



Deltares

Towards best practices

Operationalising Artificial Intelligence in Flood Forecasting and Response

Maarten Smoorenburg & Elmar Geers
and a larger Deltares and Hydrotec team

Thursday, July 3, 2025



Some examples

Weather models

Wave emulators

2D flood modelling

GNN/LSTM for rainfall-runoff

FEWS chatbot, ... or RTC-Tools

Radar nowcasting and blending

Surrogate models for urban areas

...

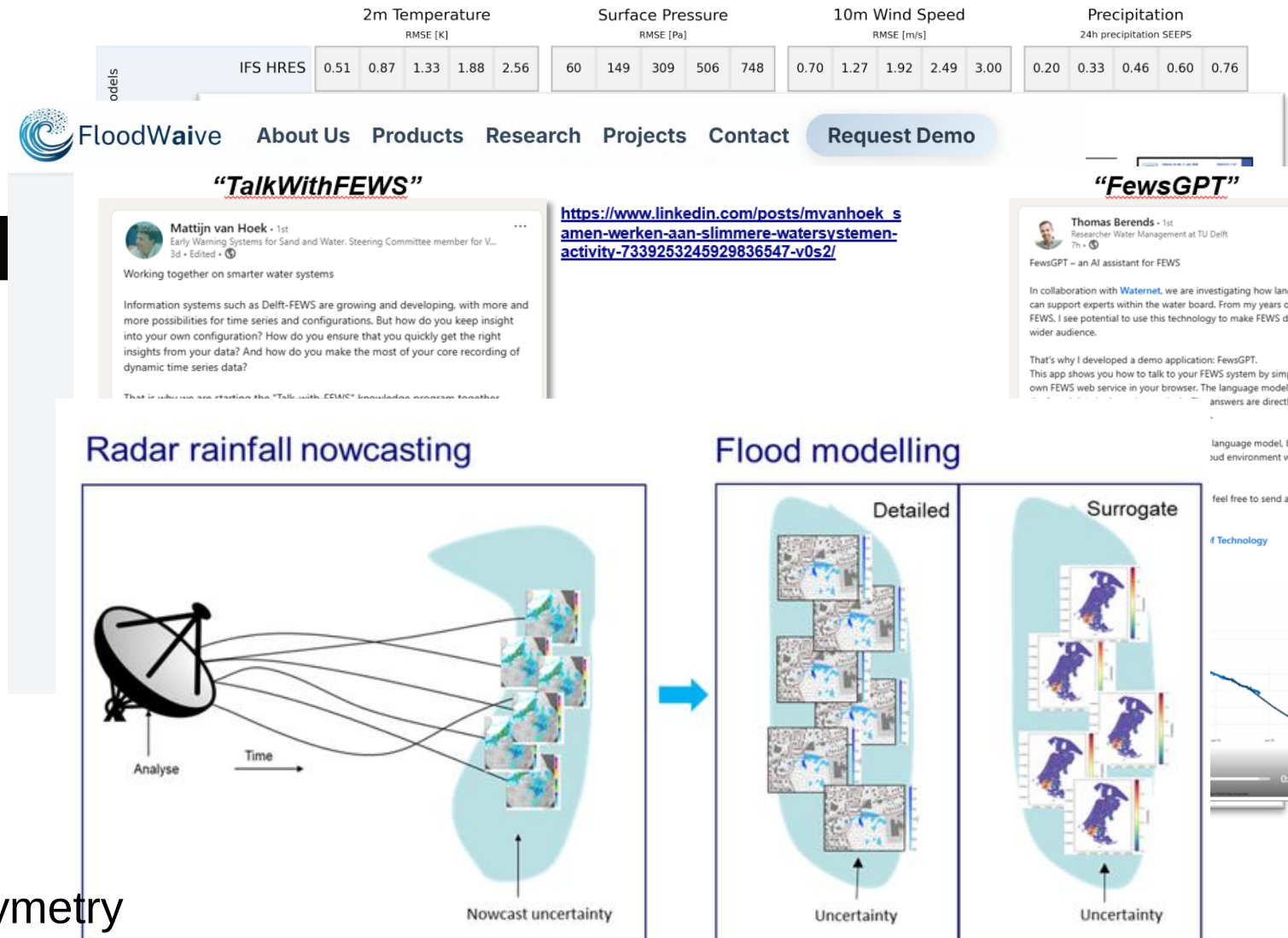
Correction and postprocessing

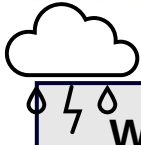
Writing flood bulletins

Earth observation of ice, water and bathymetry

...

Deltares





Weather information and pre-processing

PMT WO

Title: Investigate the feasibility of applying an **AI weather forecasting** model for pre-processing within Delft-FEWS

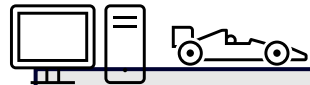
Team: Bob van Rongen & Jing Zhao

Title: Machine-learning based **downscaling and correction for post-processing rainfall** forecasts

ET

Team: Ruben Imhoff, Henrique Moreno Dumont

Goulart, Jing Deng, Albrecht Weerts



Rapid model emulators and flood forecasting approaches

MS2 L4

Title: **Surrogate** flood modelling based on **LSG** and **SFINCS**

Team: Roel de Goede, Dirk Eilander & Tim Leijnse

ET

Title: **GNN-based urban surrogate model** for flood hazard quantification in urban flood forecasting

Team: Xiaohan Li, Anaïs Couasnon, Peter Nelemans & Ruben Imhoff

PMT Hyd

MS2 L4

Title: Machine Learning Demonstrator for Flood Forecasting using the **emulator of wflow_sbm**

Team: Ali Meshgi, Peter Nelemans, Tycho Bovenschen

Title: A **GNN** based model for **storm surge forecasting**

MS2 L4

Team: Jing Zhao and Martin Verlaan

Title: **Hybrid-AI** for storm surge forecasting

ET

Team: Martin Verlaan

AI for Flood Forecasting



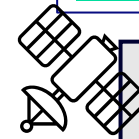
Program that funds initiative:

MS2 L4: Moonshot 2 Line 4 - Forecasting and Early Warning

ET: Enabling Technologies

PMT WO: PMT Water Operations

PMT Hyd: PMT Hydrology



Earth observation and global data for model derivation and initial states

PMT WO

MS2 L4

Title: Operational **Data Fusion of Model and EO**

Flood Maps

Team: Arjen Haag, Albrecht Weerts, Jaap Schellekens, Arnejan van Loenen, Tjalling de Jong

Title: **Generative AI for bathymetry**

ET

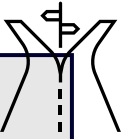
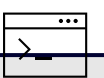
Team: Willem Tromp & Martin Verlaan

Title: **LLMs for Delft-FEWS**

ET

PMT WO

Team: Martijn Kwant, Jurian Beunk, Ruben Dahm & Dave de Koning



Post-processing, control and decisions

MS2 L4

Title: Benchmarking **AI-based post-processing** for probabilistic forecasting for the Meuse

Team: Maarten Smoorenburg, Jing Deng, Maarten Verbrugge, Jurian Beunk, Hans Korving & Thies Blokhuisen

ET

PMT Hyd

Title: Hybrid usage of **AI** and **OR** for **real-time operational management of hydraulic structures** under flood conditions

Team: Ailbhe Mitchell & Bernhard Becker

Model problems or just child's diseases?

AI may suffer from:

Dementia

Hallucinations

Overtraining

Non-deterministic behavior

And other 'weird' behavior



Beispiel NA-KI-Vorhersage Pegel Reinbek (Hamburg)

- Funktionsweise eines KI-Modells unterscheidet sich fundamental von der eines klassischen physikalisch-numerischen Modells

- Input:

tstamp	q_hamfelde	q_reinbek	q_sachsenwaldau	soil_lehm_sand	soil_sand_lehm	air_temp_grambek	prec_grambek
2023-11-13 04:00:00	0,817	2,31	1,75	120	104	1,508	0
...	...	...	...	...	...	...	...
2023-11-18 14:00:00	0,968	3,23	2,02	119	105	5,75	0
2023-11-18 15:00:00	0,964	3,2	2,02	119	105	5,158	0
2023-11-18 16:00:00	0,961	3,17	2,02	119	105	4,808	0
2023-11-18 17:00:00	0,957	3,14	1,985	119	105	4,8	0
2023-11-18 18:00:00	0,954	3,11	1,95	119	105	4,717	2,28
2023-11-18 19:00:00	0,95	3,11	1,95	119	105	4,15	8,1
2023-11-18 20:00:00	0,947	3,11	1,95	119	105	4,042	0,12
2023-11-18 21:00:00	0,943	3,11	1,95	119	105	4,125	0,72
2023-11-18 22:00:00	0,939	3,11	1,95	119	105	4,275	4,86
2023-11-18 23:00:00	0,936	3,08	1,95	119	105	4,367	4,92
2023-11-19 00:00:00	0,95	3,05	1,95	123	114	4,5	13,62
2023-11-19 01:00:00	0,982	3,08	1,95	123	114	4,6	3,84
2023-11-19 02:00:00	1,014	3,11	1,95	123	114	4,708	29,46
2023-11-19 03:00:00	1,046	3,17	1,985	123	114	4,858	29,94

- Ergebnis: 3,2 3,17 3,14 3,11 3,11 3,11 3,11 3,11 3,08 3,05 3,08 3,11 3,17

- Fazit:

- Für das Modell ist physikalische Plausibilität irrelevant. Dies eröffnet neue Möglichkeiten hinsichtlich der
- Das Modell kann auf Basis seiner „Erfahrungen“ eine Abschätzung des Ergebnisses erstellen. In diesem

Prognosedaten

10,11

12,56

36,05

5,36

9,36

0

0

0

7,56

8,65

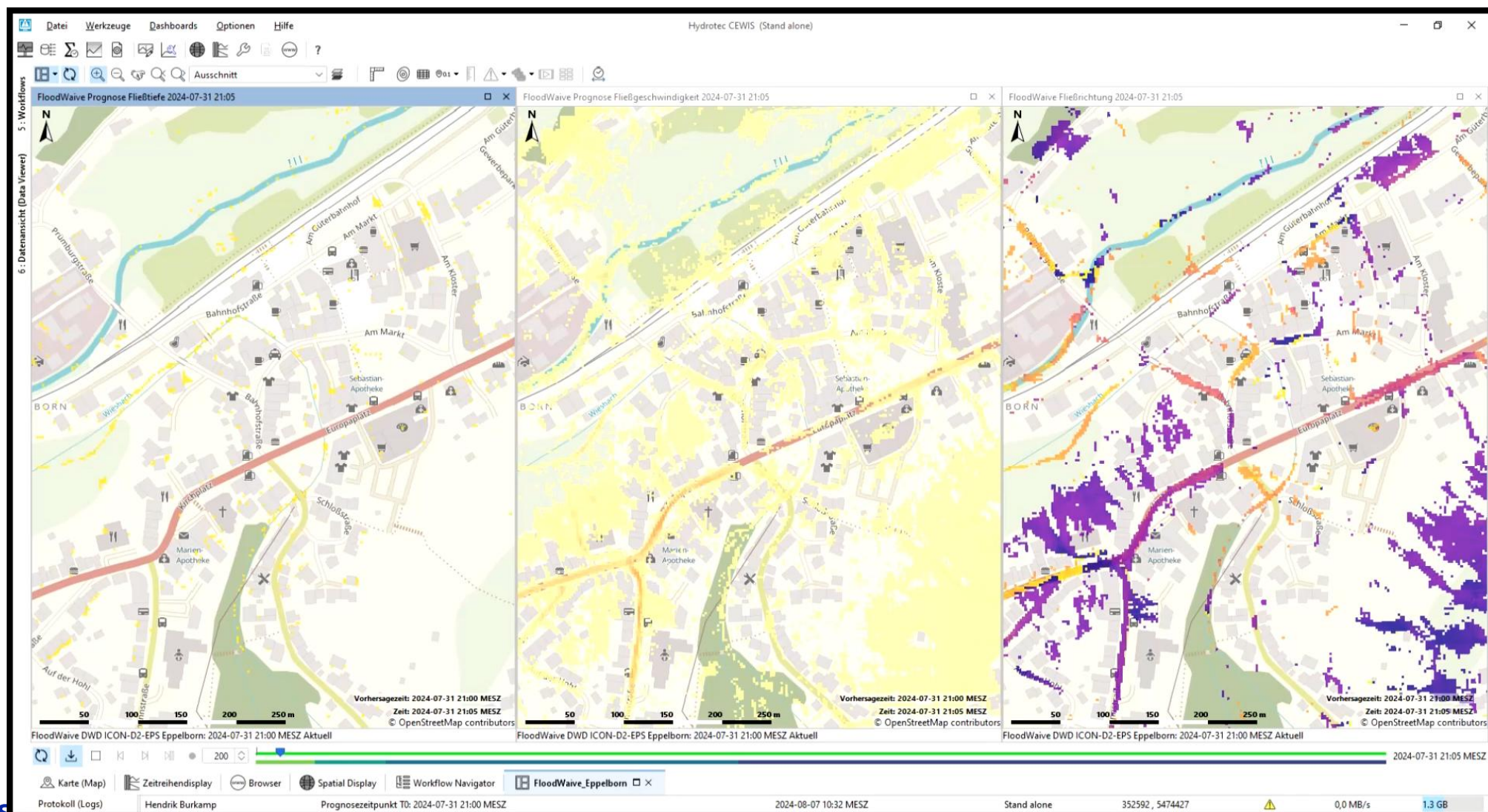
5,61

13,12

te

Beispiel FloodWaive Eppelborn

- Hydraulische Prognosen in nahezu Echtzeit



Institutional and legal frameworks

Understanding AI

Computational efficiency

Uncertainty management

Data requirements

The case for AI

Community and stakeholder engagement

Model reliability and interpretability

Ethical and social considerations

Training versus application

Cost, energy and climate

Human-AI collaboration and decision support

Sustainability and maintenance

Integration with existing systems

Data availability and quality

Why discussing this today?

1. AI has really arrived, ...
and is developing really fast



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4. **Operationalization of AI is a new challenge**

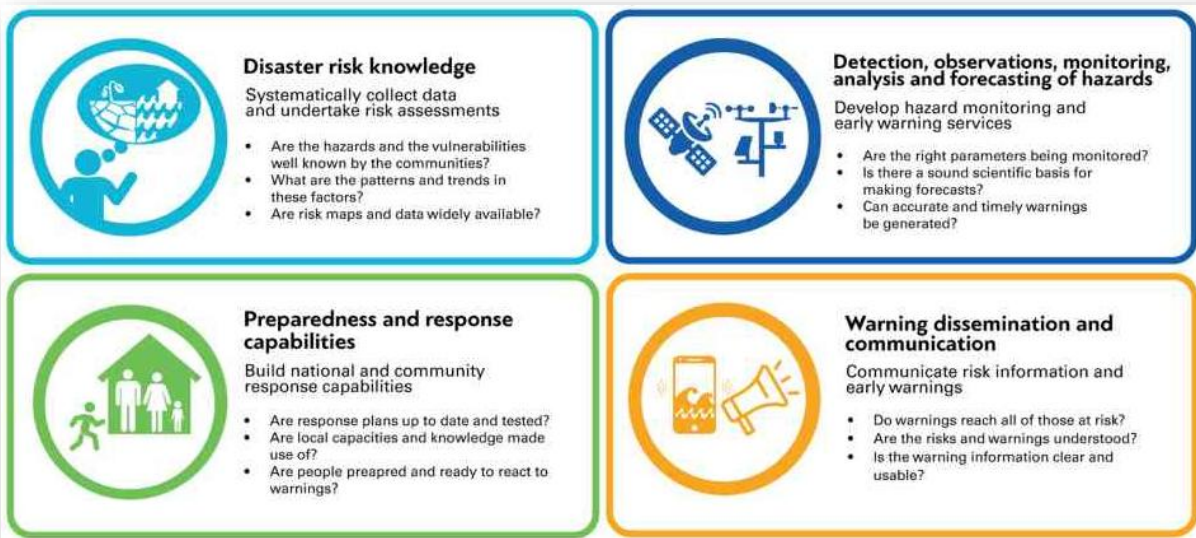




BEST

PRACTICE

Structure around EW4All



The Early Warnings for All (EW4All) initiative aims to ensure universal protection from hazardous hydrometeorological, climatological and related environmental events through life-saving multi-hazard early warning systems, anticipatory action and resilience efforts by the end of 2027, as called for by the United Nations Secretary-General António Guterres in 2022.

Risk awareness

- AI-powered models, also through their ability to do pattern analysis, can analyse vast amounts of historical flood data, satellite imagery, and climate projections to improve risk assessments.
- AI can enhance GIS-based flood mapping, making predictions more dynamic and location-specific.

Monitoring, detection and forecasting

- AI based methods can process data from weather stations (e.g. interpolation of rainfall, temperature), river gauges, and satellites in real time, detecting anomalies (e.g., drought, low flows, floods) faster than traditional methods albeit they need to be trained beforehand.
- There is a large potential for applying AI-based technology in the modelling of physical meteorological, hydrological and hydrodynamic processes as well as the estimation of *impacts* of floods.

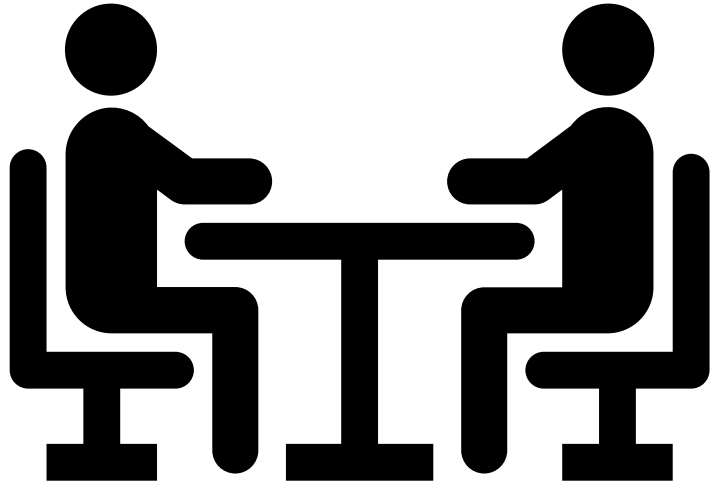
Dissemination and communication

- AI-powered chatbots and automated alert systems can distribute warnings through SMS, social media, and public announcement systems in multiple languages.
- Natural Language Processing (NLP) can improve message clarity by translating complex flood forecasts into easy-to-understand alerts.
- AI can help tailor warnings based on location, demographics, and individual risk factors.

Preparedness and response capability

AI may have a less obvious role to play in 'preparedness and response':

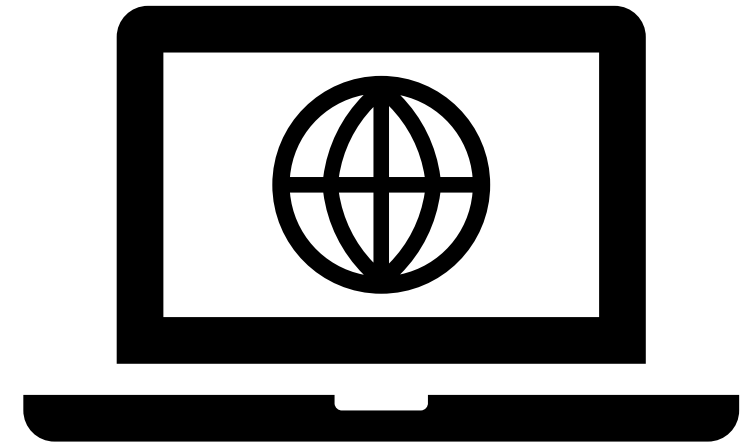
- AI cannot replace human decision-making in emergency response, evacuation planning, and resource mobilization.
- Community preparedness relies on social, cultural, and institutional factors that AI cannot fully automate.
- AI-driven predictions and alerts still require human oversight to interpret uncertainties and adapt responses accordingly.
- Last-mile challenges (ensuring people act on warnings) depend on trust, education, and accessibility, which AI cannot directly address.



Share and discuss ideas in the
FEWS/forecasting community



Document the experiences



Couple with FEWS suite

Discussion round: AI at your organizations

Please share

- your experiences?
- your expectations?
- your questions to the group?



Feel free to reach out if you want to join the conversation

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