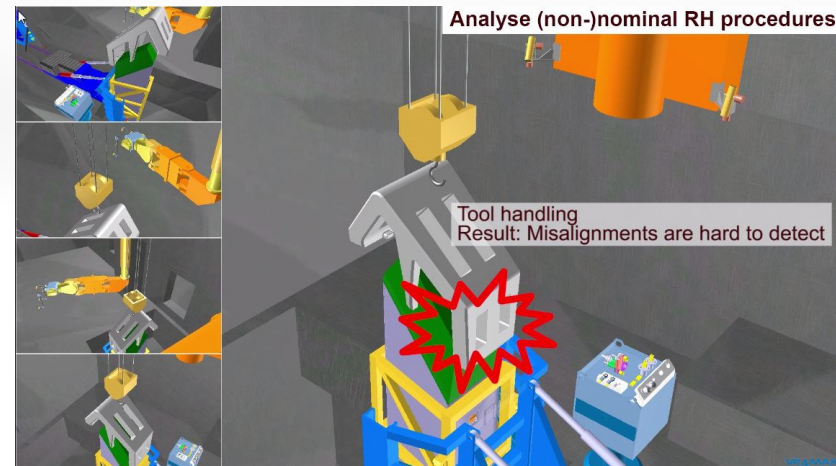
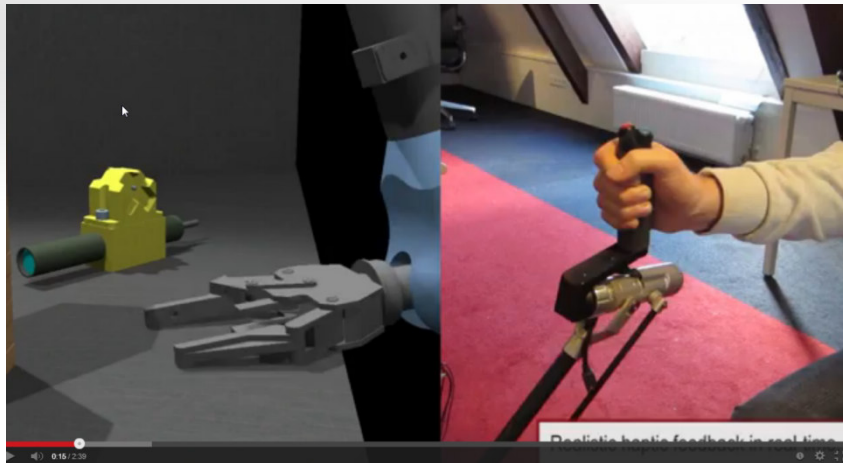


# ITER spin-out Application: Interactive maintenance simulation



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Heemskerk Innovative Technology B.V.



# HIT Activities & Partners



Support to innovative high-tech projects in critical development phases

Our activities include:

- Concept Studies
- System Studies
- System Engineering
- Project Management
- Engineering Audits
- Peer Reviews

Partners include:



# Introduction



## **Big Science & Industry – The need for maintenance**

- Big Science: Experimental operations, extreme operating conditions
- Industry: New machine, new plant, extreme investments, MTTR

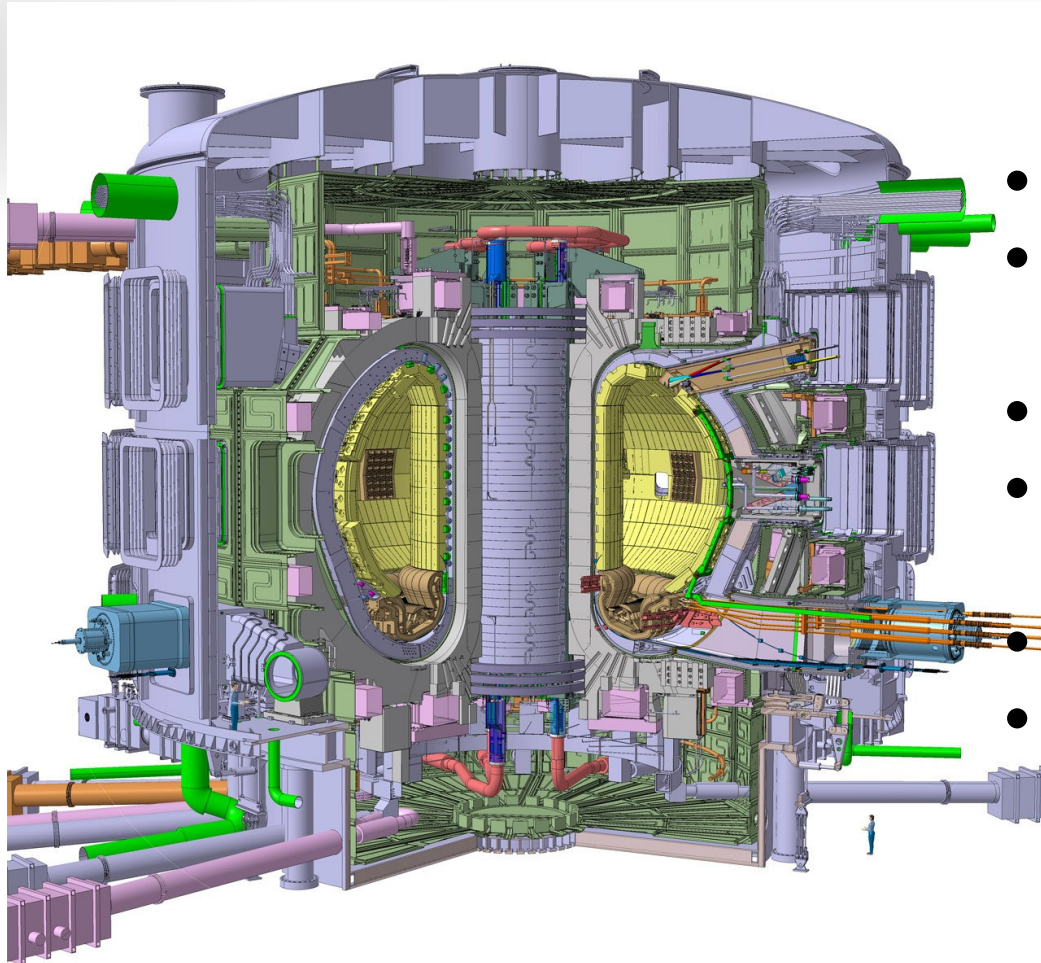
## **Developing maintenance procedures**

- While the machine or plant is still on the drawing board
- Validate complex procedures, simplify design
- Multi-operator, multi-device cooperation
- Avoid expensive 1:1 scale hardware mock-ups
- Provide early feedback on practical maintainability

## **Training and operational support**

- Basic skills, procedure training
- Non-nominal procedures, safety training
- Haptic guidance, Synthetic Viewing

# ITER



- Experimental reactor
- Mission: Prove that fusion is a viable power source
- “The sun on earth”
- Under construction in Cadarache, France
- First plasma Nov. 2020
- Plasma confined by superconducting magnets

# ITER needs Remote Maintenance



## Components fail due to extreme experimental loads

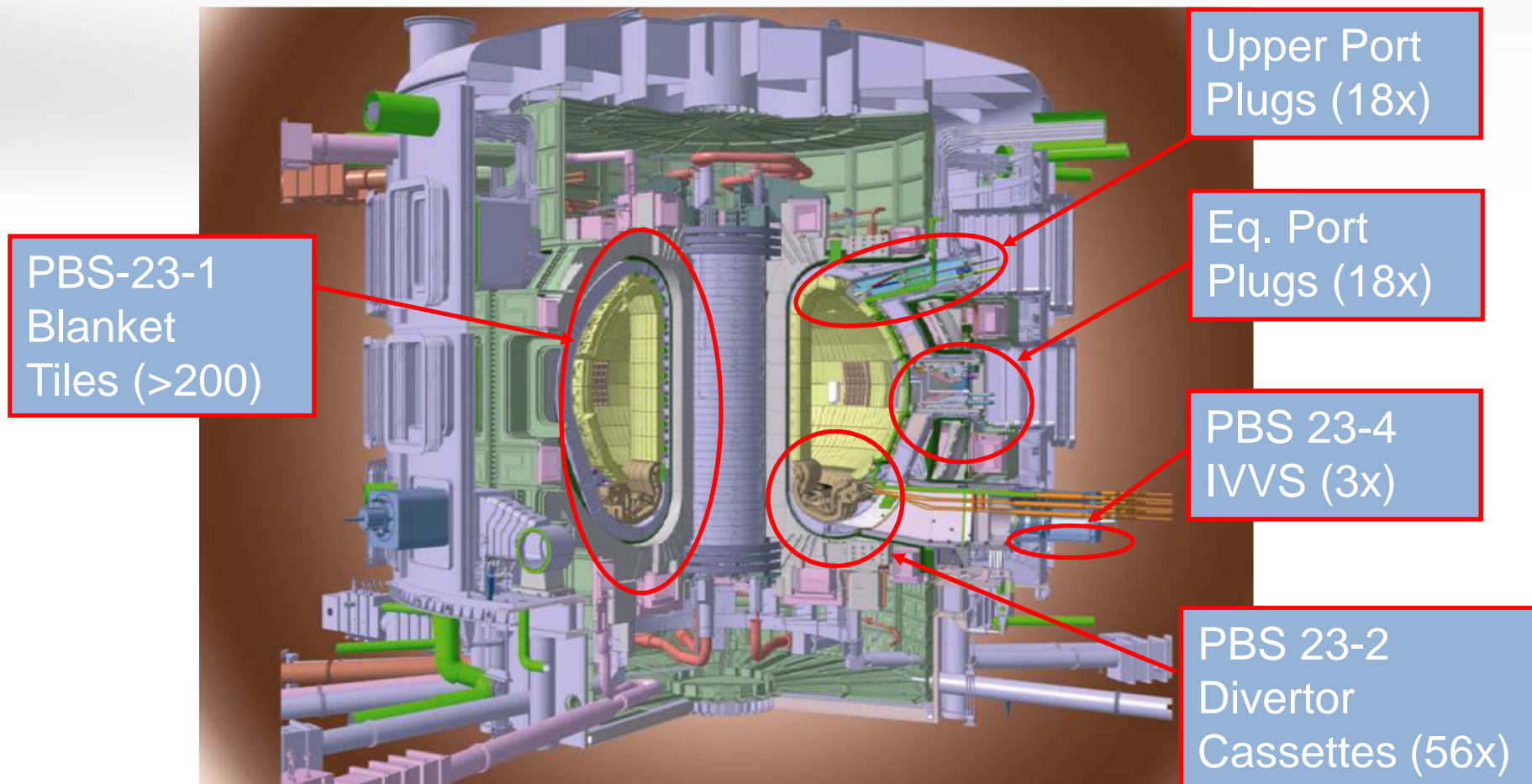
- Thermal loads:
  - Plasma Steady-state, ELMs, Disruptions
  - Neutrons Volumetric heating
  - Instrument Ohmic losses in ECRH
- Particle fluxes: Re-deposition of eroded material on optics, mirrors
- Electro-magnetic loads:
  - Sudden termination of plasma current (disruptions)
  - 15 MegaAmps in 40 ms => significant displacements
- Neutrons: Degradation of materials, optics

## No manual handling due to contamination

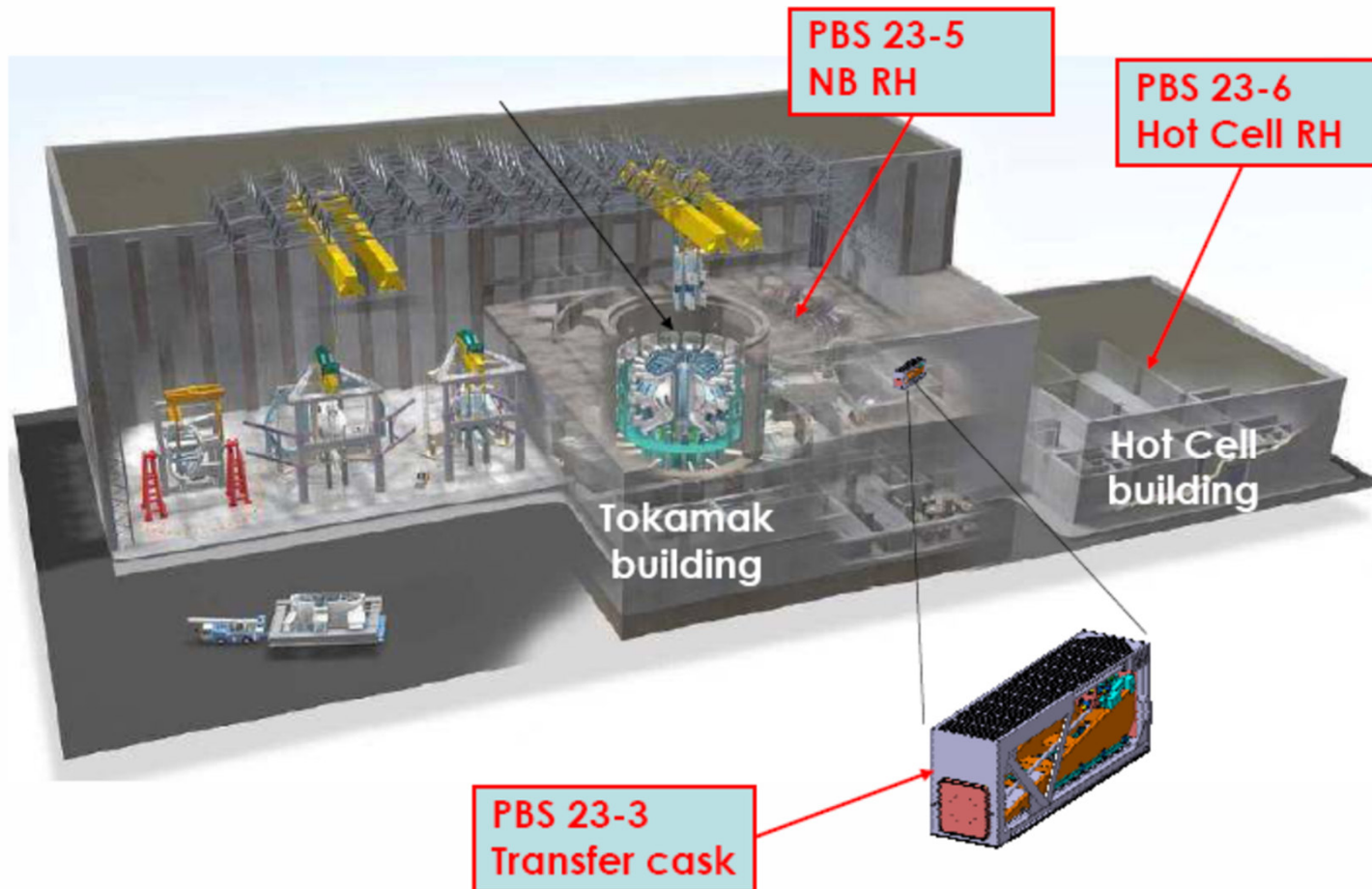
- Beryllium deposition
- Tritium
- Activation (gamma radiation)



# Parts to be maintained



# ITER maintenance logistics



# ITER Project Challenges



## **ITER is huge - 10 x larger than existing plant (JET)**

- Estimated 15E6 components
- Unprecedented Scale of Remote Handling Maintenance
- Diversity of RH systems larger than @ JET

## **ITER is a pressurised nuclear facility**

- Regulations require proof (verification and validation) of maintenance procedures (at all levels) before operation

## **ITER is a new, international scientific cooperation**

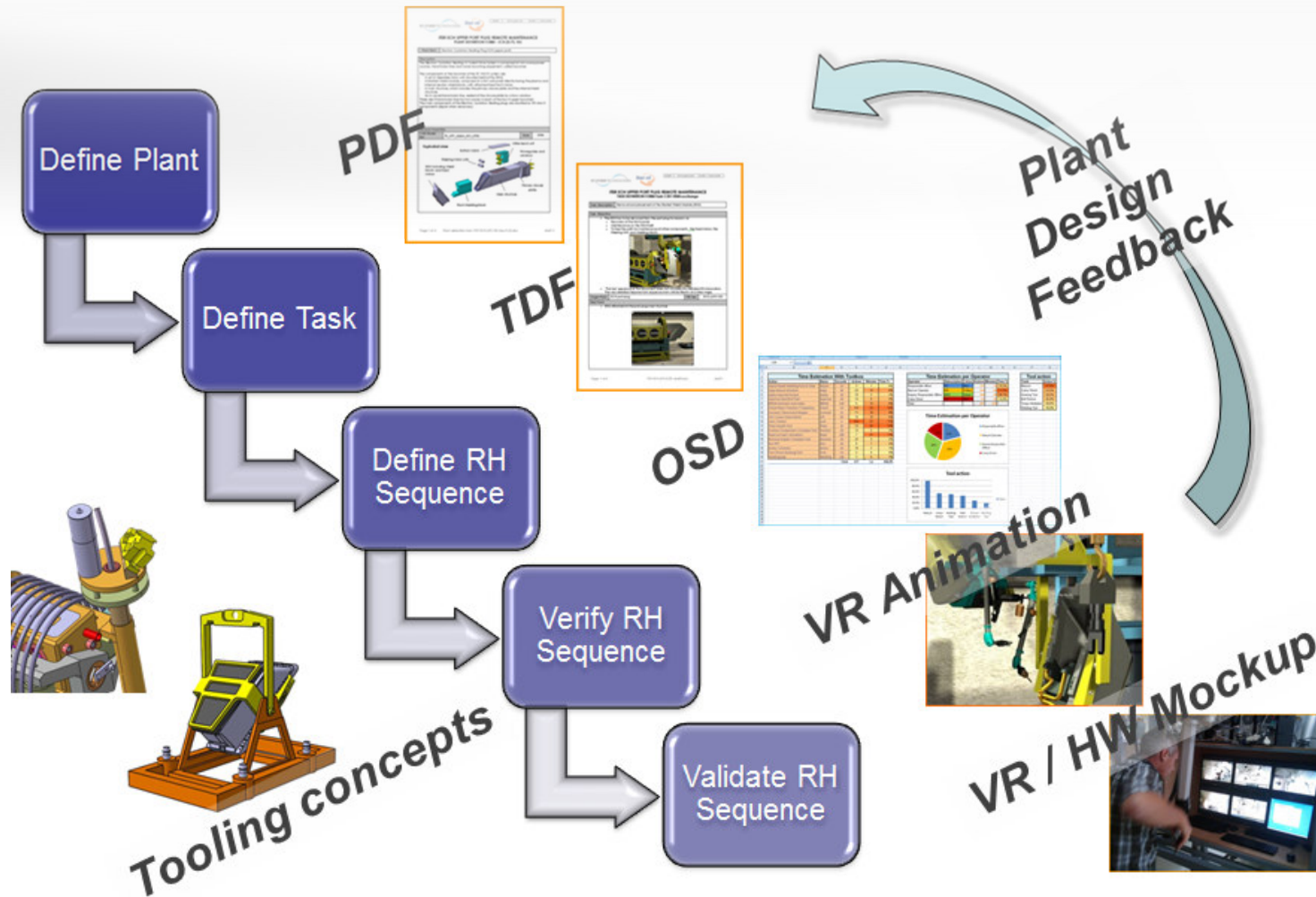
- Politics and procurement policies
- Contributions in kind
- Evolving standards



# ITER Maintenance Analysis

- **In line with International standards and methodology**
- **Starting point: Maintenance Strategy - Input from RAMI (!)**
  - When: Planned or not planned
  - What: Which components
  - Where: Hot Cell, Port Cell
  - How: Manual or with Remote Handling
- **Perform analysis with CAD, VR – check feasibility, resource usage:**
  - Effort (time) and HCF occupation
  - Spare parts to be kept in stock
  - Tooling
  - Intermediate Storage & Logistics, Waste
- **Input to formal Remote Handling compatibility review**
- **Iterate to increasing detail corresponding to design review goals**
- **Validate using interactive haptic Virtual Mock-up**

# Maintenance Analysis process

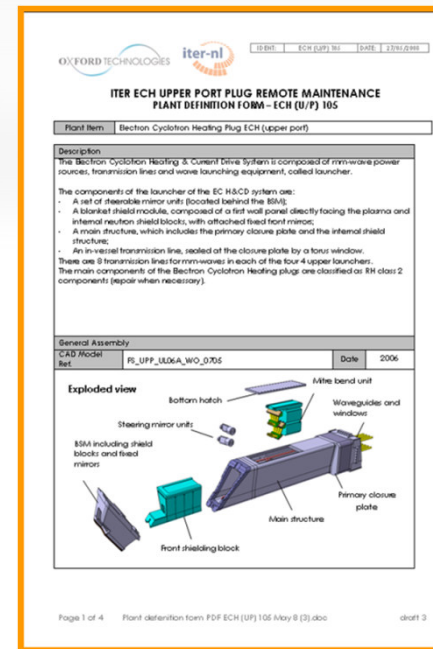


# Typical Outputs

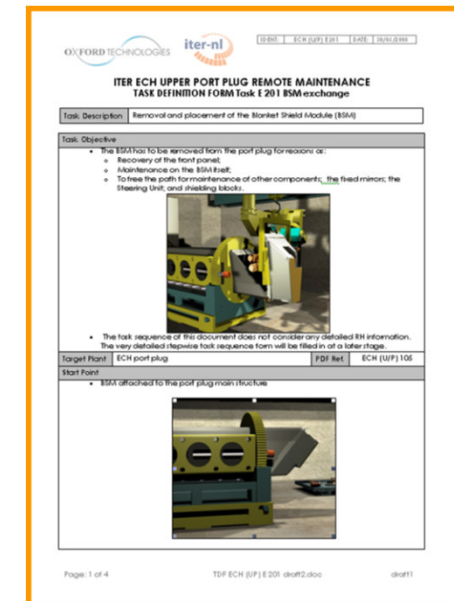
## RH Compatibility Analysis

### Results

- Plant Definition Form
- Task Definition Form
- Operational Sequence
- Time estimates, MTTR
- HCF occupation
- Space requirements
- Spare part policy
- Validated procedures
- Proposals for tooling
- Instruction movies



### TDF



# Example VR Animation

Unbolting a steering mirror in the ECH Upper Launcher

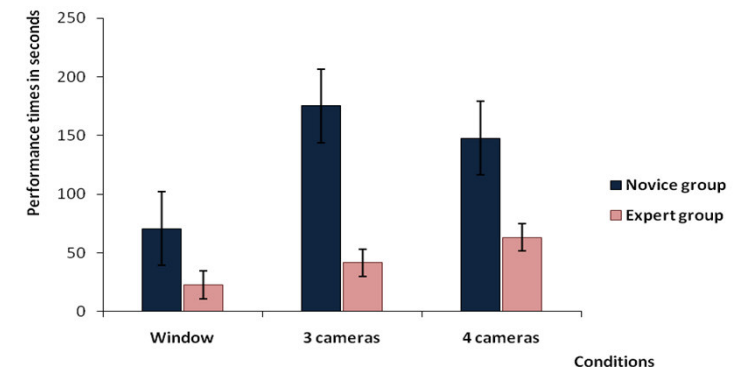
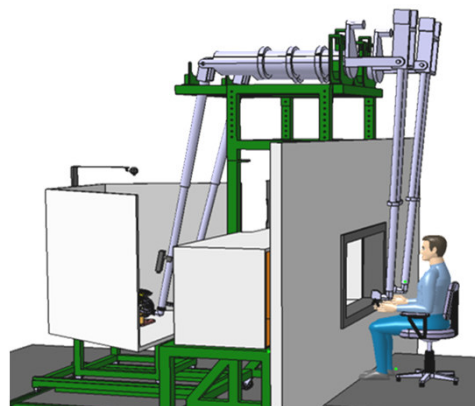




# Calibration: Can you trust VR?

## Validation of VR with HW Benchmark in RH Testbed

- Time estimates of common RH tasks
- Validation of tools and procedures

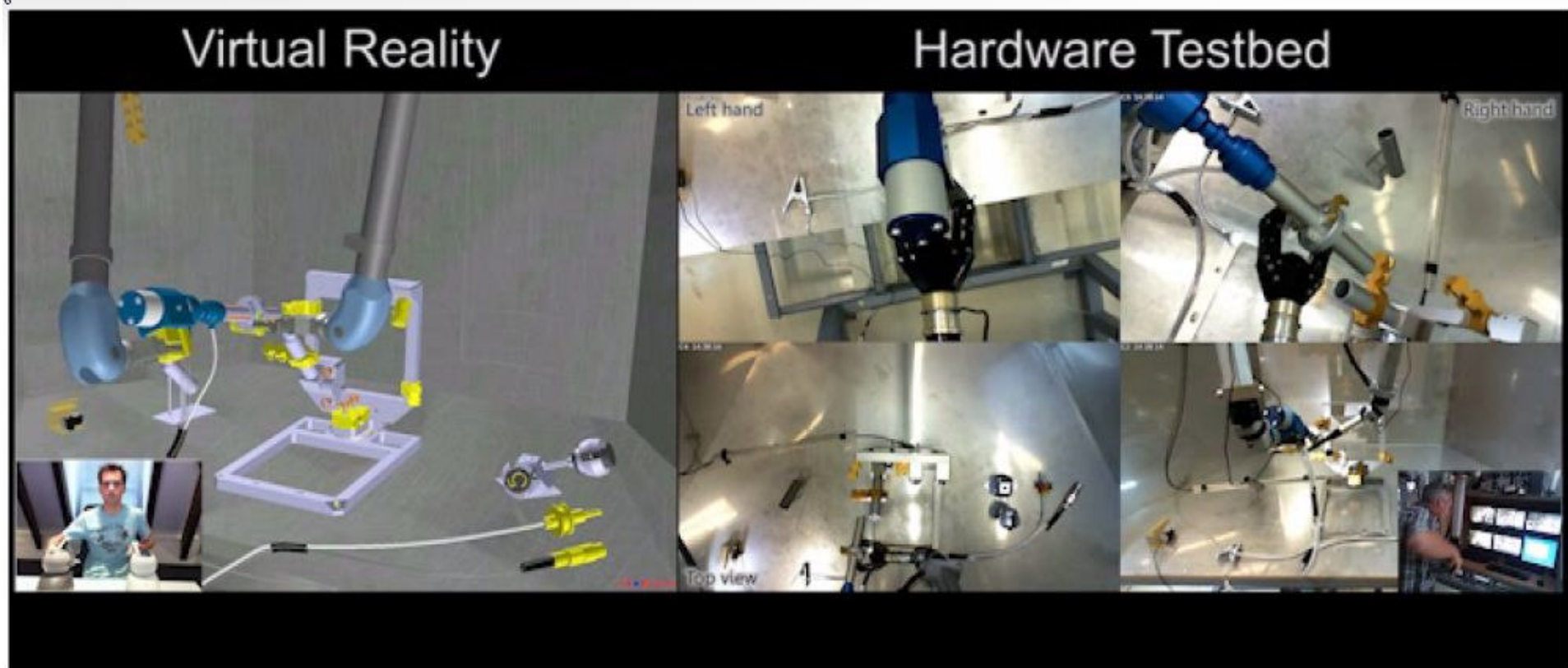


“Verifying Elementary ITER Maintenance Actions with the MS2 Benchmark Product,”  
 C.J.M. Heemskerk, B.S.Q. Elzendoorn, A.J. Magielsen, G.Y.R. Schropp, SOFT-2010

# Calibration

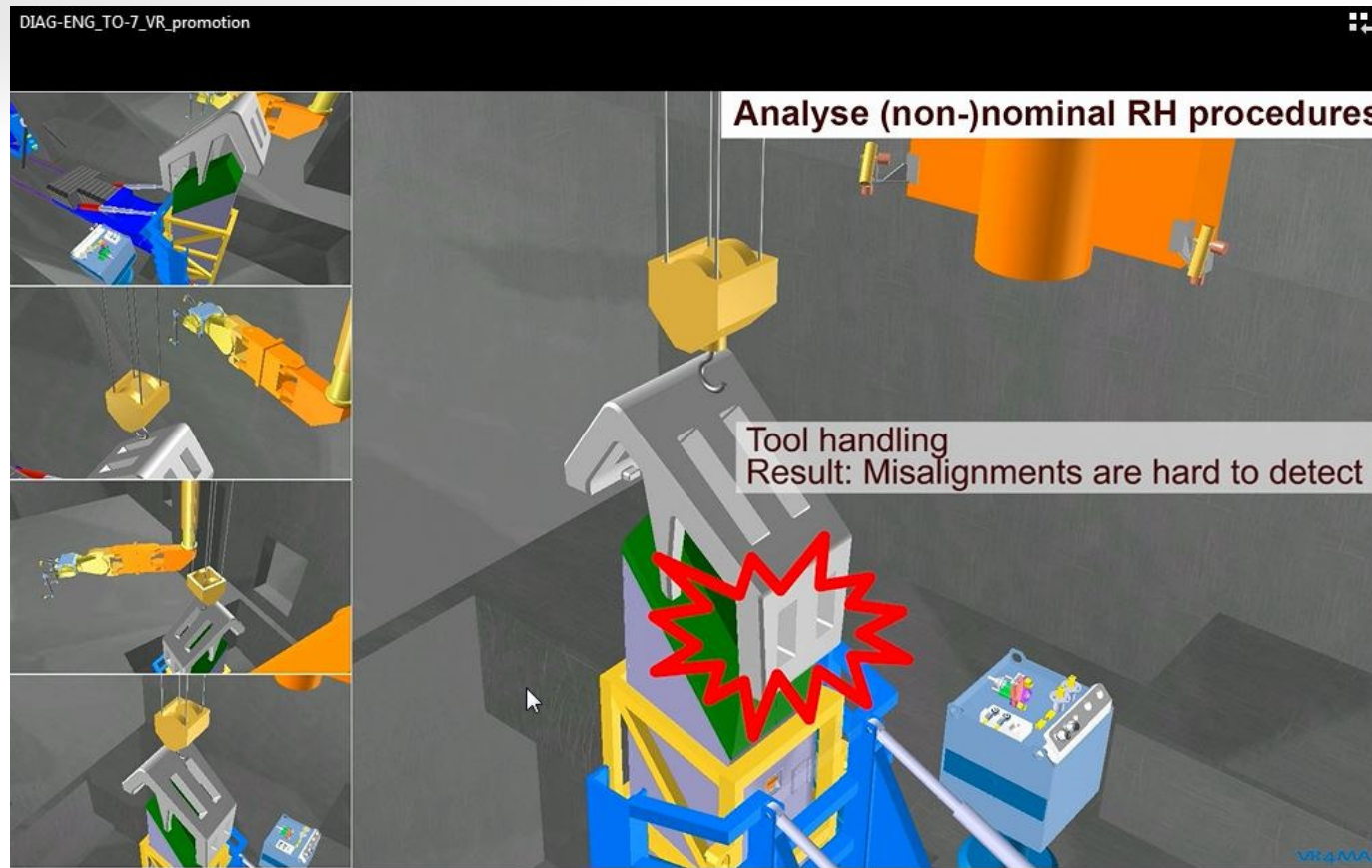


## Virtual Reality vs Hardware Testbed



# Provide design feedback

## Validate maintenance feasibility with interactive Simulation

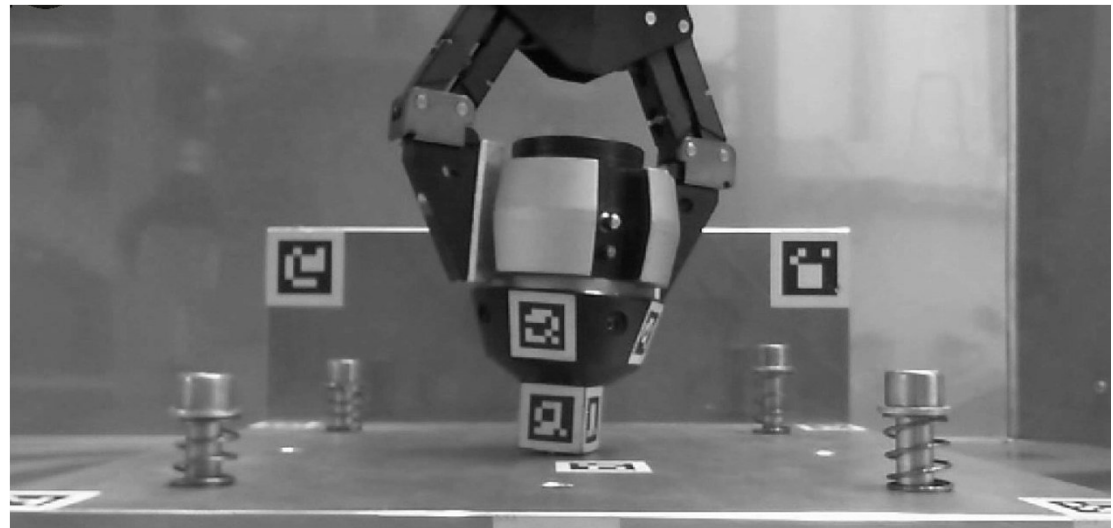




# Support operations

## Calibrated Model provides interactive guidance during operations

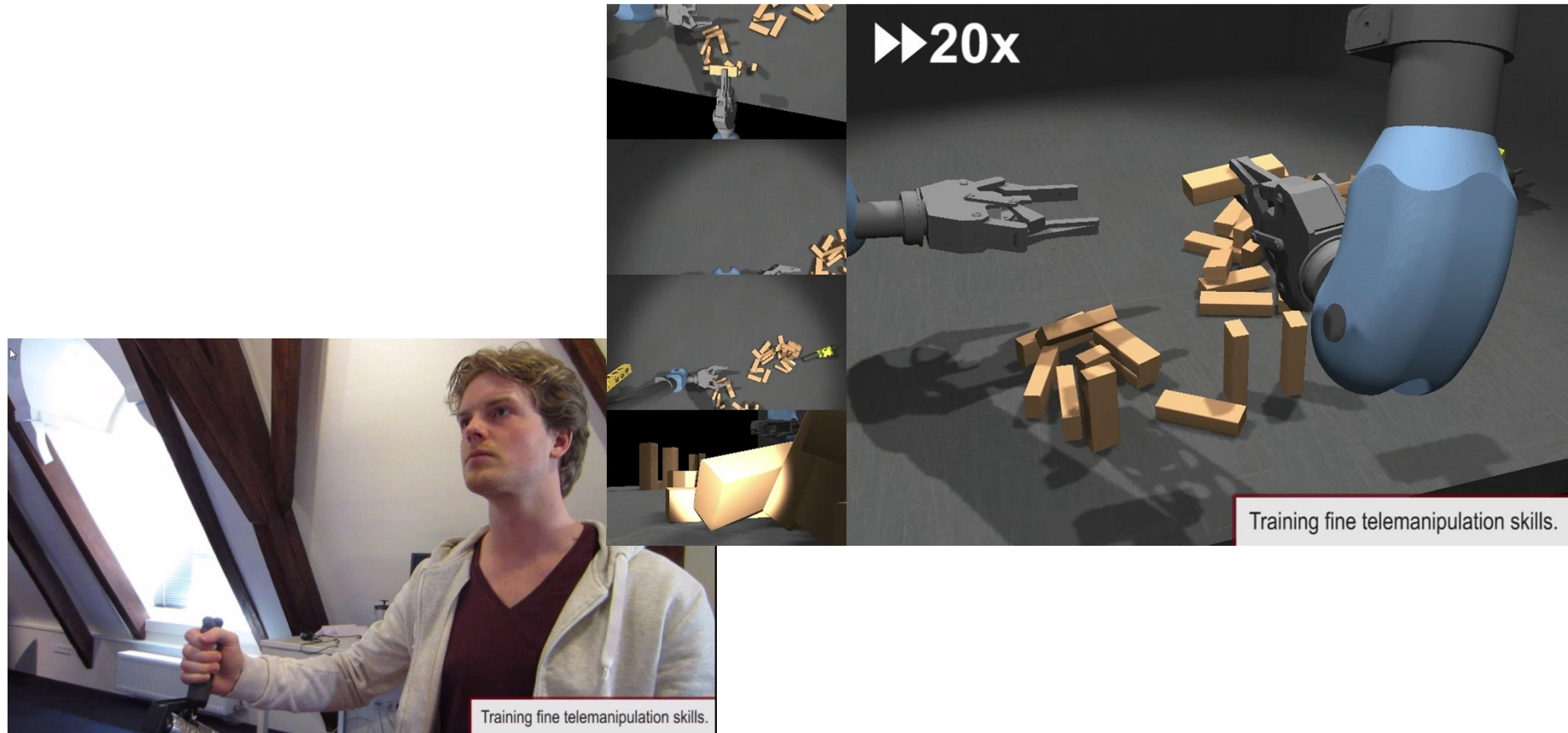
- Increase safety, reduce MTTR





# Interactive training

Train operators while facility in design phase

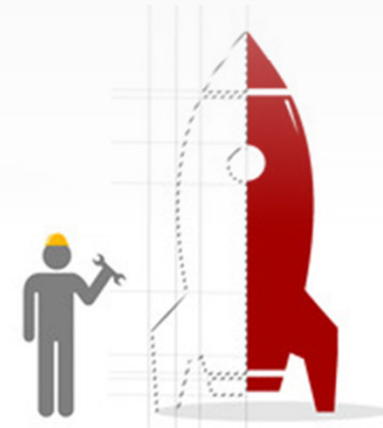


# Applications in Industry



## Analyse maintainability (in design phase)

- Reduce the time to get new facility operational
- First time right
- Reduce Mean Time To Repair
- Reduce life cycle cost



## Interactive maintenance training

- Serious game raises safety awareness
- Train operators while facility in development
- Train operators while machine is in production
- Make new facility available sooner
- Increase operational availability



# Conclusions

## **Maintenance is integral part of facility operations**

- Not just for big science facilities that operate under extreme conditions

## **It pays off to analyse maintenance procedures early**

- Interactive VR models provide early feedback on practical maintainability
- Avoid expensive 1:1 scale hardware mock-ups
- Validate complex procedures
- Increase facility availability
- Reduce life cycle cost

## **Use interactive VR models for training and support**

- Basic skills, procedure training
- Non-nominal procedures and safety training
- Synthetic Viewing, haptic guidance

# Contact and links

## Operator training with Jenga:

<http://www.youtube.com/watch?v=jWYMbVVFIEI>

## GUPP analysis:

<http://www.youtube.com/watch?v=8NJmnnKAjWQ>

## VR validation:

[https://www.youtube.com/watch?v=GZNc\\_cSQ4no](https://www.youtube.com/watch?v=GZNc_cSQ4no)

<https://www.youtube.com/watch?v=xK3Tx3pOYWQ>

## Remote Handling Study Centre

<http://www.differ.nl/en/remote-handling-study-centre>



## Contact:

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