

Tracking spent fuel bundles using AI

BASED ON [HTTPS://WWW.YOUTUBE.COM/WATCH?V=1MWDQOFQJUG&T=132S](https://www.youtube.com/watch?v=1MWDQOFQJUG&T=132S) EVERY FUEL BUNDLE SET FOR FINAL REPOSITORY CAN BE TRACKED USING AI.

PRESENTED BY:

STEFAN BÖRLIN



HONORABLE MENTION:

PRAJIT DATTA



Challenge accepted from material available on YouTube

<https://www.youtube.com/watch?v=1mWDQofQJUg&t=132s>

<https://www.youtube.com/watch?v=JjjqR6SQLuU>

Proprietary of SKB

Available at Youtube and SKB Play



Objectives of the presentation

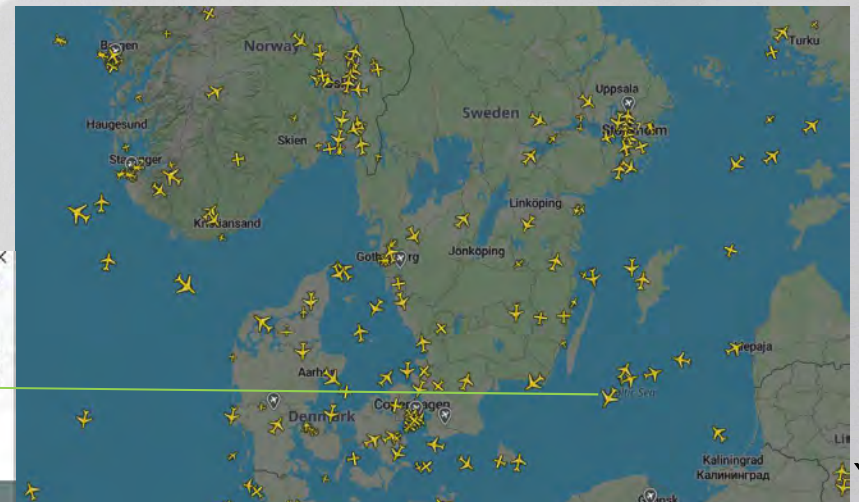
Identifying separate processes displayed in video

Suggesting AI-use cases across the complete process, combined with sophisticated programming

Suggesting diversified functions based on supposed plant implementations

Vision: "iFTF" (AI Fuel Transfer Function) / flight radar

- *Diversified* spent fuel supervision w.o. additional equipment
- Using existing installations in high security IT-zones
- Functionally isolated equipment – no jeopardizing
- Click on the Cansiter...



COMMON POSITION OF INTERNATIONAL NUCLEAR REGULATORS AND
AUTHORISED TECHNICAL SUPPORT ORGANISATIONS

Licensing of safety critical software for nuclear reactors



IFTF

iFTF - Pre-requisites and assumptions

The encapsulation plant is not yet designed

Where information is missing in the video, we have made assumptions to create a use case

SKB has been notified we have done this study

No prototype programming has been made

Used definitions each with individual ID's:

- Storage frame
- Drying frame
- Copper canister
- Shielded frame
- Transport cask



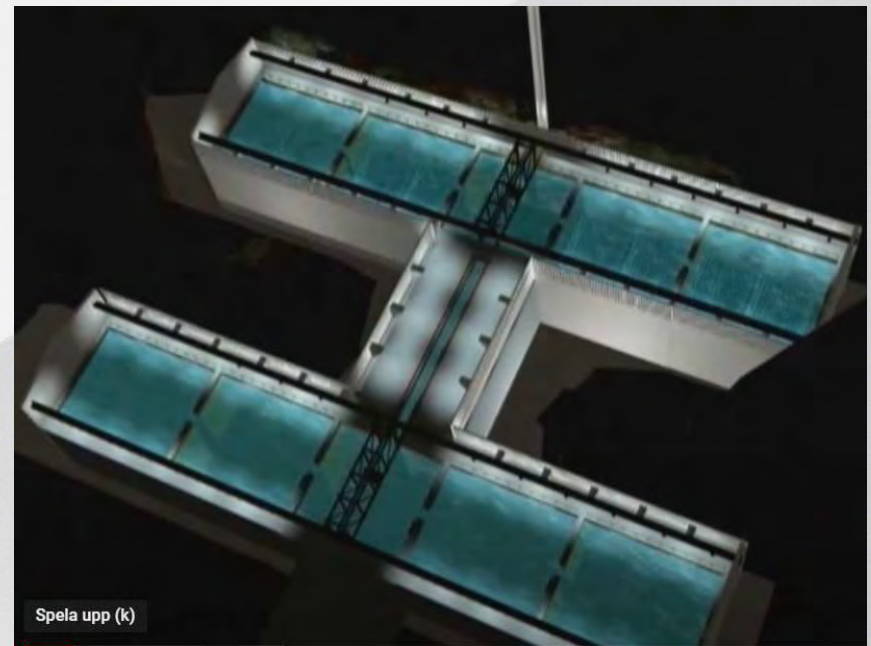
SKB - Underground storage pools

We count 8 separate storage pool

Assumption: Each storage location and each storage frame have unique ID's

Assumption: No single spent fuel element is moved into a drying frame in storage pools (according to video) Alas, storage frames are transported to the surface.

Why interim storage? In 40 years, heat reduced by 90 % (SKB R-10-01), 300 years gamma radiation levels at 1/1000 (Timbro)



IN STORAGE POOL

Setup of process presentation

Process described in Italics



- Signals available
- ID's available
- AI-functions available

Conclusion 1

Conclusion 2

...

IN STORAGE POOL

Locating, lifting and transporting fuel to encapsulation

*Storage frames with 5*5 spent fuel elements (see pictures later)*

Assumption: No tools to handle individual fuel bundles

Spent fuel ID's assumed to be stored and linked to Storage frame ID in knowledge "Database".

@order of fuel transport released:

- 5*5 spent fuel bundle ID's provided to iFTF
- Storage frame ID known.
- Location known
- Video camera continuously monitoring
- Location of fuel transport machine is known and available

Based on above information:

iFTF know the location of 25 spent fuel bundles.

iFTF set alarm if fuel transport machine and known position mismatch

OCR can be used to verify spent fuel bundle ID and Storage frame ID – matched with "database"



Fuel elevator transport from fuel pools to surface and re-loading pool

Seems to be the sole fuel transport to the surface



- Motion detection of the fuel elevator available
- Fuel elevator Elevation level available
- Fuel elevator Grippped weight known

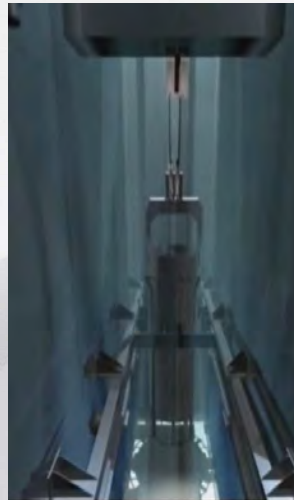
Based on the information given, iFTF can calculate a continous, non-verified position during transfer. Non AI, automatic data analysis.

VISION AGAIN AND VALID POSITION

Fuel elevator sub-merged in re-loading pool in encapsulation plant

Fuel elevator basket submerged in re-loading pool

Possibly positioned on a Trolley which moves the fuel elevator basket into position beneath fuel handling machine (see upcoming slides)



- Video available
- Fuel handling machine position available (see next slide)
- Fuel elevator Level indication
- Weight indication
- Trolley position

Based on the information available, iFTF can verify the Fuel Elevator is in submerged position (AI combined with automatic data analysis)

IFTF can likely read the storage frame ID (OCR)

MEANWHILE ABOVE WATER

The fuel handling machine, info about surface activities

Fuel is submerged in water!

Location of griphook available in 3D

Griphook activated / deactivated available.

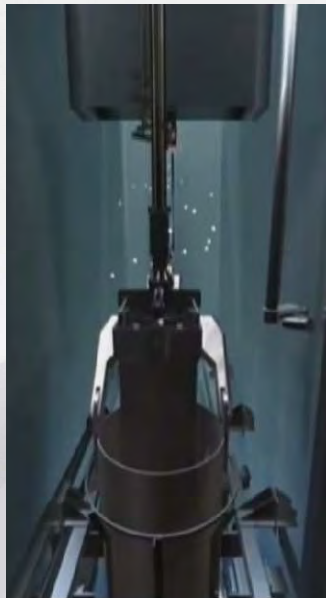
Video available (operator facing a screen)



Separating storage frame from fuel elevator basket

Fuel elevator basket positioned below the fuel handling machine.

*The storage frame (containing 5*5 spent fuel elements) lifted from the elevator*



- Level indication griphook available
- Weight in griphook available
- Griphook activated /deactivated available
- Video available
- Fuel handling machine position available

Based on the information above, iFTF can calculate the position of 5*5 spent fuel elements (non-AI, automatic data analysis)

Moving the storage frame from fuel elevator position to re-loading position

Fuel machine lifting storage frame

Fuel machine moving storage frame to re-loading position

Fuel machine lowering the storage frame into re-loading position



- Fuel machine position 3D
- Vision available

Based on the information above, iFTF can calculate the position of 5*5 spent fuel elements (non-AI, automatic data analysis)

Several storage frames side by side with drying frames in the un-loading pool

*Storage frame 5*5 acc this picture!
Individual position ID (Right)*

*Drying frames, 12 positions,
individual position ID (Left)*



- Storage frame 5*5 acc this picture!
Individual position ID (Right)
- Drying frames, 12 positions,
individual position ID (Left)

Based on the information above, iFTF can calculate the position of 5*5 spent fuel elements (non-AI, automatic data analysis)

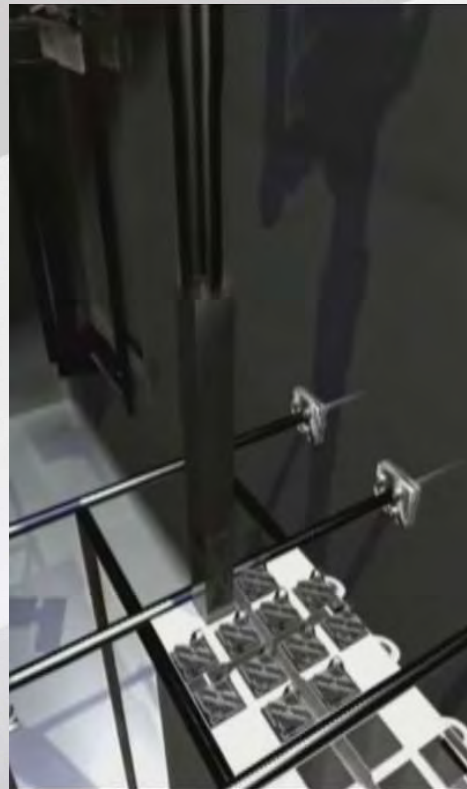
Individual fuel bundles positioned in specific location in drying frame

Drying frame ID

Drying frame position ID

Spent fuel bundle ID

Video available



- Storage frame ID read by OCR
- Drying frame ID read by OCR
- Drying frame individual position ID known and read by OCR
- Spent fuel bundle ID read by OCR

Based on the information above, iFTF can calculate the position of individual spent fuel elements (AI combined with automatic data analysis)

Spent fuel bundle ID in drying frame position
Verified!

AI-validation of correct position in drying frame

Drying frame lifted

Drying frame moved to docking position under drying cell using the fuel handling machine and a trolley



- Fuel handling machine position 3D
- Griphook activated / de-activated available
- Drying frame ID available
- Trolley position available
- Video

Based on the information above, iFTF can calculate the position of individual spent fuel elements (AI combined with automatic data analysis)

Spent fuel bundle ID in drying frame position remains Verified!

Drying frame moved to unloading position

Using the fuel handling machine, drying frame positioned on a trolley and moved into position under the drying cell



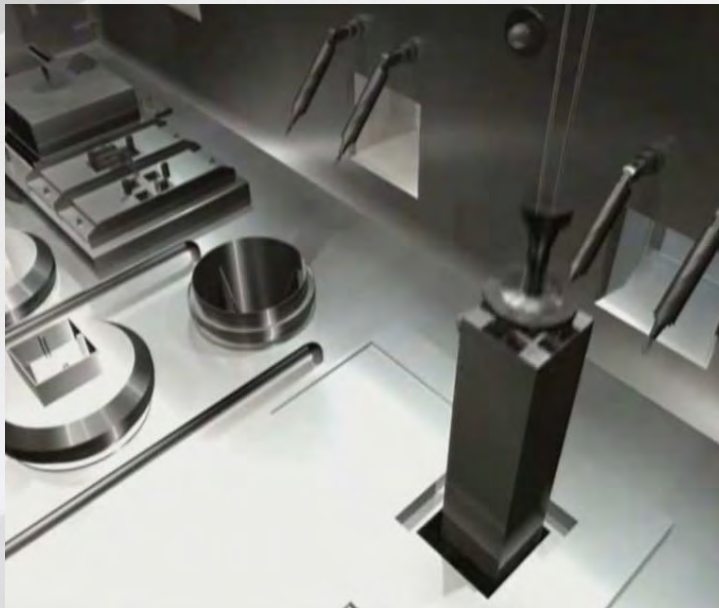
- Fuel handling machine position 3D available
- Griphook acitated / deactivated available
- Trolley position available
- Video

Based on the information above, iFTF can calculate the position of individual spent fuel elements (non-AI, automatic data analysis)

Spent fuel bundle ID in drying frame position remain verified.

Drying frame from re-loading pool unloading position to drying vessel

Drying frame lifted from trolley position into Drying cell using overhead crane in drying cell.



- Trolley position available
- Hatch position available
- Over head crane position 3D available
- Grip hook activated / deactivated available
- Video available

Based on the information above, iFTF can calculate the position of individual spent fuel elements (non-AI, automatic data analysis)

Spent fuel bundle ID in drying frame position remain verified.

Drying frame to drying vessel

Drying frame moved by overhead crane into drying vessel



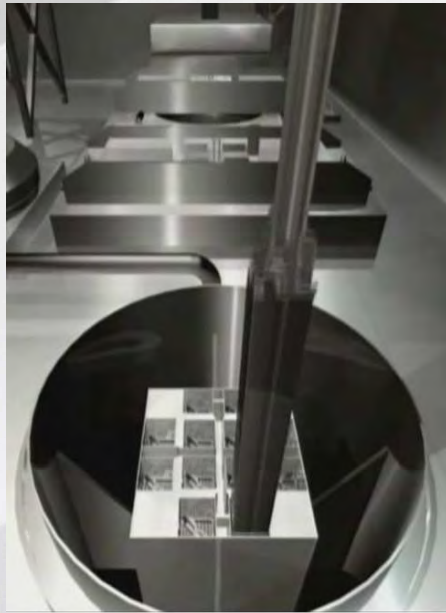
- Lifting device position 3D available
- Grip hook activated / deactivated available
- Drying cask lid position available
- Video available

Based on the information above, iFTF can calculate the position of individual spent fuel elements (non-AI, automatic data analysis)

Spent fuel bundle ID in drying frame position remain verified.

Spent fuel moved from drying cask to copper canister

After drying, individual spent fuel elements lifted from drying frame position in drying cell using overhead crane (with griphook for individual handling)



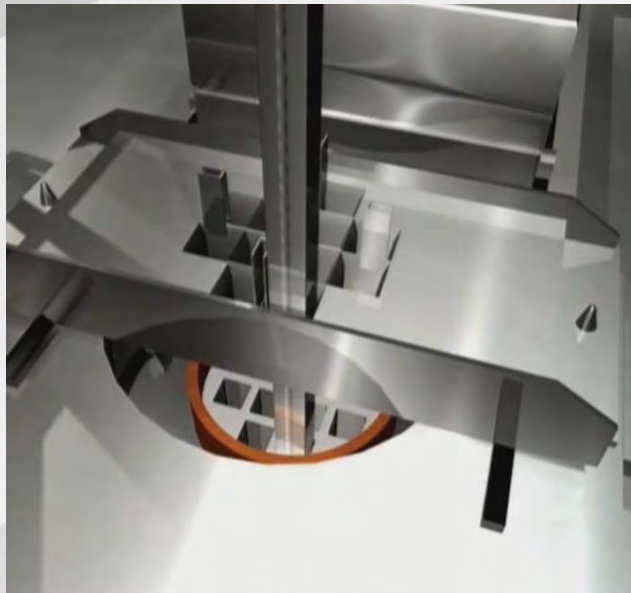
- Overhead crane position 3D available (individual spent fuel element position)
- Individual spend fuel element ID read (OCR)
- Grip hook activated / deactivated available
- Drying cask lid position available
- Copper canister position available
- Copper canister ID available
- Video available

Based on the information above, iFTF can calculate the position of individual spent fuel elements (AI combined with automatic data analysis)

Spent fuel bundle ID in position re-verified

Individual spent fuel bundles located in copper canister

In extension of lifting individual spent fuel elements in the previous description, the elements are moved into iID'd position in the copper canister.



- Overhead crane position 3D available (single spent fuel element position)
- Grip hook activated / deactivated available
- Copper canister position available
- Copper canister ID available
- Copper canister location ID available
- Video available

After lidding, no more visual of the spent fuel (or its ID)

Based on the information above, iFTF can calculate the position of individual spent fuel elements (AI combined with automatic data analysis)

AI-validation of correct position in copper canister

Detaching and lowering copper canister into shielded frame on-board an air cushion truck

The fully loaded (12 spent fuel elements) is released from the drying cell and lowered into a shielded frame

Air cushion trucks move shielded frame with copper canister between manufacturing cells



- Vertical position of copper canister available
- Copper canister clamping activation available
- Shielded frame ID available
- Air cushion trucks ID available
- Weight possibly available as indirect measurement of lift resistance
- Video of shielded frame available

Based on the information above, iFTF can calculate the position of individual spent fuel elements (non-AI, automatic data analysis)

Copper canister ID not verified.

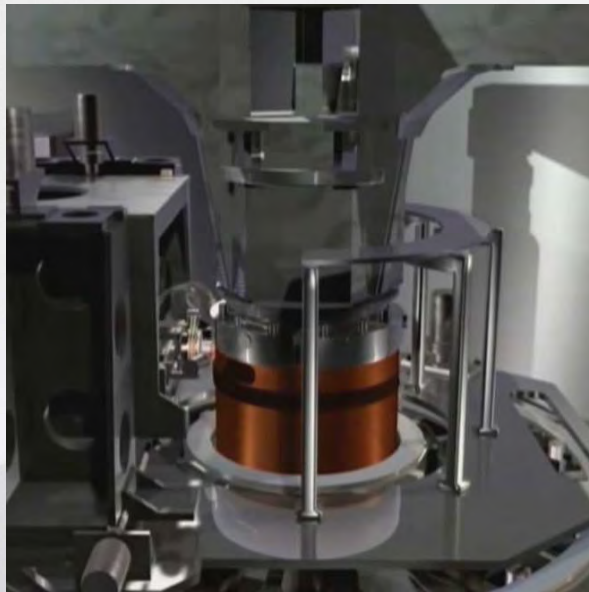
Shielded frame ID verified

Process steps (inerting, welding and machining)

Shielded frame clamped in position under each cell.

Copper canister hoisted into operation position and clamped

*Encapsulation
process commences*



- Position position of copper canister available
- Shielded frame ID available
- Video available

Based on the information above, iFTF can calculate the position of individual spent fuel elements (non-AI, automatic data analysis)

Copper canister ID verified (OCR from video)

Shielded frame ID verified (OCR from video)

Ultrasonic and X-ray verification of weld

Shielded frame clamped in position under each cell.

Copper canister hoisted into operation position and clamped

NDT commences



- Vertical position of copper canister available
- Shielded frame ID available
- Video available

Based on the information above, iFTF can calculate the position of individual spent fuel elements (non-AI, automatic data analysis)

Copper canister ID verified (OCR from video)

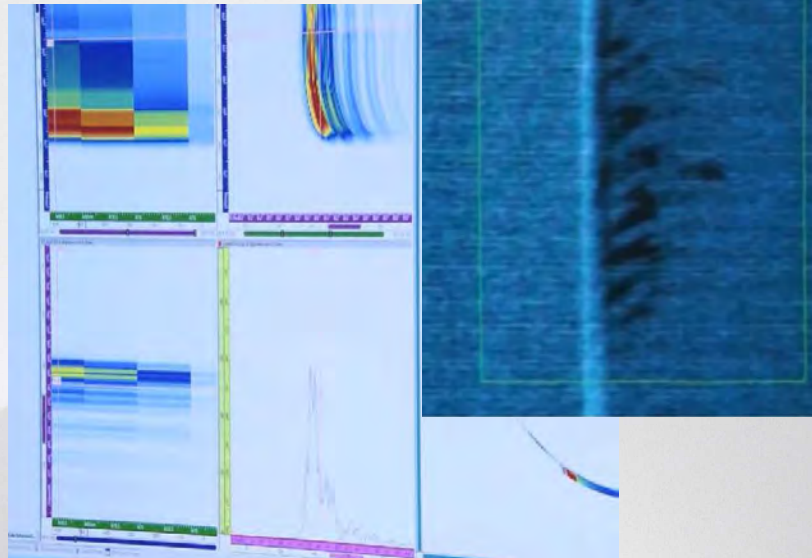
Shielded frame ID verified (OCR from video)

Analysing Ultrasonic and X-ray measurement results

Off-line varification possible

Expert analysers

Swift approval of test results necessary for process flow



- iFTF not involved.
- AI functions read the images
- AI functions provides a statement
- Operator (Expert) approves/disapproves
- Possible automation

Separating copper canister from Shield – see next slides for actions above roof

Similar to process steps, but copper canister hoisted full length.

Radiation shield and copper canister moved up for surface radiation detection

Griphook (next process step) used to lift copper canister inside caroussel



- Vertical position of copper canister available
- Griphook activated / deactivated available
- Shielded frame ID available
- Video of shielded frame available

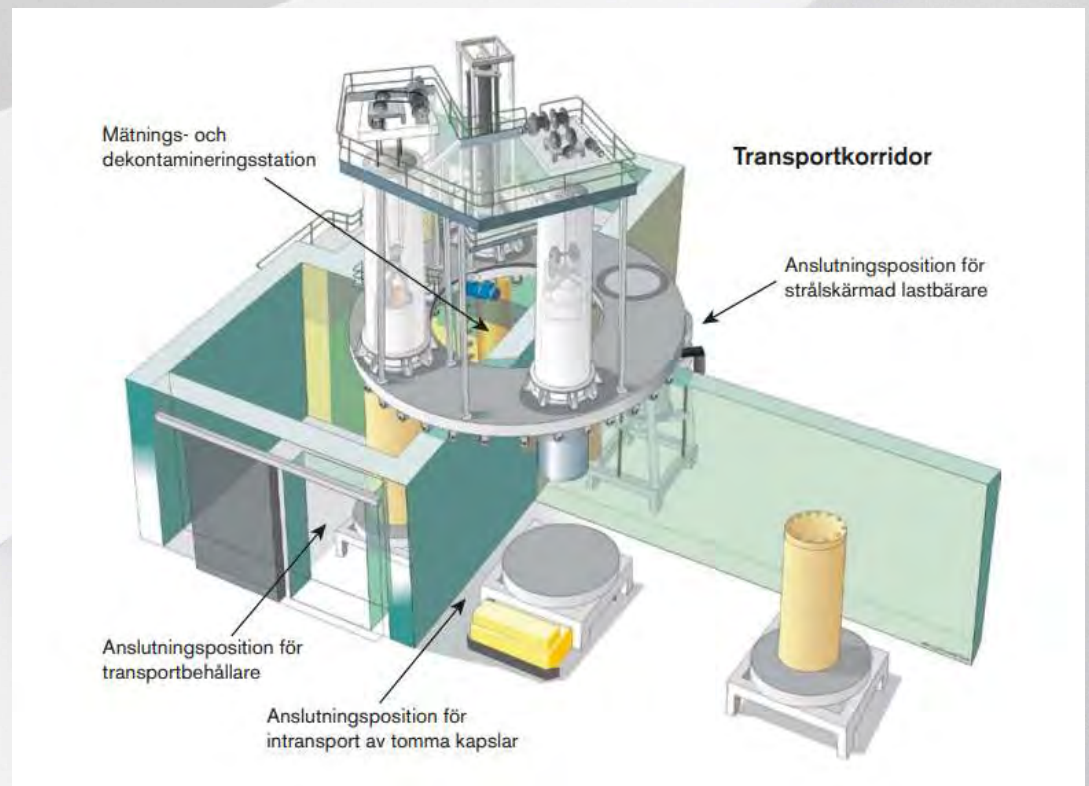
Based on the information above, iFTF can calculate the position of individual spent fuel elements (non-AI, automatic data analysis)

Copper canister ID not verified

Shielded frame ID verified (OCR from video)

Describing the tracking complexity (R-10-01)

- Synchronizing videos necessary
- Synchronizing process signals necessary



Detecting radioactive contamination and final transportation

Over head crane caroussel with griphook lifts copper canister from shielded frame

Over head crane caroussel griphook lowers the coppercanister into measurment and cleaning positions.

Over head crane caroussel griphook hoists the copper canister from cleaning.

Overhead crane caroussel moves into transport position



- Over head crane caroussel 3D-position available
- Overhead crane Griphook activated / deactivated available (assumed not to be released during the full process)
- Video of caroussel available
- Video of copper canister NOT available (radiation)
- Assumption: Copper canister ID read by OCR in surface contamination detection station.

Based on the information above, iFTF can calculate the position of individual spent fuel elements (AI and automatic data analysis)

Copper canister ID verified (OCR from video)

Merging the copper canister into a transport cask

Over head crane caroussel moved to transport position

Copper canister lowered into transport cask.

Transport cask moved by air cushion truck

Transport cask lid put into position

- Overhead crane 3D-position available (above roof)
- Griphook activated / deactivated available
- Griphook weight sensor
- Before lidding transport cask, video of Copper canister ID (OCR) assumed.
- Video of overhead crane caroussel available
- Video of transport cask available
- Transport cask ID available

Based on the information above, iFTF can calculate the position of individual spent fuel elements (AI and automatic data analysis)

Copper canister ID verified (OCR from video)



Lifting and transporting the transport cask from loading position to transport position

Overhead crane moves transport cask from copper canister merging position



- Overhead crane 3D position available
- Video of transport cask available
- Transport cask ID available

Based on the information above, iFTF can calculate the position of individual spent fuel elements (AI and automatic data analysis)

Transport cask ID verified (OCR from video)

Positioning on truck

Overhead crane positions transport cask on transport vehicle



- Overhead crane 3D position available
- Video of transport cask available
- Transport cask ID available

Based on the information above, iFTF can calculate the position of individual spent fuel elements (AI and automatic data analysis)

Transport cask ID verified (OCR from video)

Leaving the building (and the first video)

Gate opens and vehicle drives out



- Video of transport cask available
- Transport cask ID available
- Vehicle ID available
- Assumption: GPS location device available on transport cask (and truck)

Based on the information above, iFTF can calculate the position of individual spent fuel elements (AI and automatic data analysis)

Transport cask location (GPS) available

Transport by boat from interim storage to final repository

GPS-tracking available



Conclusions iFTF

AI-techniques used:

- OCR
- Pattern recognition
- Measurement analysis and Expert Advisors

Additional useful AI-techniques:

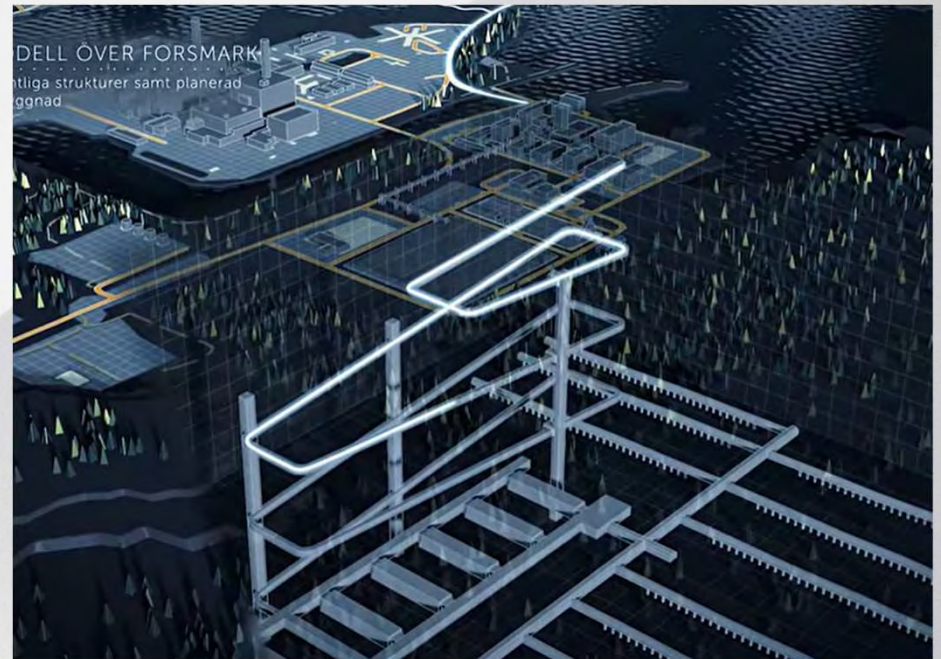
- Supply chain analysis
- Staff behavior analysis

Existing process signals used:

- Database information
- Overhead crane 3D position
- Overhead crane load signal
- Griphook activation / weight
- Video

IT-security measures

- Isolating devises
- Data diodes
- Separate computer capacity in high security IT-zones
- Complexity! Alternatives?



Alternatives?

- Set-up a network communicating with the ROV and one, two, three or more SPOT's.
- Diversification
- Jeopardizing
- Photos by Boston Dynamics and Heriot-Watt University



The final repository – Another use case presentation

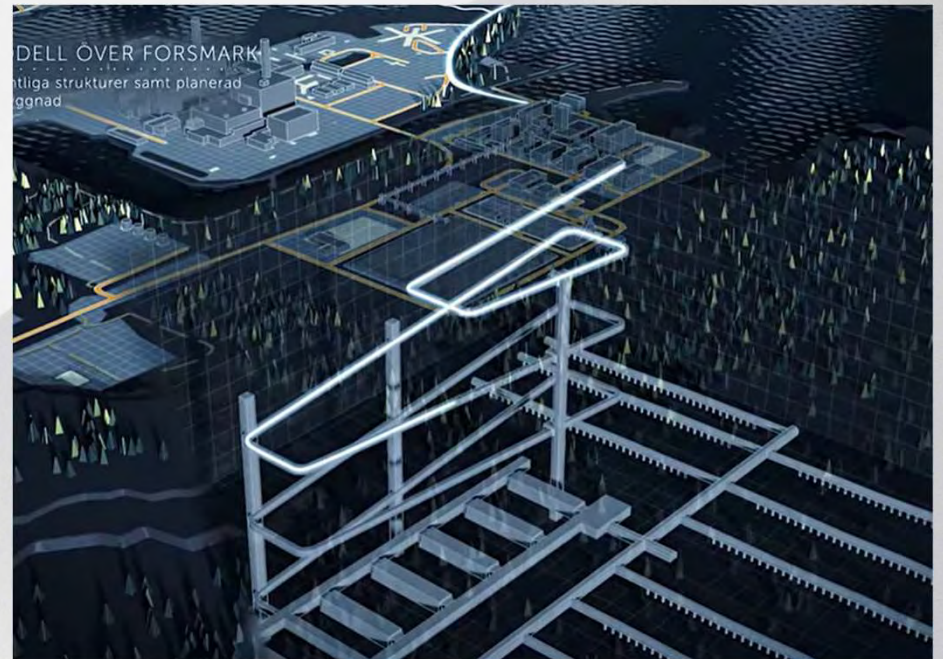
Next year we could add more use cases, driving down that mine

<https://www.youtube.com/watch?v=JjjqR6SQLuU>

Self driving vehicles

Logistic challenges (only one way down (and up))

Read-back to database



iFTF - Vision coming alive?

Using AI and automatic data analysis

- Fuel bundle ID
- Copper canister ID
- Transport cask ID
- Location

Online

AA 943 23x
Copper canister ID



SKB
Oskarshamn
10h50m ago

SKB
Forsmark
In 1h50m

05:19 CST
Scheduled 05:00

11:40 CEST
Scheduled 11:30

Duration: 12h30m - Distance: 4783 NM

