UNIVERSITY OF CAMBRIDGE
Department of Engineering

As-Built Modelling and Assessment

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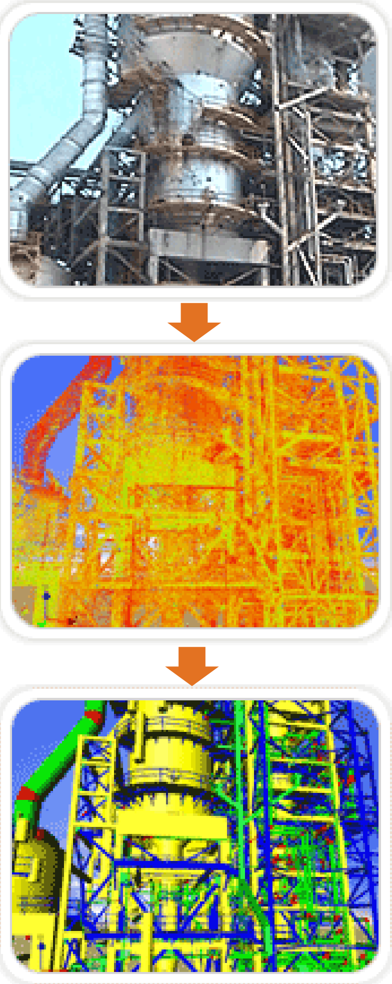
Civil, Structural and Environmental Engineering

Restoring and Improving Urban Infrastructure

- Engineering Grand Challenge (NAE, 2008)
- Lack of viable methods to map/label existing infrastructure
  - E.g. 2/3 of modelling effort spent manually converting raw data to geometric model (Jaselskis et al., 2008)
    - Result: As-built models not produced for most new and retrofit construction
    - Leads to rework and design changes (NAE, 2008)
      - Cost up to 10% of installed costs (Reddington, 2005)
      - Lead to reduced sustainability (significant material waste)



How do you build better infrastructure?

Novel construction materials may help address some of these challenges. But dramatic progress may be possible only by developing entirely new construction methods. Most of the basic methods of manual construction have been around for centuries — even millennia. Advances in computer science and robotics should make more automation possible in construction, for instance, greatly speeding up construction times and lowering costs. Electricity networks linking large central-station and decentralized power sources will also benefit from greater embedded computation.

Outline

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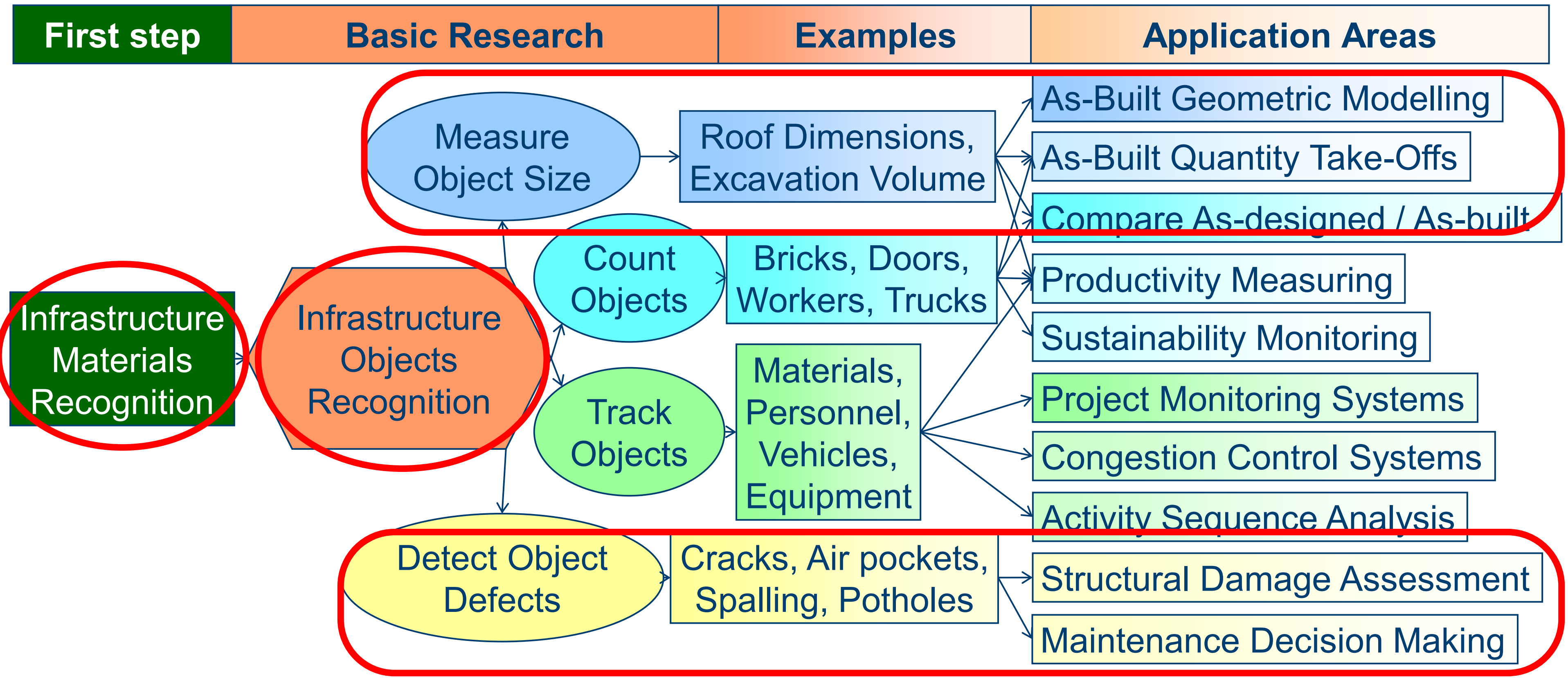
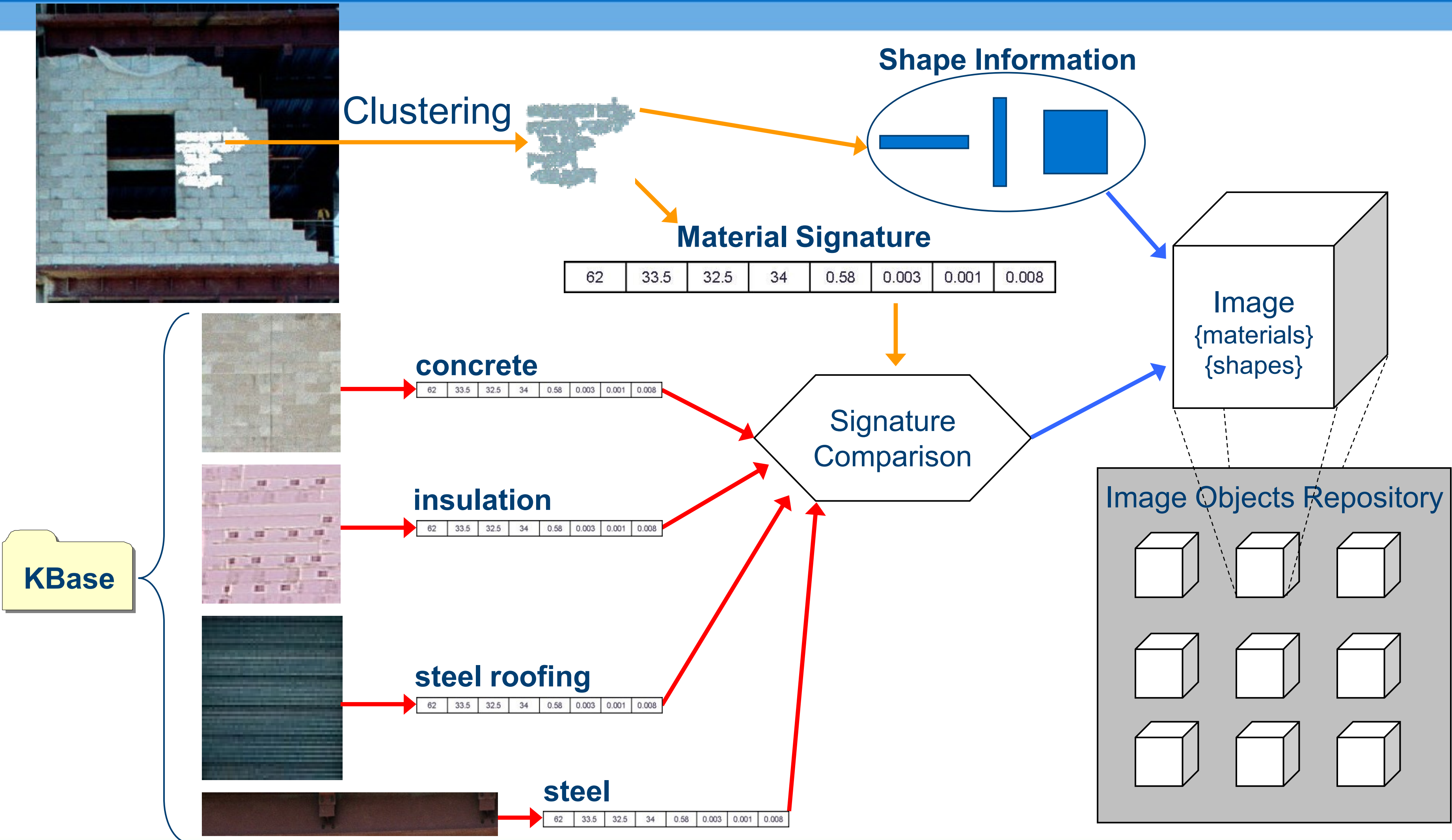
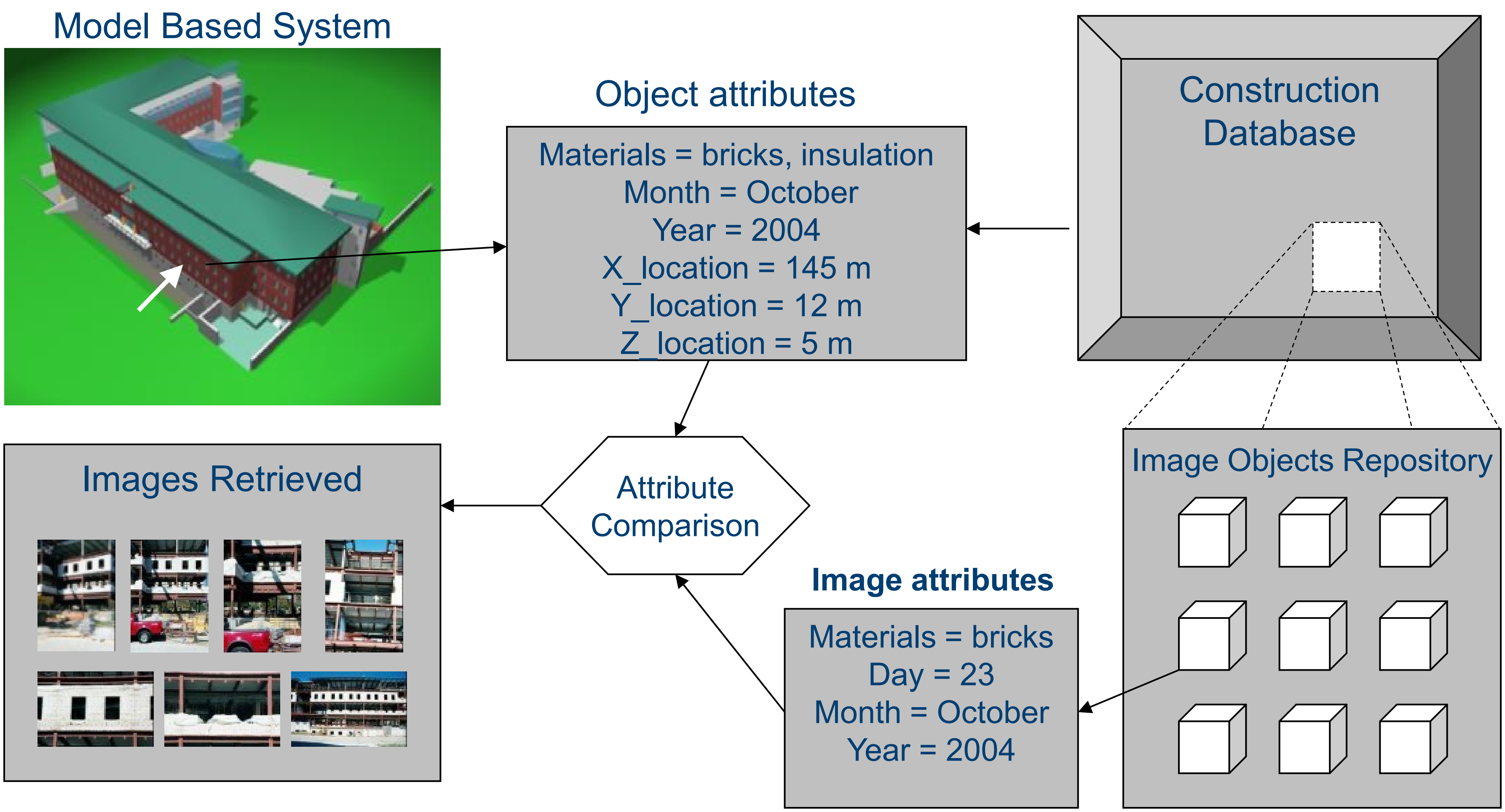


Material Based Image Classification



Multi-modal Image Retrieval



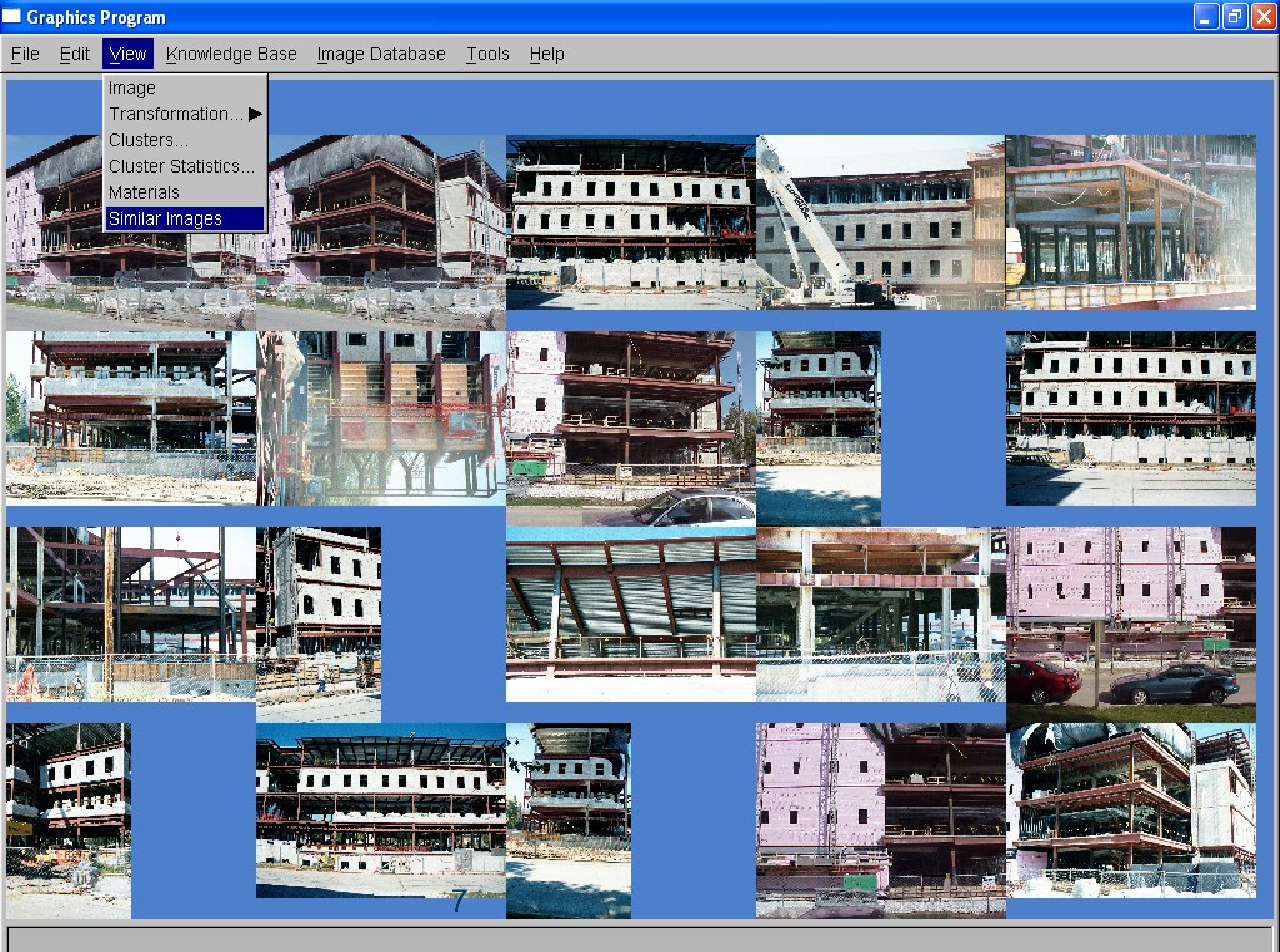

Graphics Program
File
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Image Database
Tools
Help
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Transformation...
Clusters...
Cluster Statistics...
Materials
Similar Images

Infrastructure Objects Recognition

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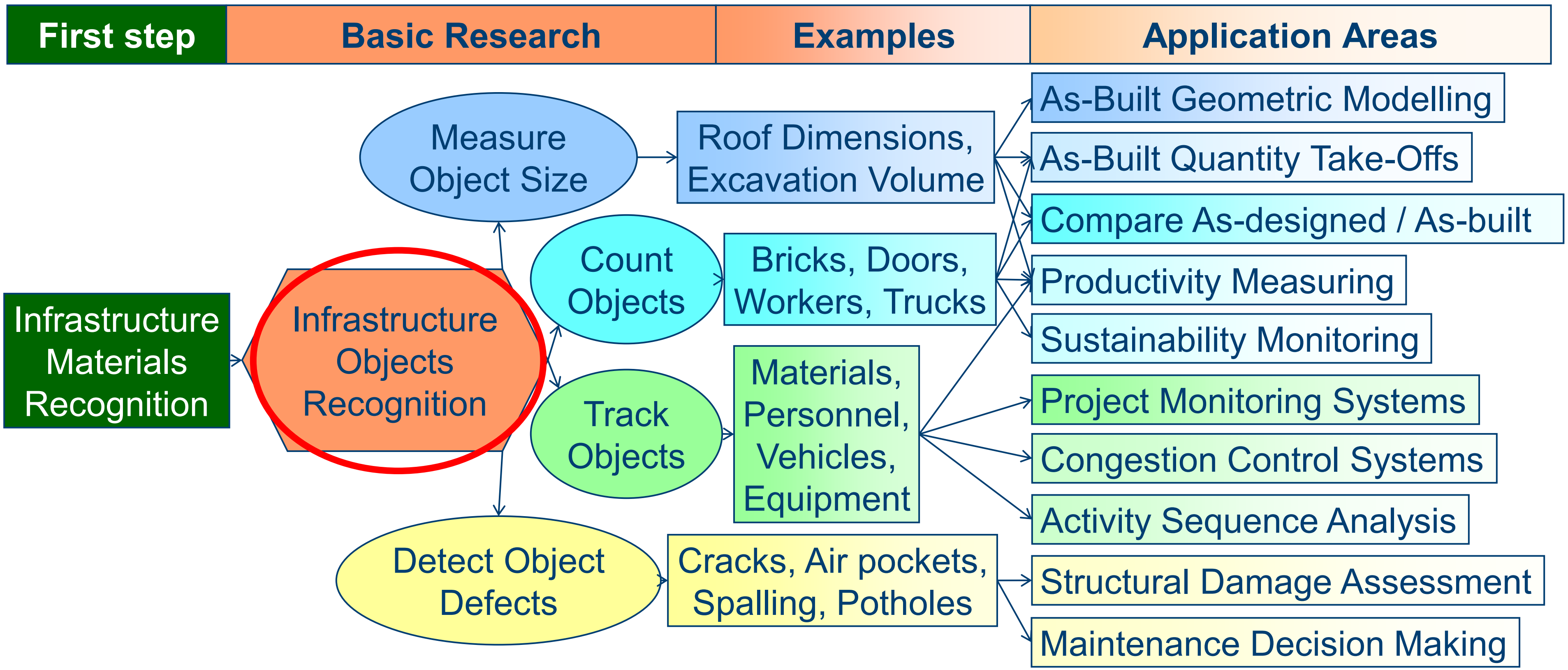
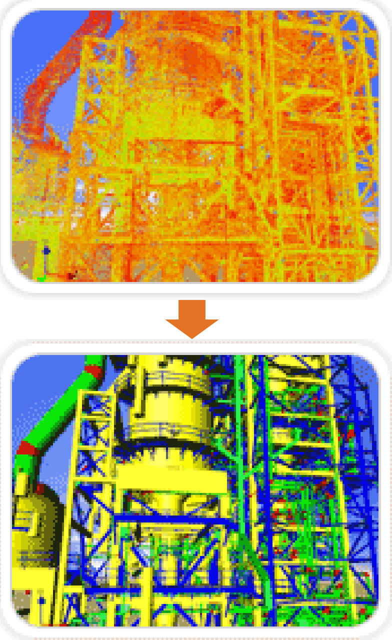
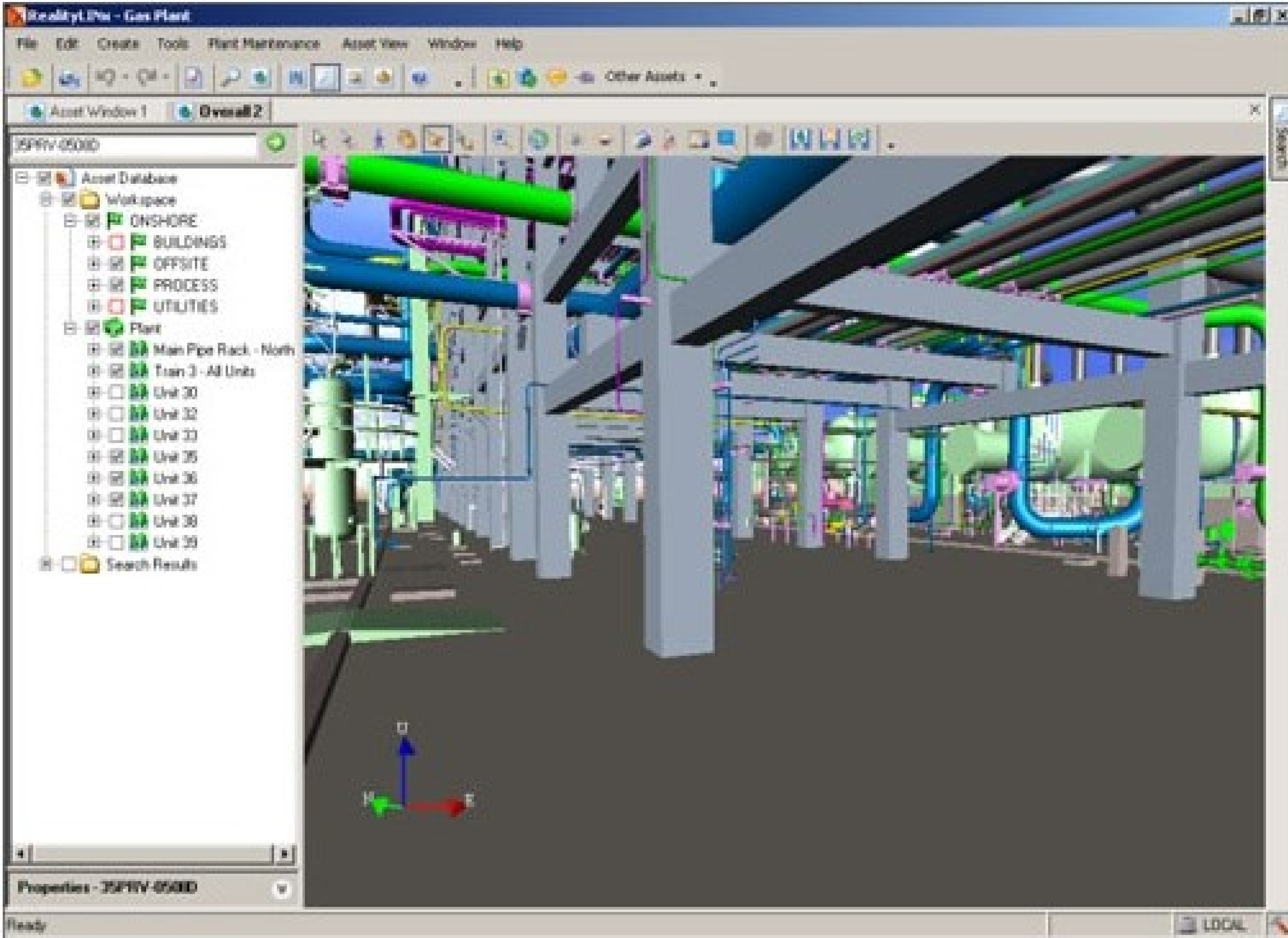


From spatial/visual data to a 3D Model

- Point clouds / images have no knowledge of the elements they contain
  - What they are made of
  - Which points/pixels belong to which entities
- Cannot provide any other as-built information besides spatial measurements
  - i.e. material info, health info, etc.
- Purpose of as-built modelling = Convert spatial/visual data to information rich, object-oriented model

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Other Assets
Asset Window 1
Overall 2
Asset Database
Workspace
ONSHORE
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Infrastructure Objects Recognition

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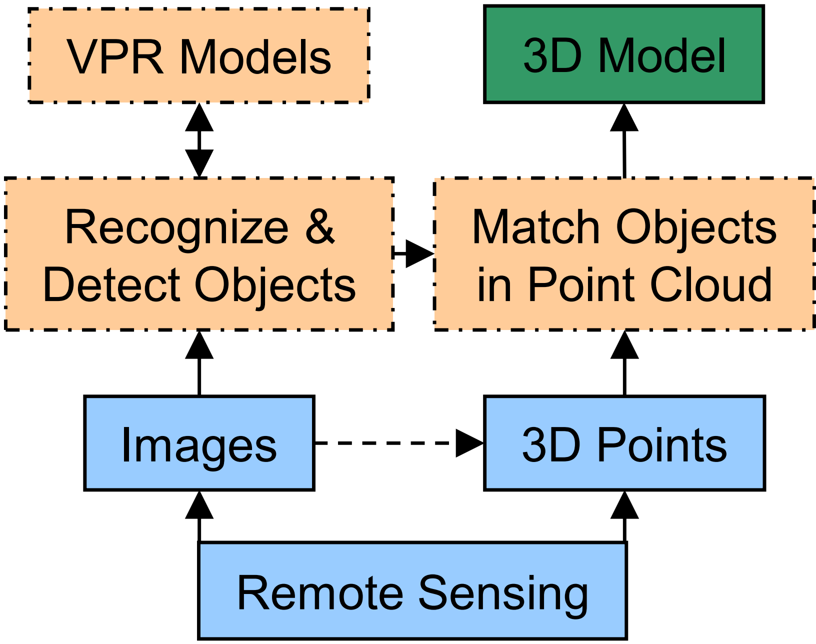

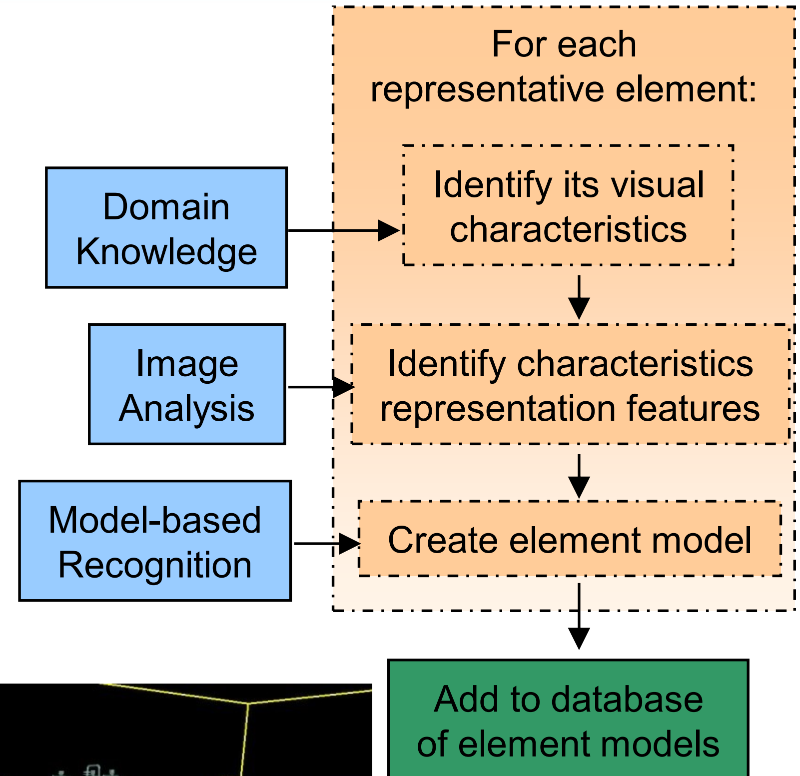

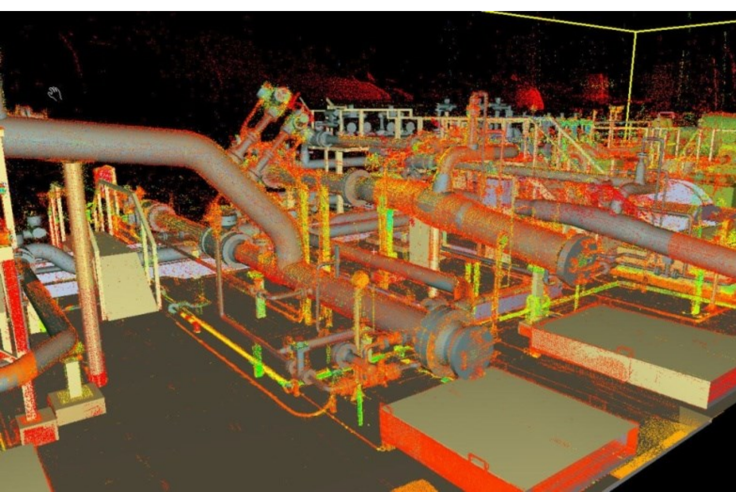

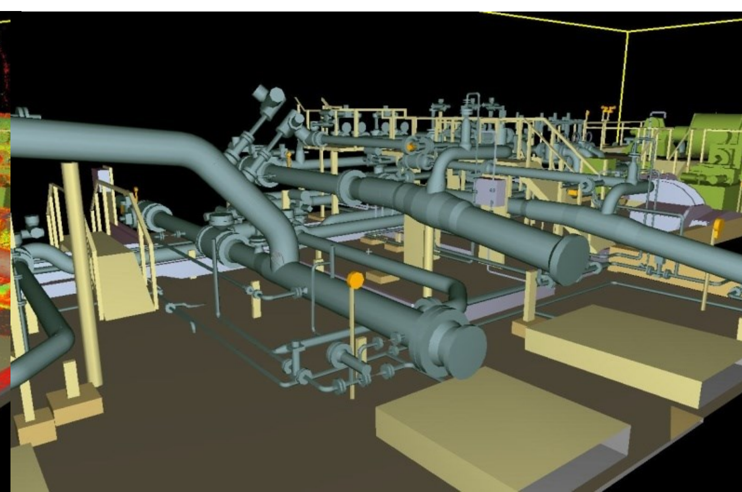

Results – Columns Detection

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- 89.1% precision (TP/TP+FP)
- 79.1% recall (TP/TP+TN)
- 320x240, 25 fps on a netbook

As-Built Geometry

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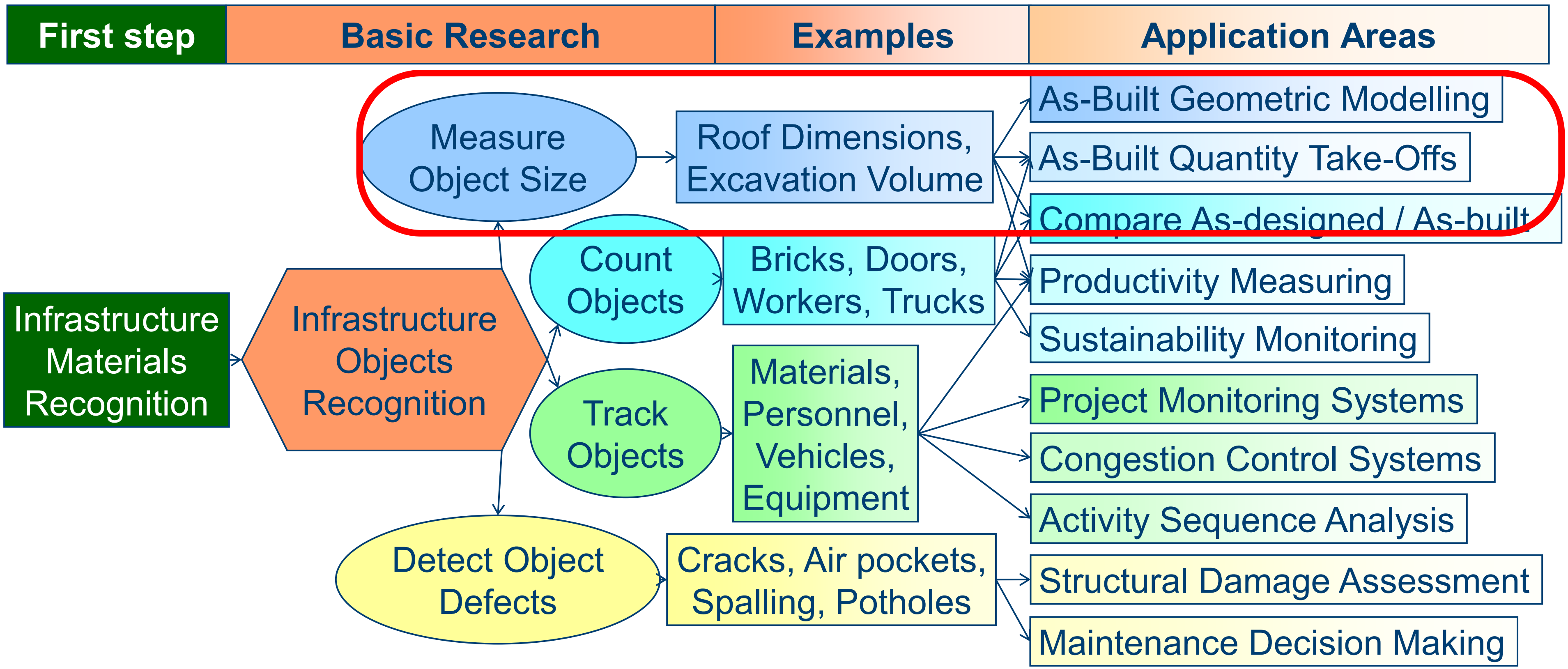
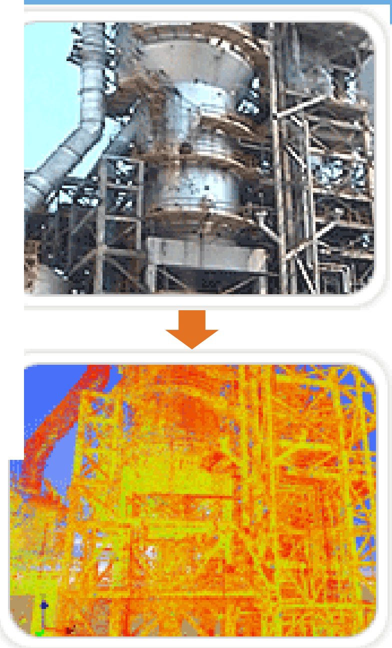
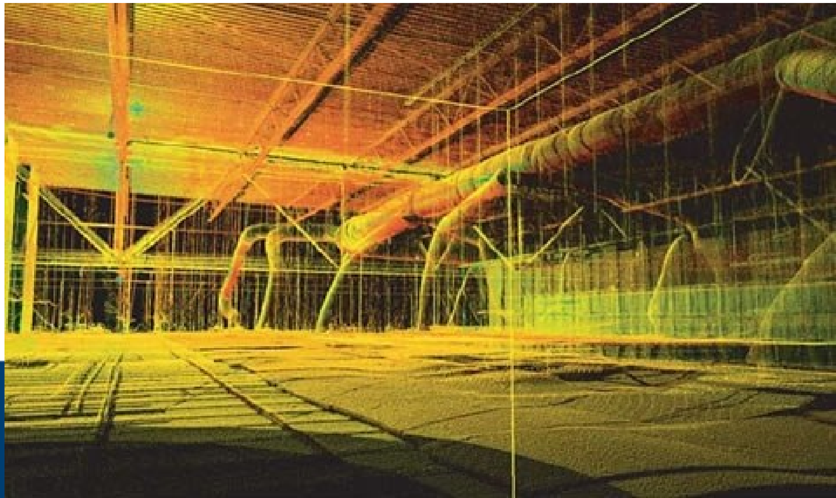


Real World Infrastructure to 3D Points

- Measuring object size needs 3D data
- Getting adequate/accurate 3D data is costly
  - Device costs (i.e. laser scanner) + Labour (data collection + post processing man-hou
  - Result: Small/medium sized on-going and completed projects cannot afford it
    - Let alone getting 3D data frequently, throughout the construction phase



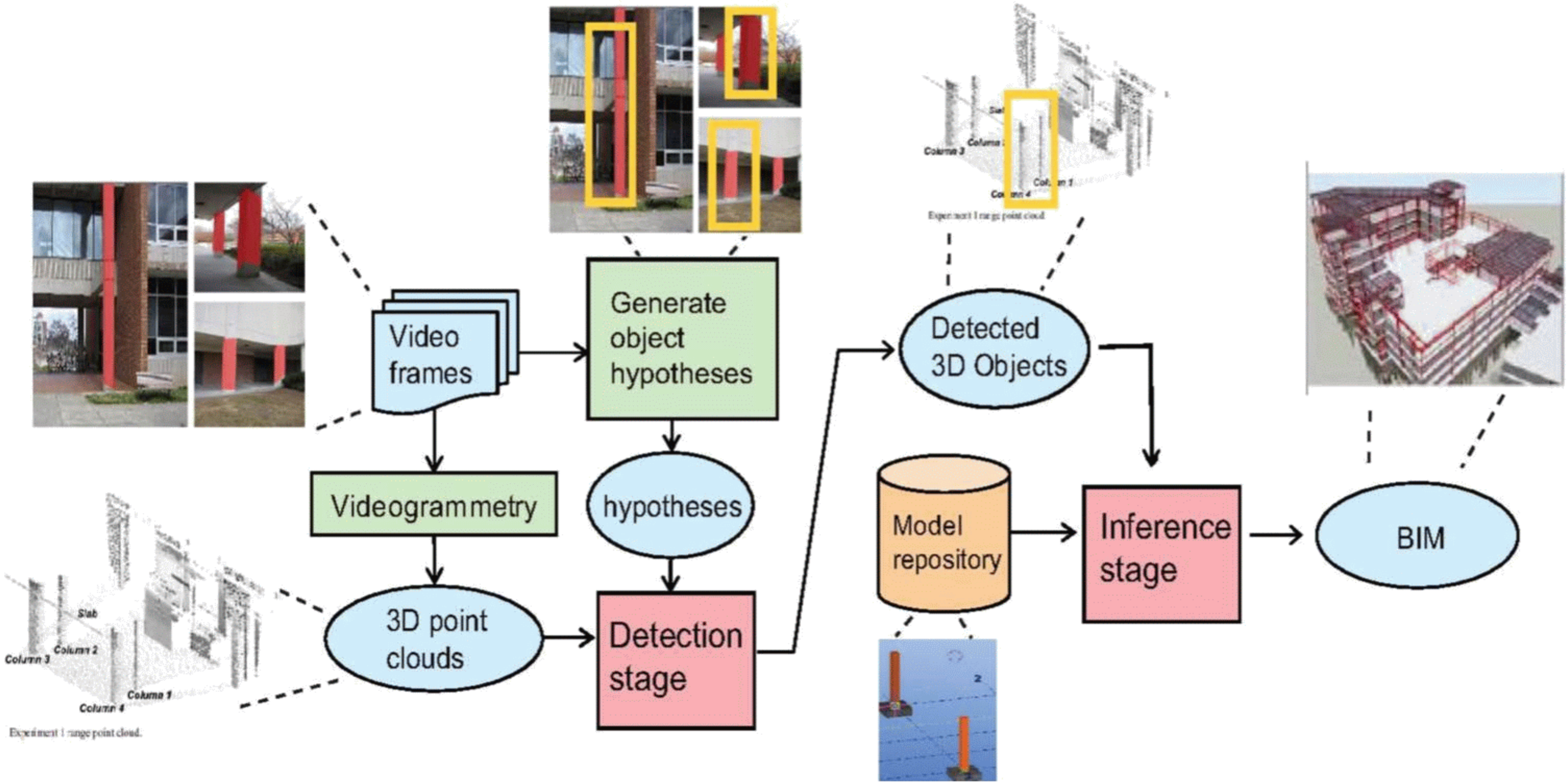


Coordinating Efforts

Marie Curie
IRSES Program

EUROPEAN COMMISSION

- Consortium established in 2008 to formalize the as-built modeling



Damage and Defects Assessment

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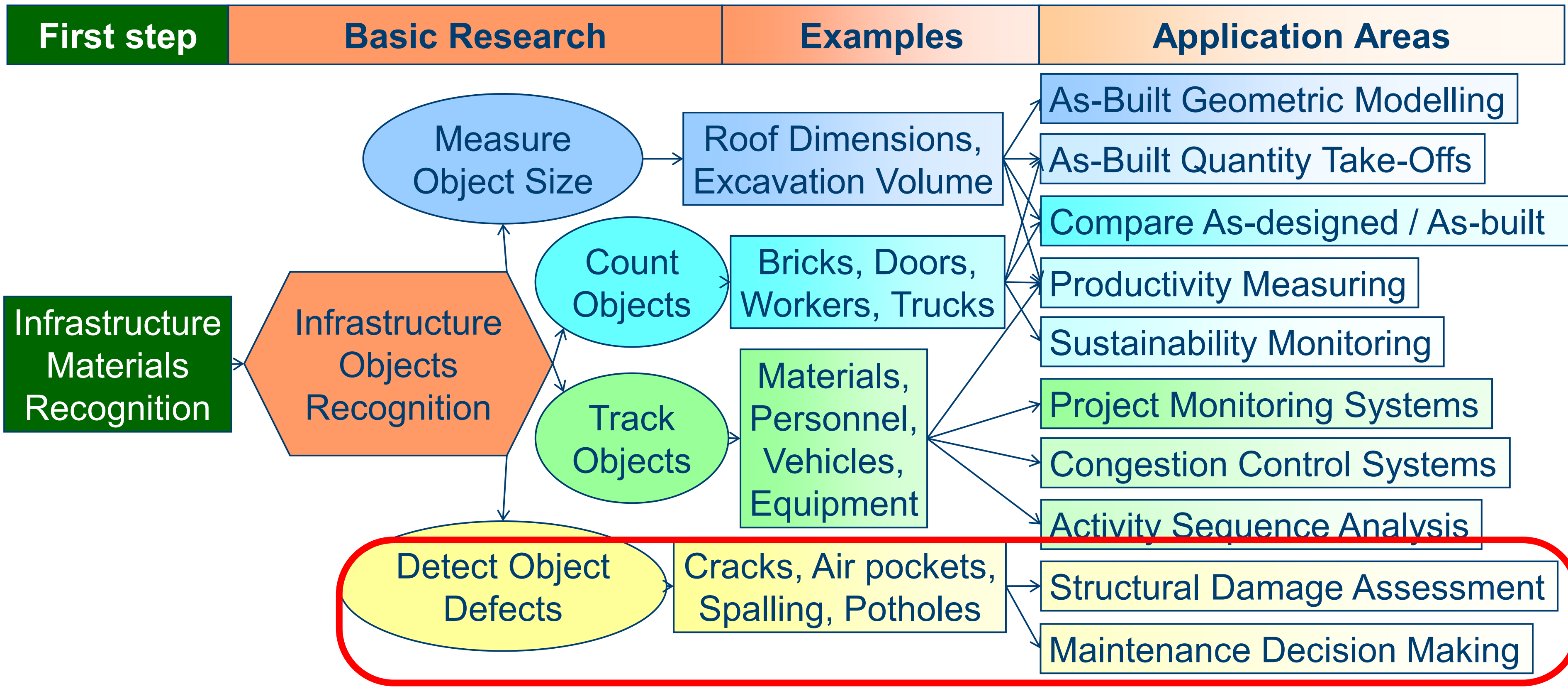
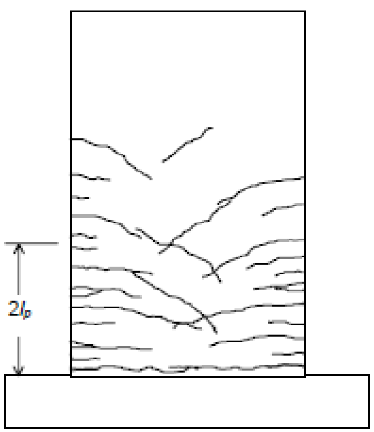


Post-Earthquake Structural Safety Assessment

- FEMA 306 (rapid)
- ATC-20 (rough)
- FEM (detailed)

Severity	Description of Damage
Insignificant $\lambda_K = 0.8$ $\lambda_Q = 1.0$ $\lambda_D = 1.0$	*Criteria:* • No crack widths exceed 3/16 in., and • No shear cracks exceed 1/8 in., and • No significant spalling or vertical cracking *Typical Appearance:*  Note: *l_p is length of plastic hinge. See Section 5.3.3*

Damage Level	Performance Level	Qualitative Performance Description	Quantitative Performance Description
I	Cracking	Onset of hairline cracks	Barely visible residual cracks
II	Yielding	Theoretical first yield of longitudinal reinforcement	Residual crack width ~ 0.008in (0.2 mm)
III	Initiation of Local Mechanism	Initiation of inelastic deformation. Onset of concrete spalling. Development of diagonal cracks.	Residual crack width 0.04in – 0.08in (1 – 2mm). Length of spalled region > 1/10 cross-section depth.
IV	Full Development of Local Mechanism	Wide crack widths/spalling over full local mechanism region.	Residual crack width > 0.08in. (2mm). Diagonal cracks extend over 2/3 cross-section depth. Length of spalled region > ½ cross-section depth.
V	Strength Degradation	Buckling of main reinforcement. Rupture of transverse reinforcement. Crushing of core concrete.	Lateral capacity below 85% of maximum. Section depth expands to > 5% of original member dimension.

Field Observations				Conclusions	
Pronounced Horizontal Cracks	Pronounced Diagonal Cracks	Incipient Concrete Curshing/ Spalling	Long. Bar Buckling	Damage Level	Possible Failure Type
No	Yes	No	No	III	Shear
No or Yes	Yes	Yes	No or Yes	IV or V	Shear
Yes	No	No	No	II or III	Flexure
Yes	No	Yes	No	IV	Flexure
Yes	No	Yes	Yes	V	Flexure

Problem Statement & Objectives

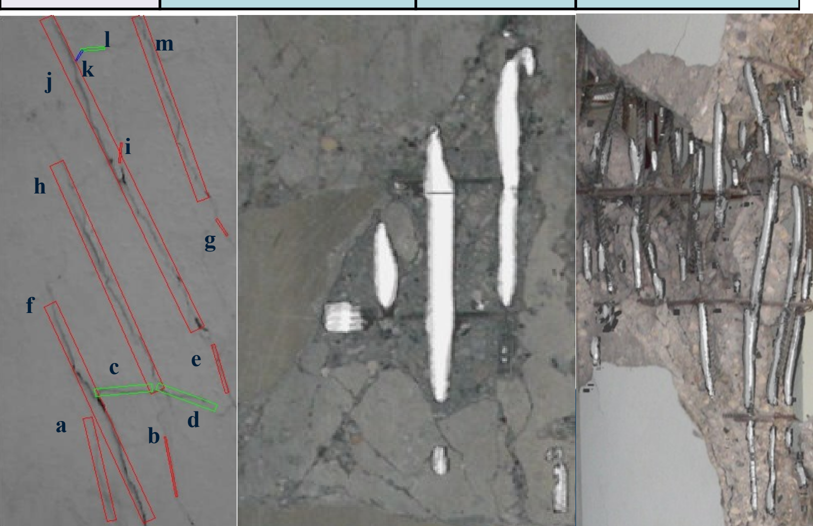
- Problem
  - Earthquakes create huge inspection demand within seconds, takes weeks to months to assess all structures
    - In the mean time
      - ERs risk their lives in unsafe buildings (FEMA codes)
      - People stay out waiting for assessment (ATC codes)
- Objective
  - Shift the research focus from accuracy to speed
    - Get useful measurements automatically

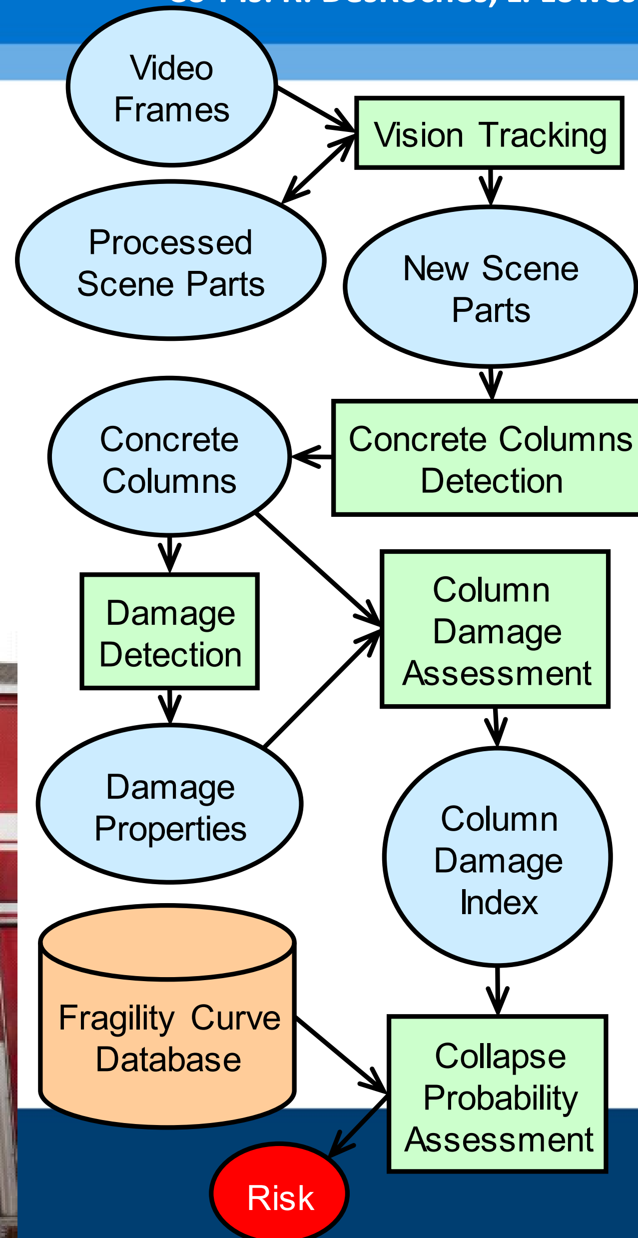
Rapid Safety Assessment

Grant #1000700
Co-PIs: R. DesRoches, L. Lowes

- Get rapid measurements from video
- Translate them to remaining bearing capacity
- Warn if collapse is imminent

	|Δ| - Orientation	|Δ| - L / W*	|Δ| - Max W / W*
Average	3.29°	2.21%	0.35%
Std	2.70°	2.90%	0.49%





…and there is much left to do

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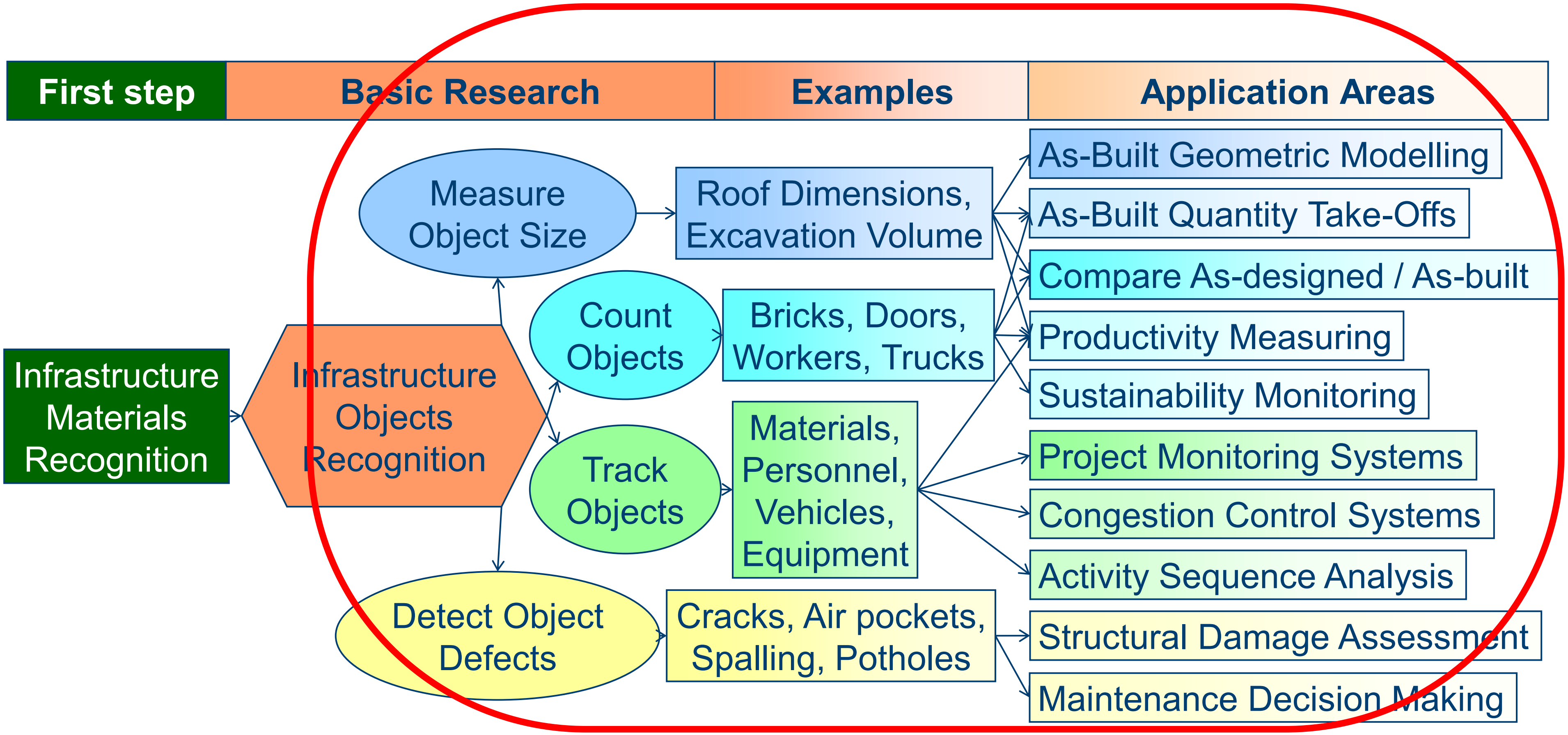

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Future Research Directions

- Automation solutions for improved productivity and sustainability in construction
- Building objects detection and inference methods
- Sustainable pavement assessment methods
- As-is bridge modeling (BrIM) / highway asset mapping
- Vehicle classification and tracking for congestion pricing, stop-and-go waves estimation, etc.
- Automation advances in structural safety inspection
- UAV navigation for post-disaster structural assessment

Thank you!

Questions?

NSF EUROPEAN COMMISSION DAAD METALFORMING Architectural Machines GDOT Keeping Georgia on the Move