

Long Term Operation of Concrete Infrastructures

A joint-effort by EDF & EPRI

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J. Wall EPRI
J. Salin EDF R&D*

EPRI

ELECTRIC POWER
RESEARCH INSTITUTE



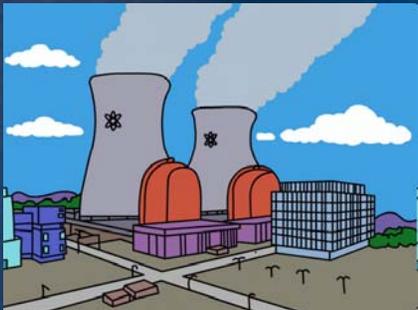
CHANGER L'ENERGIE ENSEMBLE

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OUTLINE

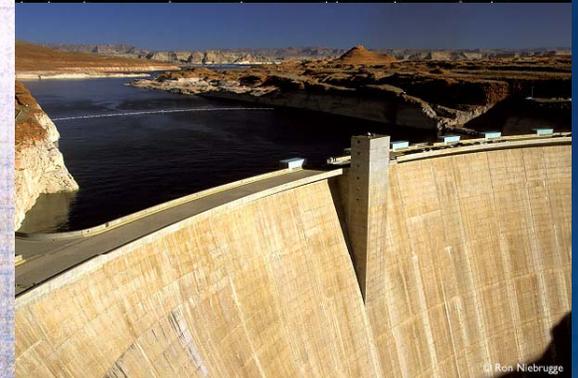
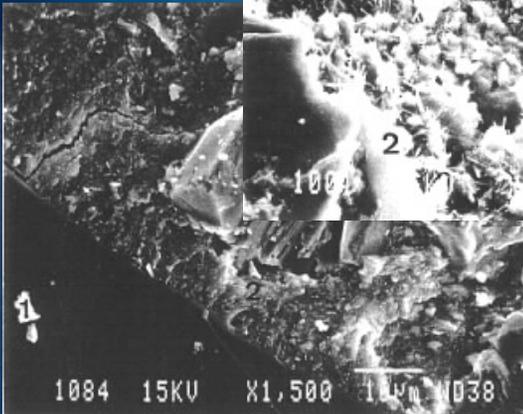
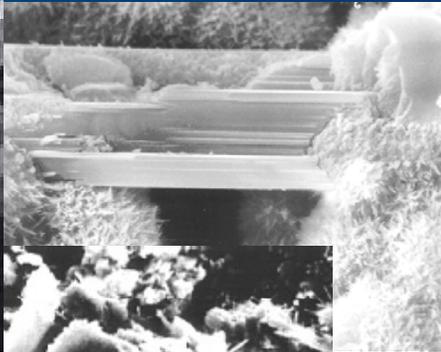
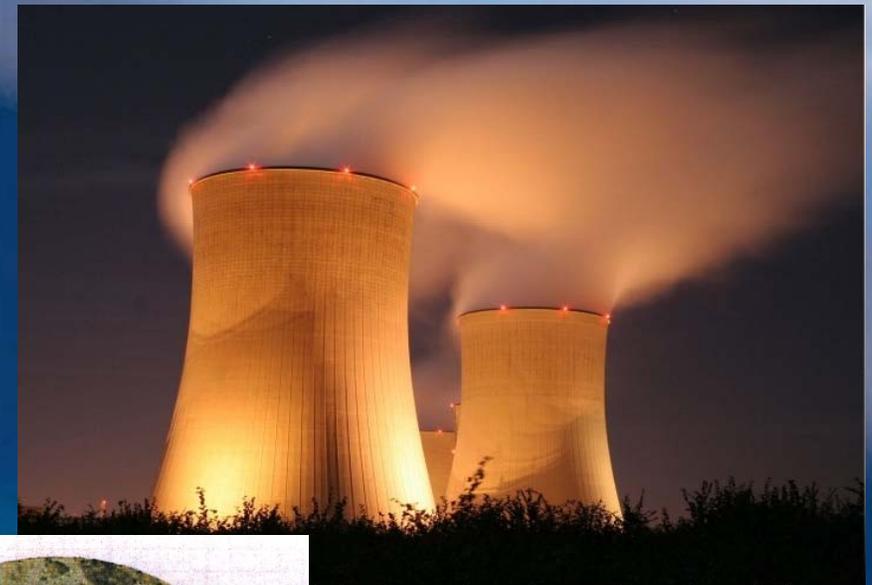
- Does concrete matter?
- Aging Management Issues
- R&D Joint Programs
- Conclusions



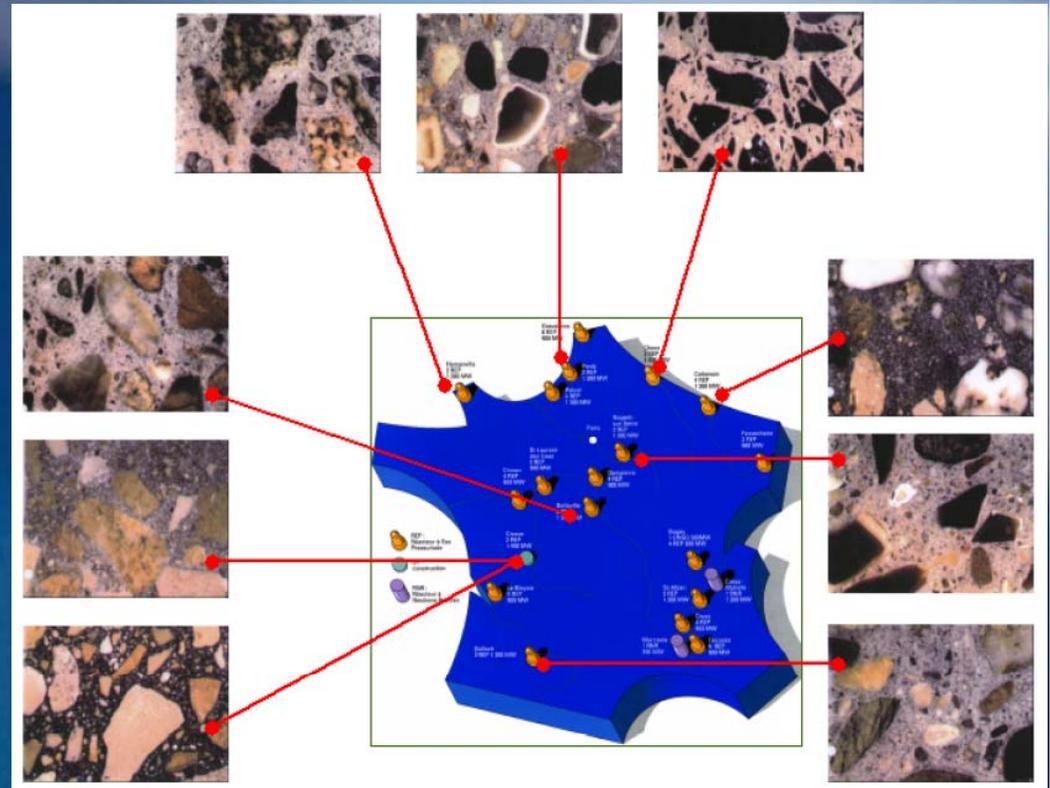
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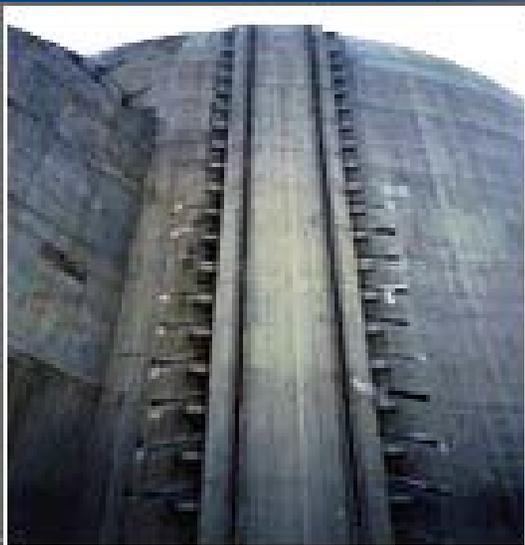
CONCRETE IS A COMPLEX MATERIAL...



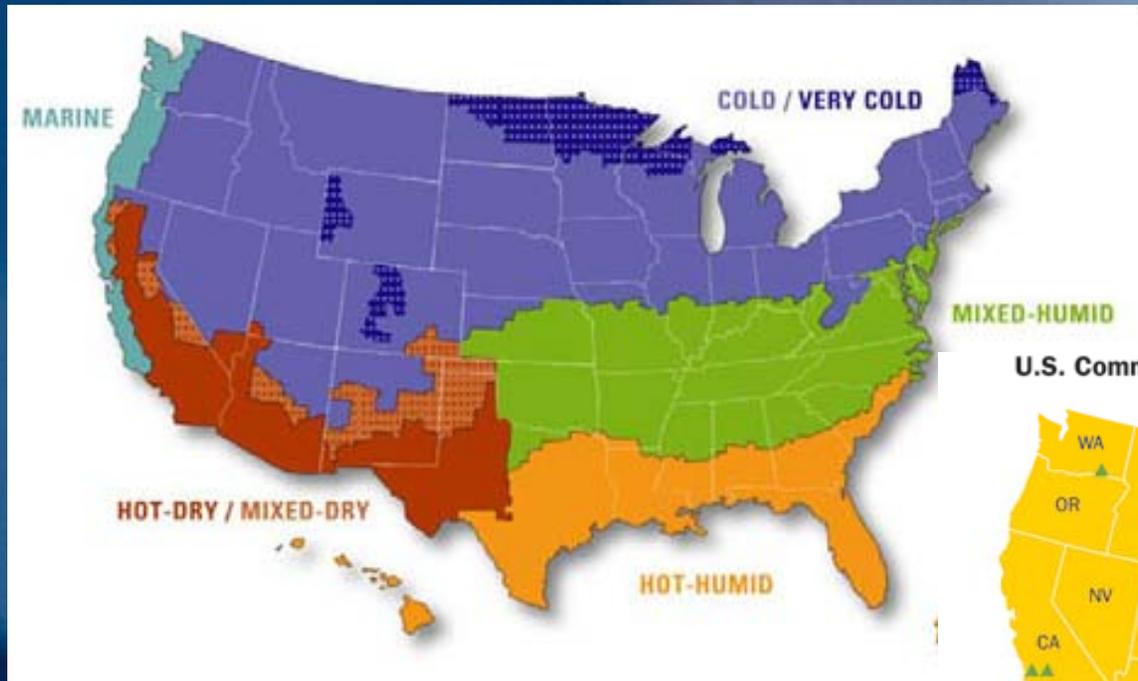
... MADE WITH LOCAL RAW PRODUCTS...



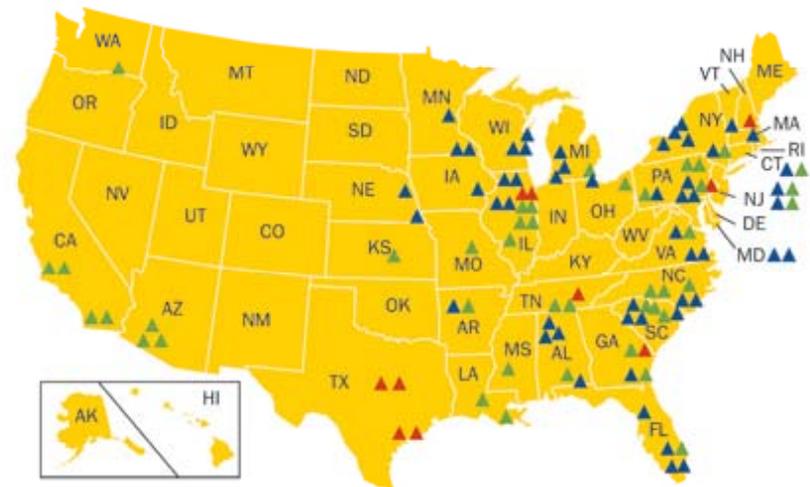
IN INTERACTION WITH STEEL...



AND SUBJECTED TO DIFFERENT ENVIRONMENTS!



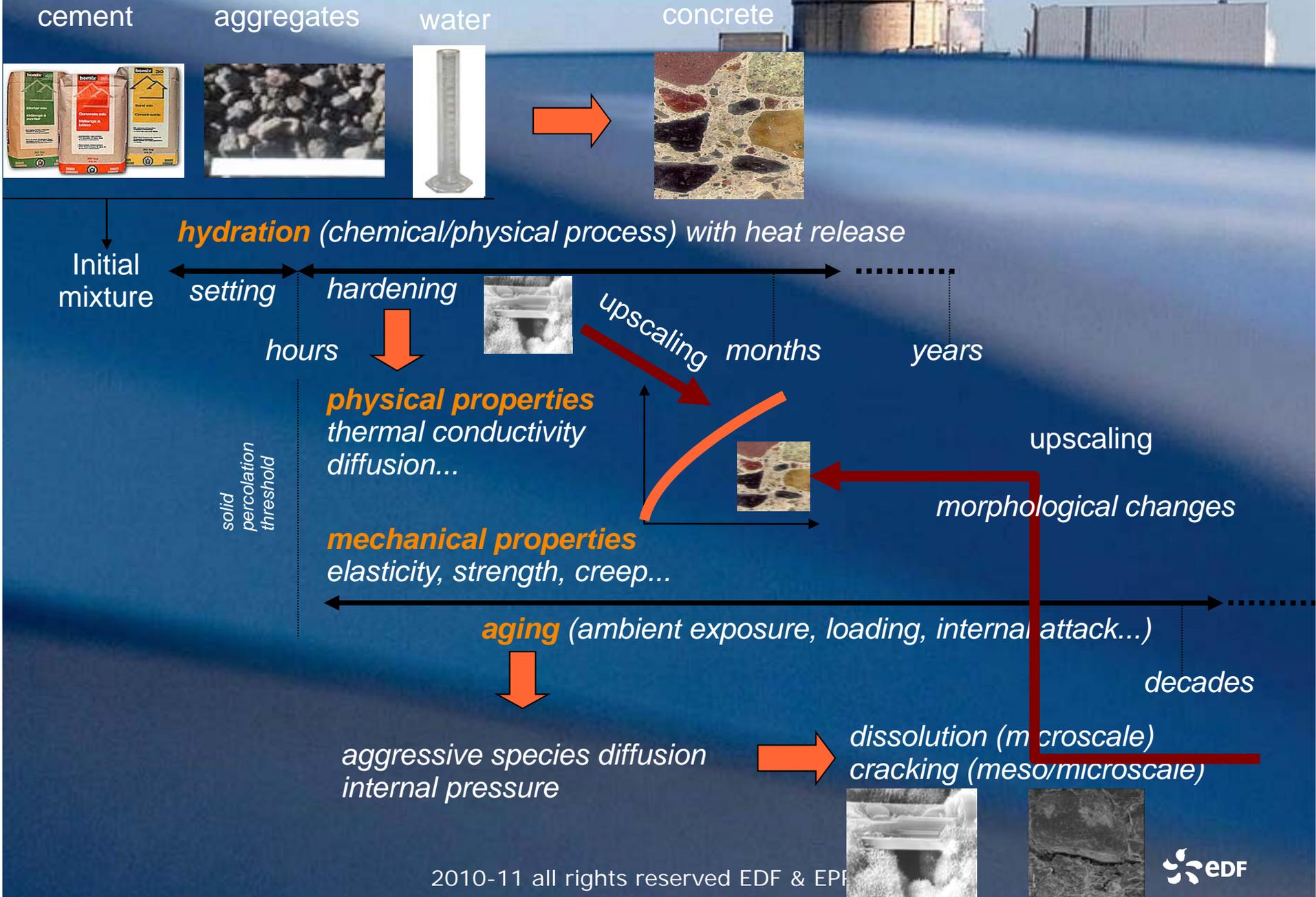
U.S. Commercial Nuclear Power Reactors—Years of Operation



Years of Commercial Operation	Number of Reactors
△ 0-9	0
▲ 10-19	10
▲ 20-29	42
▲ 30-39	52

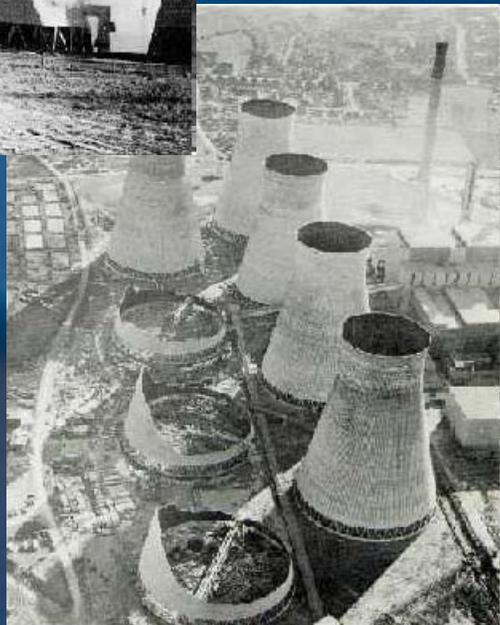
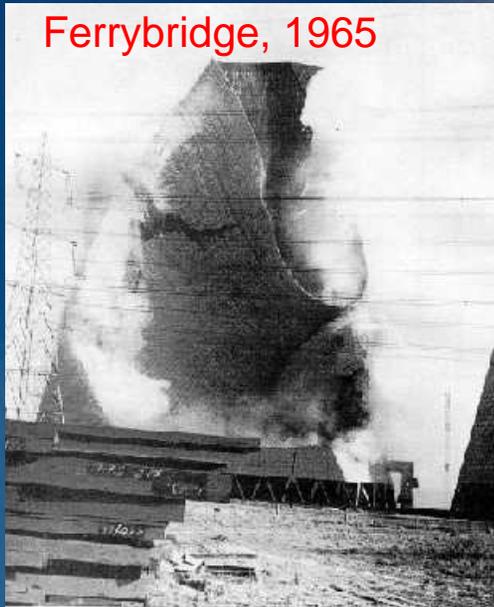
Source: U.S. Nuclear Regulatory Commission

A CONCRETE LIFE: GROWING UP AND GETTING OLD...



Concrete infrastructures may not last forever!

Ferrybridge, 1965

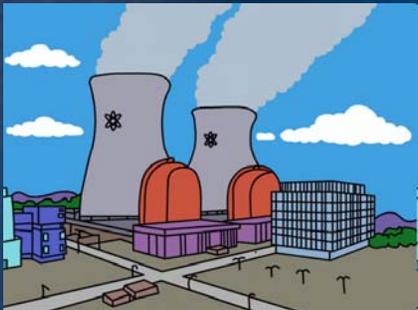


Minneapolis, 2007



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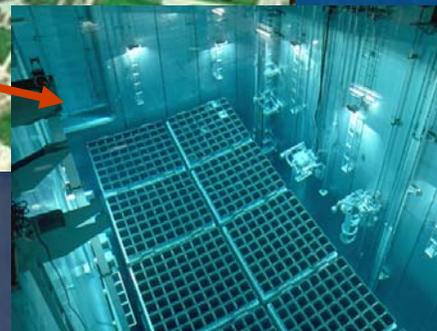
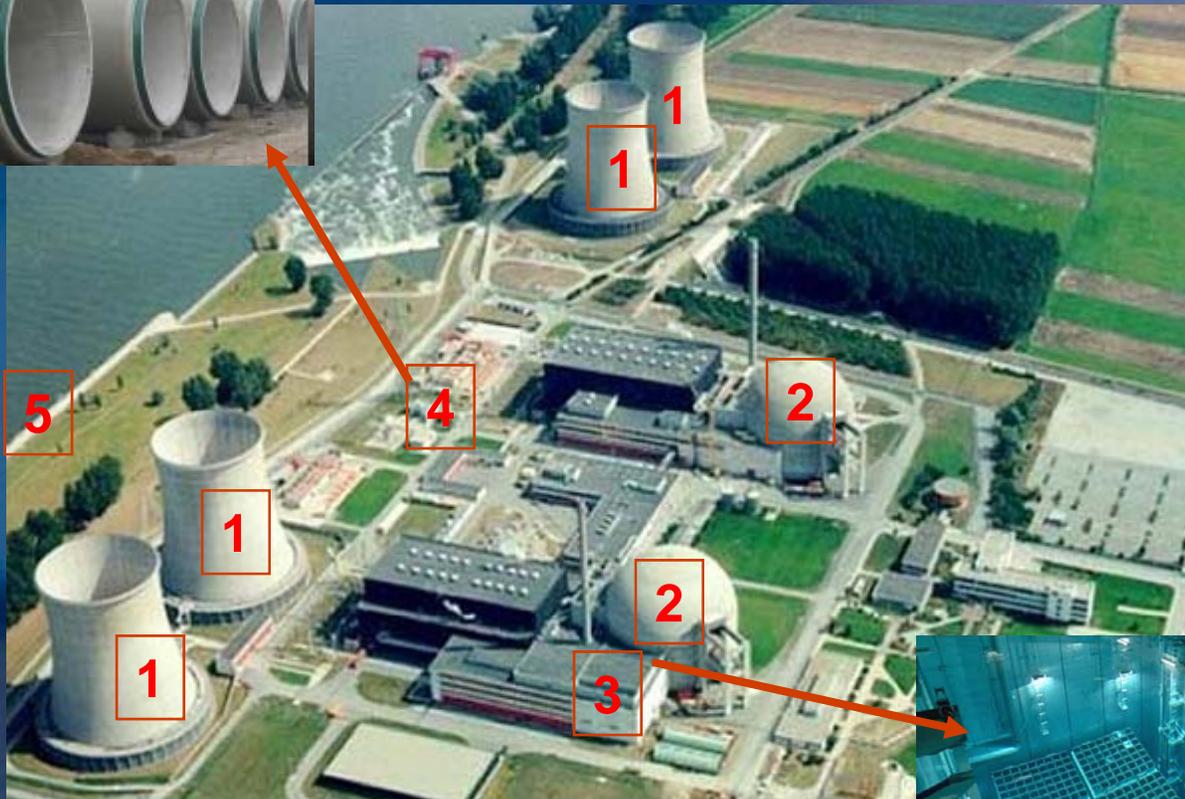
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Civil Structures of Interest

2 Unit Nuclear Plant (PWRs)

- 1 – Cooling Towers**
- 2 – Containments**
- 3 – Spent Fuel Pools/Transfer Canal**
- 4 - Buried (Prestressed) Concrete Pipe**
- 5 – Intake Structure**



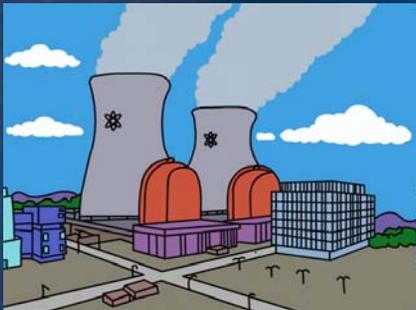
Degradation Causes of Interest for LTO

A NON RANKED LIST

- Chronic radiation exposure (biological shielding and RPV supports)
- Chronic exposure to high temperature (containment near steam generators and steam penetrations)
- Chloride attack and re-bar corrosion (generic – throughout plant)
- Boric acid leaching of concrete and attack of rebar (spent fuel pools, transfer canals)
- Corrosive soil attack (foundations, buried pipes, raft)
- Effects of concrete damage on post-tensioning system integrity (containment)
- Creep (containment)
- Internal swelling (ASR, DEF... massive structures)
-

OUTLINE

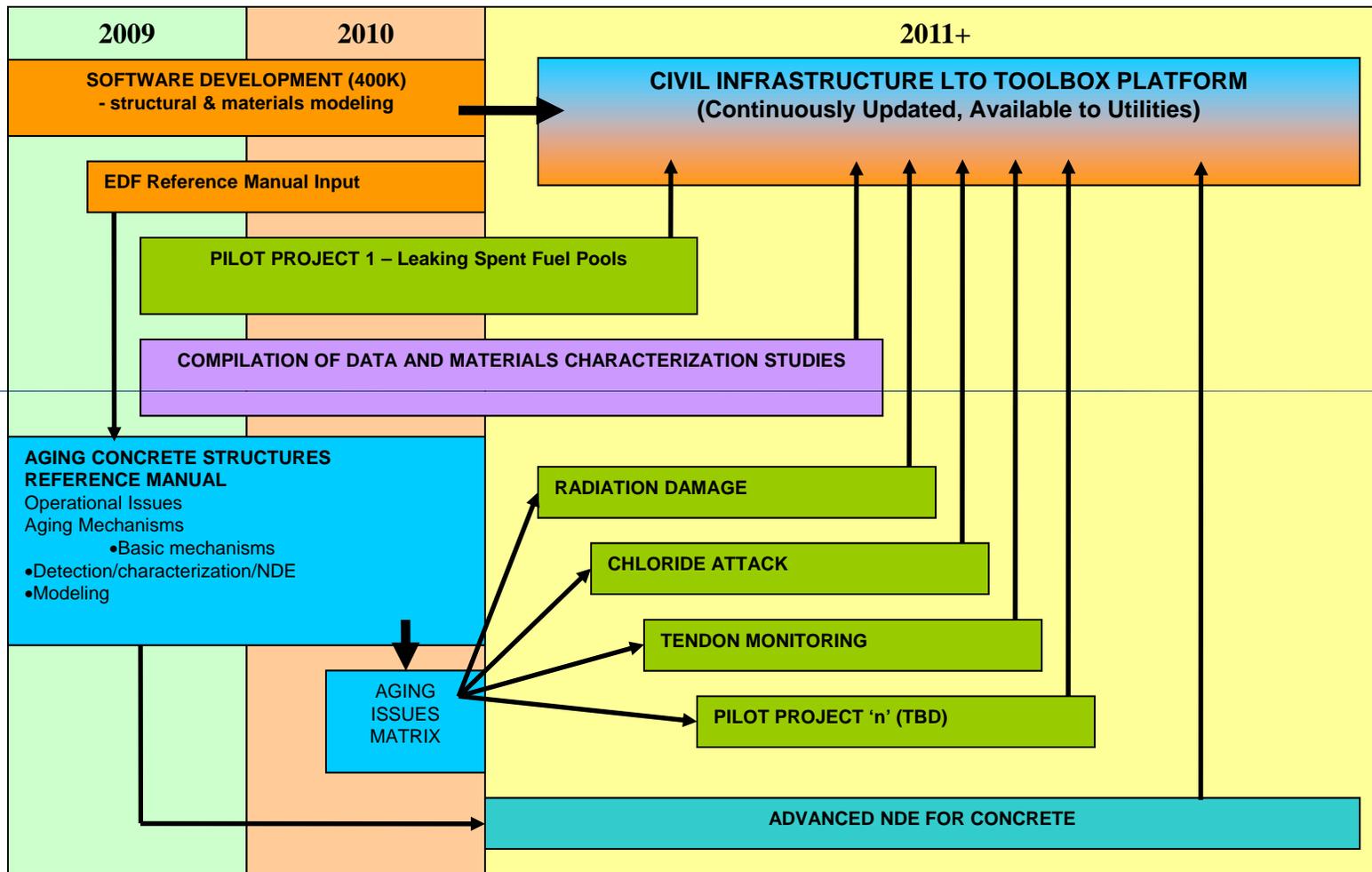
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EPRI & EDF Strategy



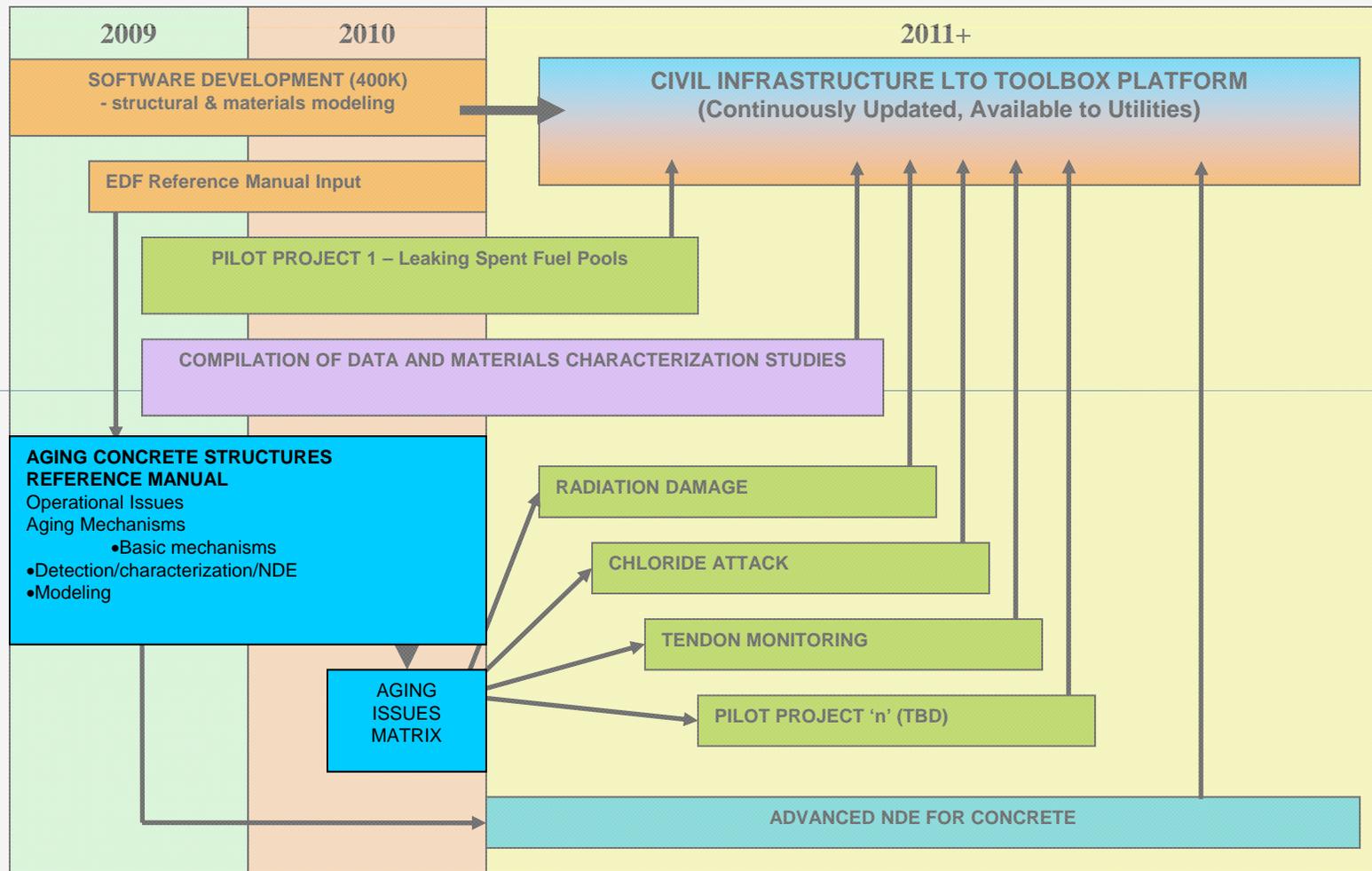
 EPRI LTO/TF Funded

 DOE Funded
(Project approved but funding not committed yet)

 MAI Funded

 Funding to be designated
(EPRI/DOE/MAI/Utilities)

EPRI & EDF Strategy: Aging Issue Matrix



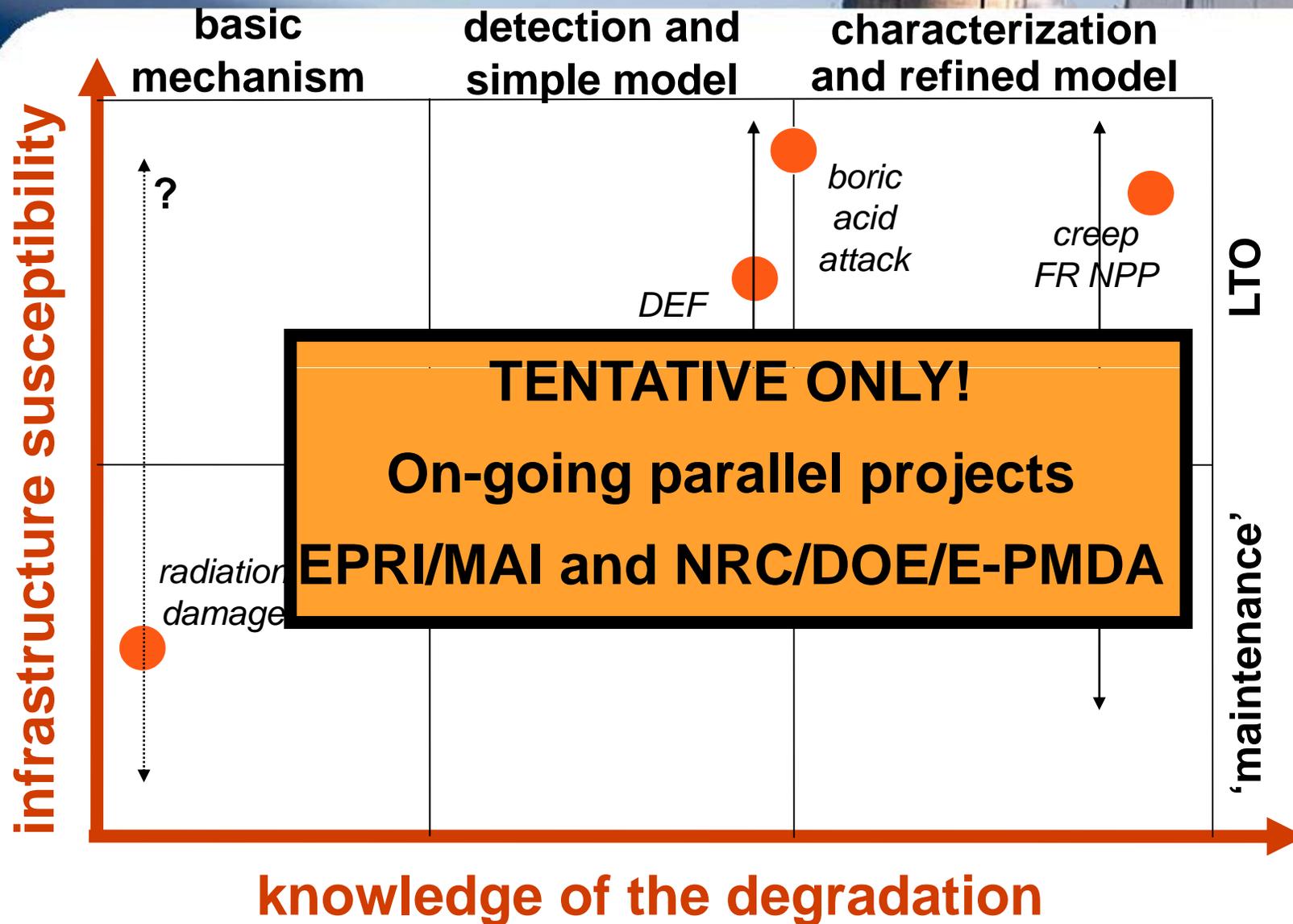
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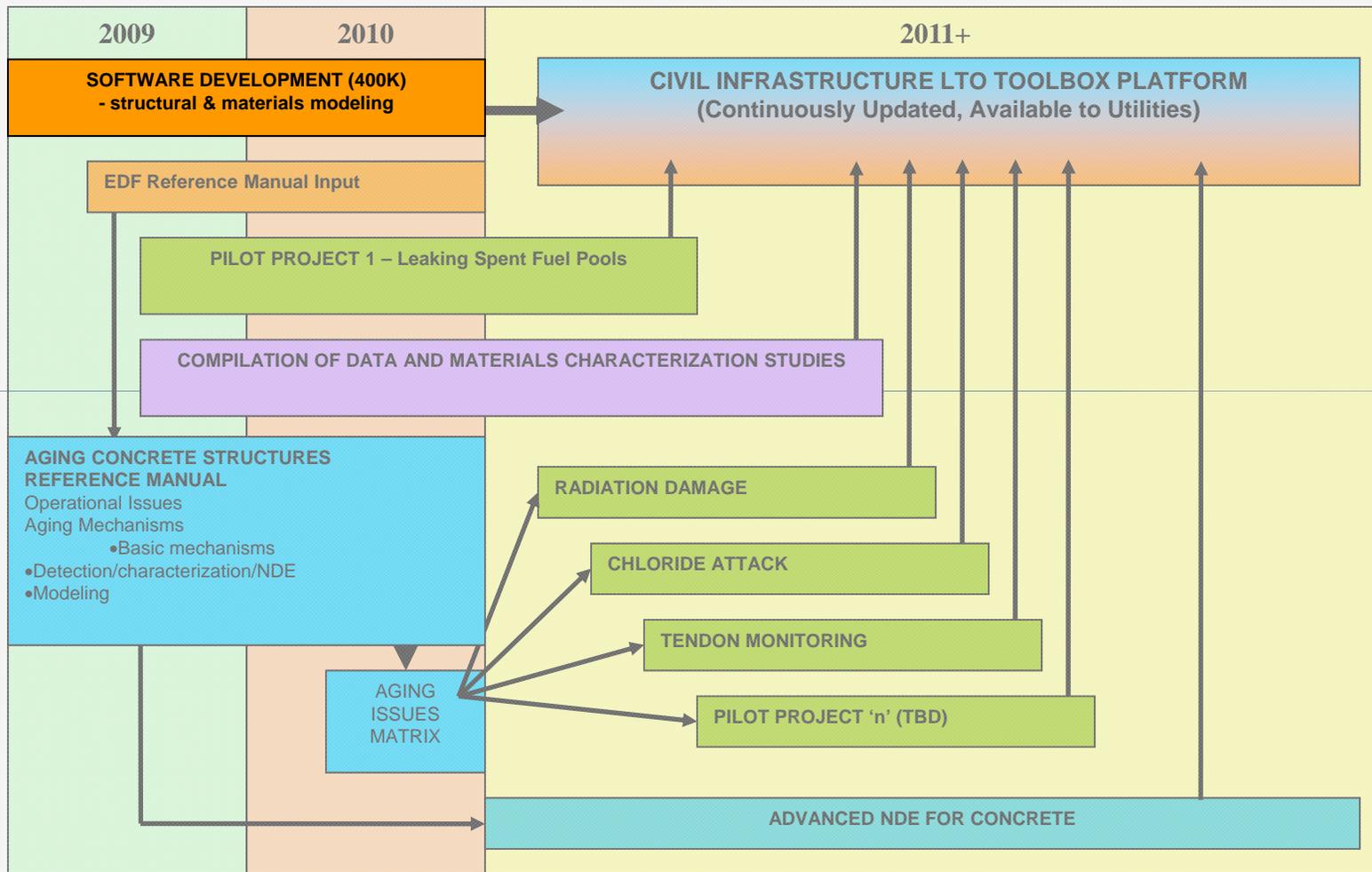
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Ranking Priorities and Gaps Identification



EPRI & EDF Strategy: Software development



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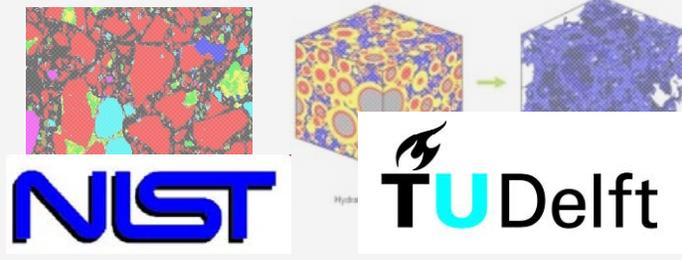
3D modeling

0D modeling

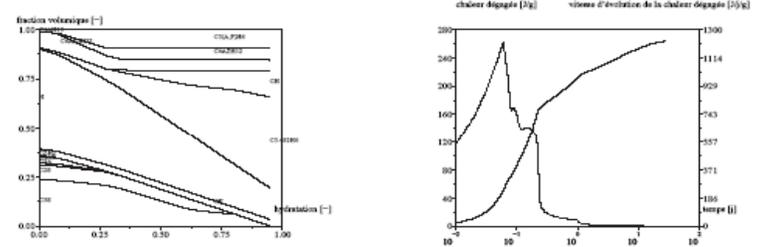
microscale *cement paste*



build 3D microstructure from initial cement particles distribution and virtual hydration



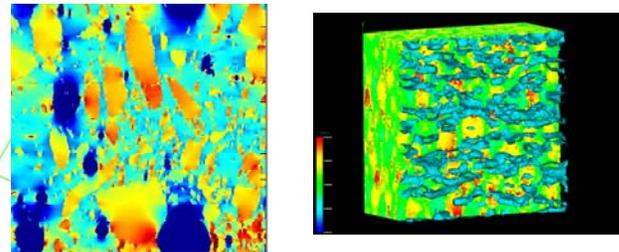
build 0D microstructure (volume fraction) from initial cement composition and virtual hydration



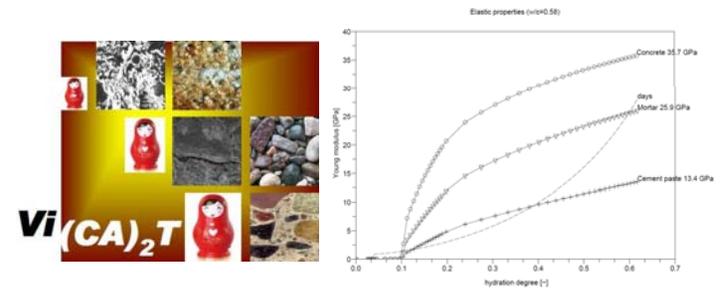
mesoscale *mortar & concrete*



build 3D microstructure from aggregate distribution and compute effective properties



compute effective properties using homogenization schemes

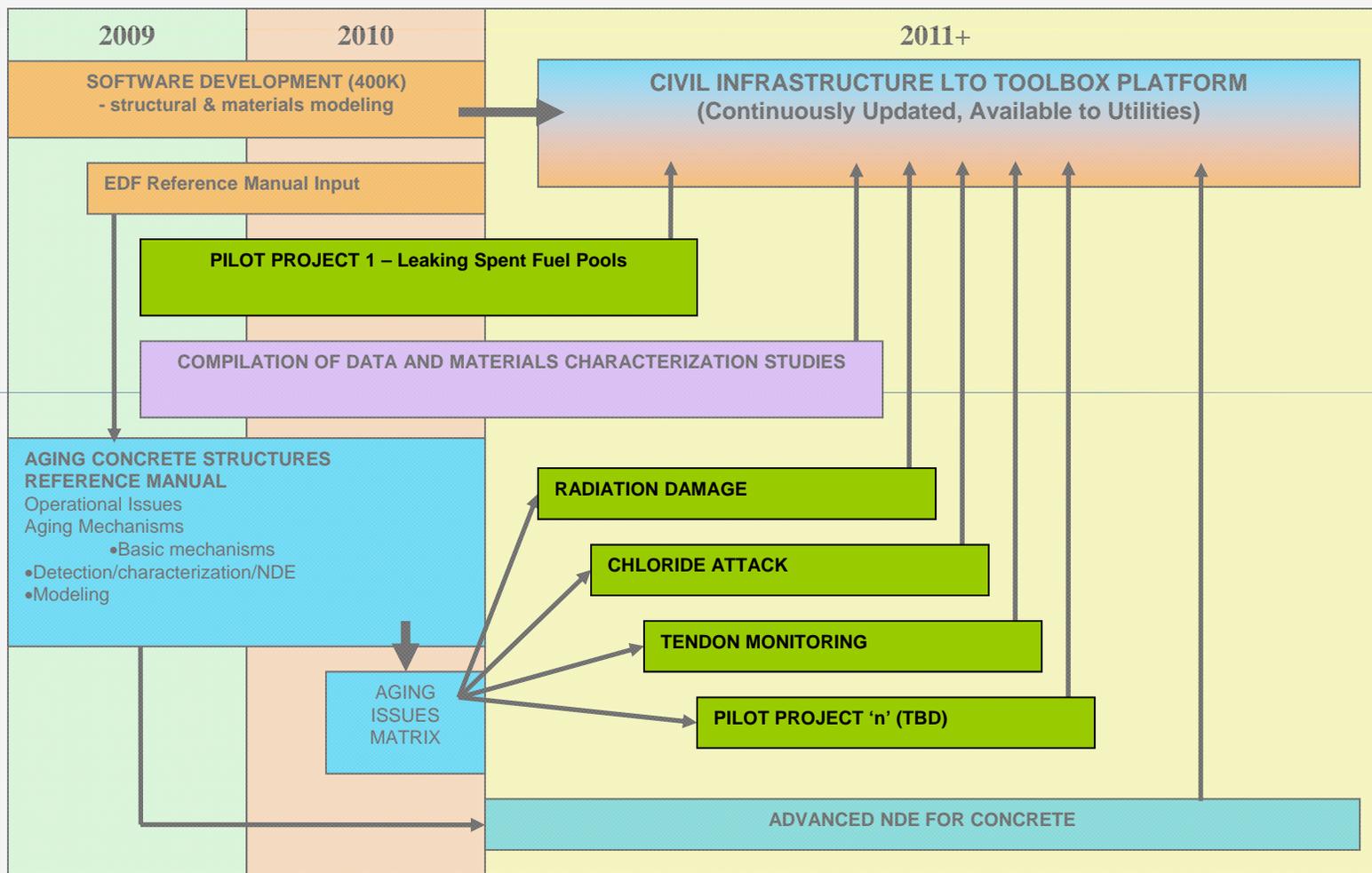


R&D purpose



practical purpose

EPRI & EDF Strategy: Pilot Projects



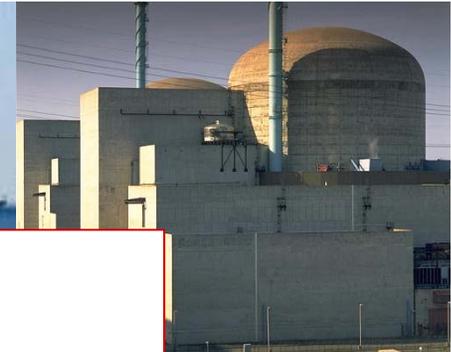
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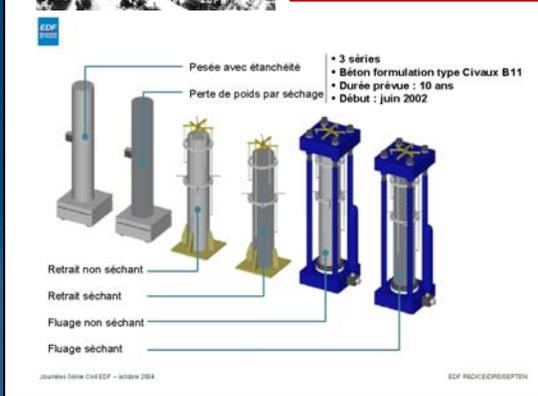
Example of a recent success at EDF

QUANTITATIVE ESTIMATION OF NPP CONTAINEMENT RESIDUAL LIFE WITH REGARDS TO DELAYED STRAINS



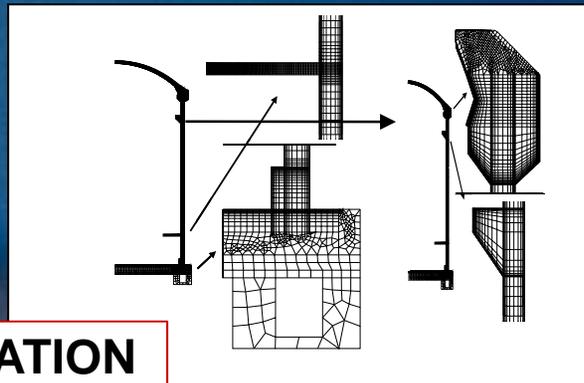
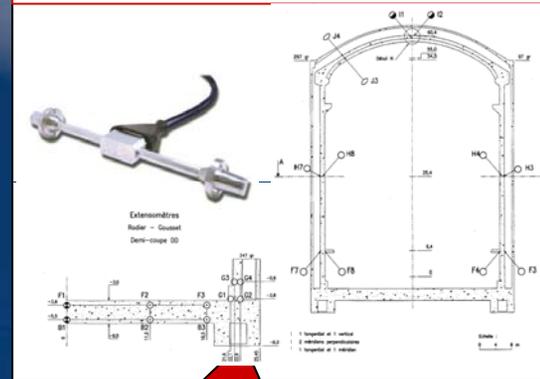
MATERIALS SCIENCE

- basic mechanisms
- lab tests



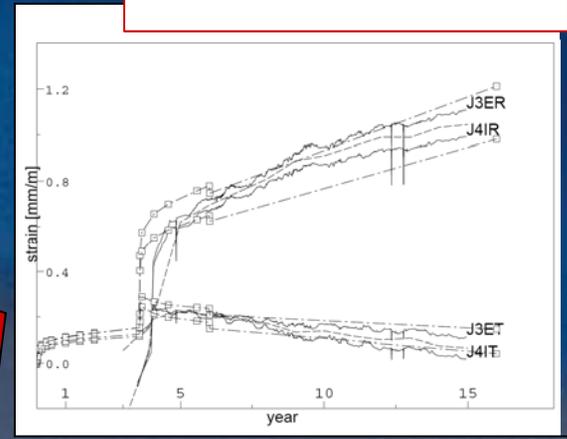
MONITORING

- feed-back
- bayesian approach



COMPUTATION TH-M FEA

FEM/MONITORING PREDICTION



Example of an on-going Pilot Project at EPRI

Chloride attack and corrosion of prestressed reinforced concrete

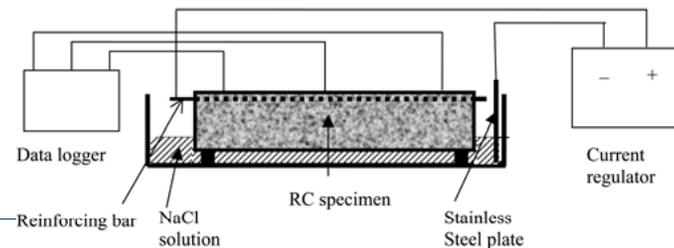


step 0

lab test
(crack vs. corrosion patterns, NDE...)

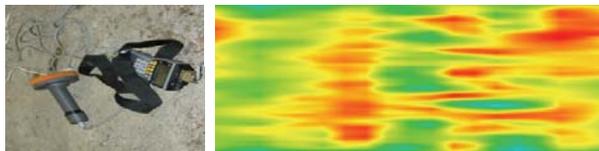
step 1

degradation of refurbished materials
(crack vs. corrosion patterns, NDE...)



step 2

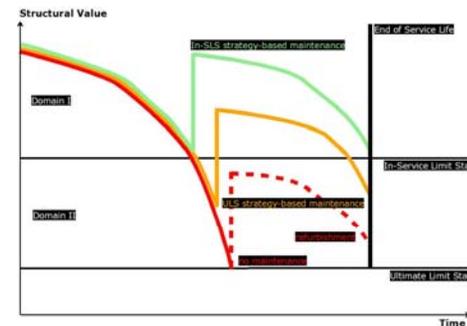
NDE benchmark during outage



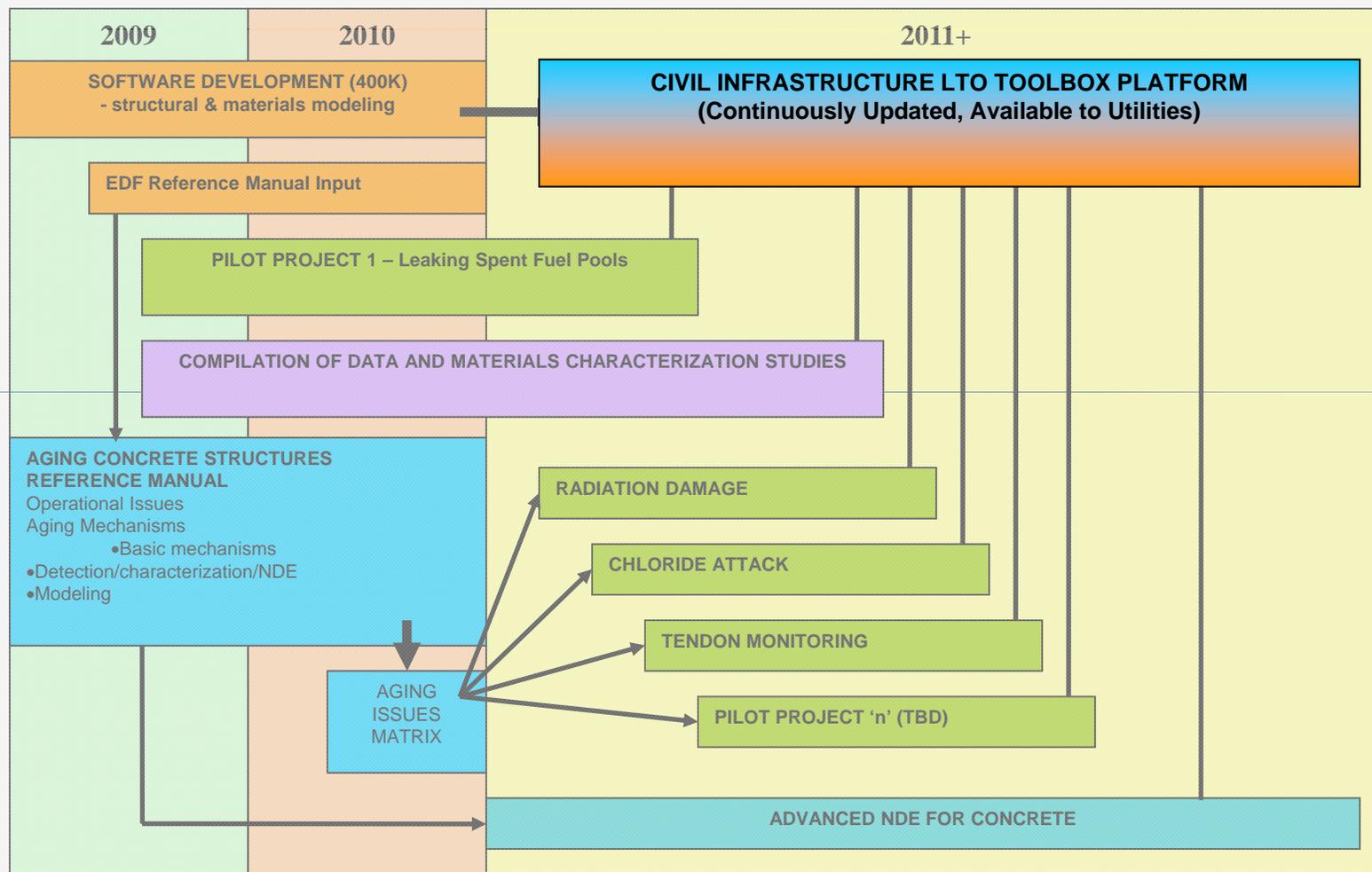
[Mul irt, 2011] experiment

step 3

probability- based structural assessment



EPRI & EDF Strategy: LTO Toolbox Platform



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(Project approved but funding not committed yet)



MAI Funded

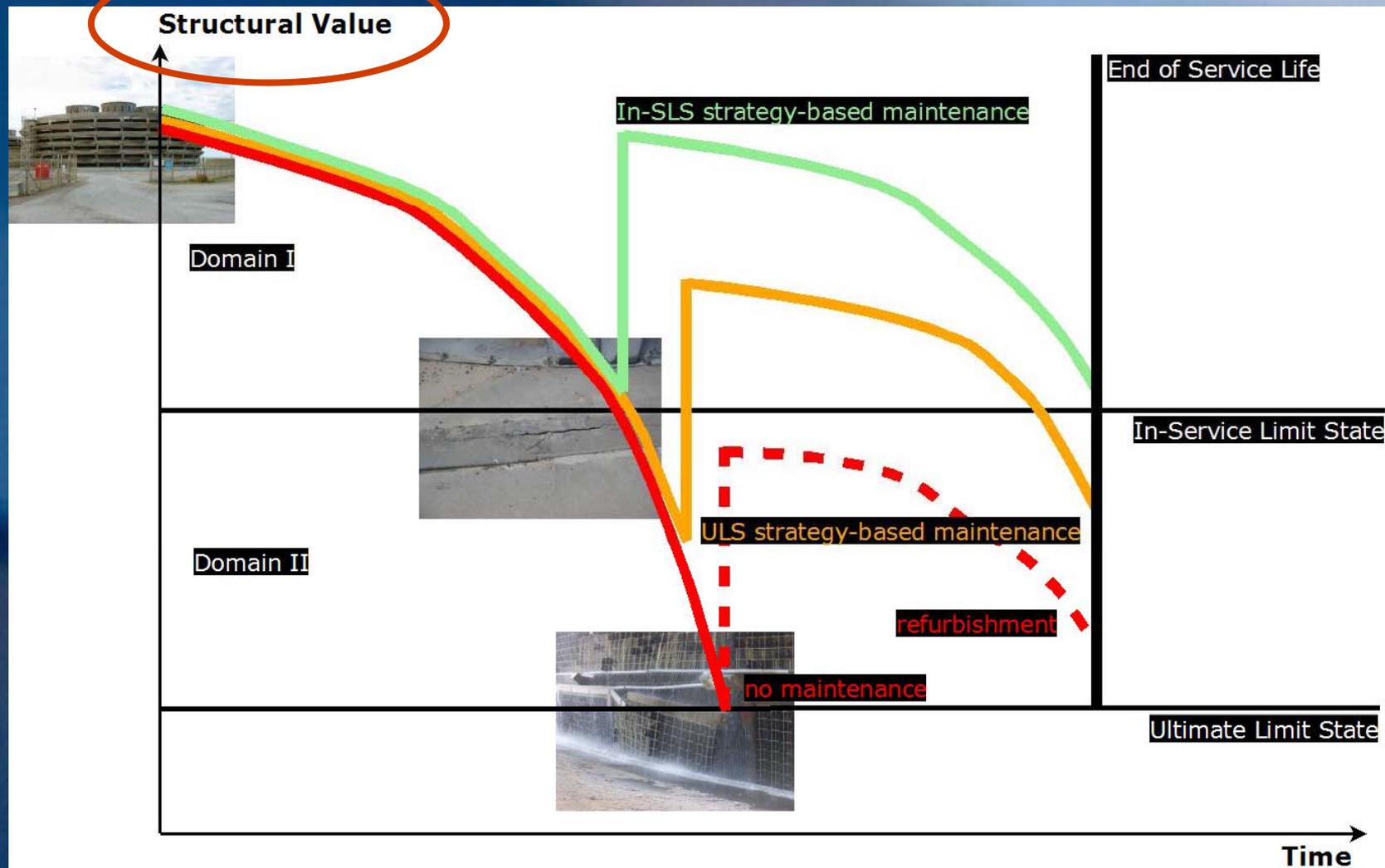


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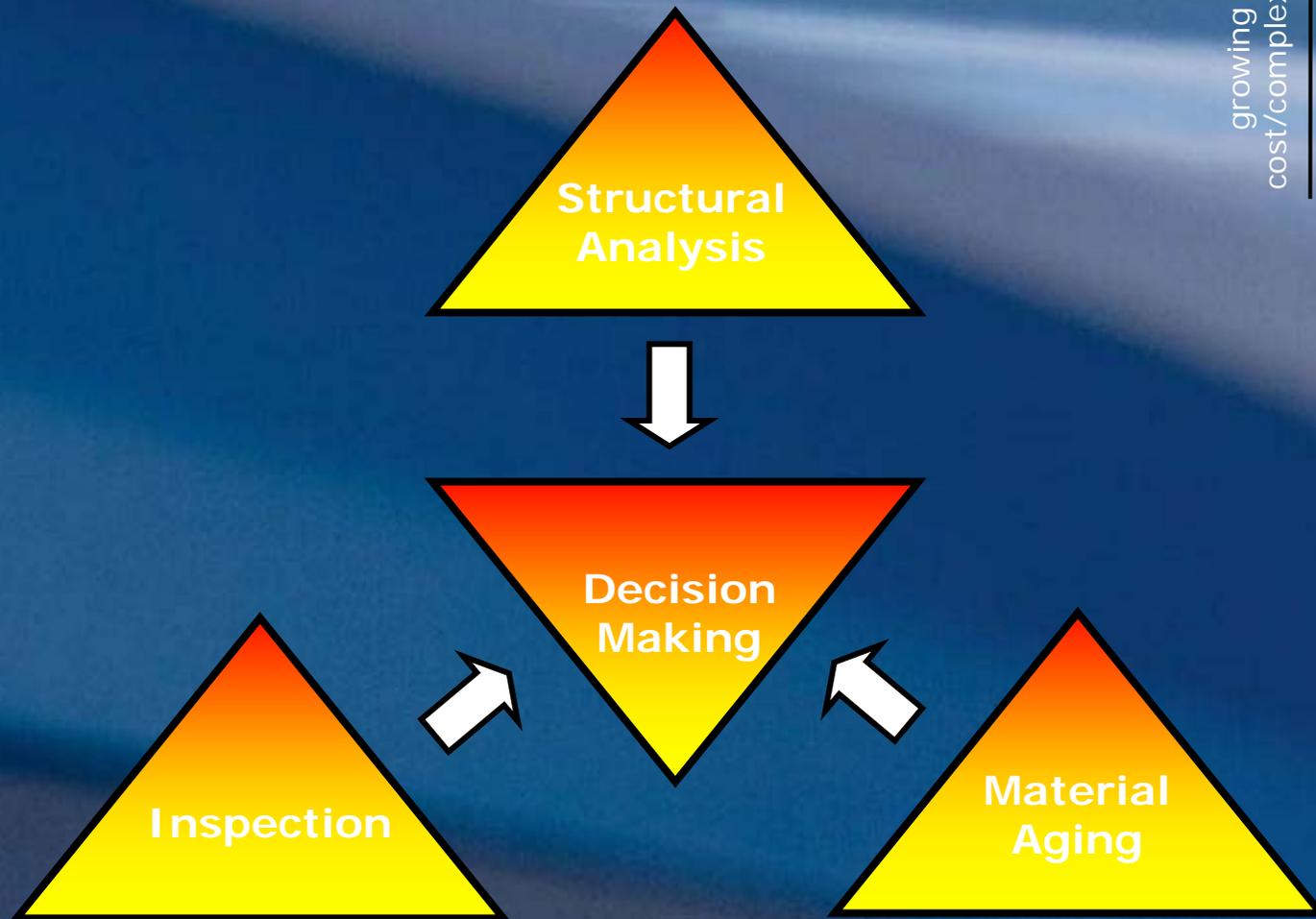
Aging Management

#1 safety

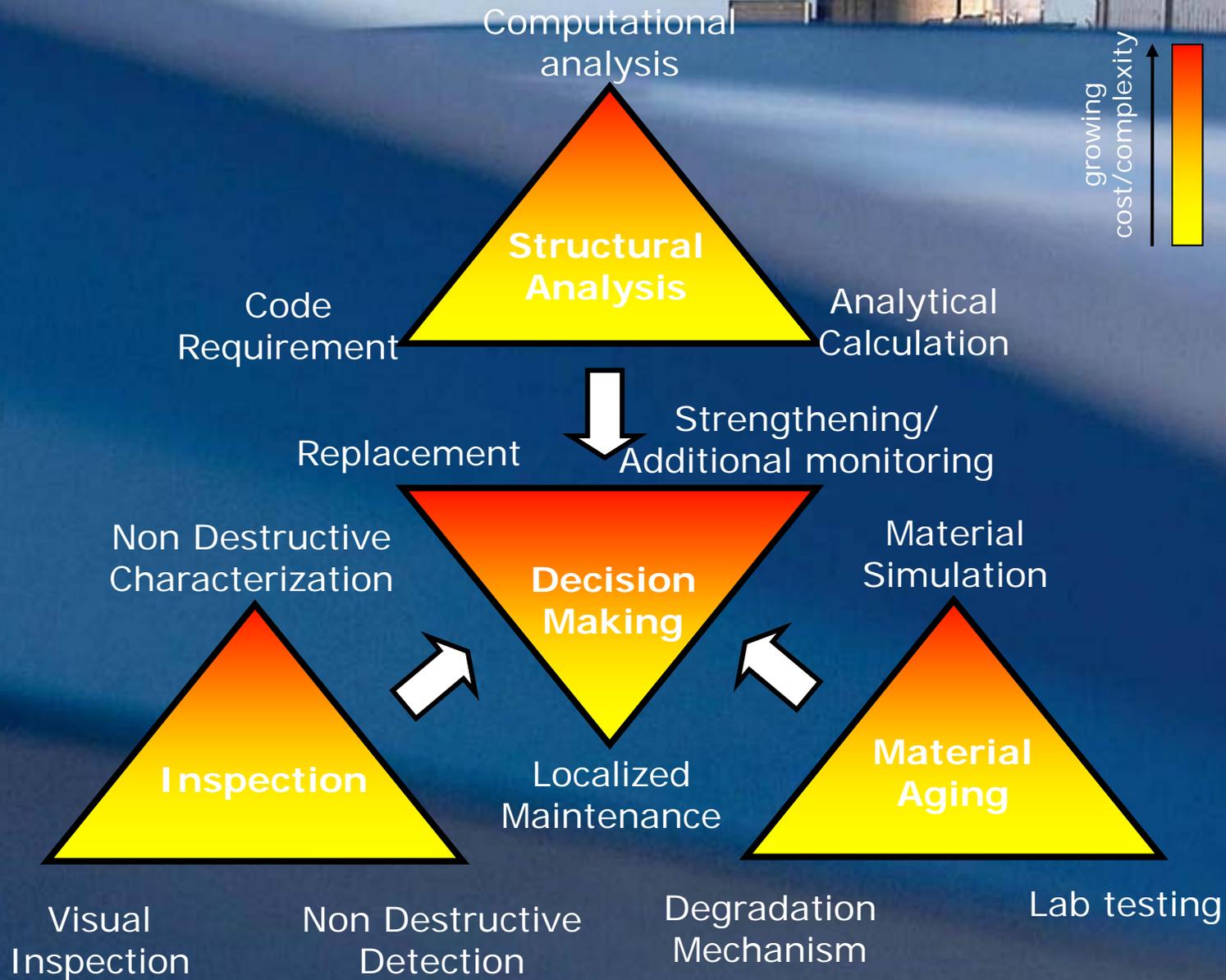
#2 economically viable operation



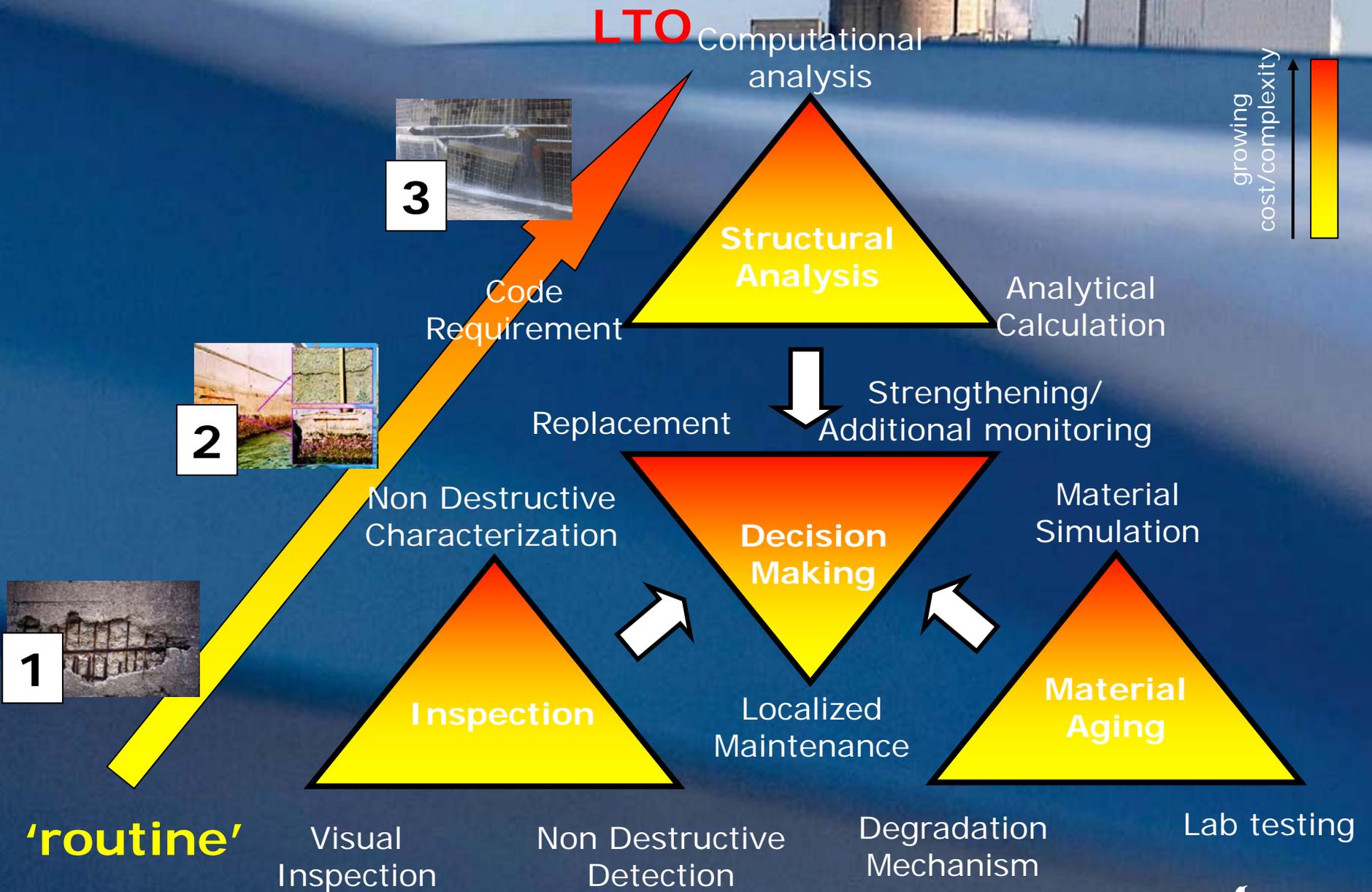
THE THREE PILLARS OF DECISION...



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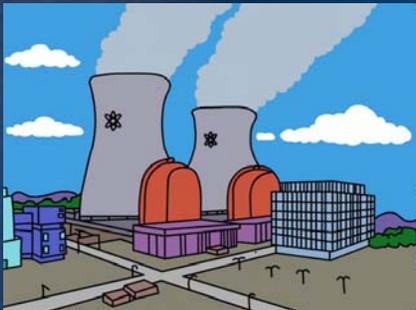


WHAT ABOUT LTO?



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Some important reminders

1. Recent major events regarding concrete:

- tritium contamination of site groundwater
- large outer containment delamination

2. Costs associated to Civil Infrastructures can be huge

- CR3 shutdown for nearly 1 ½ yr.
- FHWA estimation \$8.3B/yr (bridges)

3. There are generic degradation modes but each concrete/environment is specific

4. Effective aging management programs require basic materials knowledge, inspection techniques and structural analyses

5. Not all issues find their answers in 'expertise-based' qualitative analysis