

Challenges of Video Monitoring for Phenomenological Diagnostics in Present and Future Tokamaks

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Motivations

- **First performance level of ITER VIS/IR diagnostic** based on **real-time qualitative** analysis of data [Reichle]

- Operational use:

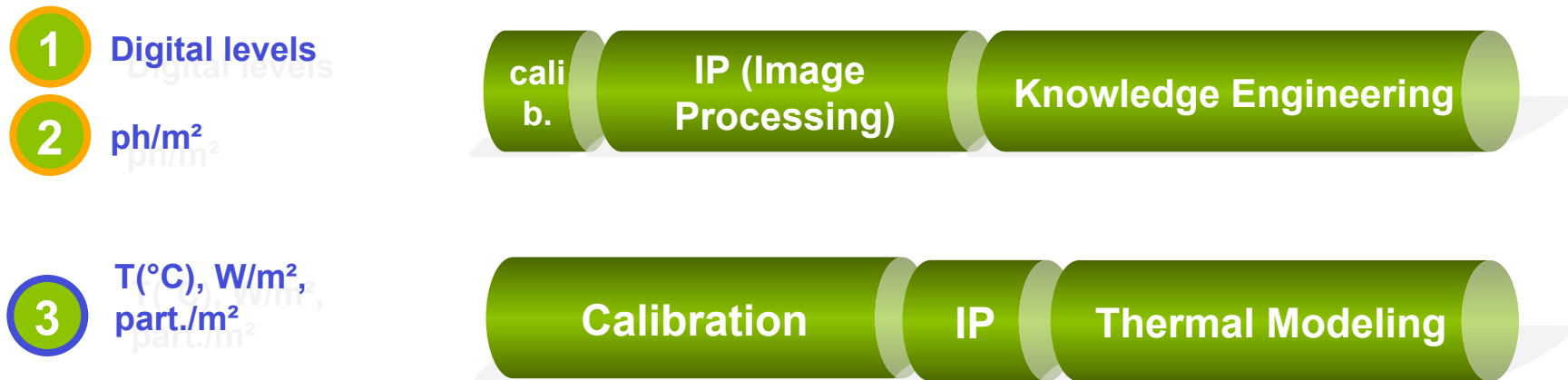
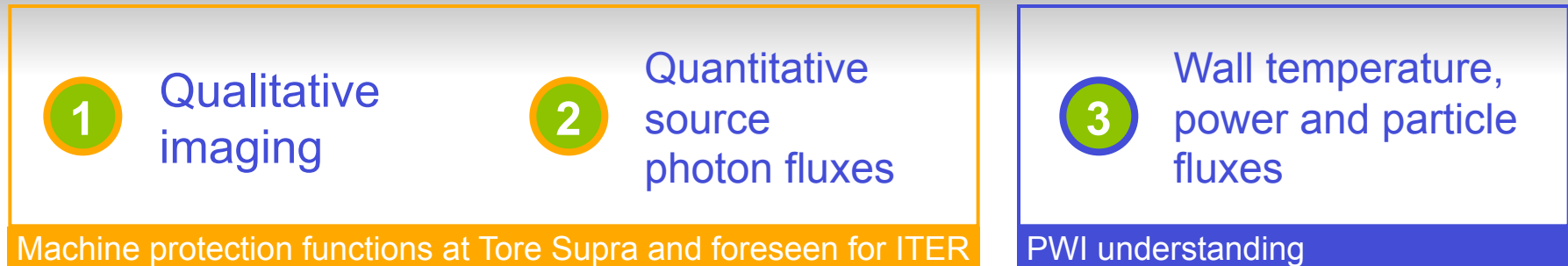
- **Abnormal thermal event identification** (hot spots)
- **Event precursor identification** (disruption, arcs)
- **ELMs characterization** (structure, frequency)
- **Detection & tracking of MARFE, dust and pellet**
- **Localization of impact of fast particles during RF and alpha heating**

- **Tore Supra as a good starting point**

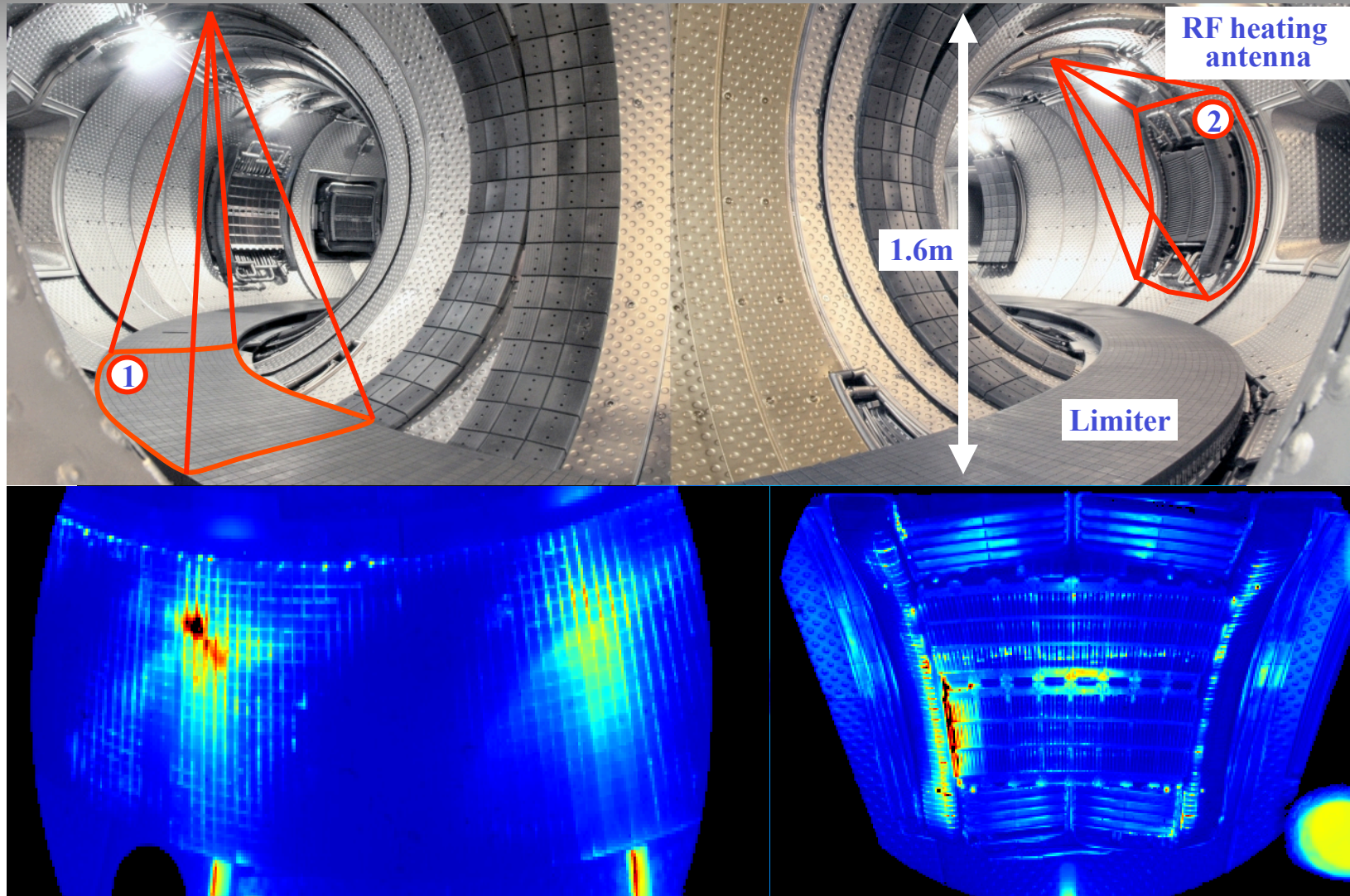
- **Long pulses** operation, actively cooled PFCs
- **Existing real-time plasma control system**
[Guilhem, Moreau]

- 1 Qualitative imaging
- 2 Quantitative source photon fluxes
- 3 Wall temp., power and particle fluxes

Performance Level vs. R&D Efforts



Video Monitoring During Tore Supra Operation



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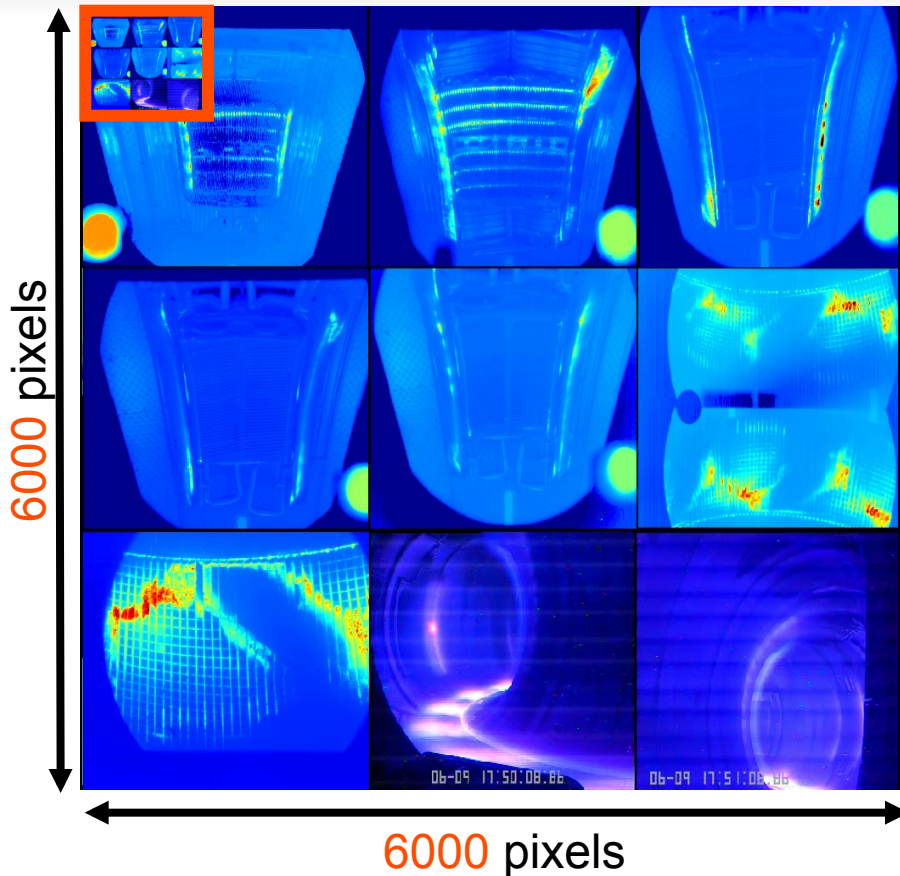
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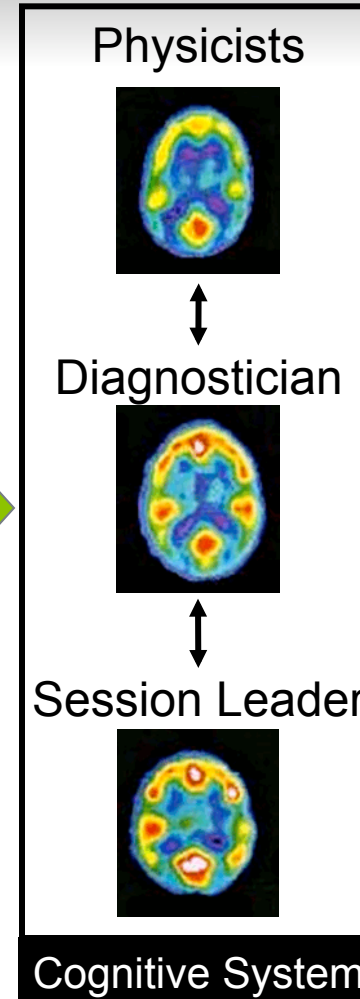
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Imaging Data Interpretation During Operation

Tore Supra Control Room Network



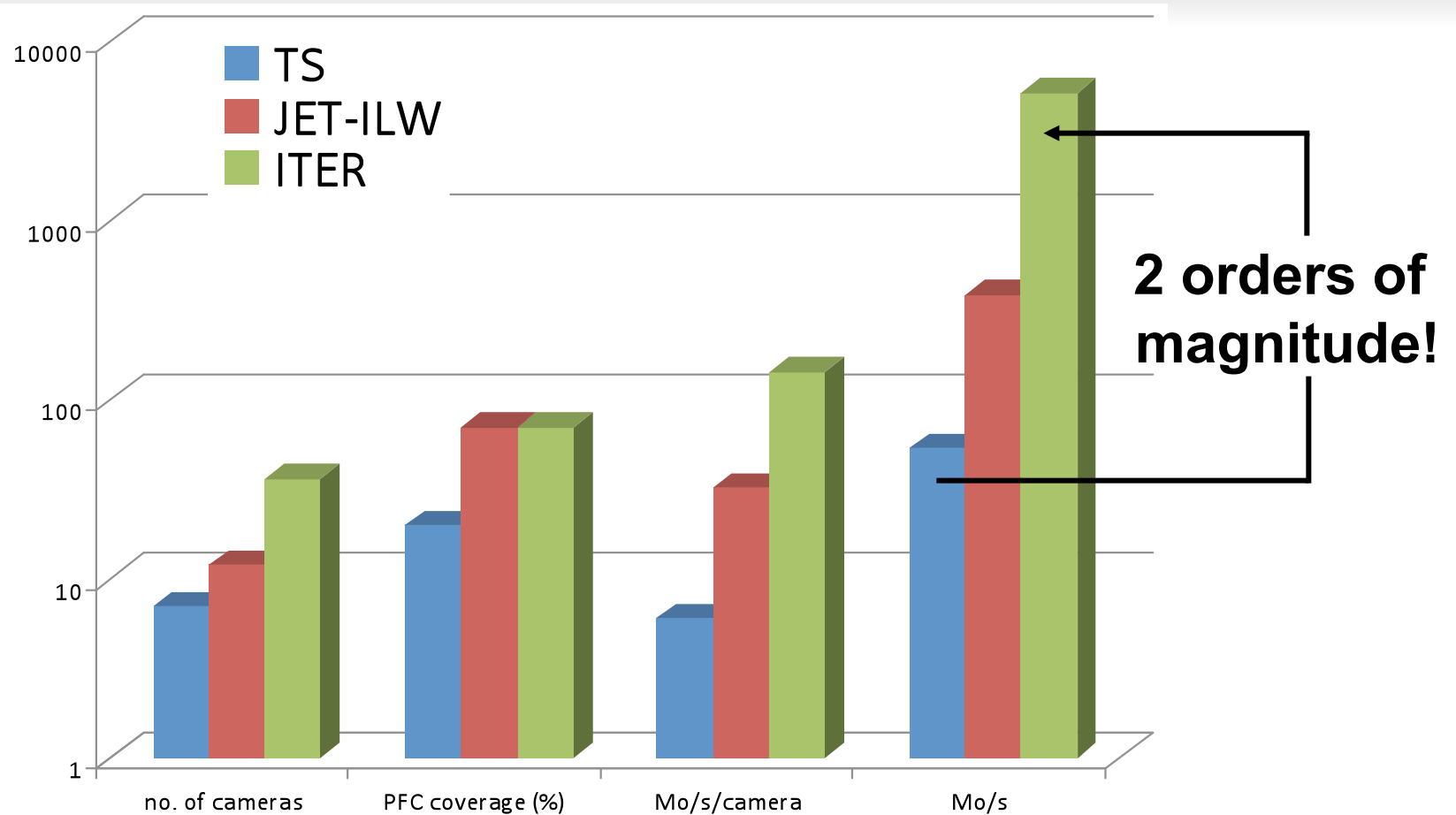
monitored surface = 650 m²



X 10 ?

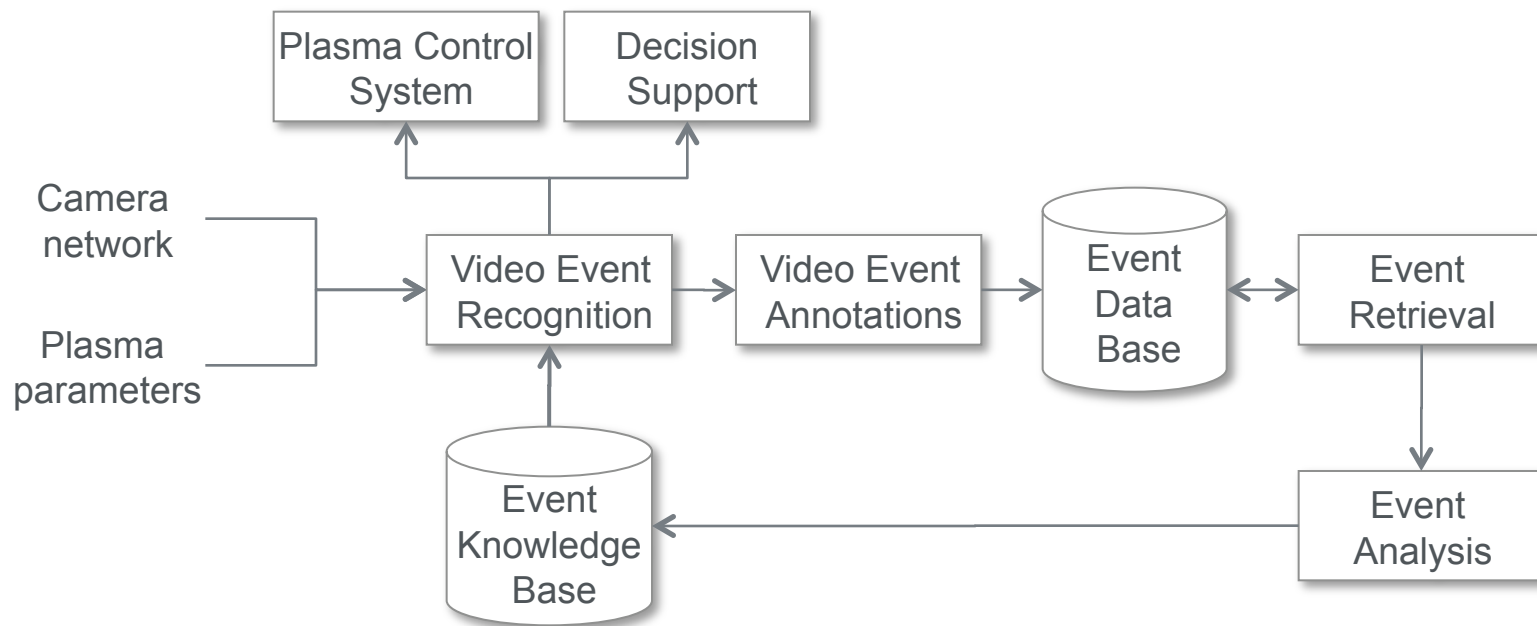
Decision Taking

Massive Data Production

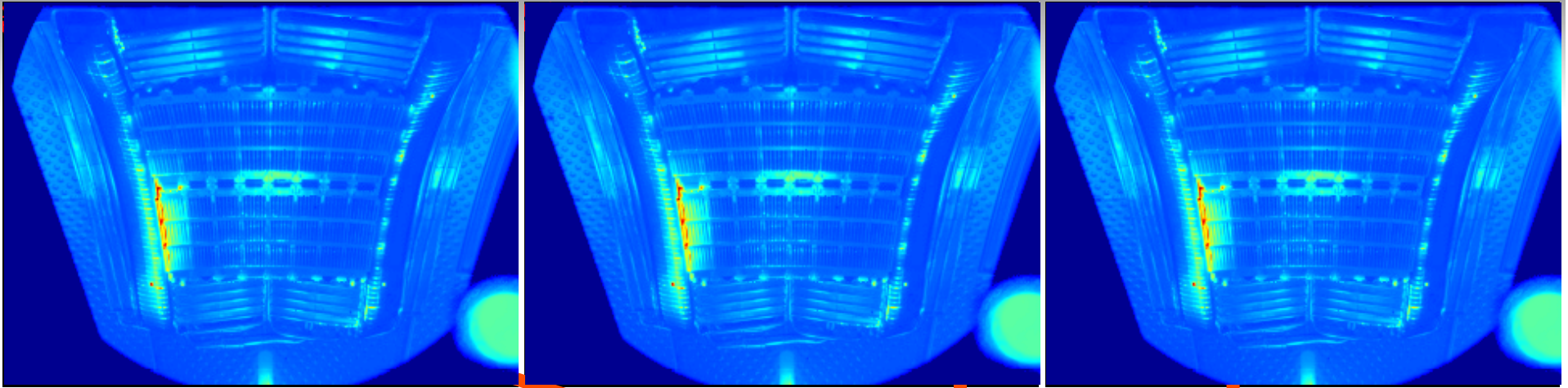


Proposed Approach

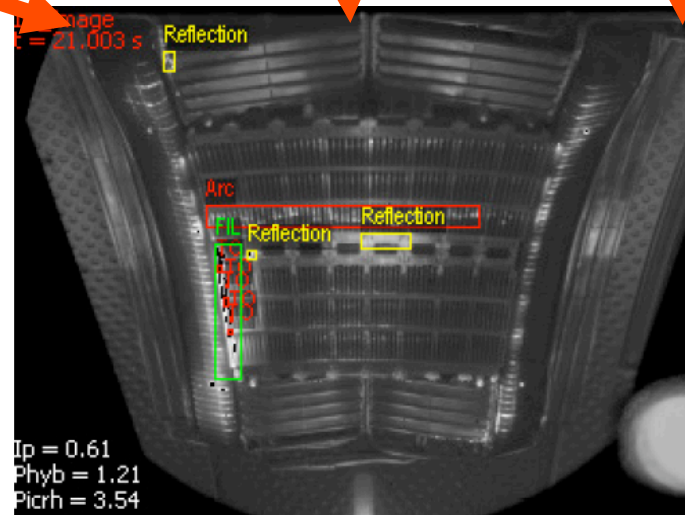
- An Integrated Framework for:
 - **Automatic** detection & recognition of abnormal events
 - **Real time** analysis during plasma operation
 - **Efficient** event data storage and **retrieval**



Automatic Event Detection & Recognition



- **Goal-oriented detection**
(Parallel computing)
- **Pattern recognition**
(shape, size, position, duration...)
- **Multi-sensor data analysis**
(image + plasma scenario parameters)



FIL = impacts of
Fast Ion Losses

TO = Threshold
Overrun

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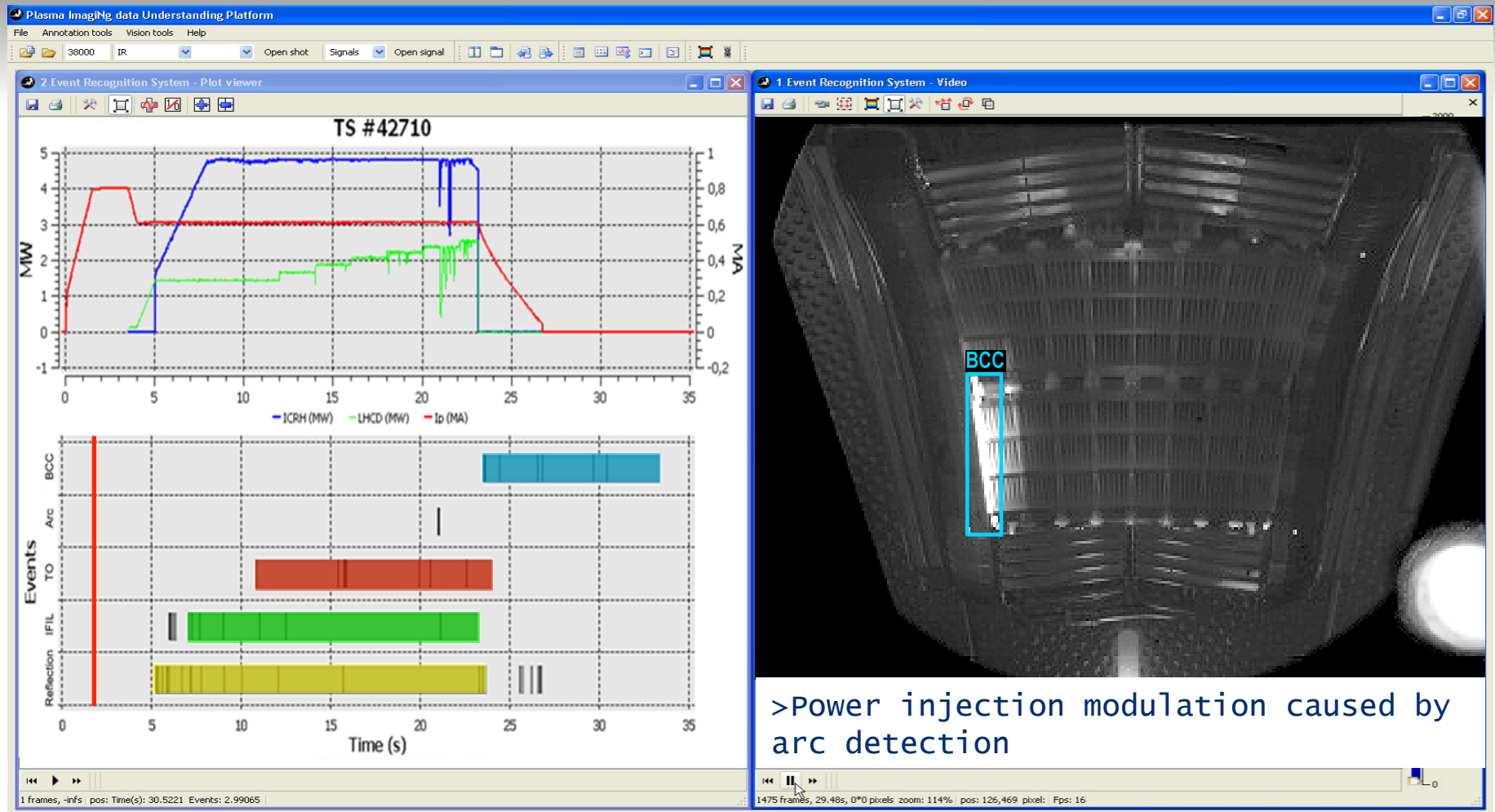
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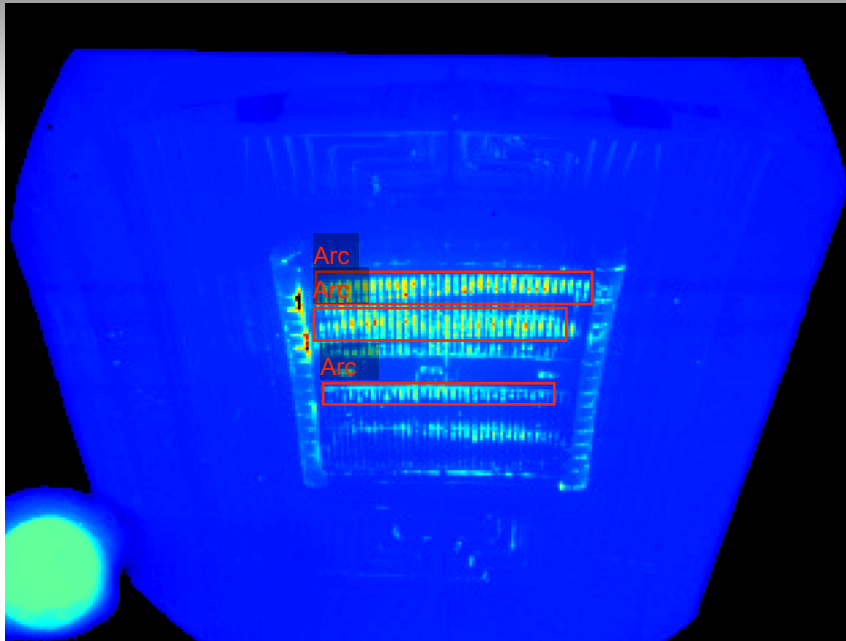
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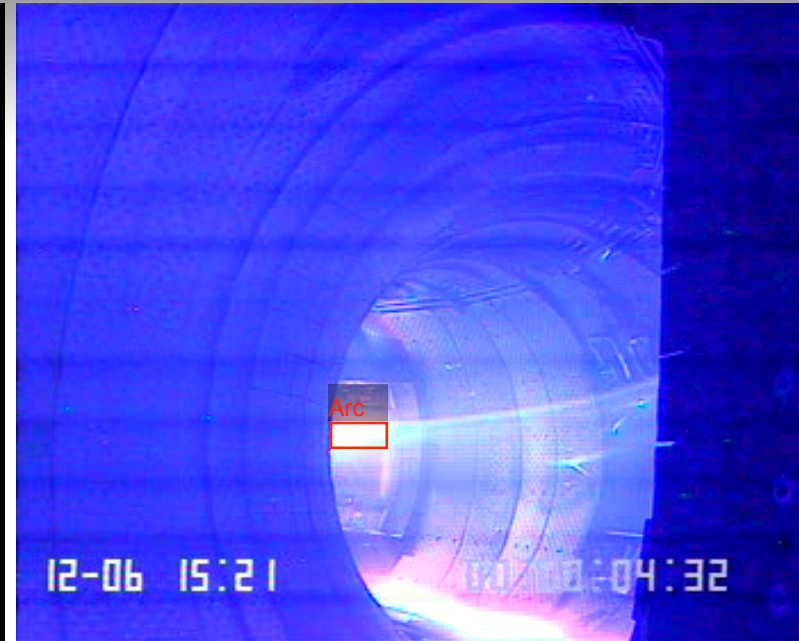
Decision Support System



System Reusability



TS LHCD **IR** closed view

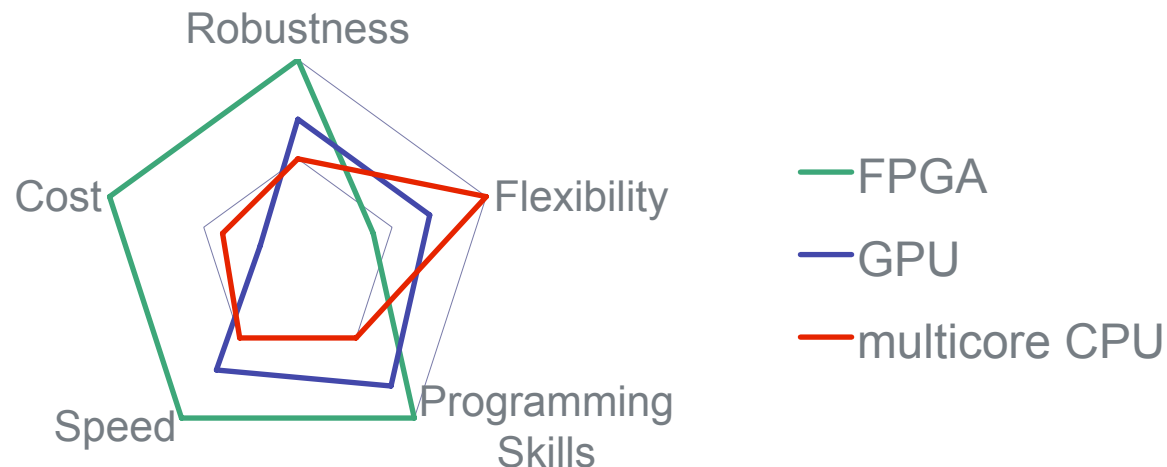


TS **visible** wide angle

- **Event** detection & recognition based on the **same algorithms**
- Reasoning rules inferred from the **same ontology**

High Performance Computing

- **Test of several hardware acceleration supports:**
 - FPGA for pixel-level parallelization (e.g. intensive pixel-wise operations)
 - GPU for buffered operations
 - Multicores CPUs for task-level parallelization



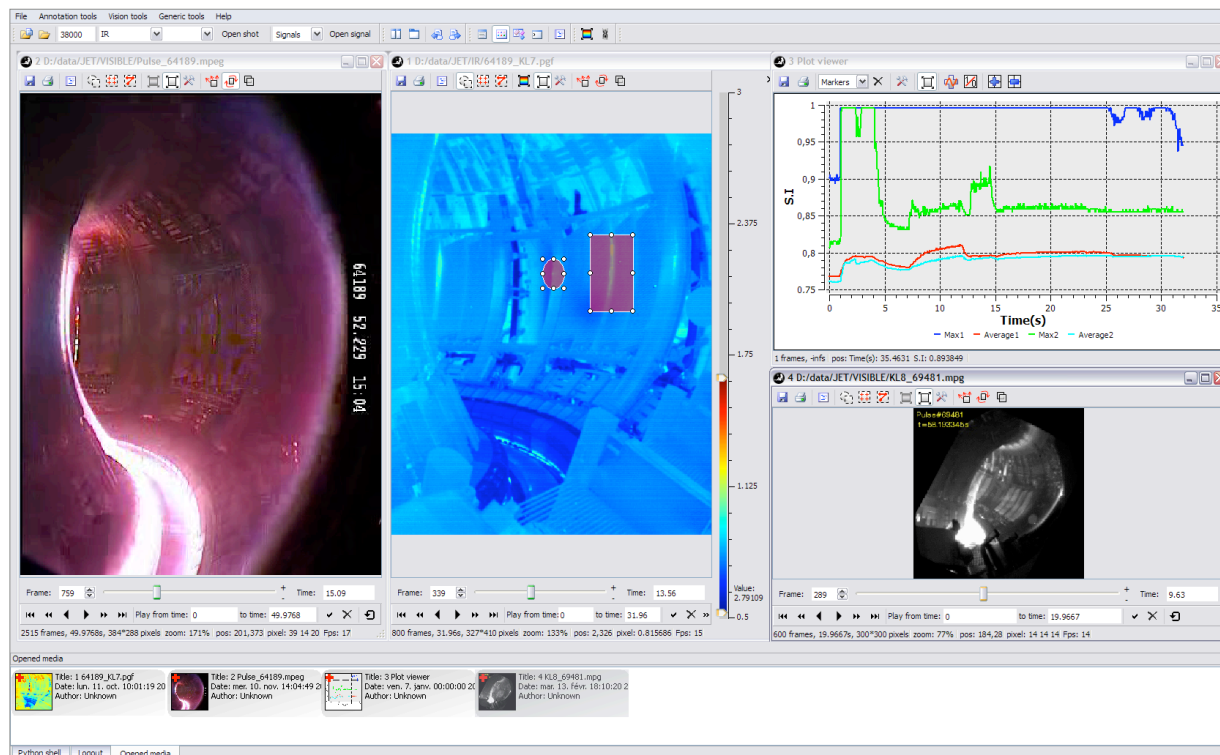
Summary

- **Phenomenological Diagnostics:**
 - Necessary input for machine protection functions **and** physics understanding
 - A **multi-disciplinary** approach mixing physics knowledge modelling, advanced image processing, software engineering and high performance computing
- **Technological challenges:**
 - One ITER plasma discharge = ~**TBytes** of imaging data
 - **Real time** control for machine protection = 1-100 ms for image processing tasks

Contributions to Identified Needs

- **Development of an intelligent vision-based system for phenomenological analysis based on video monitoring**
 - **Automatic** and **real time** event recognition (arcs, ELMs, hot spots, etc.) with **hardware acceleration** supporting
 - Generation of **event data bases** for off-line PWI studies
 - **Multi-sensor** data merging for improving system robustness
- **System scaled for different viewing systems incl. ITER-like views (VIS/IR WAV system)**
 - Daily use at Tore Supra during plasma operation
 - Ready to be applied on **JET ITER-like** views
 - On-going tests on simulated images of ITER IR WAV system

- Open software platform for the scientific community. Feel free to ask us if this fits with your needs.



Thank you for your attention.

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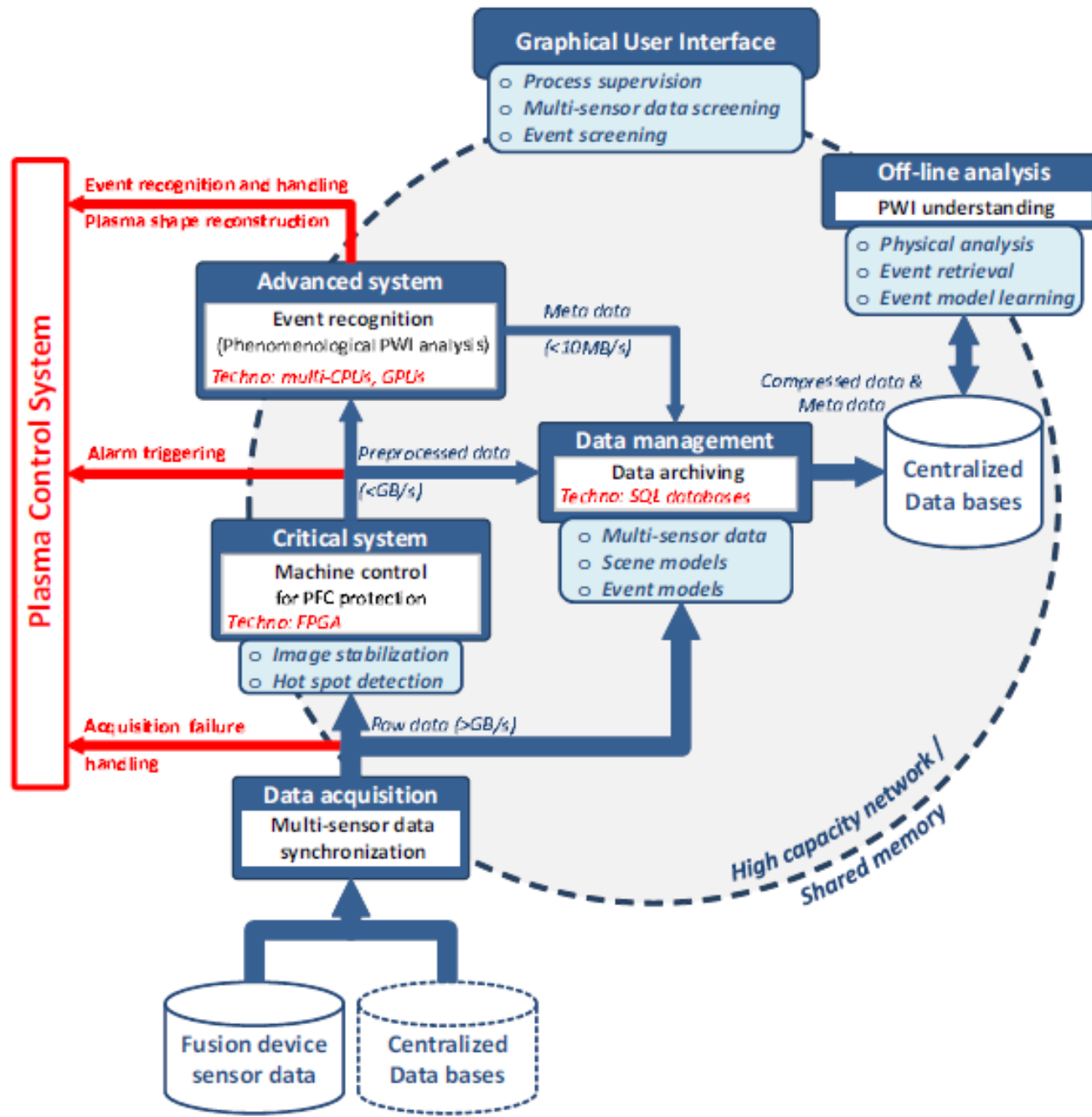
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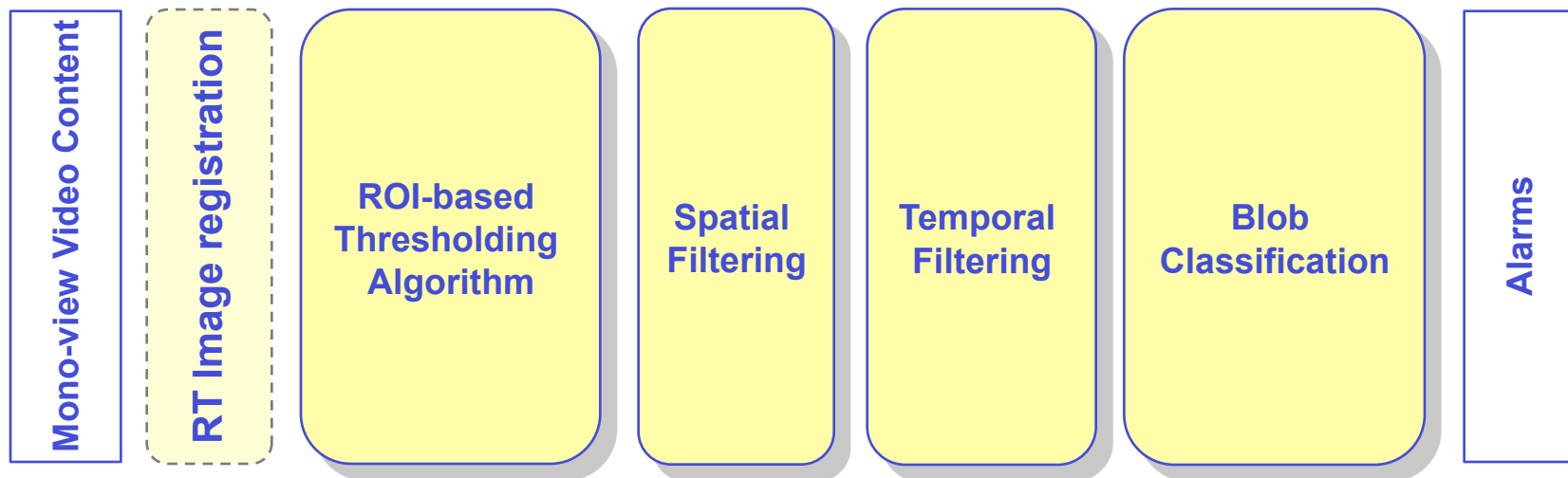
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Vision System Workflow

- *Historical Approach* (TS, AUG, JET-ILW)

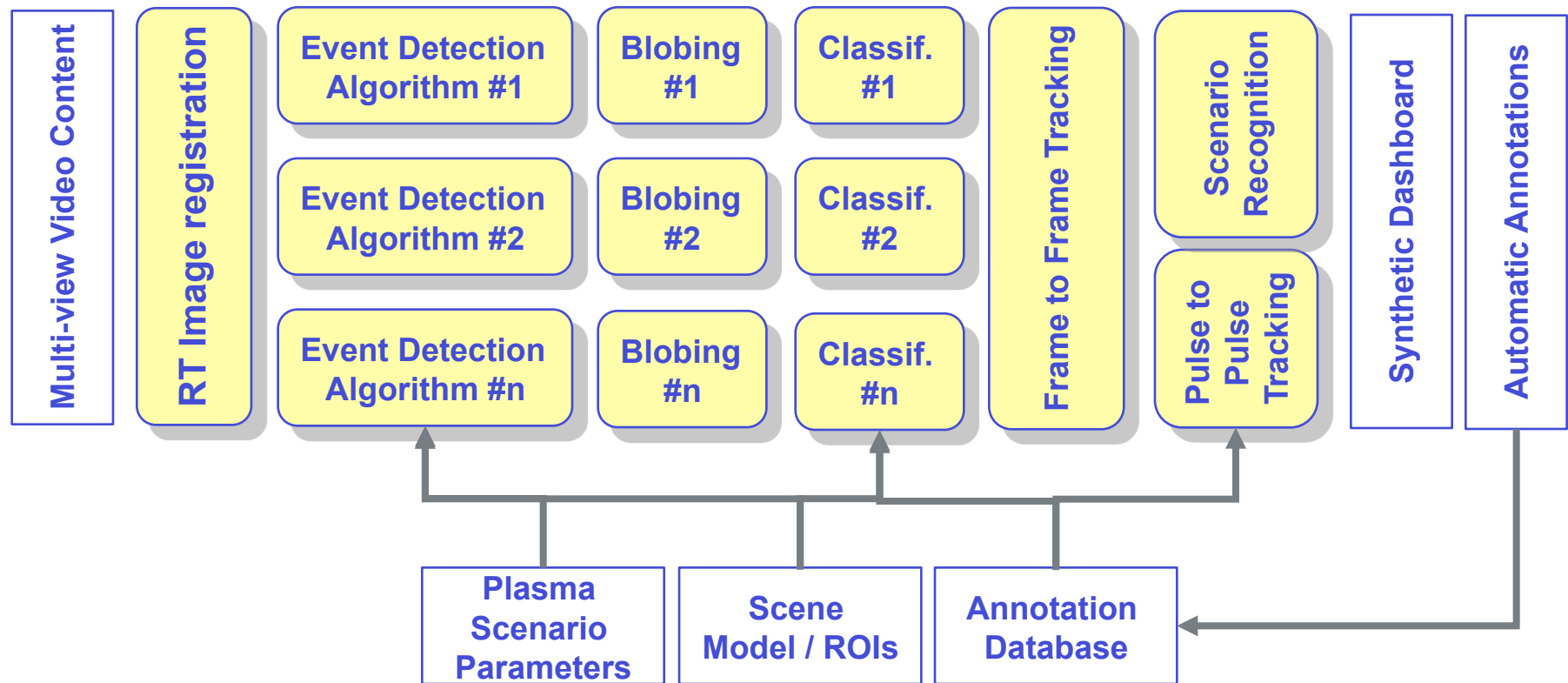


User-defined ROIs

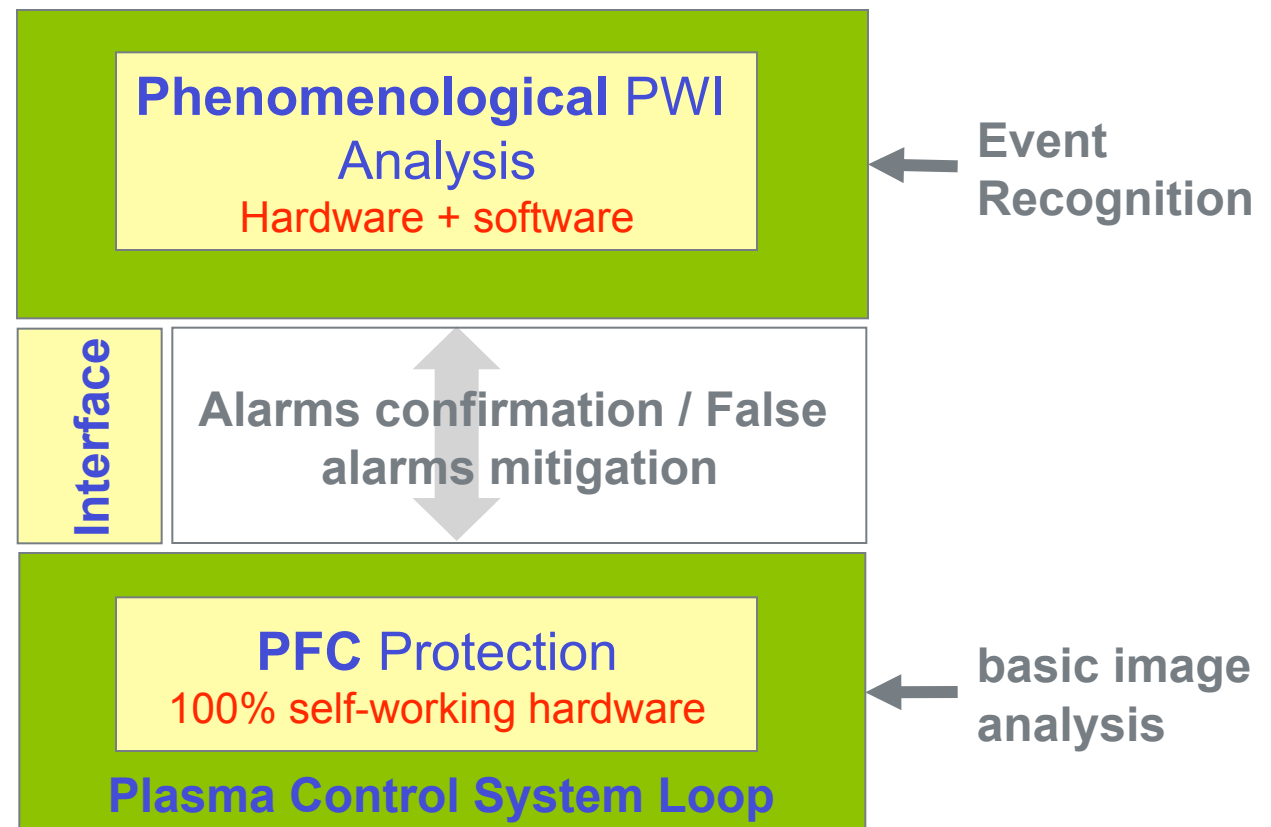
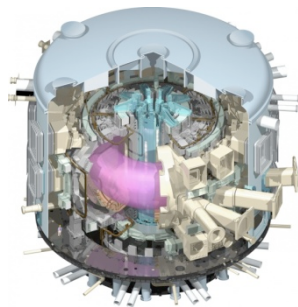
- ROI manually edited between 2 pulses
- **Empirical** thresholds set by “experience”

Vision System Workflow

- Cognitive Vision Approach

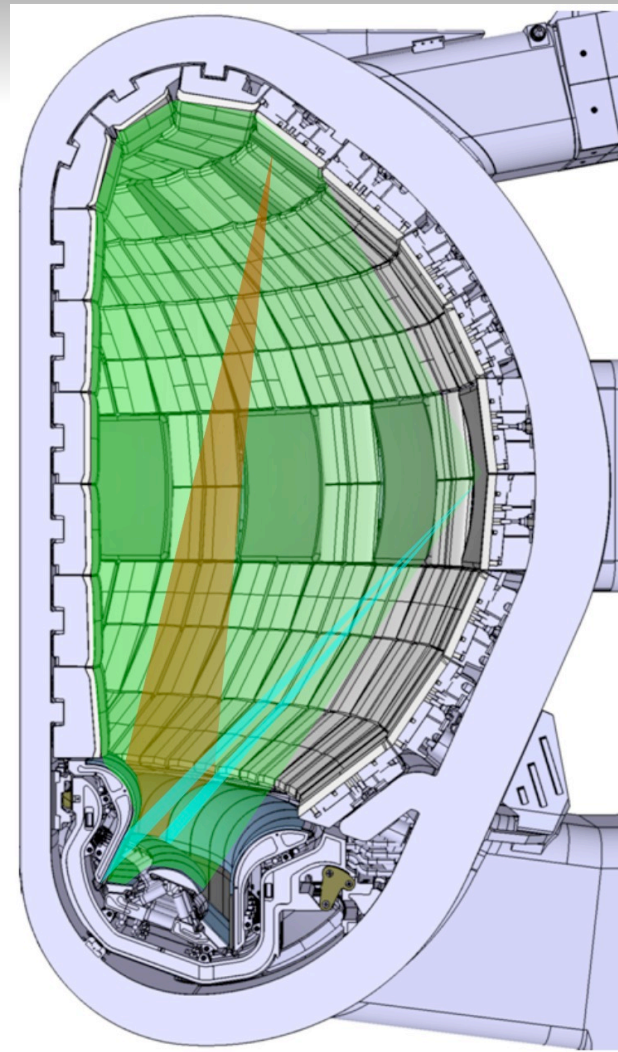


Real Time System Integration



ITER Viewing System

“Upper Vis/IR TV” (USA)
outer target
(operations + physics)



“Equatorial Vis/IR TV” (EU)
inner target + dome + main wall
(operations + physics)

“Divertor Vis/IR TV” (Japan)
inner and outer vertical target
views, high-speed, high spatial
resolution (~3 mm) (physics)

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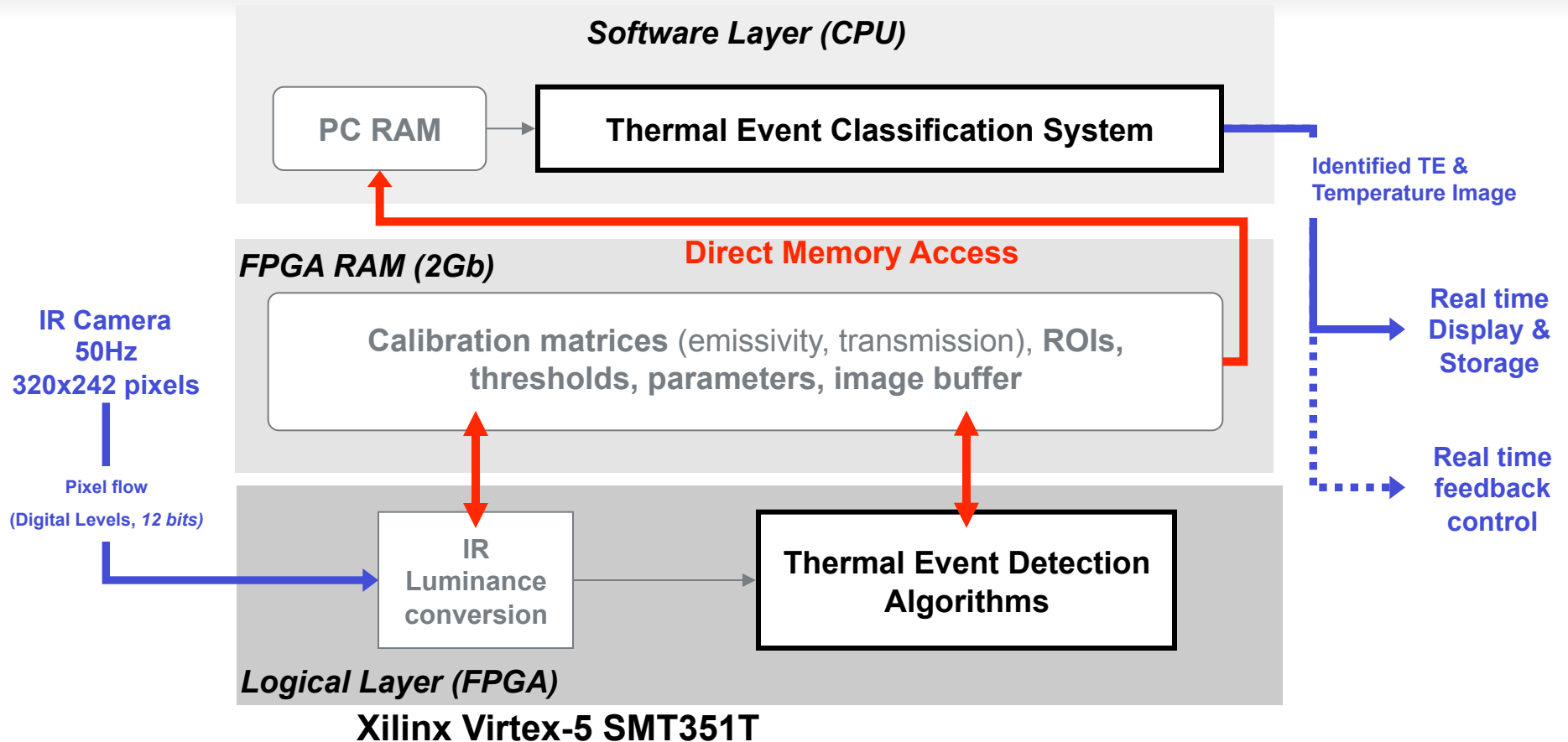
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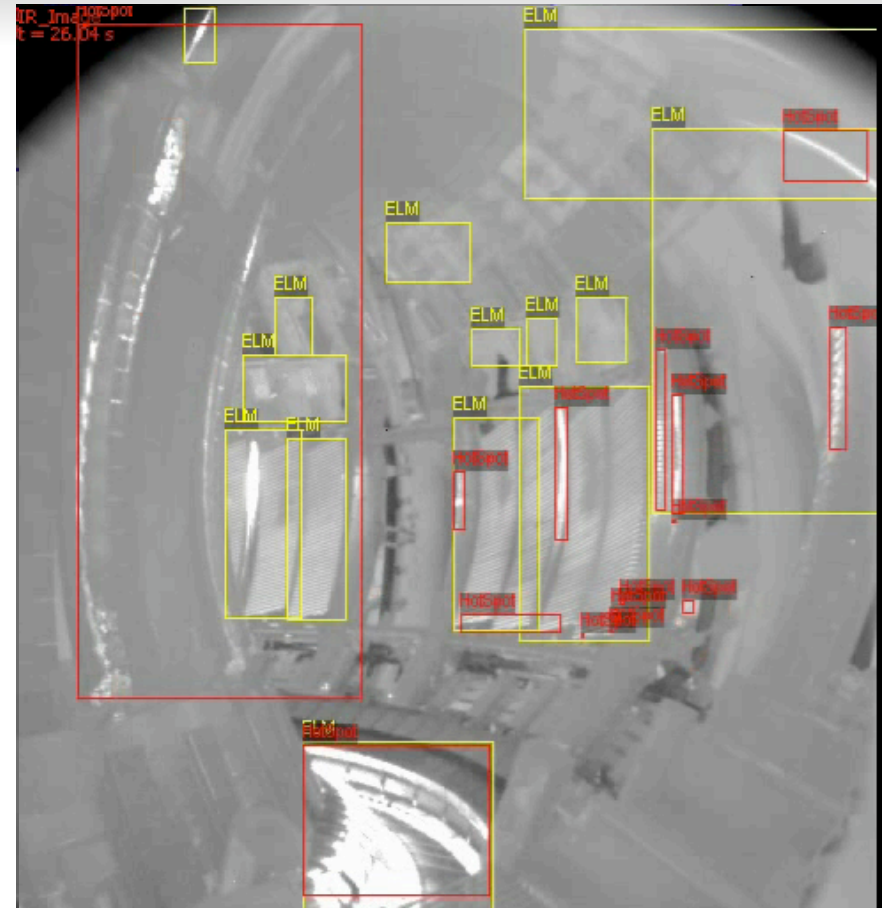
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Real-Time System Workflow



System Reusability (from TS to JET)

- Input = IR wide angle view (KL7)
 - **Persistent Hot spot** detection in **red**
 - **Transient Event** recognition in **yellow**
- (here heat load IR patterns on PFCs during ELMs)



JET wide-angle IR KL7