONOME SYSTEMEN

AGENDA

1. Digital Twins and AI in Advanced Processing
   Jan Post – Philips
2. Mech-AI-tronics
   Bayu Jayawardhana – Rijksuniversiteit Groningen
3. Mayflower Autonomous Ship (MAS 400)
   Ronald Teijken - IBM

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Faculty of Science and Engineering

University of Groningen, the Netherlands

Digital Twins and AI in Advanced Processing of a Complex Material

Jan Post

Industrial maturity in Industry 4.0 according the Acatech standard

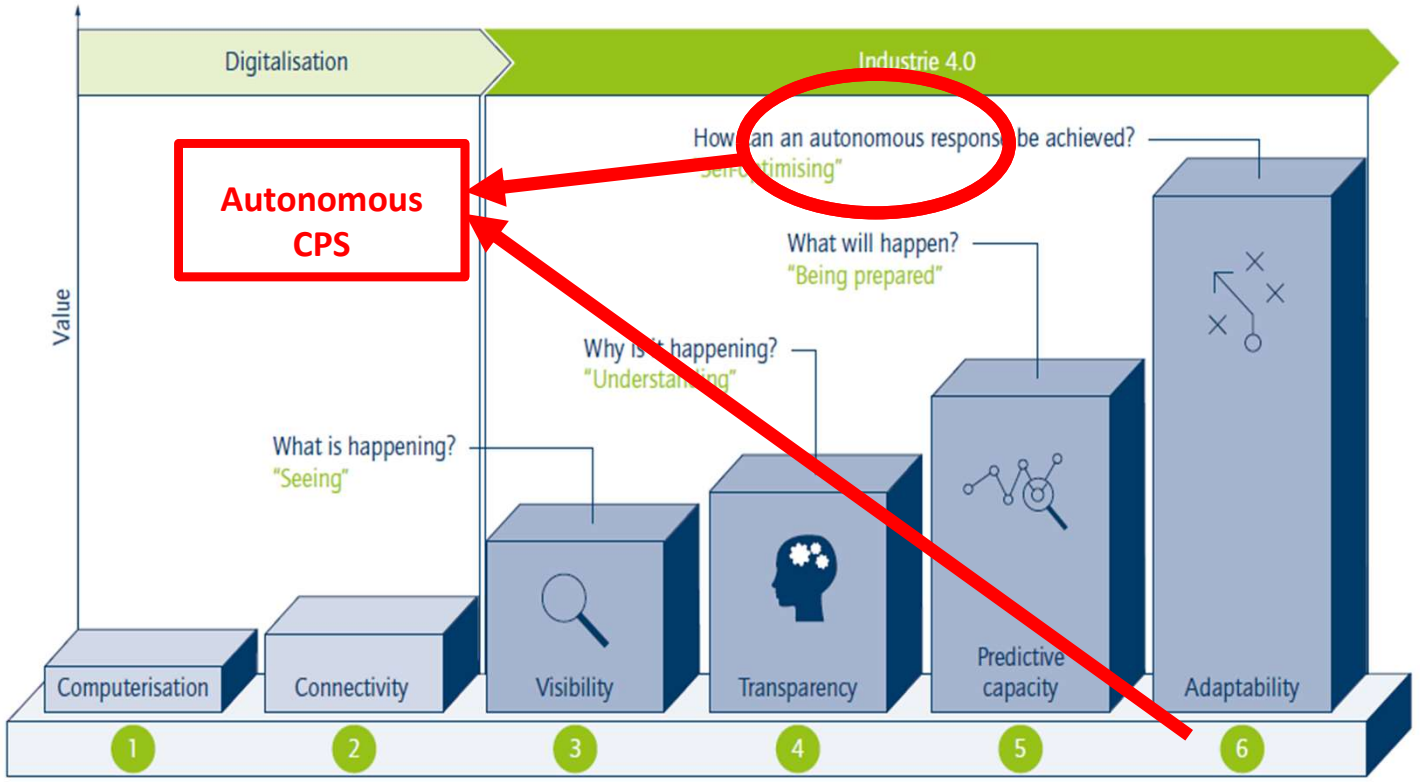
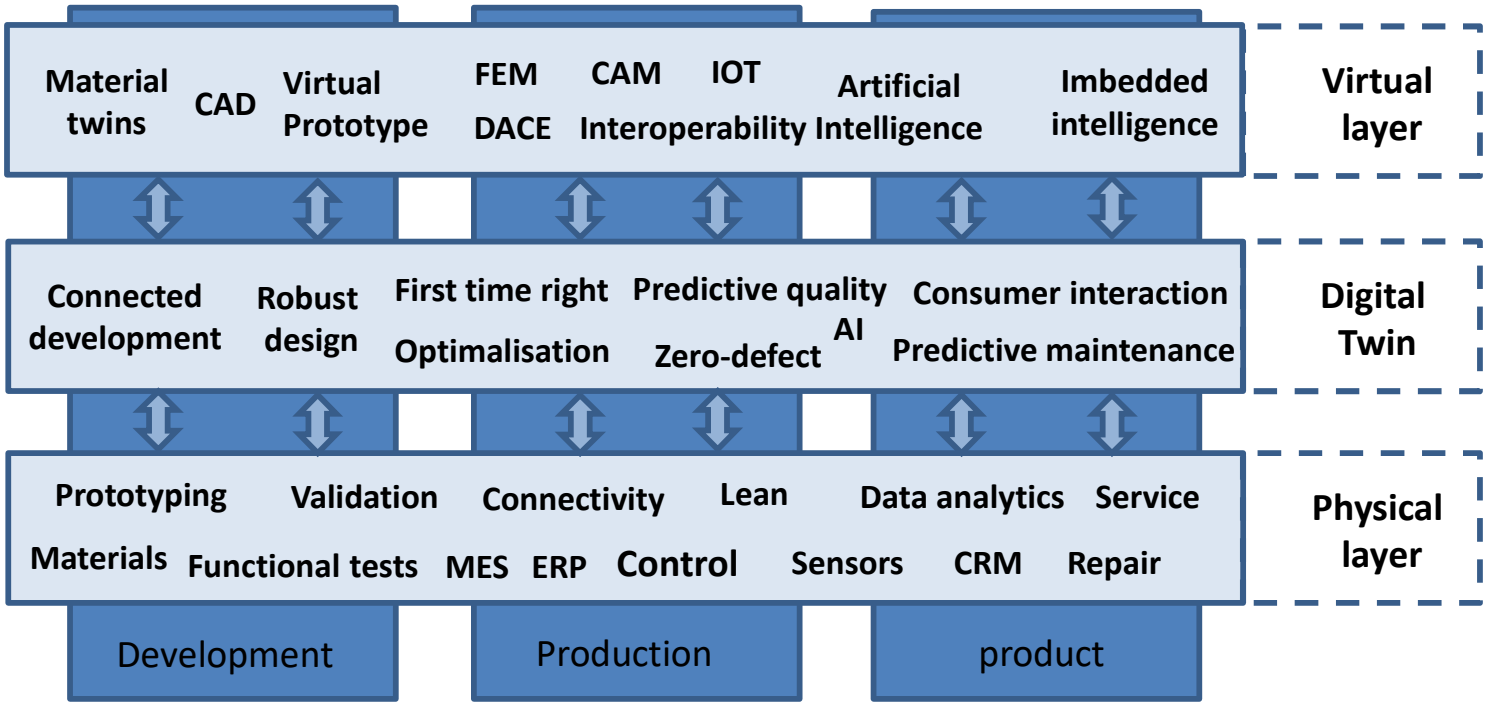
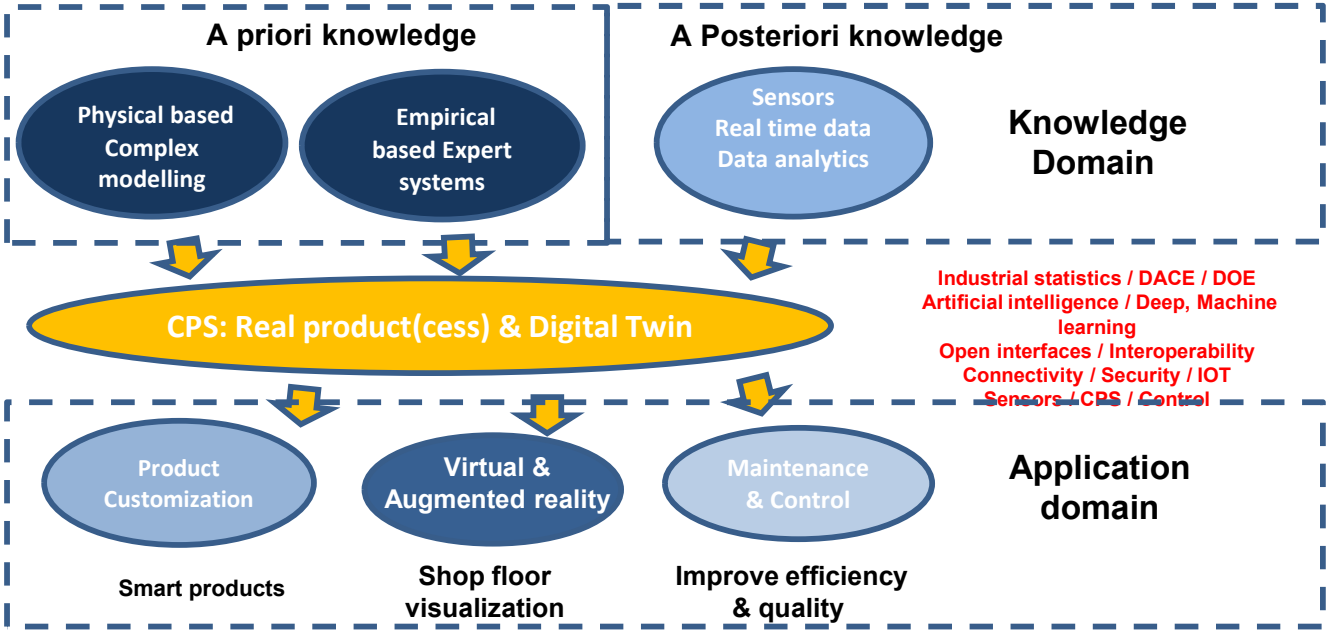


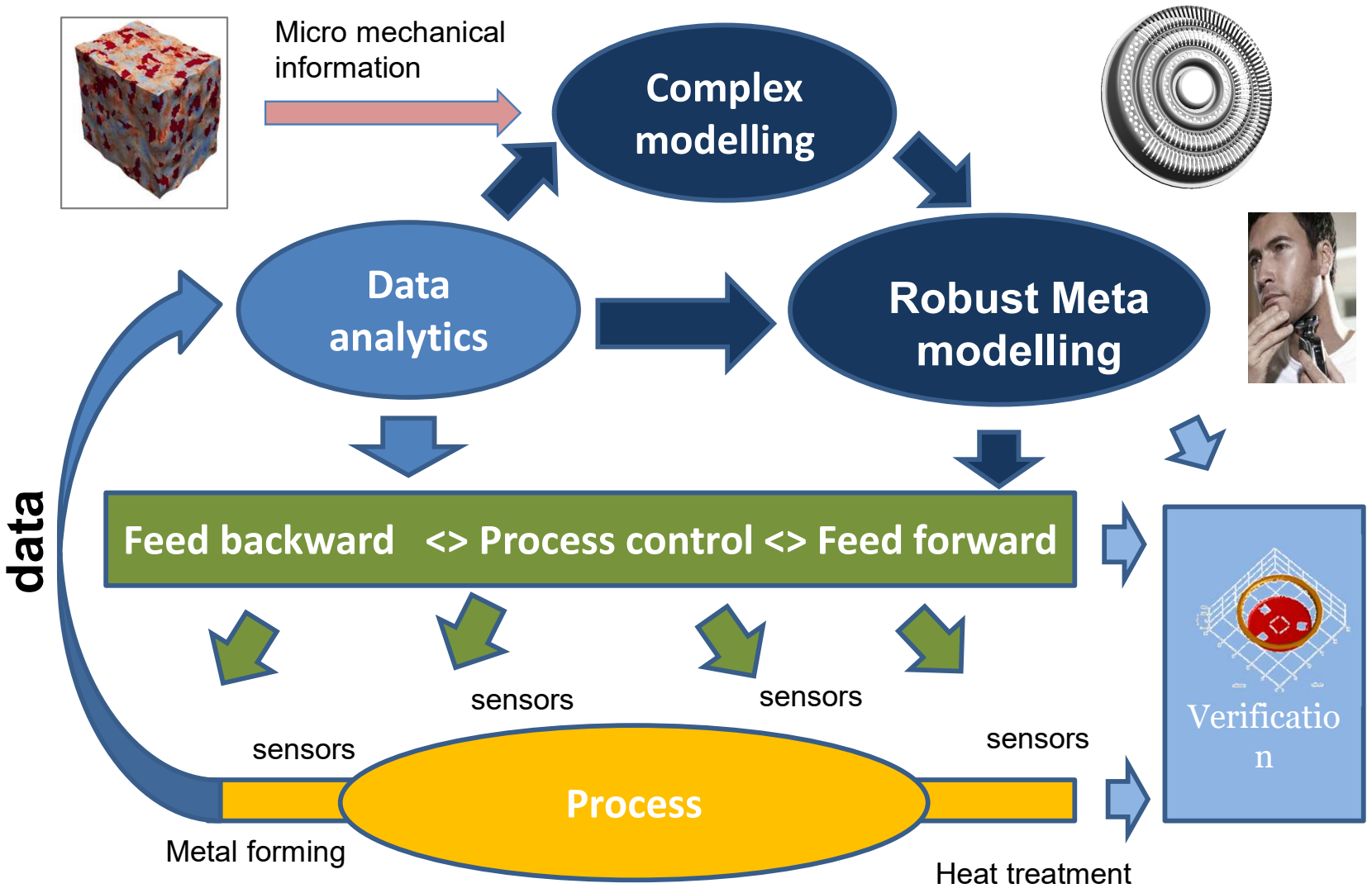
Figure 5: Stages in the Industrie 4.0 development path (source: FIR e. V. at RWTH Aachen University)

The Layers in a Digital Twin Platform



The digital Twin Concept:
The Future, data/model driven, Industrial Digital Platforms for autonomy in Zero defect, Human interaction & predictive quality in products/machines.




Micro mechanical information
Complex modelling
Data analytics
Robust Meta modelling
data
Feed backward <> Process control <> Feed forward
sensors
sensors
sensors
sensors
Process
Metal forming
Heat treatment
Verification

rijksuniversiteit groningen

PHILIPS

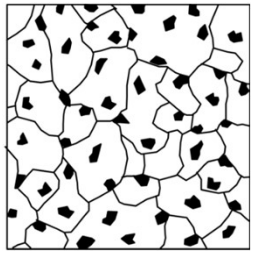
11 December 2023

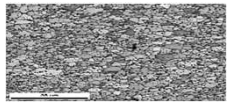
From experiment to FEA using Crystal Plasticity & Neural Networks

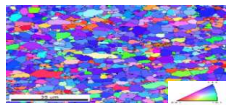
Soheil Solhjoo, Jan Post, Antonis I. Vakis

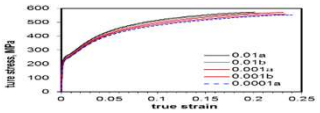
Advanced Production Engineering (APE)
Engineering and Technology Institute of Groningen (ENTEG)
Faculty of Mathematics & Natural Sciences
University of Groningen, the Netherlands

Damask (Max Planck)



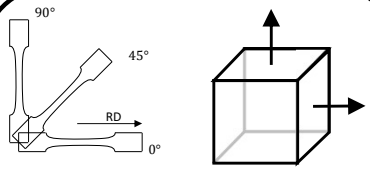


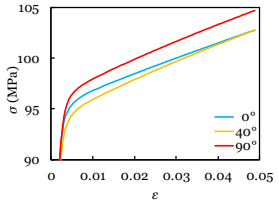


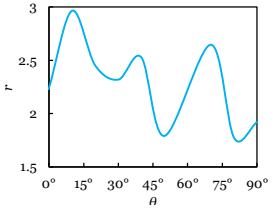


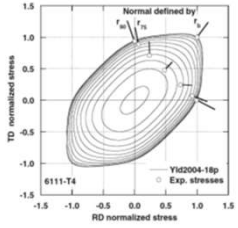
Experiments

Virtual Lab





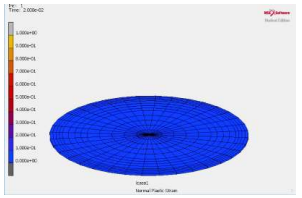


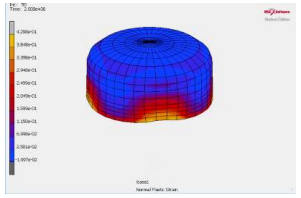


Constitutive Behavior

Neural Networks (machine learning)

FEM



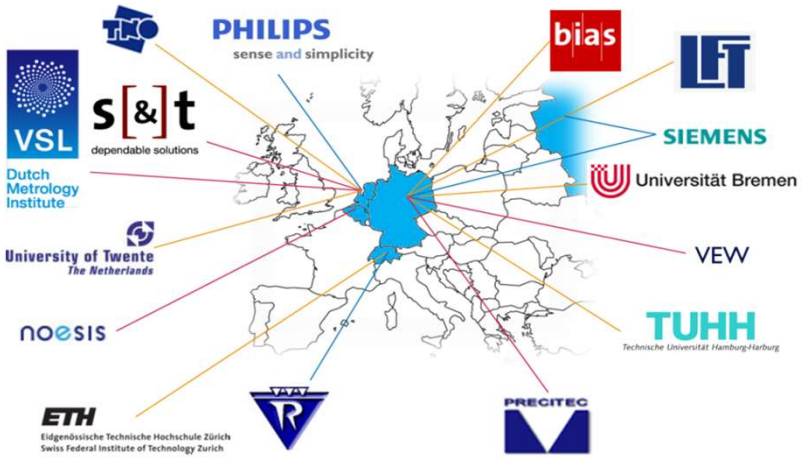


MEGaFiT

Manufacturing Error-free Goods at First Time

Summarized

- Project start: Dec 2011
- Duration: 36 months
- Partners: 15
- Total cost: 10.9M€
- EU funding: 7.1M€



The work leading to these results has received funding from the European Community's Seventh Framework Programme under grant agreement n° FP7–285030

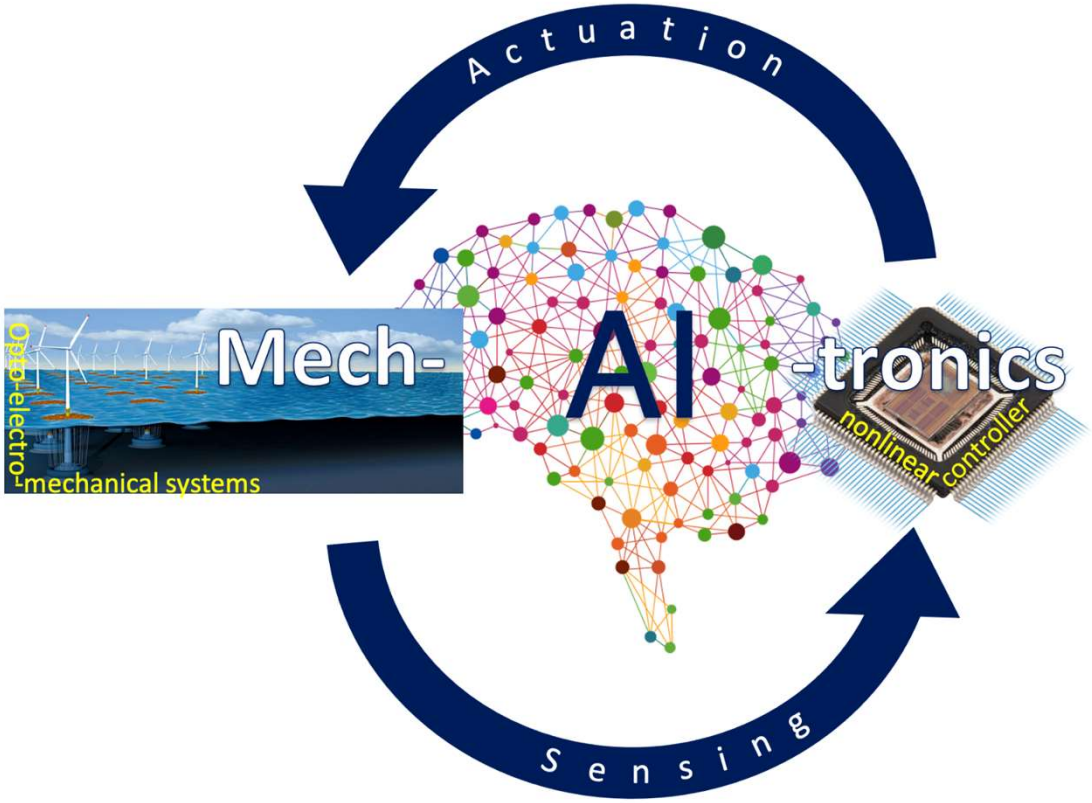
Demonstration

The work leading to these results
has received funding from the
European Community's
Seventh Framework Programme
under grant agreement n° FP7-285030

Where is the AI?

- Machine learning and deep learning in material science
- Machine learning based Material twins as a part of Physical modelling
- Deep learning in online sensors
- Machine learning based surrogate models for optimization
- Machine learning based control systems

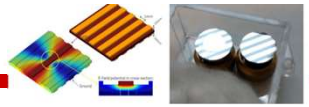
Questions



Bayu Jayawardhana
Faculty of Science & Engineering, University of Groningen
https://www.rug.nl/staff/b.jayawardhana

university of groningen / faculty of science and engineering

university of groningen



Nieuwe generatie van hightechsystemen

Vermindering van de ontwikkeltijd (kosten)

EUV photolitography
- 2006

Airbus A380
1998 - 2005

2012 - 2015

2008 - 2012

n 1 SpaceX
2002 - 2008

BigDog - Boston Dynamics
1992 - 2005

Systems complexity

Hybride AI + Model-gebaseerde aanpakken

Toenemende eisen aan veiligheid en systeemprestaties voor hightechsystemen

DJI Mavic s
2015-20

VR Oculus
2016 - 2019

Co AI
(O ilot)
20 2016

azon alexa
ts predecessor:
Ivo (2002-2006)

WAYMO
Waymo
Autonomous
car
2009 - 2014

AI-based/data
approac

Physics/model-based

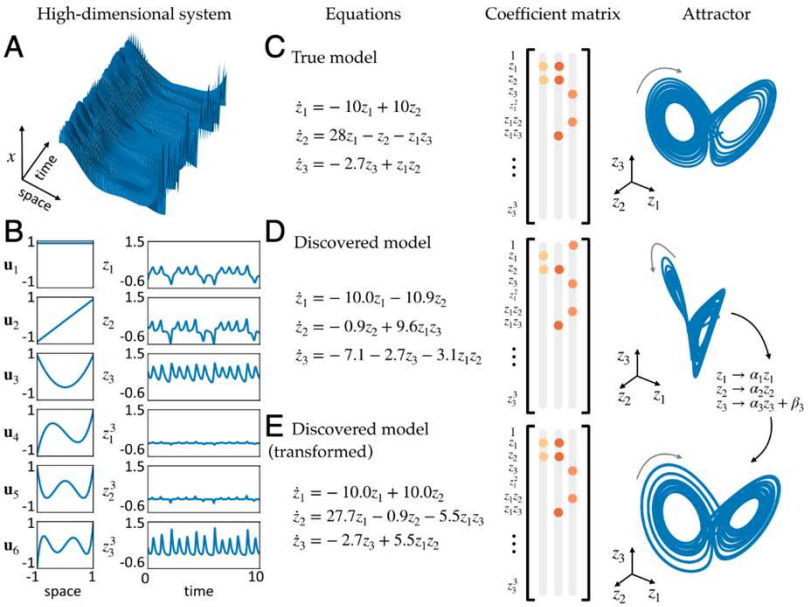
JOB SCARCITY INDICATOR 1st QUARTER 2021	STRESS LEVEL	CATE Y
Agricultural professions	1.42	
Business economics and administration professions	1.72	
Commercial professions		
Creative and linguistic prof		
Ser		verage
Information		very tight
		average
Public admi	1,82	tight
	1,06	average
nical professions	2,53	tight
t and logistics professions	1,39	average
ealthcare and welfare professions	2,03	tight
Total	1,45	average

Het verkorten van de ontwikkelingstijd kan **NIET** worden bereikt door het uitbreiden van het engineeringteam

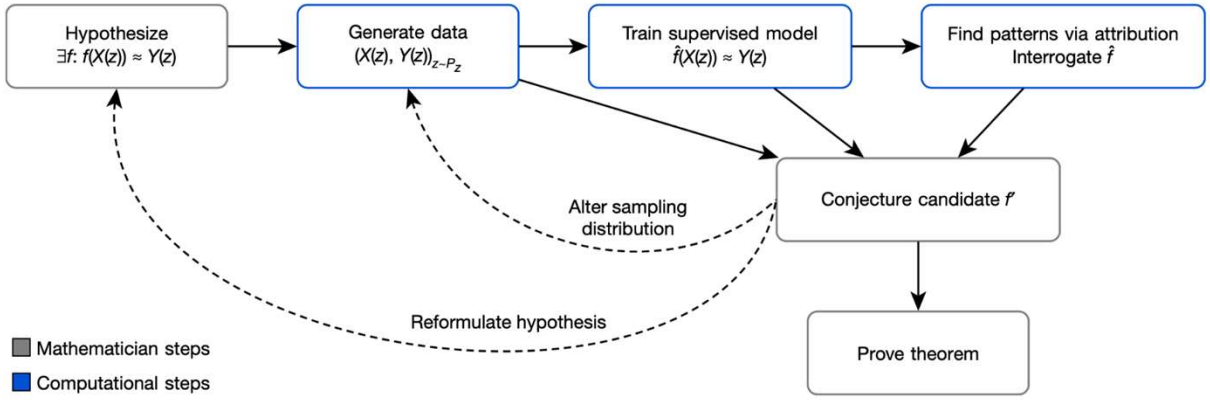
Development time (years)

The stress level index from UWV of Dutch labour scarcity in Q1 2021 (Reitsma et al., 2021)

AI in wetenschappelijke ontdekkingen



Champion etal.,
Data-driven discovery of coordinates and governing equations, PNAS, 2019



Davies etal., Advancing mathematics by guiding human intuition with AI, Nature, December 2021

AI als universele approximator (tegenwoordig) towards AI as universele controles

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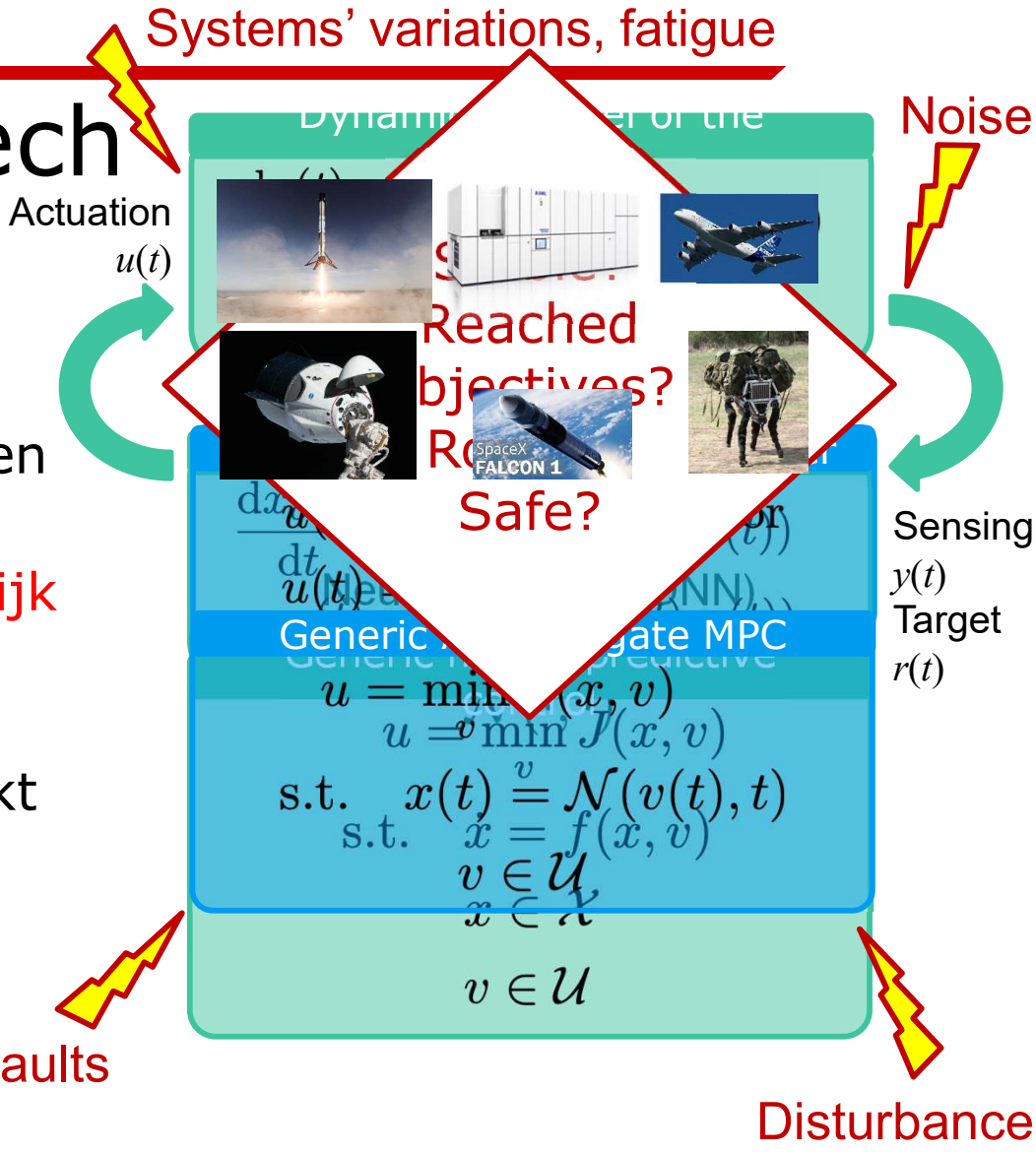
Controle van high-tech systemen

- Uitdagingen:
  (i). Complexiteit (niet lineairiteit); en
  (ii). Beperking in huidige methoden
- Impact: Gebrek aan precisie, moeilijk te automatiseren en lange ontwikkeltijd
- AI-methoden zijn nog **NIET** geschikt als universele controllers



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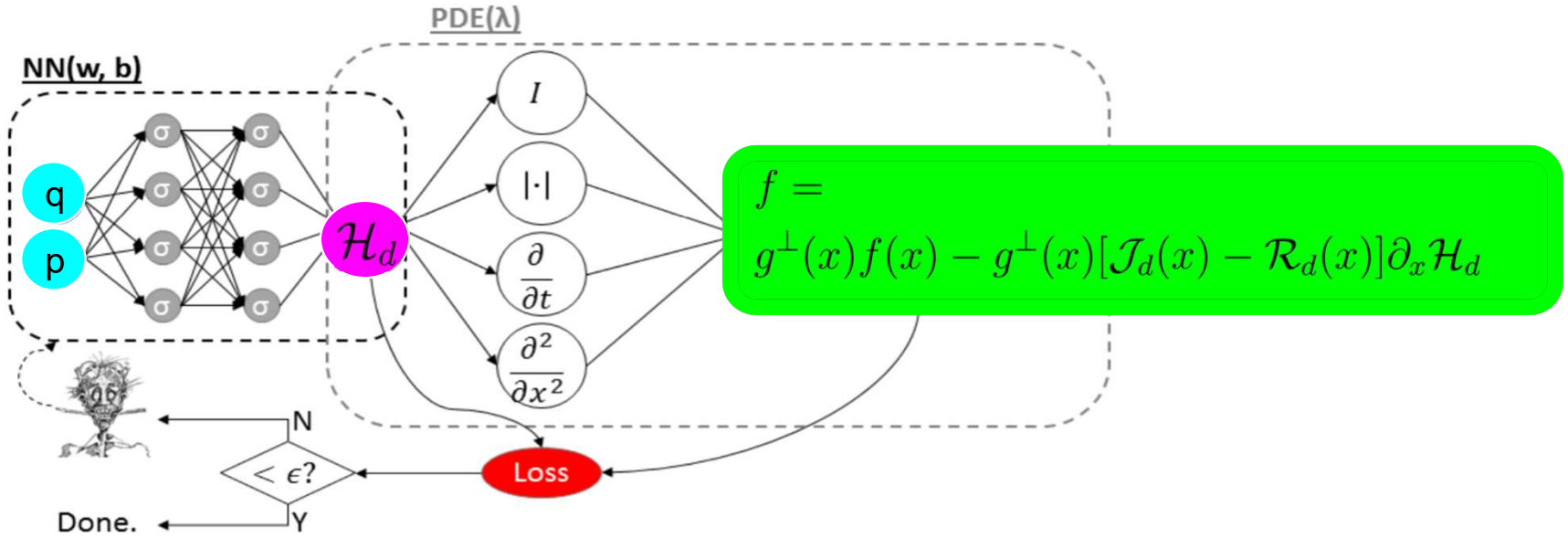
Uitdagingen en Kansen

Hoe AI-methoden en modelgebaseerde aanpakken kunnen worden geïntegreerd voor het ontwerp van complexe engineering systemen met gegarandeerde prestaties, veiligheid en robuustheid

AI as universal approximators (present day) → towards → AI as universal controllers

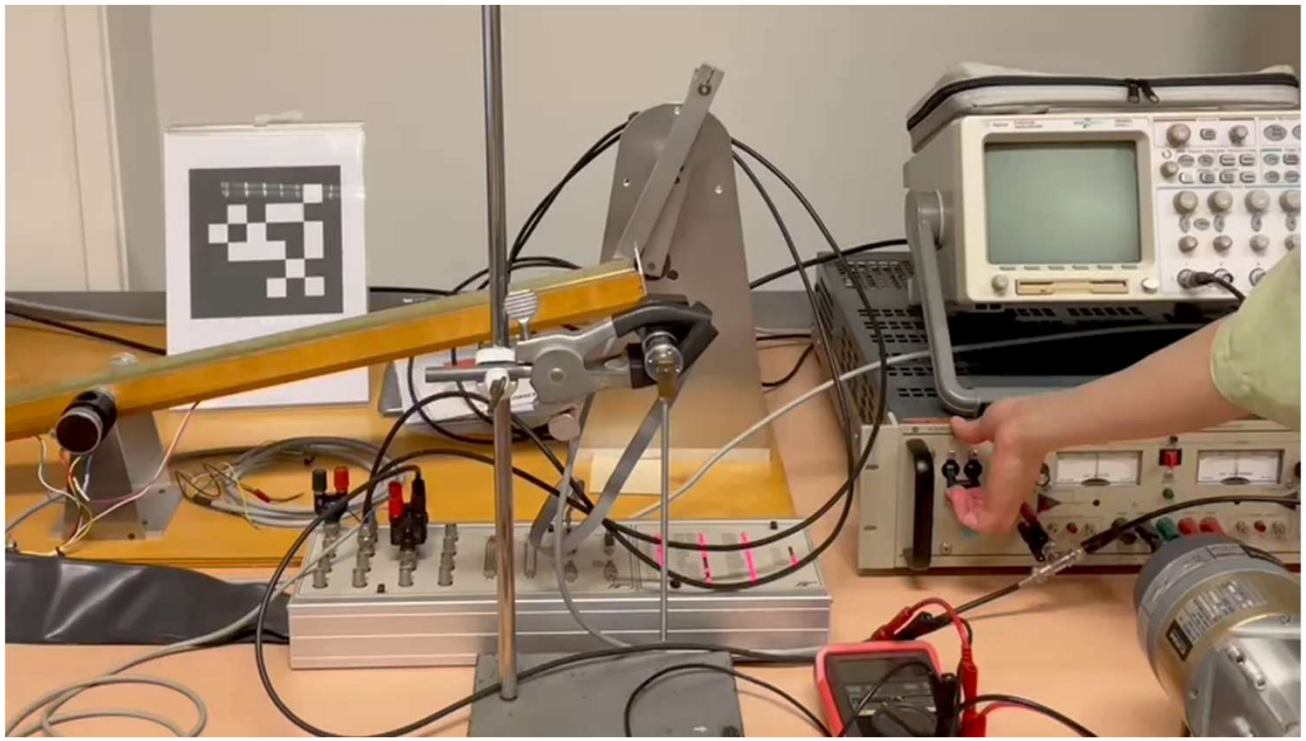
Control Systems Informed NN



Adapted from George Karniadakis MLTP2020 presentation

*S. Sanchez, R. Reyes-Baez, **B. Jayawardhana**, "Total Energy Shaping with Neural Interconnection and Damping Assignment - Passivity Based Control," 4th Annual Learning for Dynamics & Control Conference, Stanford University, 2022.
*S. Sanchez, R. Reyes-Baez, **B. Jayawardhana**, "Stabilization of Underactuated Systems of Degree One via Neural Interconnection and Damping Assignment Passivity Based Control," Proc. 61st IEEE Conf. Decision & Control, Cancun, 2022.

Control Systems Informed NN



Credit: V. Tajgler, IEM bachelor project @Univ. Groningen (2022)

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Control-systems Informed AI scheme

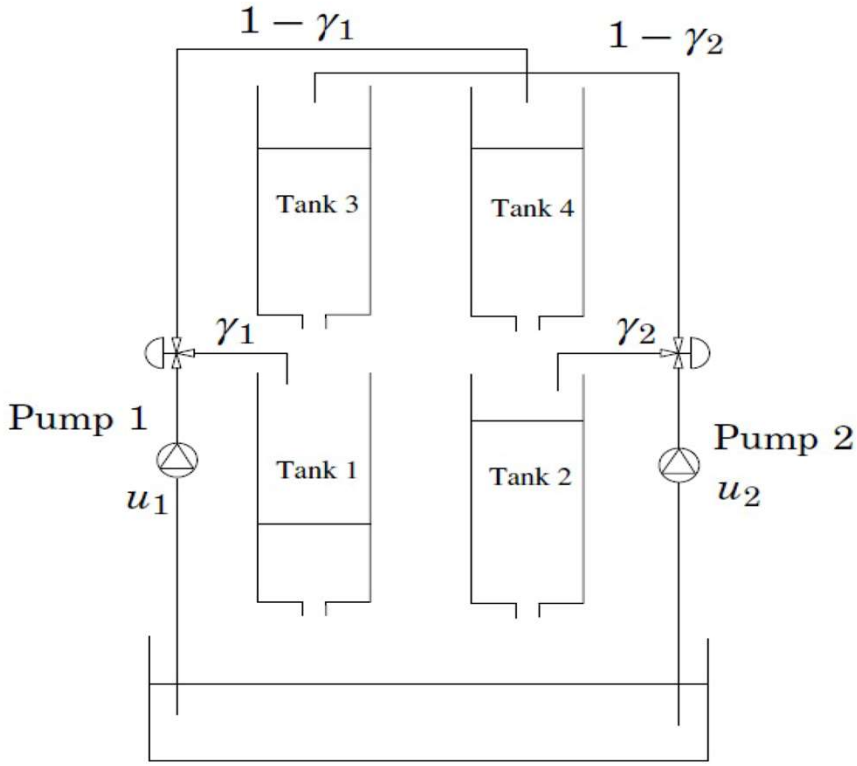
Control Systems

$$\begin{bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \\ \dot{x}_3(t) \\ \dot{x}_4(t) \end{bmatrix} = \begin{bmatrix} -\frac{a_1}{A_1}\sqrt{2gx_1} + \frac{a_3}{A_1}\sqrt{2gx_3} + \frac{\gamma_1 k_1}{A_1}u_1 \\ -\frac{a_2}{A_2}\sqrt{2gx_2} + \frac{a_4}{A_2}\sqrt{2gx_4} + \frac{\gamma_2 k_2}{A_2}u_2 \\ -\frac{a_3}{A_3}\sqrt{2gx_3} + \frac{(1-\gamma_2)k_2}{A_3}u_2 \\ -\frac{a_4}{A_4}\sqrt{2gx_4} + \frac{(1-\gamma_1)k_1}{A_4}u_1 \end{bmatrix},$$

$$y(t) = k_c \begin{bmatrix} x_1 & x_2 \end{bmatrix}^\top.$$

DNN

$$x = \mathcal{H}(x)$$



- Niet-lineaire Model Predictive Control (NMPC) kunnen met digital twin berekend worden
- De data kunnen gebruikt worden om een AI model te trainen

K.H. Johansson, "The quadruple-tank process: a multivariable laboratory process with an adjustable zero," IEEE Trans. Control Syst. Technol., 8(3):456-465, May 2000.

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Control Systems Informed AI with MPC

Mayflower Autonomous Ship (MAS 400)

Ronald Teijken

IBM

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The Mayflower (1620)

Leiden (NL) => Plymouth (UK) => Plymouth, MA (US)

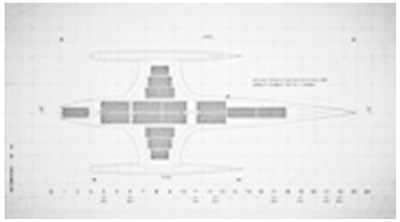
Where it all started

The original Mayflower set sail from Plymouth, England, in 1620 with the famous "**Pilgrim Fathers**" to settle in America.

400 years later, the **Mayflower Autonomous Ship** needs neither crew nor Pilgrims.

Brett Phaneuf - realized his vision of building a unique autonomously working research ship, equipped with numerous sensors, AI systems and high-tech technology.

Powered by AI and drawing on energy from the sun the Mayflower has global mission of discovery and collect data to help safeguard the future of the ocean.



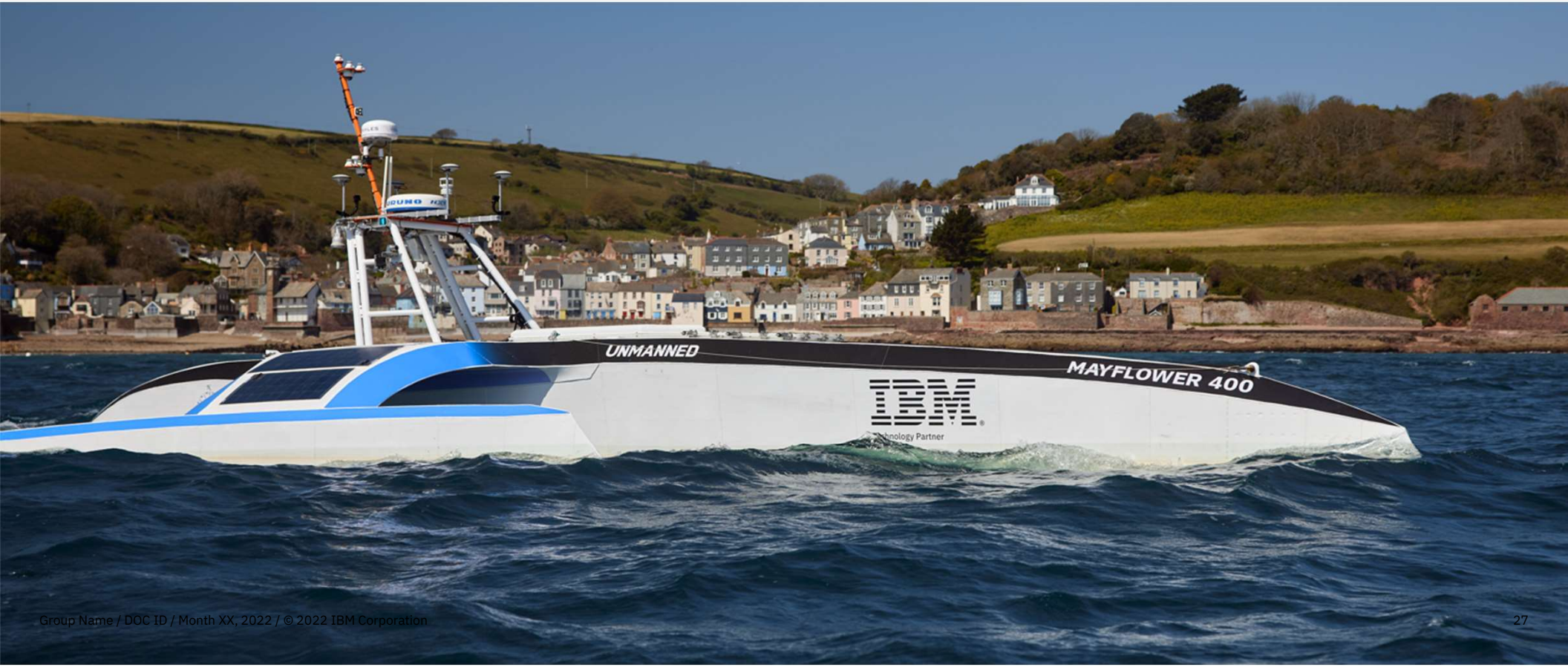
Did you know …

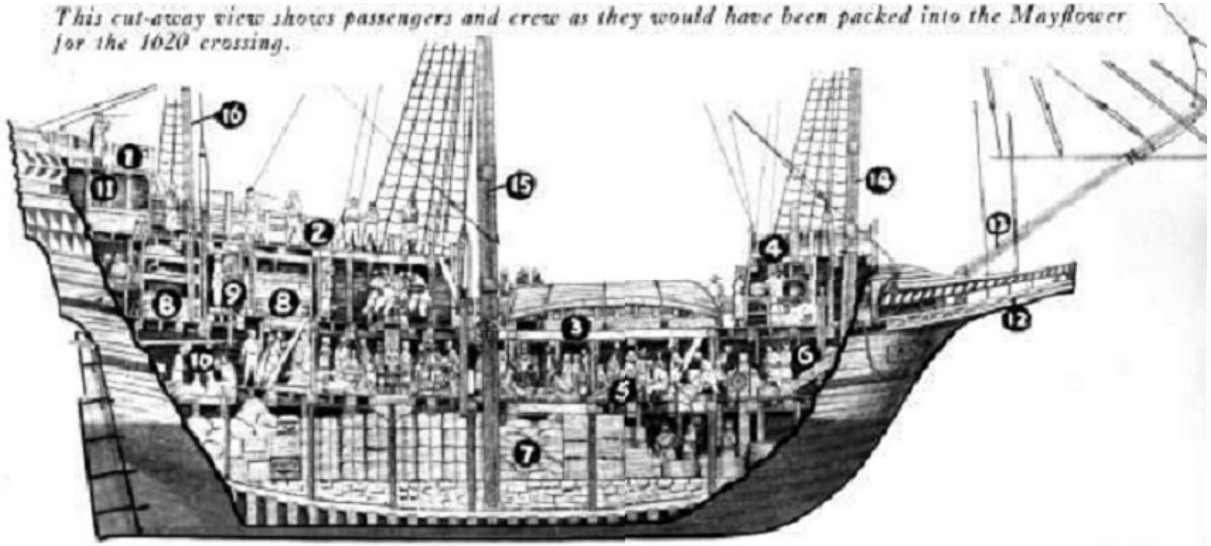
- Nearly **80%** of earth's oceans have never been explored!

- **50%** of the oxygen we breathe is produced by the oceans

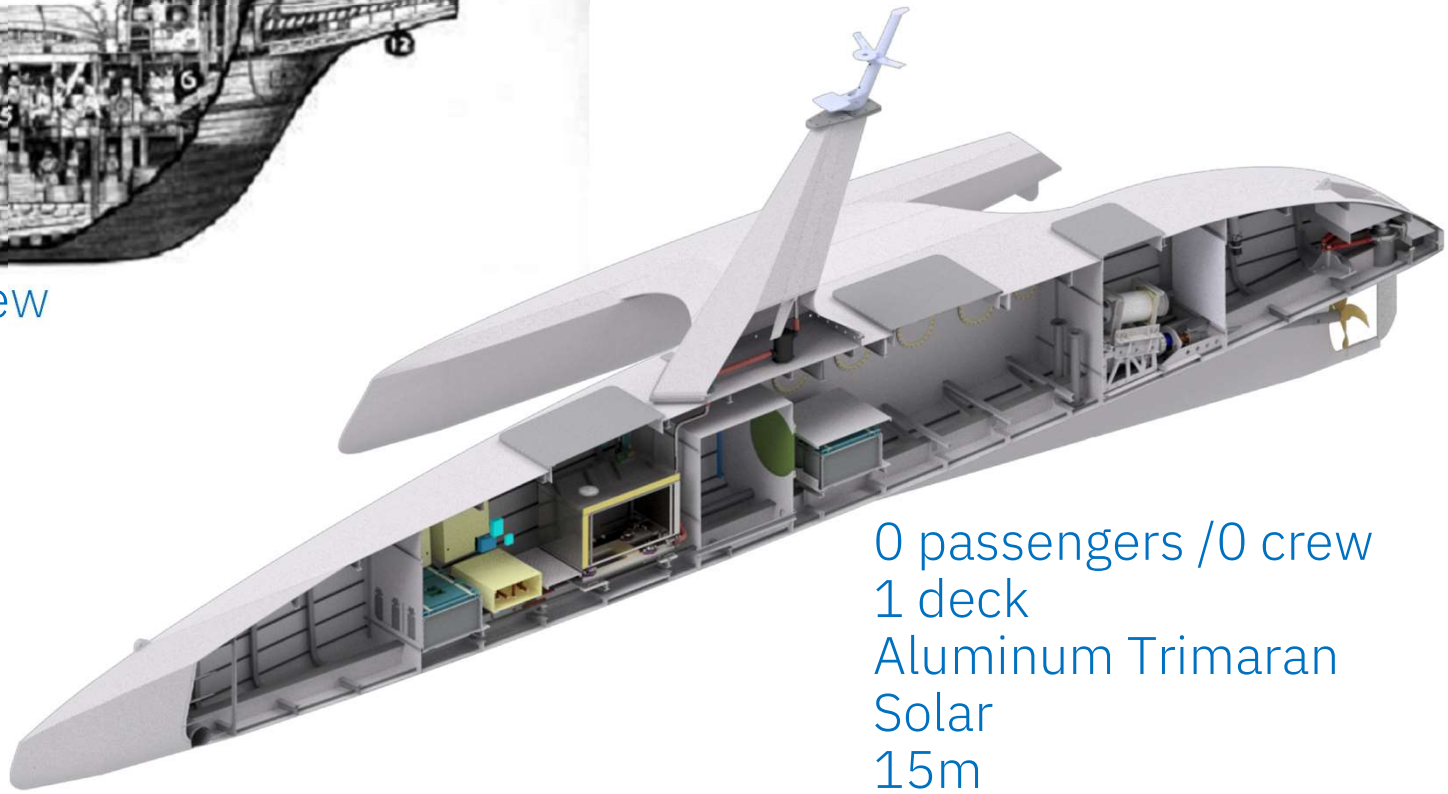
- **90%** of all global trade is ocean-based transport

Mayflower 400!

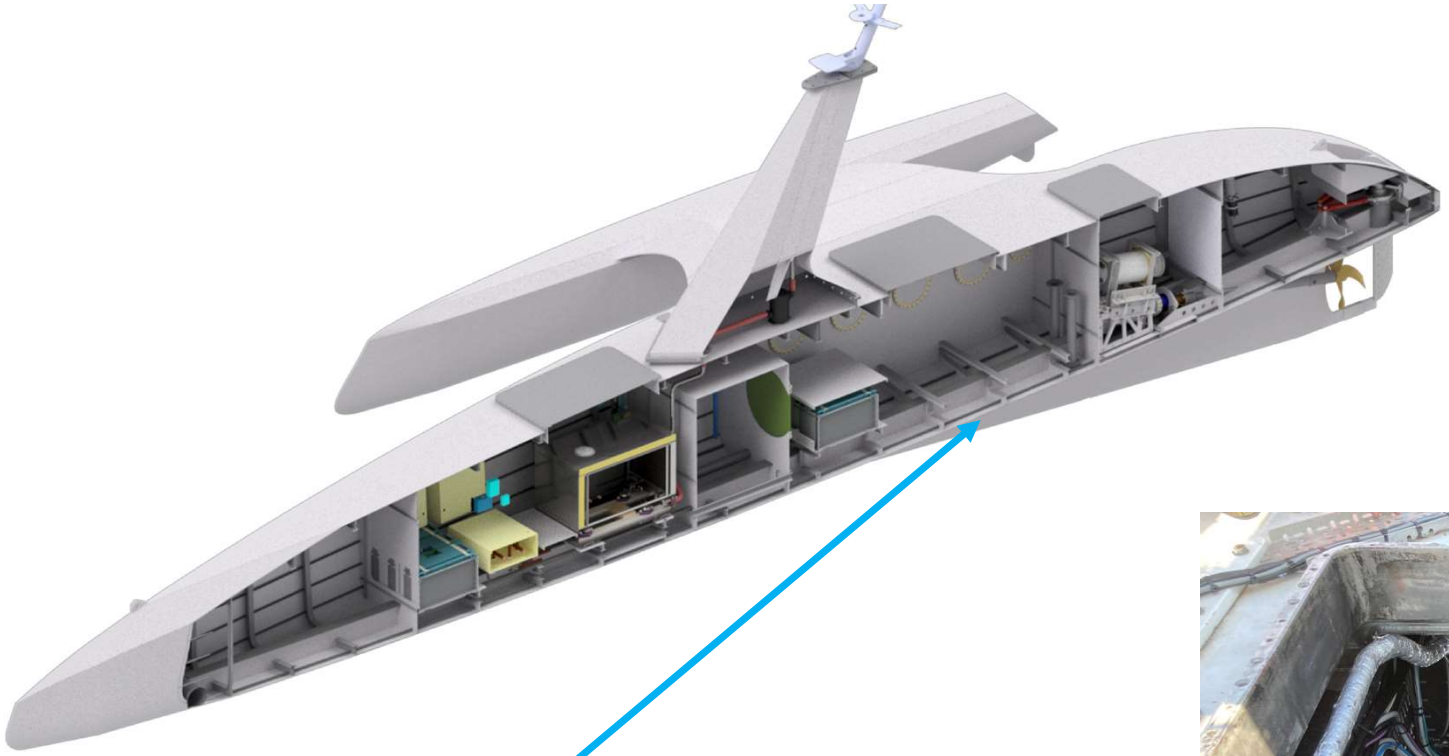


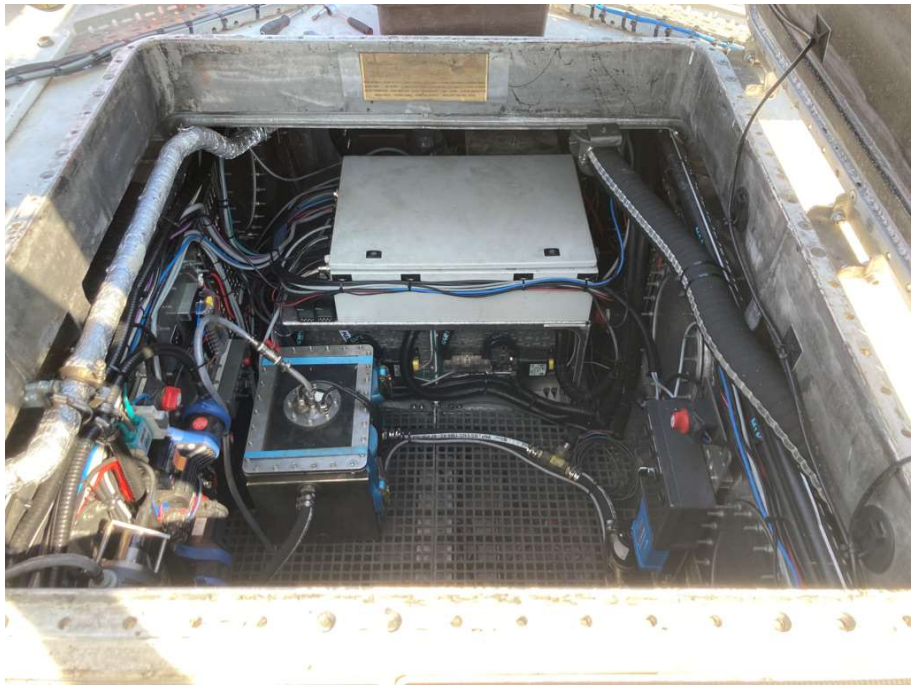


102 passengers / 30 crew
4 decks
Wooden “Fluyt”
Wind
30 - 34m
Merchant



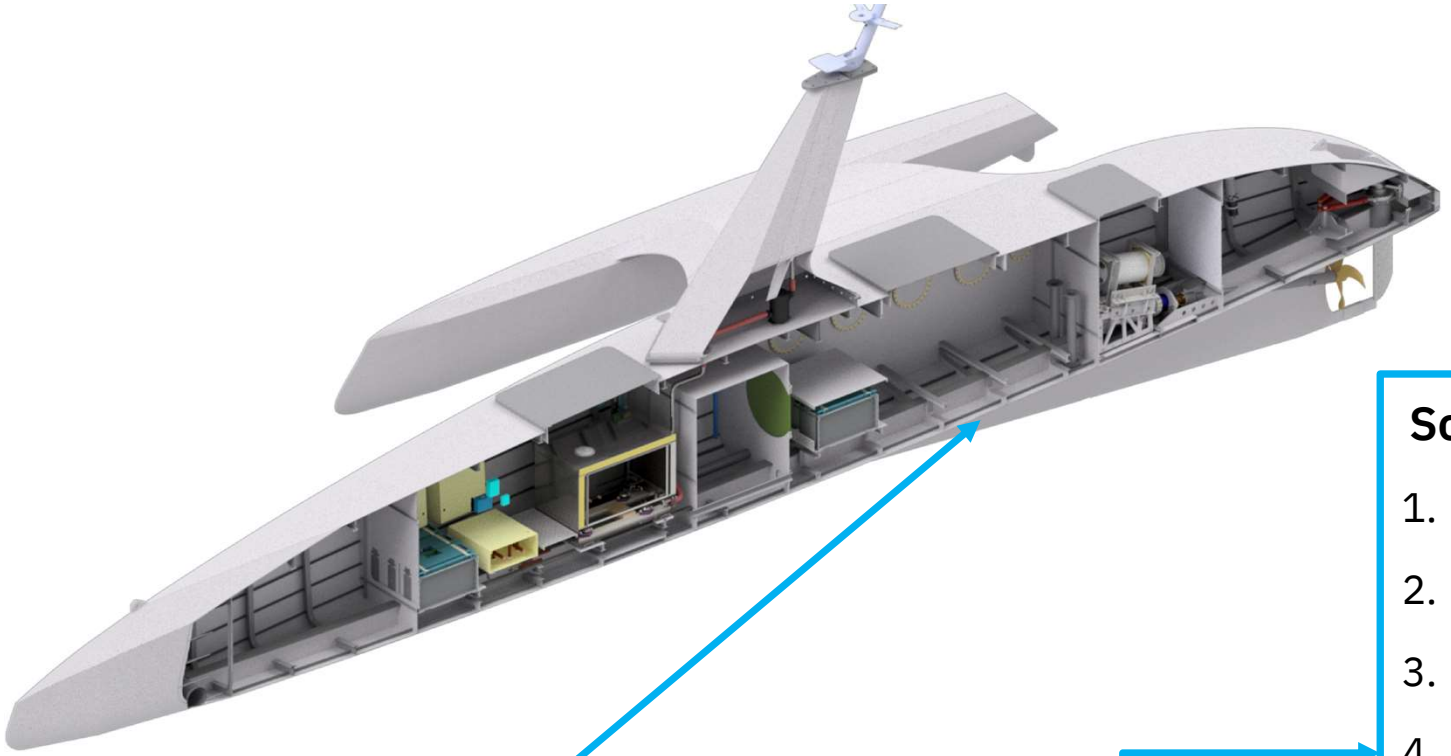
0 passengers /0 crew
1 deck
Aluminum Trimaran
Solar
15m
Research





Experiments Bay

- Common IT + storage infra services + coms for the experiments
- Scientific Package



Experiments Bay

- Common IT + storage infra services + coms for the experiments
- **Scientific Package**

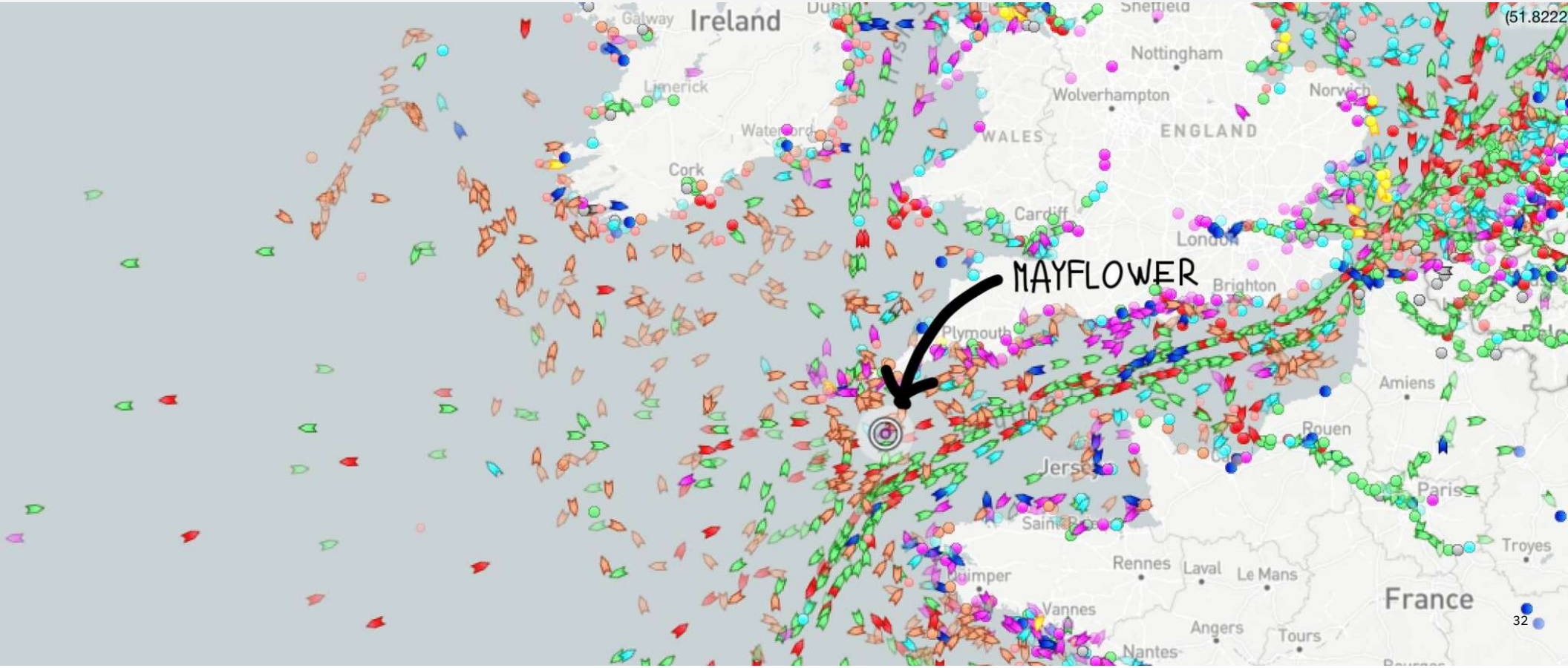
Scientific Package Content

1. Oceanography
2. Microscopic Marine Life
3. Ocean Chemistry
4. Open Ocean Sea Level
5. Wave Energy
6. Whale Song
7. Anomaly Detection
8. Intelligent Navigation

Planned Mission – June 2021

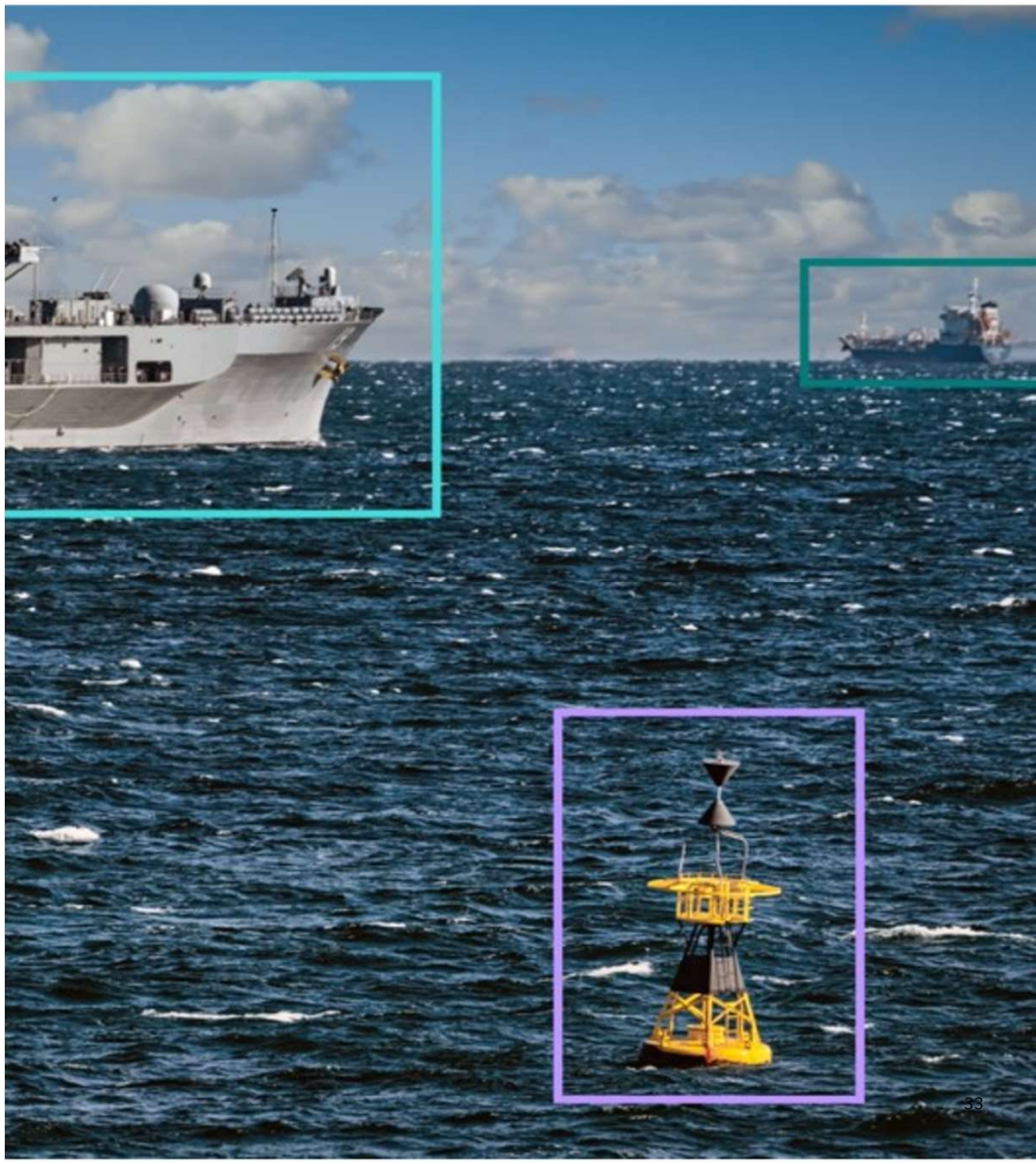
"To be the 1st crossing of the N-Atlantic by an unmanned vessel."

Reality ...


Ireland
Galway
Limerick
Cork
WALES
ENGLAND
Wolverhampton
Nottingham
Norwich
Cardiff
London
Brighton
Plymouth
MAYFLOWER
Amiens
Rouen
Paris
Troyes
Rennes
Laval
Le Mans
France
Vannes
Angers
Tours
Nantes
(51.8222

Decisions made in an instant

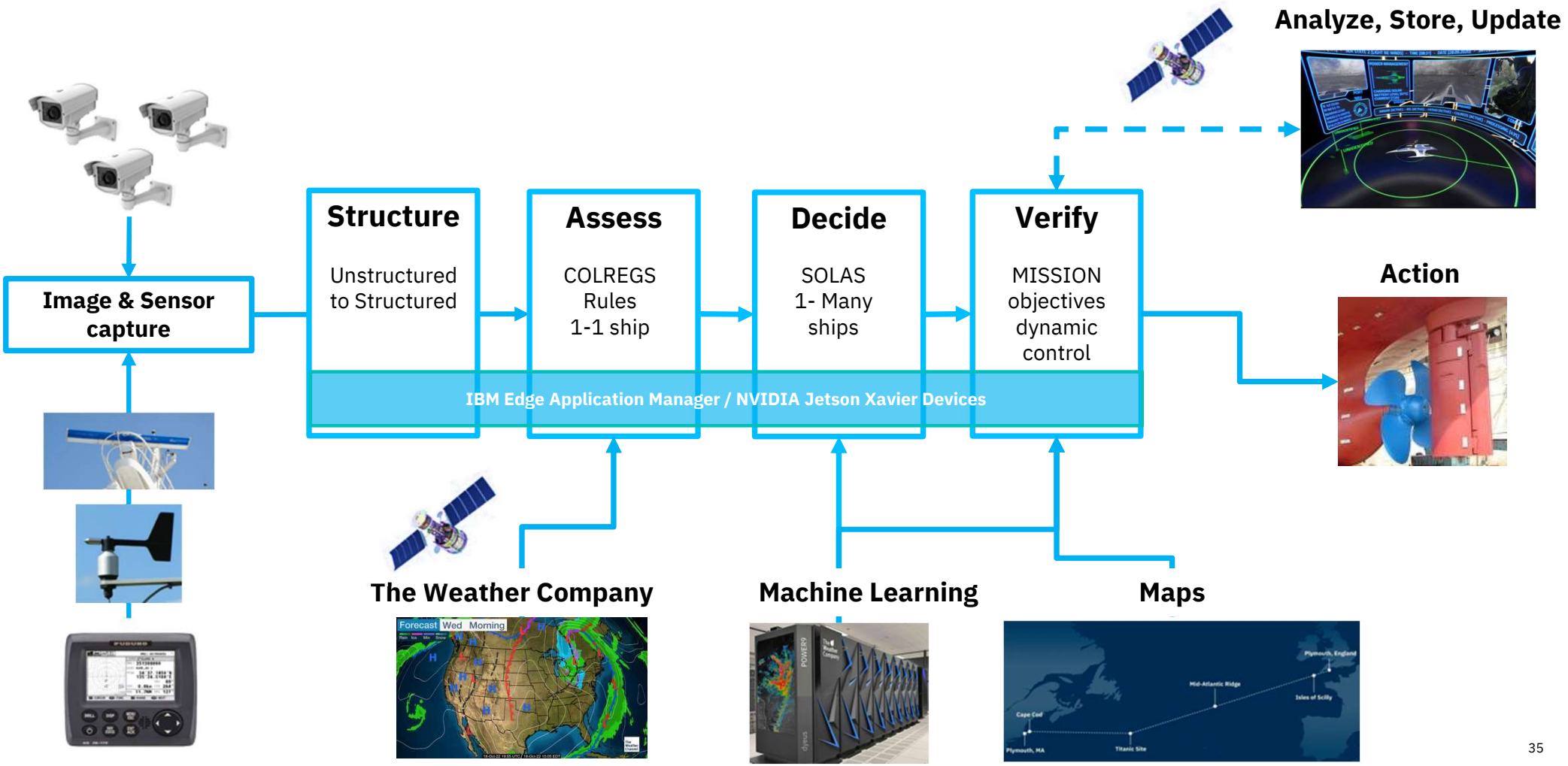
- Is this image an iceberg, a buoy, a drifting container or a fishing ship?
- Should I give way or stand on?
- What is the fastest route to this waypoint?
- What speed to use with the current batteries level?
- What is the safest route to destination considering weather?



The AI-Captain

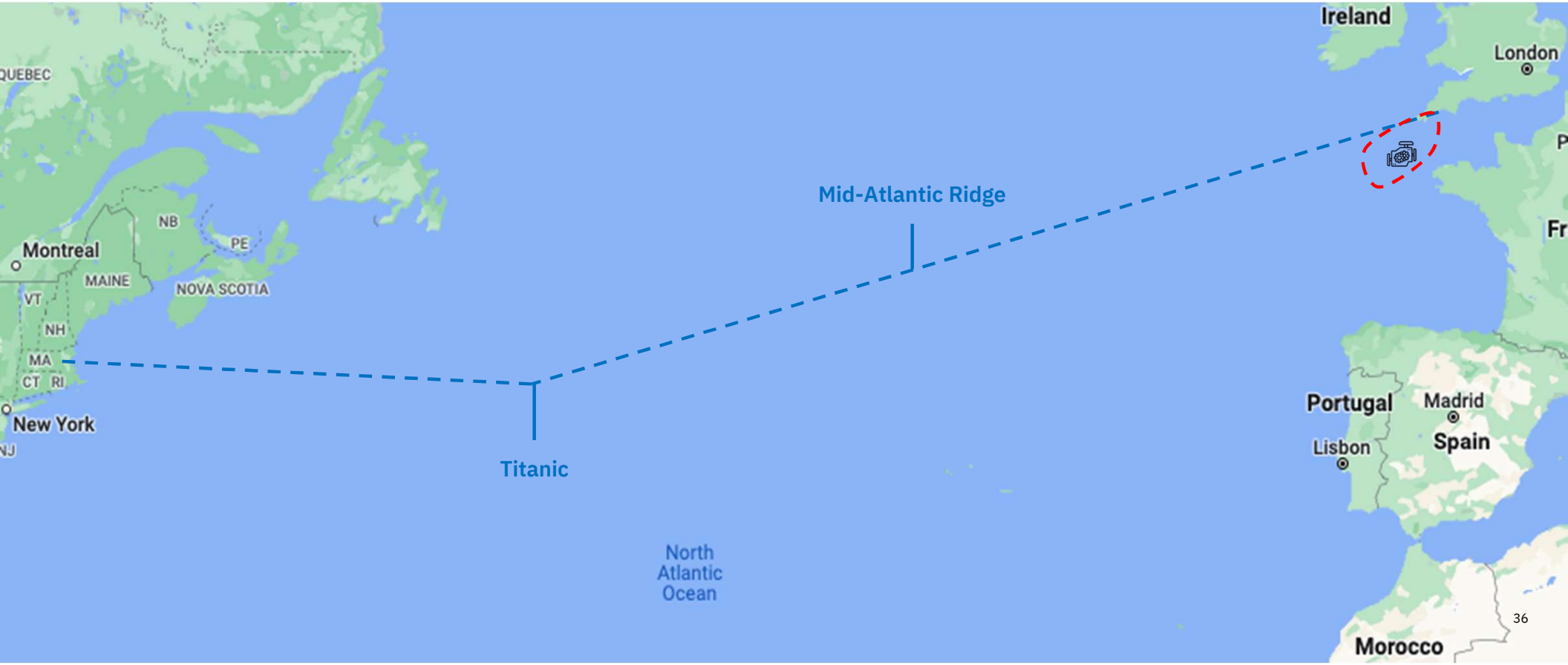
- Detects and identifies potential hazards to make real-time decisions on how to respond and navigate
- Collects information on nearby vessels with an Automatic identification system (AIS)
- Interprets radio broadcasts and weather forecasts
- Optimizes the ship’s route using visual and radar data
- Monitors atmospheric & oceanographic conditions

An ‘AI Captain’ Provides **Automated Decision Making**



Planned Route

Attempt 1 – 2021 - Fail

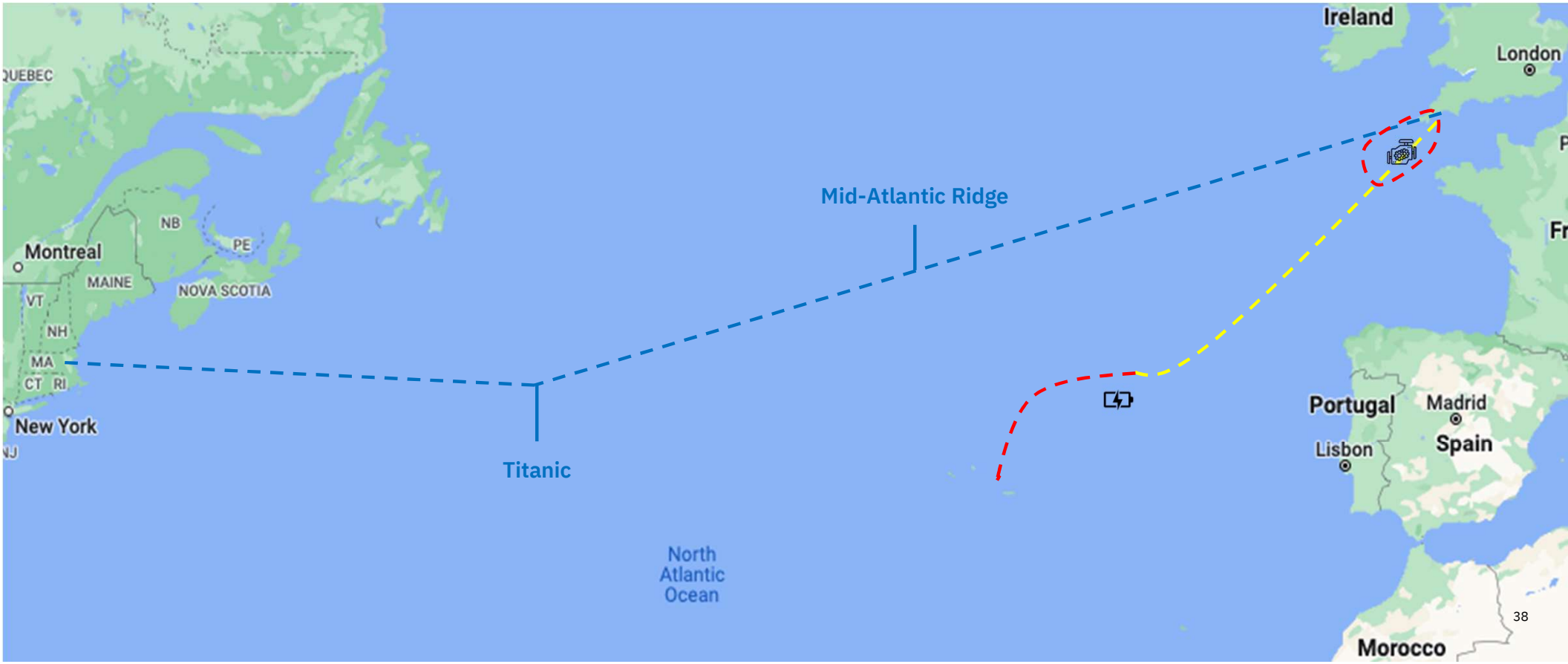


Planned Route

Attempt 1 – 2021 - Fail

Attempt 2 – 2022

Attempt 2 – 2022 - Troubled



Horta, Azores

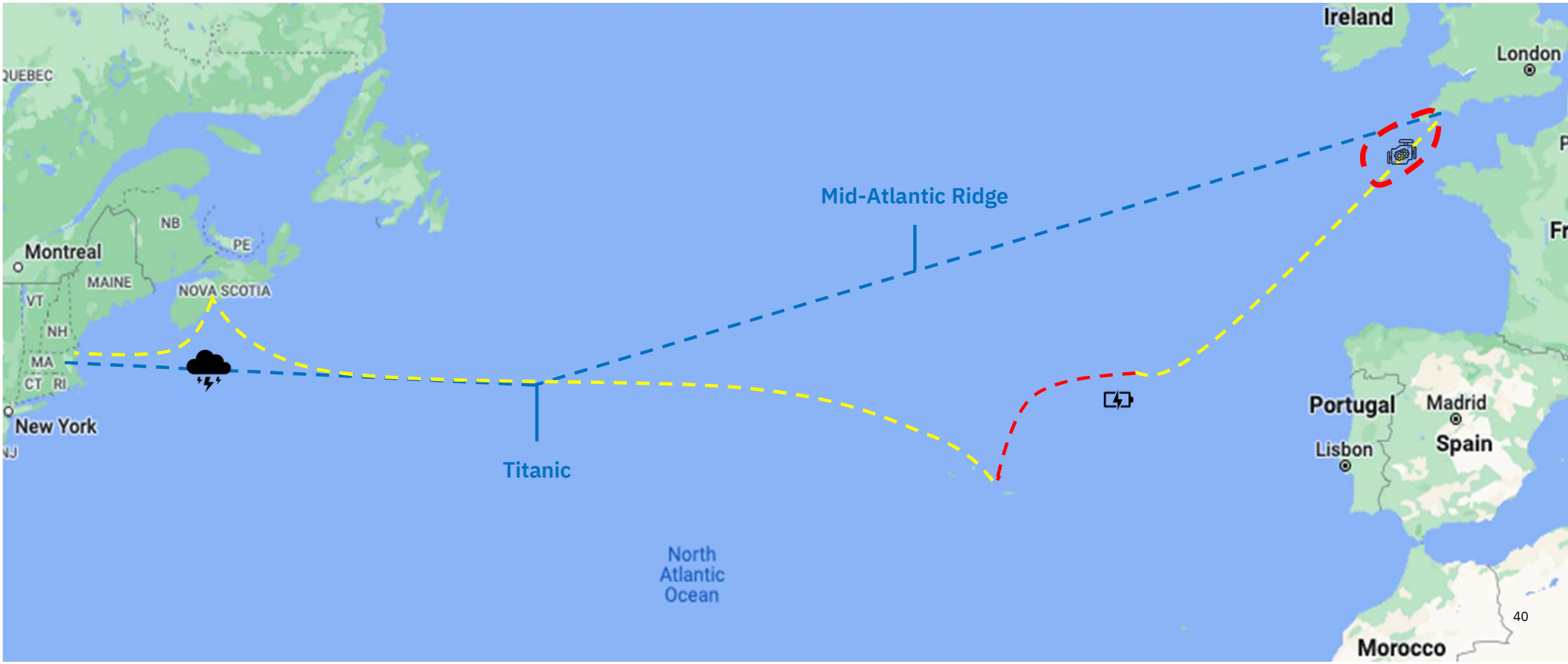
"Horta's marina is a primary stop for yachts crossing the Atlantic Ocean, and its walls and walkways are covered with paintings created by visitors noting the names of their vessels, crews, and the years they visited."

Planned Route

Attempt 1 – 2021 - Fail

Attempt 2 – 2022 - Troubled

Final Leg – 2022 - Success



Arrival at Plymouth, MA, USA

(What is wrong with this video ?)

Mayflower Autonomous Ship (MAS 400)

Thank you!

FME AI FOR INDUSTRY JAAREVENT

Bedankt voor je aandacht!

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