Fission Battery Initiative Workshop Series: Transportation and Siting for Fission Batteries

Moderators:

- Abhinav Gupta (NCSU)
- Abdollah Shafieezadeh (OSU)
- Chandrakanth Bolisetti (INL)
- Elmar Eidelpes (INL)

Fission Battery Lead and Support Staff:

- Vivek Agarwal (INL)
- Dayna Daubaras (INL)
- Erik Schuster (INL)

March 15, 2021

INL National University Consortium
IDAHO NATIONAL LABORATORY

Fission Battery Initiative Workshop Series: Transportation and Siting for Fission Batteries

Today's workshop will discuss siting and transportation of fission batteries, including connections to spent nuclear fuel management practices, site-independent fission battery deployment, critical regulatory challenges and other relevant topics.

Goals:

- Initiate conversations on issues and hurdles related to fission battery transportation and siting.
- Promote the identification of research and development needs to support fission battery siting and transportation.
- Foster community building and share the current state of understanding on fission batteries among stakeholders.
- Identify the potential stakeholder needs in order to make fission batteries a reality.

The Fission Battery Initiative envisions developing technologies that enable nuclear reactor systems to function as batteries and to be referred as fission batteries.

March 15, 2021

Transportation and Siting for Fission Batteries

Introduction: "Fission Battery" Vision Defined

12:00	Welcome	Elmar Eidelpes (INL)
12:05	Fission Battery Initiative	Vivek Agarwal (INL)

Session 1: Lessons Learned from Waste Management Session

Chair: Elmar Eidelpes, INL

Topics: Insights in spent nuclear fuel management practices will be discussed and the connection to fission battery siting and transportation will be established.

12:20	Transportation Issues – Fission Batteries	Alan Wells (consultant)
12:40	DOE Nuclear Waste Management Transportation and Handling Tests	Sylvia Saltzstein (SNL)

Session 2: Regulatory Perspective
Session Chair: Abhinav Gupta, NCSU

Topics: The perspective of the U.S. regulator on fission battery transportation and siting will be addressed.

1:10	Transportation of Radioactive Material	David Pstrak (U.S. NRC)
1:30	Modernizing the Regulatory Framework for Advanced Reactor Siting	Robert Schaaf (U.S. NRC)
1:50	Break	

Session 3: Industry and Other Stakeholder Perspectives
Session Chair: Abdollah Shafieezadeh, OSU

Topics: This session focuses on the perspective of industry and other stakeholder representatives on fission battery transportation and siting, and questions related to advanced reactor development and licensing.

2:30	Flexible Siting	Emma Redfoot (Oklo)
2:50	Technological Innovations in Management of Transportation: Advances in Visual Sensing	Abhinav Gupta (NCSU)
3:10	Issues in Commercial Reactor Siting	George Griffith (INL)

Panel Discussion

Moderator: Chandrakanth Bolisetti, INL

A moderated panel discussion to discuss the key takeaways and roadblocks identified within this workshop, with a Q & A session for the audience to interact with the panel.

Panel Members: Emma Redfoot (Oklo), Alan Wells (Consultant), Bernie White (U.S. NRC), George Griffith (INL)

3:40	Panel Discussion and Q & A	
4:55	Closing Remarks	Abdollah Shafieezadeh (OSU)

February 10, 2021

Vivek Agarwal, Ph.D.
Technical Lead, Fission Battery Initiative

Fission Battery Initiative

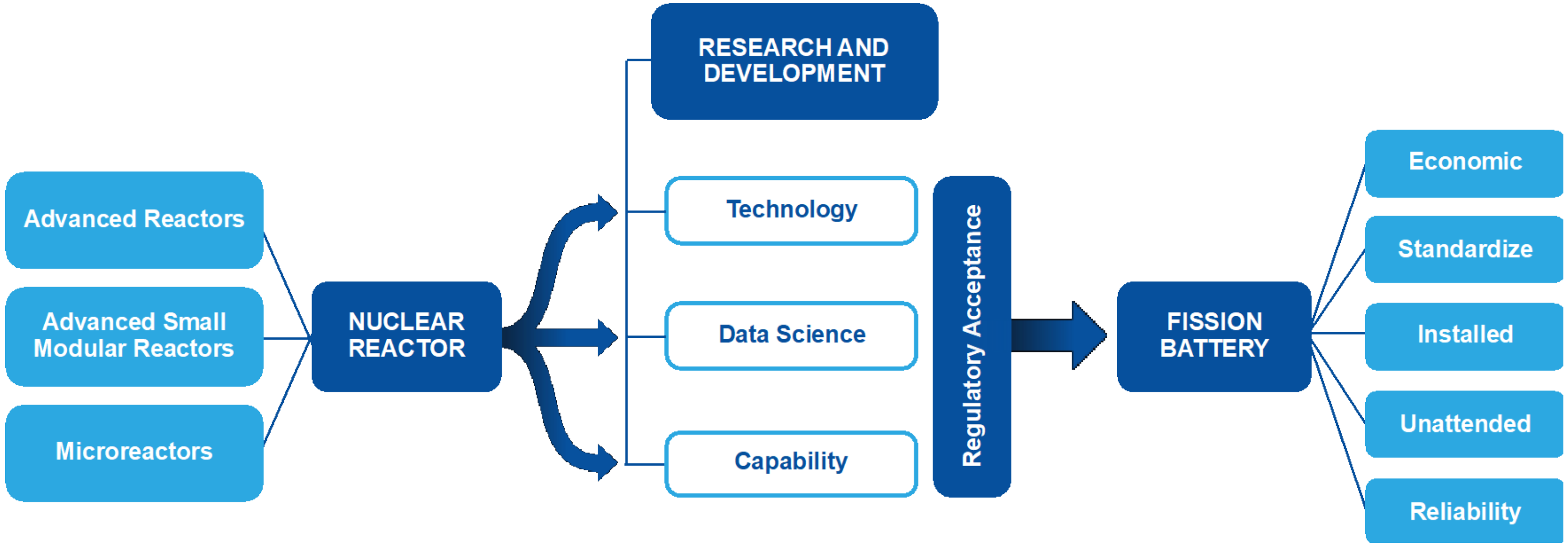
Nuclear Science and Technology

Idaho National Laboratory

Fission Battery Initiative

Vision: Developing technologies that enable nuclear reactor systems to function as batteries.

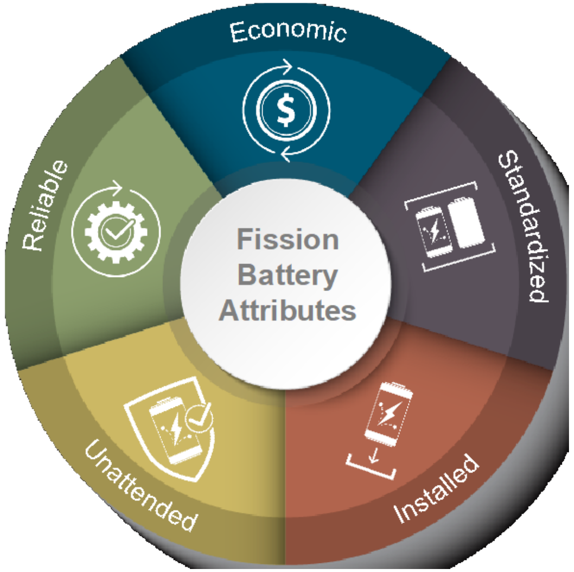
Outcome: Deliver on research and development needed to provide technologies that achieve key fission battery attributes and expand applications of nuclear reactors systems beyond concepts that are currently under development.



Research and development to enable nuclear reactor technologies to achieve fission battery attributes

Fission Battery Attributes

- **Economic** – Cost competitive with other distributed energy sources (electricity and heat) used for a particular application in a particular domain. This will enable flexible deployment across many applications, integration with other energy sources, and use as distributed energy resources.
- **Standardized** – Developed in standardized sizes, power outputs, and manufacturing processes that enable universal use and factory production, thereby enabling low-cost and reliable systems with faster qualification and lower uncertainty for deployment.
- **Installed** – Readily and easily installed for application-specific use and removal after use. After use, fission batteries can be recycled by recharging with fresh fuel or responsibly dispositioned.
- **Unattended** – Operated securely and safely in an unattended manner to provide demand-driven power.
- **Reliable** – Equipped with systems and technologies that have a high level of reliability to support the mission life and enable deployment for all required applications. They must be robust, resilient, fault tolerant, and durable to achieve fail-safe operation.



Fission Battery Workshop Series

- **Jointly INL and National University Consortium are organizing workshops across five areas:**
  - Market and Economic Requirements for Fission Batteries and Other Nuclear Systems
  - Technology Innovation for Fission Batteries – Next workshop is February 24, 2021
  - Transportation and Siting for Fission Batteries – March 15, 2021
  - Security Scoping for Fission Batteries – April 02, 2021
  - Safety and Licensing of Fission Batteries – April 16, 2021

- **Expected outcomes:**
  - Each workshop outcomes are expected to outline the goals of each fission battery attribute

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TRANSPORTATION ISSUES: FISSION BATTERIES

Alan H Wells, PhD, PE

March 15, 2021

Criticality Safety Considerations

- Structural –
  - Significant yielding of structure is a concern if it affects fissile system geometry.
  - Neutron absorbers are generally not structural and are lower temperature materials.
- Neutronic –
  - Partial credit for neutron absorbers due to manufacturing issues and neutron channeling concerns. (75-90 %)
  - independence, redundancy and diversity of the safety measures; engineered versus administrative; passive or active IAEA SSG-27, Section 4.1. Also Criterion 22, 10 CFR 50 Appendix A, Protection System Independence.

Transportation Regulations –
10 CFR 71 and IAEA Specific Safety Requirements-6

- Criticality Safety – Fully Flooded at Optimum Moderation. Moderator Exclusion allowed for Double-Sealed Transportation Container.
- Structural – Transportation Impact equivalent to 9 meter drop onto unyielding surface and 1 meter pin puncture drop. High g-loads (55 g).
- Shielding – Dose Rate Limit 10 mrem/hour at 2 meters from package boundary for Normal Conditions of Transport and 1 rem/hour on contact for Hypothetical Accident.

Transportation Regulations –
10 CFR 71 and IAEA Specific Safety Requirements 6

- Thermal – 30 minute engulfing fire at 800°C.
- Containment – Helium Fill Gas. Source Terms plus Release Fractions (PWR are documented). Leak Rates must be calculated for Normal Conditions and Hypothetical Fire Conditions. (ANSI/ANS-14.5, NUREG/CR-6487)
- Handling – Fresh, delivered to site, non-radioactive. For return after service, burned, radioactive; packaging for transport becomes complicated. Delay prior to packaging may be needed.

Regulatory Issues

- 10 CFR 51 – Modal Study Revision?
- Reactor Containment Vessel as Transportation Package Containment?
- Moderator Exclusion for Reactor? How to manage double-sealing.
- k-effective limit 0.95? Burnup credit? (ANSI/ANS 8.27) Reactor can exceed k-eff of 1.0, transportation limit is 0.95, so protection systems must be robust.
- Normal and Accident Release fractions for Containment analysis for new fuel types (or old types used in new ways)? (DOE-HDBK-3010-94 [2013])

Transportation for Recovery After Accident

- Fermi-1 U/Mo Melted Fuel – Hot Cell Examination

Transportation of Radioactive Material

David Pstrak
Division of Fuel Management
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission

Transportation and Siting for Fission Batteries Workshop
March 15, 2021

Domestic Transportation Regulations

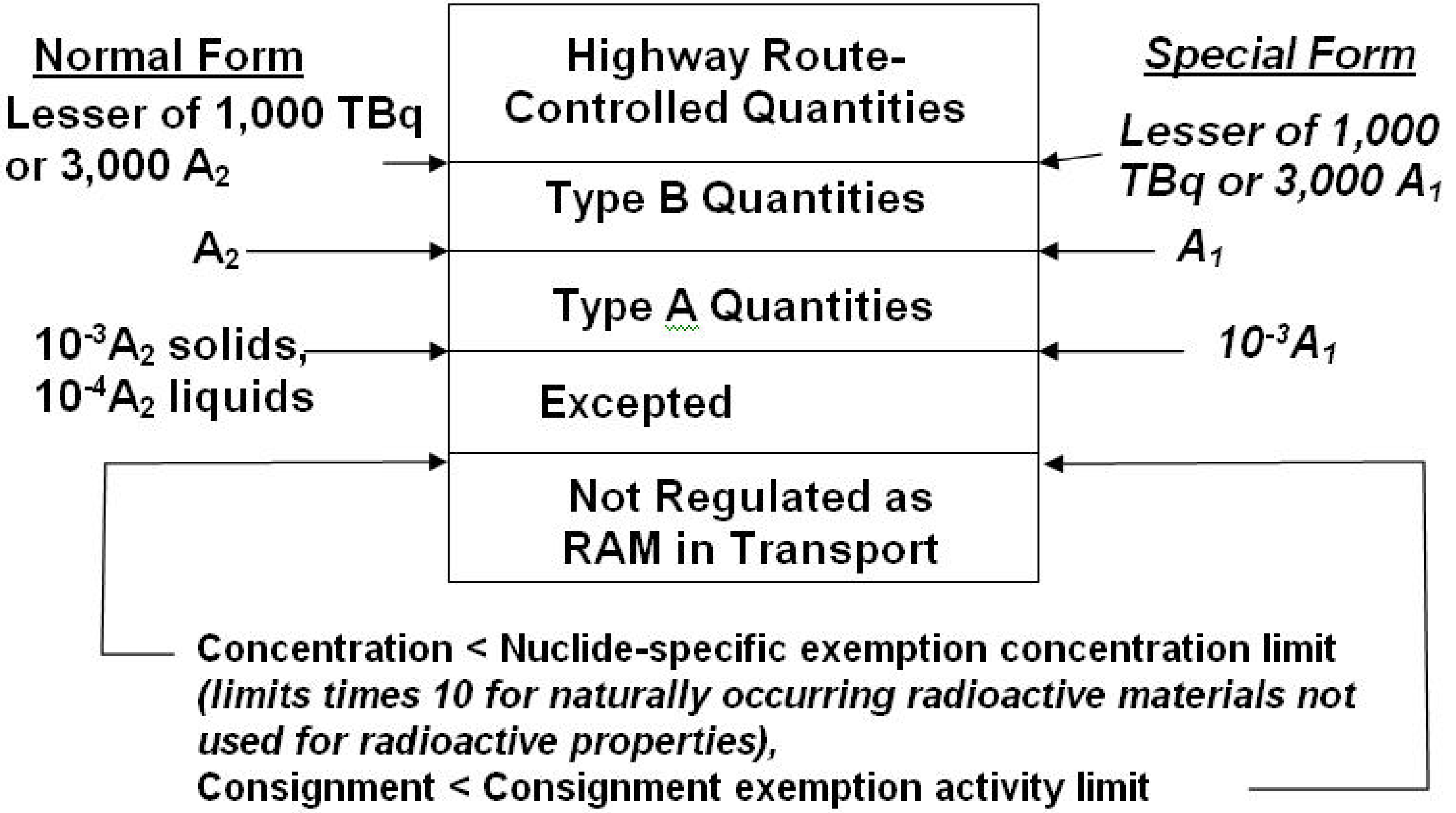
U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

- U.S. Nuclear Regulatory Commission (NRC) and U.S. Department of Transportation (DOT) co-regulate radioactive material transportation
  - NRC transportation regulations (10 CFR Part 71)
  - DOT transportation regulations (49 CFR Parts 107; 171 – 180)
- NRC only regulates a portion of radioactive material transportation
- NRC and DOT regulations are compatible
- The Memorandum of Understanding (MOU)

  (44 FR 38690), published July 2, 1979, delineates the respective agency responsibilities

http://www.nrc.gov/what-we-do/regulatory/enforcement/moudot.pdf

Activity and Packaging Types



Transportation Packages

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

- Type A fissile package (Type AF)
  - Less than a Type B quantity (less than A_2 value in 10 CFR Part 71, Table A-1)
  - A_2 value for uranium (U) with enrichment ≤20 weight percent U-235 is unlimited (see Table A-1)
- Type B package (Type B or Type BF)
  - Greater than A_2 value from 10 CFR Part 71, Table A-1
  - Enrichments >20 weight percent U-235, mass dependent

Packaging and Transportation

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Philosophy

- Three safety functions
  - Shielding – limit external radiation dose rates
  - Containment – limit release of radioactive material
  - Subcriticality – prevent criticality in transport
- NRC reviews/approves the package design that was evaluated

Transportation Tests

- Normal conditions of transport (10 CFR 71.71)
  - Hot and cold temperatures
  - Reduced and increased external pressure
  - Vibration
  - Water spray
  - Free drop (1 to 4 feet)
  - Corner drop
  - Compression test
  - Penetration test
- Hypothetical accident conditions (10 CFR 71.73)
  - 30-foot drop test
  - 40-inch puncture test
  - 30-minute fire at 1,475 degrees Fahrenheit
  - Immersion test

Transportation Tests cont’d

- Tests for fissile packages transported by air (10 CFR 71.55(f))

- Tests for plutonium package transported by air (10 CFR 71.88, 10 CFR 71.64 and 10 CFR 71.74)

Package Approval Criteria

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

- Type AF ⇒ Type BF package
- Criticality safety
  - Single package
  - Array of packages
- Containment—Type B packages only
  - Leakage rate testing for Type B packages (10 CFR 71.51, "Additional Requirements for Type B Packages")
- Shielding
  - Dose rates in 10 CFR 71.47, "External Radiation Standards for All Packages" after tests for normal conditions of transport
  - Dose rate less 1 rem/h at 1 m from the package surface after tests for hypothetical accident conditions (10 CFR 71.51)

Unlimited A_2 Type AF
Unshielded package

⇒ Fission battery Usage

$$A_2 \text{ for mixture} = \frac{1}{\sum_i \frac{f(i)}{A_2(i)}}$$

Heavily shielded Type BF package

Radiation level limits (10 CFR 71.47 and 49 CFR 173.441)

<table>
<tr><th colspan="5">Package and Vehicle Radiation Level Limits (§ 173.441)[1]</th></tr>
<tr><th colspan="2"></th><th>Nonexclusive Use Shipment</th><th colspan="2">Exclusive Use Shipment</th></tr>
<tr><th colspan="2"></th><th>Open or Closed Transport Vehicle</th><th>Open (flat-bed)</th><th>Closed Transport Vehicle</th></tr>
<tr><td rowspan="3">Package Limits:</td><td>External Surface</td><td>2 mSv/h (200 mrem/h)</td><td>2 mSv/h (200 mrem/h)</td><td>10 mSv/h (1000 mrem/h)</td></tr>
<tr><td>Transport Index (TI)[2]</td><td>10</td><td colspan="2">No limit</td></tr>
<tr><td>Criticality Safety Index (CSI)[5]</td><td>50</td><td colspan="2">No limit</td></tr>
<tr><td rowspan="9">Transport Vehicle Limits (highway and rail):</td><td>Any point on the outer surface</td><td>N/A</td><td>N/A</td><td>2 mSv/h (200 mrem/h)</td></tr>
<tr><td>Vertical planes projected from outer edges</td><td rowspan="4"></td><td>2 mSv/h (200 mrem/h)</td><td>N/A</td></tr>
<tr><td>Top of</td><td>Load: 2 mSv/h (200 mrem/h)</td><td>Vehicle: 2 mSv/h (200 mrem/h)</td></tr>
<tr><td>2 meters from</td><td>Vertical Planes: 0.1 mSv/h (10 mrem/h)</td><td>Outer Lateral Surfaces: 0.1 mSv/h (10 mrem/h)</td></tr>
<tr><td>Underside</td><td colspan="2">2 mSv/h (200 mrem/h)</td></tr>
<tr><td>Occupied position</td><td>N/A[3]</td><td colspan="2">0.02 mSv/h (2 mrem/h)[4]</td></tr>
<tr><td>Sum of package TIs</td><td>50</td><td colspan="2">No limit</td></tr>
<tr><td>Sum of package CSIs[5,6]</td><td>50</td><td colspan="2">100</td></tr>
</table>

[1] The limits in this table do not apply to excepted packages. [§§ 173.421, 173.424, 173.426, and 173.428]
[2] The dimensionless number equivalent to maximum radiation level at 1 meter (3.3 feet) from the exterior package surface is in mrem/h rounded up to the next tenth. [§ 173.403]
[3] No dose limit is specified, but separation distances apply to packages with RADIOACTIVE YELLOW-II, RADIOACTIVE YELLOW-III, or CSI labels. (§ 177.842)
[4] Does not apply to carriers if operating under a state or federally-regulated radiation protection program and if personnel wear radiation dosimetry devices. [§ 173.441(b)(4)]
[5] These provisions do not apply to shipment by vessel. See § 176.700–720 for the vessel requirements.
[6] The number of packages containing fissile material stored in transit in any one storage area must be limited so that the total sum of the CSIs is ≤50 and such groups of packages must be spaced at least 6 meters (20 feet) from other such groups. [§§ 173.457 and 173.459]

Contact Information

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Modernizing the Regulatory Framework for Advanced Reactor Siting

March 15, 2021

Robert Schaaf, Sr. Environmental Project Manager
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards

Introduction

- NRC mission
- Traditional regulatory framework
- Purposes of NRC siting review
- Regulatory framework modernization efforts
- Opportunities for stakeholder participation

Nuclear Regulatory Commission

- Created in 1974
- Independent Executive Branch Agency
- Mission
  - *to license and regulate civilian use of radioactive materials to provide reasonable assurance of adequate protection of public health and safety, to promote the common defense and security, and to protect the environment.*

https://www.nrc.gov/about-nrc.html

Regulatory Framework – Siting

- Legislation
  - Atomic Energy Act
  - National Environmental Policy Act (and others)
- Regulations
  - Title 10, *Code of Federal Regulations* (Parts 50, 51, 52, and 100)

https://www.nrc.gov/about-nrc/regulatory.html
https://www.nrc.gov/reactors/new-reactors.html
https://www.nrc.gov/about-nrc/regulatory/licensing/nepa.html

Purposes of Siting Review
Safety & Security

- Natural and man-made hazards to plant
  - Seismic
  - Flooding
  - Hurricanes/Tornados
  - Infrastructure (rails lines, pipelines, facilities)
- Security
- Emergency planning

Purposes of Siting Review Environmental

- Project purpose and need
- Impacts to natural and human environment
  - Water quality
  - Ecology
  - Human health
  - Socioeconomic
  - Historic and cultural resources
  - Fuel cycle & waste
  - Others…
- Alternatives

Advanced Reactor Licensing Modernization

- Policy Statement (1986, 2008)
- Readiness Assessment (2001)
- Vision & Strategy (2016)
- Implementation Action Plan (2017)
- Program Status Reports (latest – 2021)

https://www.nrc.gov/reactors/new-reactors/advanced/policy-issues.html

https://www.nrc.gov/reactors/new-reactors/advanced/details.html#visionstrat

Licensing Modernization
Siting Review – Safety & Security

- New 10 CFR Part 53
- Emergency Preparedness
- Physical Security

https://www.nrc.gov/reactors/new-reactors/advanced/details.html#part53
https://www.regulations.gov/docket/NRC-2015-0225/document
https://www.regulations.gov/docket/NRC-2017-0227/document

Licensing Modernization
Siting Review – Environmental

- Interim Staff Guidance
  - COL/ESP-ISG-027, Light Water SMRs
  - COL/ESP-ISG-029, Micro-reactors
- Generic Environmental Impact Statement
- 10 CFR Part 51

https://www.nrc.gov/reading-rm/doc-collections/isg/col-app-design-cert.html

https://www.nrc.gov/reactors/new-reactors/advanced/details.html#advRxGEIS

Stakeholder Engagement

- Rulemaking public comments
- Advanced reactor stakeholder meetings
- Part 53 rulemaking meetings

https://www.nrc.gov/reactors/new-reactors/advanced/details.html#stakeholder

https://www.nrc.gov/pmns/mtg

Conclusion

- Detailed siting reviews for power reactor license applications
- Modernizing regulatory framework for advanced nuclear reactors
- Stakeholder feedback is encouraged
- Continue to ensure our core mission to protect public health and safety and the environment

https://www.nrc.gov/reactors/new-reactors/advanced.html

OKLO INC

Flexible siting

Emma Redfoot | March 2021

Fission battery | Siting and transportation

About us

Raised the first-ever, modern, venture-led, series A for a fission company

Granted an INL site use permit from Department of Energy

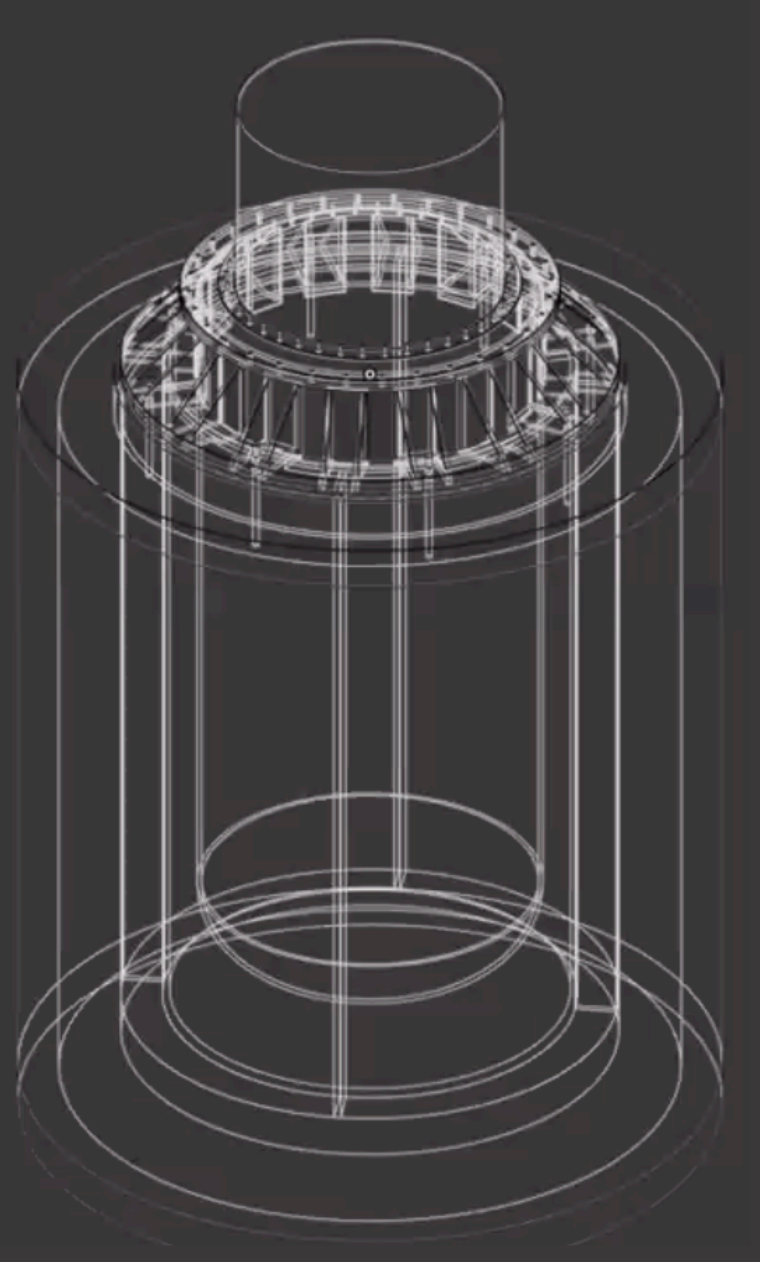
Selected to demonstrate recycle of spent fuel at Idaho National Laboratory

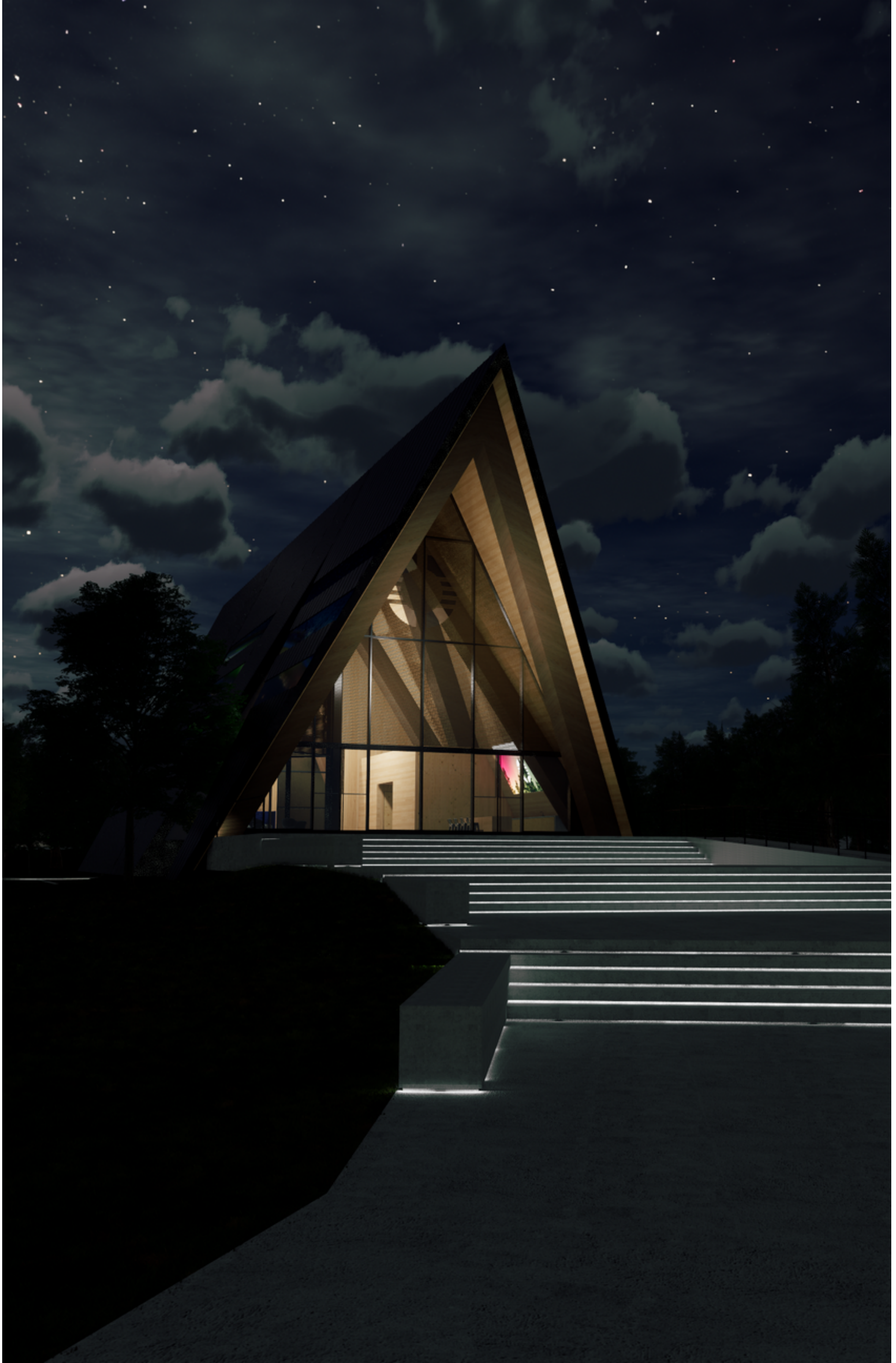
Became the first advanced fission company in the country to have a license application accepted by the U.S. Nuclear Regulatory Commission

Oklo develops clean energy generation sources with advanced fission to mitigate the social and environmental impacts of pollution as well as energy poverty.

Fast facts

- 20 year fuel life
- 1-2 MWe output
- Integrated with solar
- No water use
- Cooled by natural forces
- Recycles nuclear waste
- Saves 1,000,000 tons of CO_2





Flexible siting

Flexible siting principles

Designing a reactor that can be flexibly sited involves:

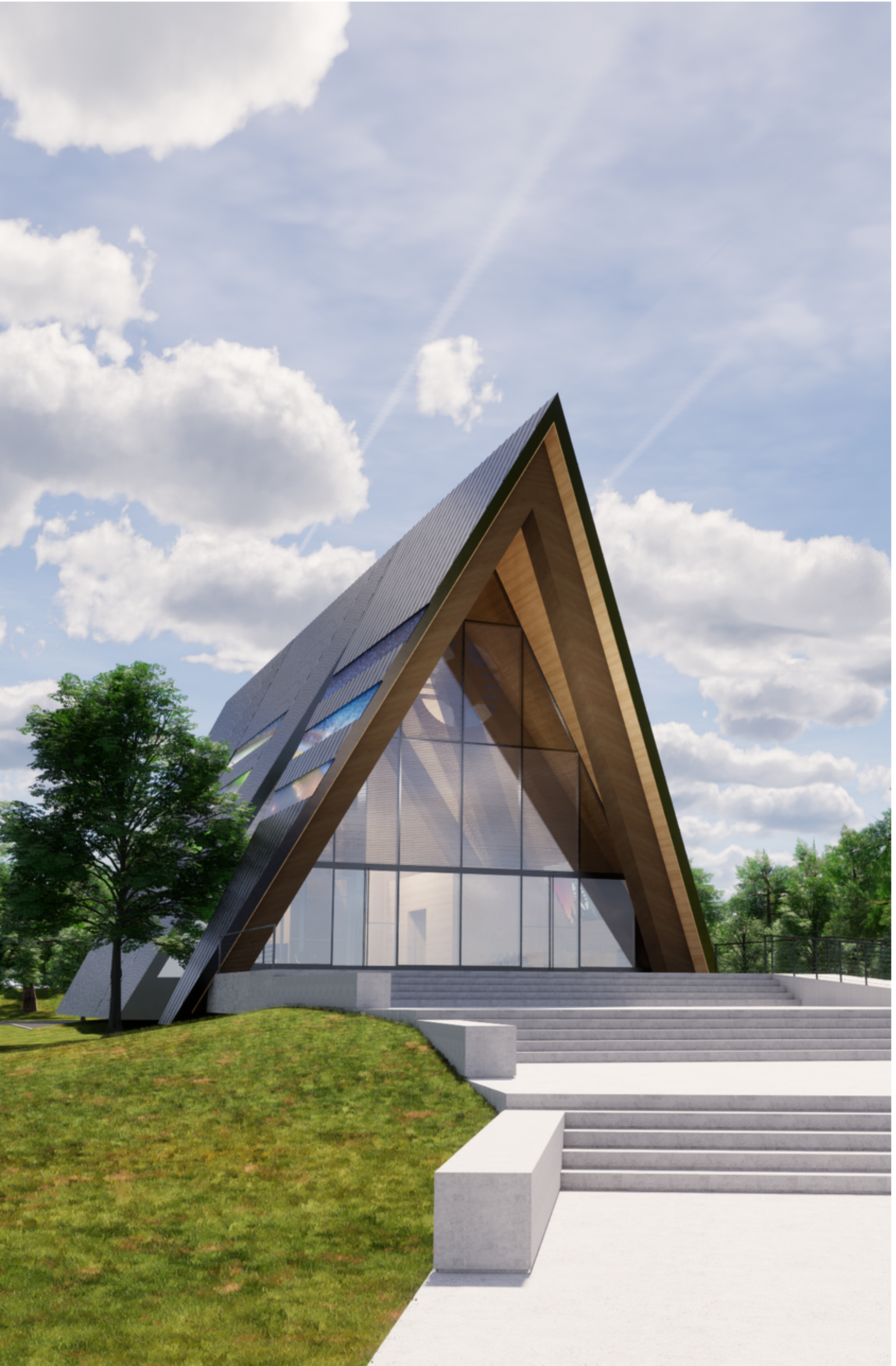
- **Robust design**
  - Deterministically demonstrating the design can sustain the safety challenges presented by most or all external hazards.
- **Minimal operations resource requirements**
  - Not relying on site specific characteristics (e.g. a source of water or a nearby population for staffing) for the safe operation of the plant.

Flexible siting benefits

- **Site selection focused on cultural and ecological characteristics**
  - The ability to selectively choose sites that avoid important characteristics, such as being culturally relevant or home to endangered or threatened species.
- **Choose site based on community preferences**
  - Siting in a location most beneficial to a community based on the insight and consent of the local people.
- **Robust design**
  - The robust design required for a high degree of site flexibility results in a low-risk facility that presents negligible radiological risk to the public visiting the facility.
- **Cost effective**
  - Minimal site-specific investigations need to be presented as part of the safety case in a license application to the Nuclear Regulatory Commission (NRC).

Siting vs environmental analysis

Siting	**Environmental**
Included in the final safety analysis report (FSAR) to ensure that the environment does not pose an unaccounted-for risk to the nuclear facility.	Included in the environmental report to ensure that the nuclear facility does not pose an unaccounted-for risk on the environment.



External hazards methodology

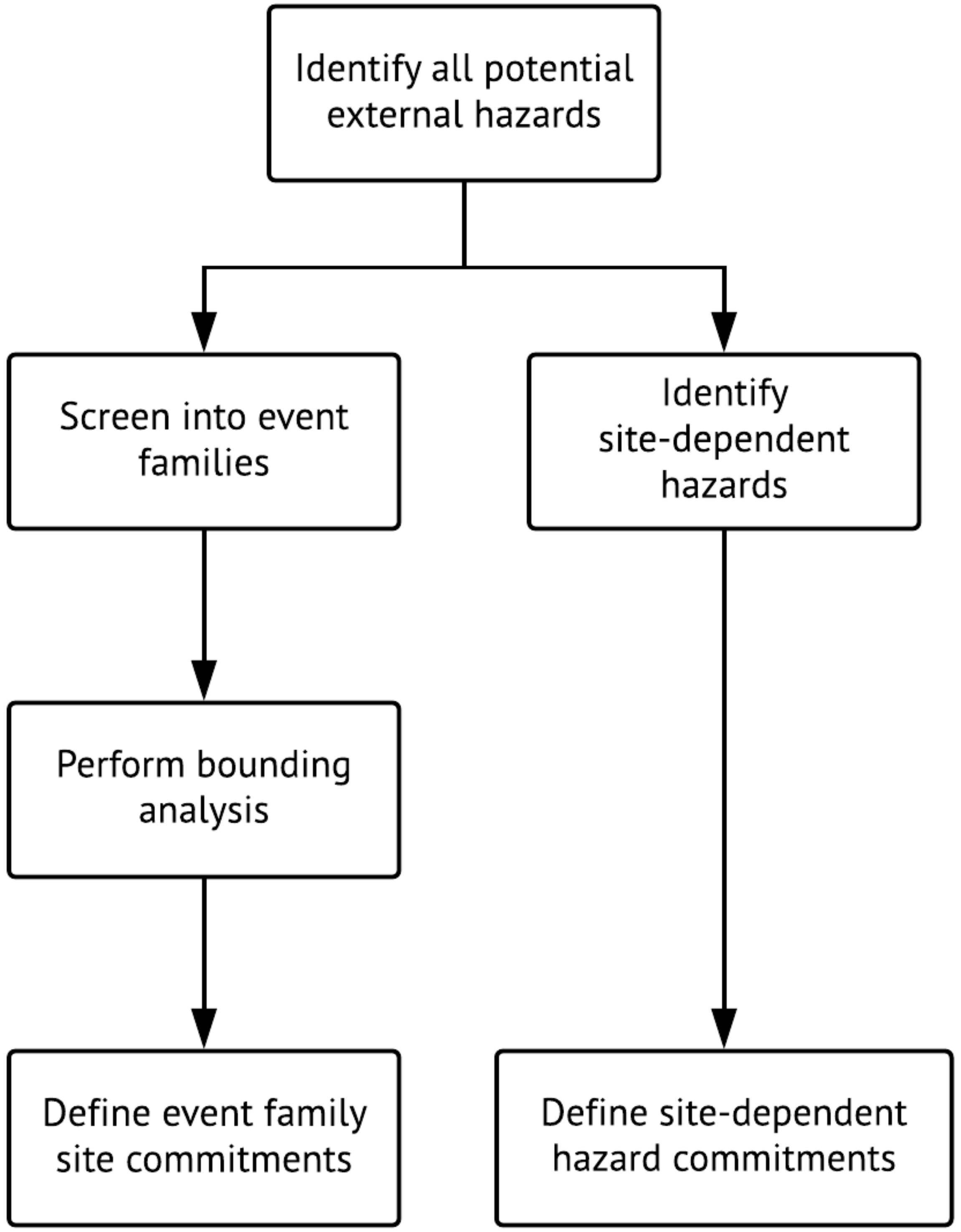
Aurora COLA Submitted March 2020, Accepted June 2020

Main takeaway

The site characterization data included in a license application needs to be based on the **risk presented** by the fission battery.

Oklo external hazards methodology

Site commitment:
A commitment for Oklo to perform a specific action when undergoing site selection for the Aurora.



Intense precipitation example for the Aurora

Example external hazard:

Intense precipitation

Screen into event families:

1. Cause a flood
2. Challenge the powerhouse integrity

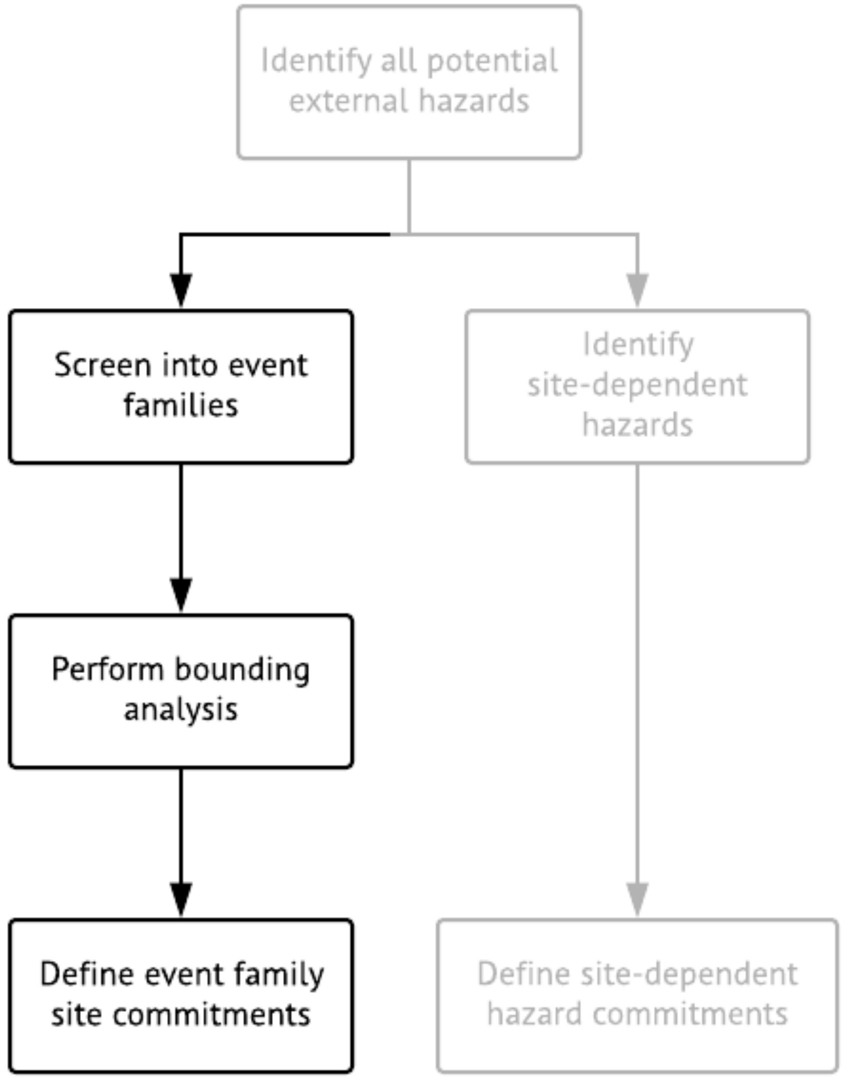
Perform bounding analysis:

1. Assume the entire building floods
Result: Safety of the Aurora unchallenged by a flood.

2. Assume the powerhouse collapses
Result: safety of the Aurora unchallenged by powerhouse collapse

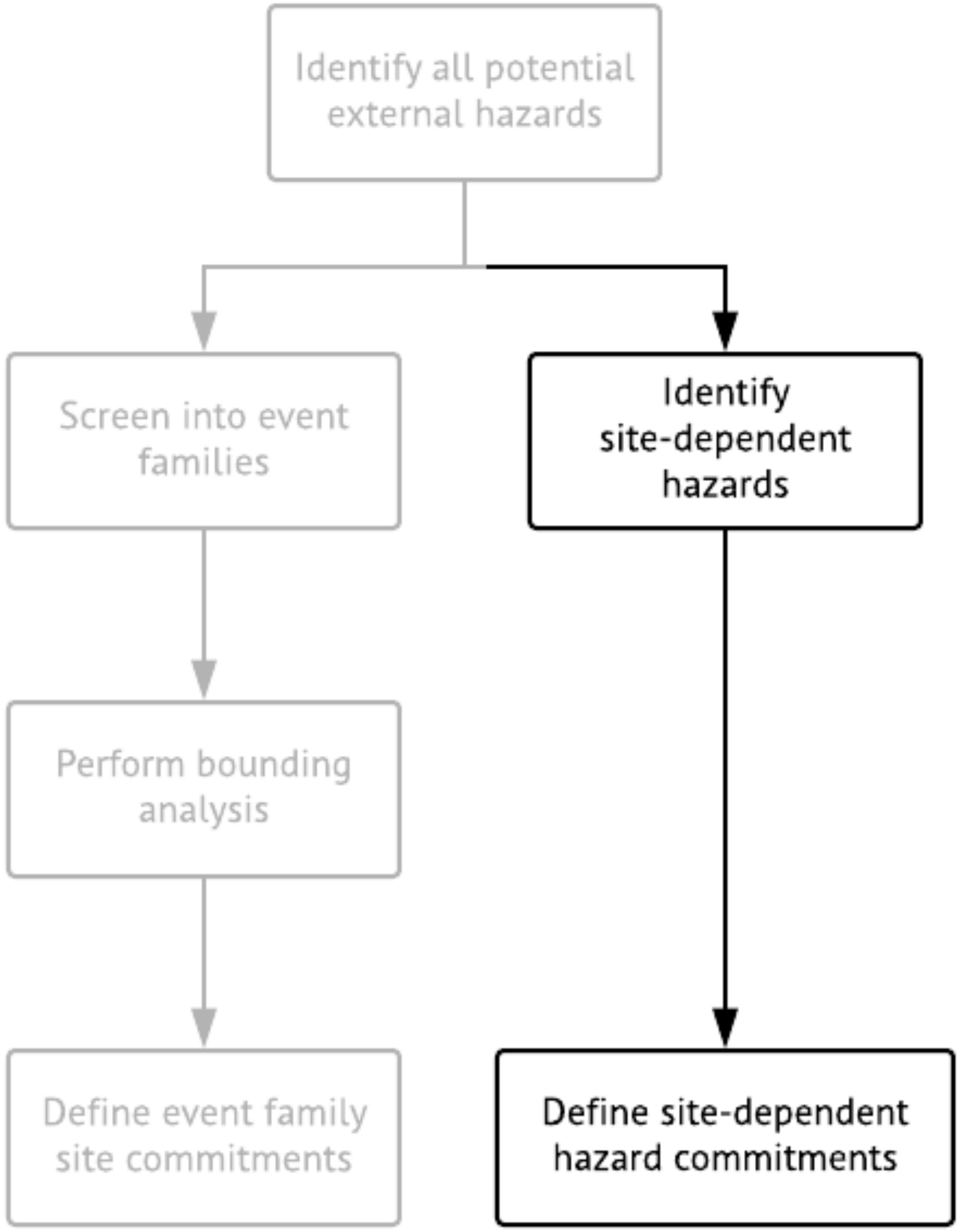
Define event family site commitments:

1. No flooding event family site commitment
2. No powerhouse collapse event family site commitement



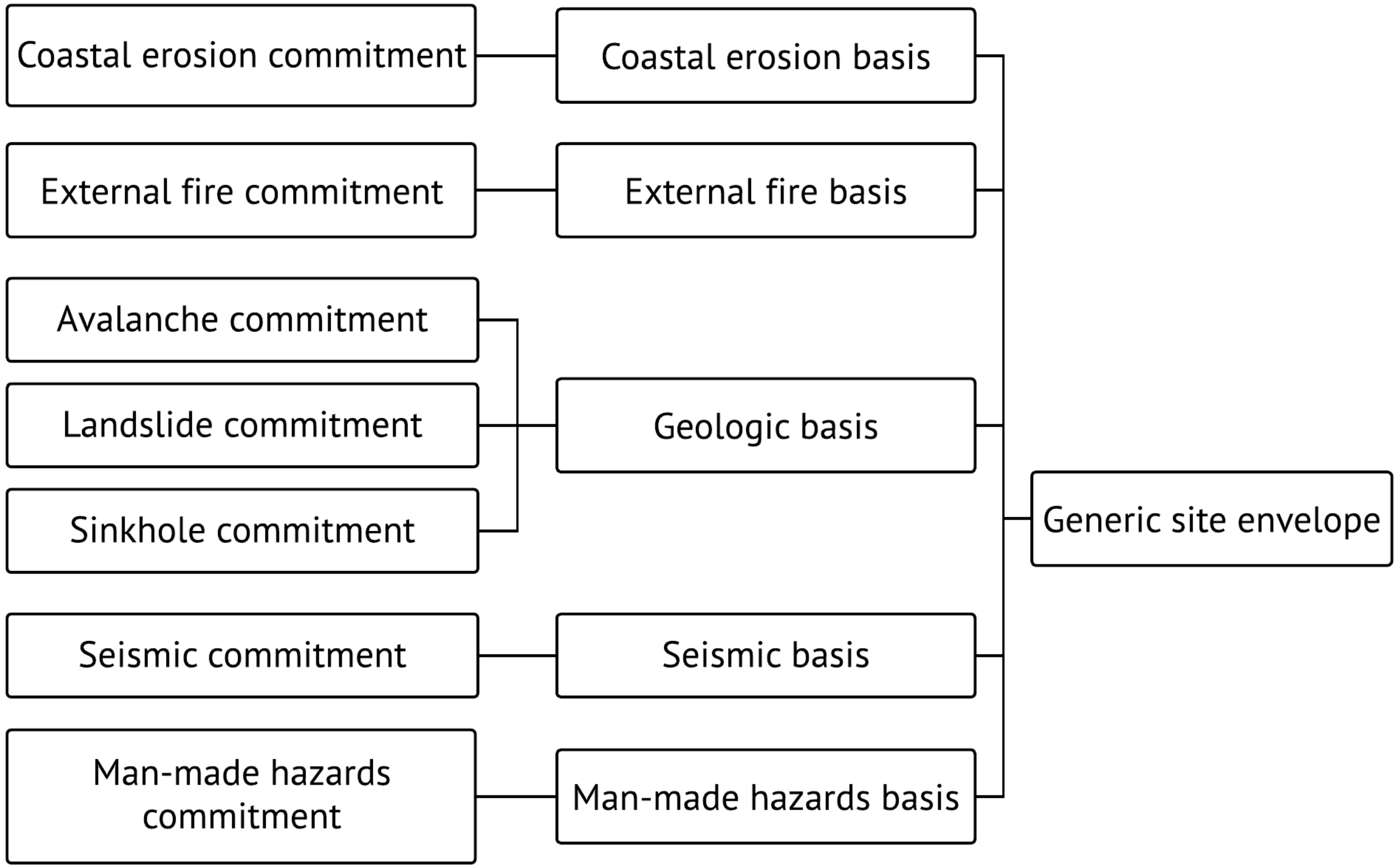
External hazards addressed with site commitments

- Avalanche
- Coastal erosion
- Forest fire
- Grass fire
- Landslide
- Sinkhole
- Seismic event
- Man-made blast hazard



Site characterization for the Aurora

Generic site envelope:
Site characteristics that could impact the safety case



Site commitment bases

Coastal site basis: The proposed site will not damage the Aurora reactor by coastal hazards.

External fire basis: The proposed site will not damage the Aurora facility due to an external fire.

Geologic basis: The proposed site will not damage the Aurora facility due to soil or topographic characteristics.

Man-made hazards basis: The proposed site will not damage the Aurora reactor by an explosion.

Seismic basis: The proposed site will not damage the Aurora reactor by a large ground acceleration.

Landslide site commitment example

Landslide commitment:
"Additional information will be provided on whether the proposed site is in a landslide-prone environment. If the proposed site is in a landslide-prone environment, further investigations are necessary to evaluate the potential landslide concerns."

Provide site specific information on:

- History of landslides within a 2-mile radius
- Information on slopes greater than 15 degrees with a 2-mile radius

Conclusion

- Flexible siting can be done for robust designs with minimal resource requirements
- Flexible siting allows minimizing disturbance of ecologically and culturally significant sites
- The regulatory focus for siting for the Aurora is on ensuring the safety of the facility and minimal impact to the environment


Thank you

Technological Innovations in Management of Transportation: Advances in Visual Sensing

Abhinav Gupta
Professor & Director of
Center for Nuclear Energy Facilities and Structures
Dept. of Civil, Construction, and Environmental Engineering
NC State University
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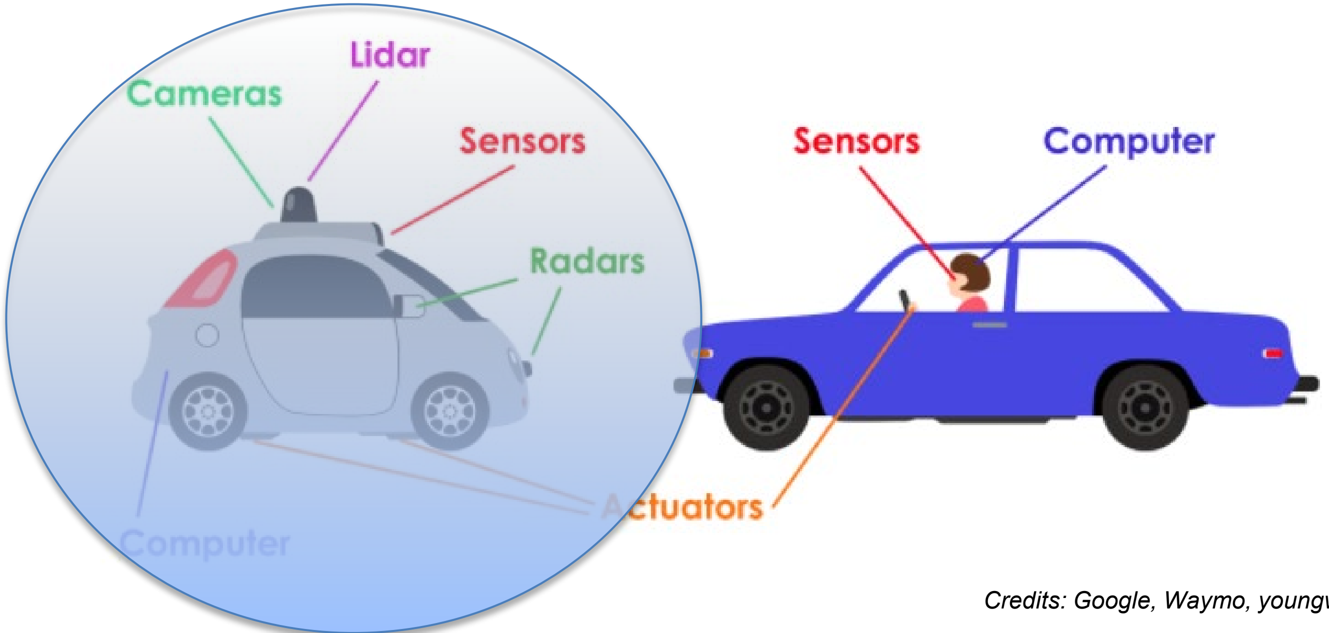
Emerging Importance of Visual Sensing

Self-driving Vehicles

- **360 degree LiDAR sensor**: Bird's eye view, mounted on top
- **Perimeter LiDAR sensor:** front and rear bumper, as well as on each side just above the front wheels.
- **Front-facing, long-range camera on the roof:** 360 vision system that can see 500 meters away.

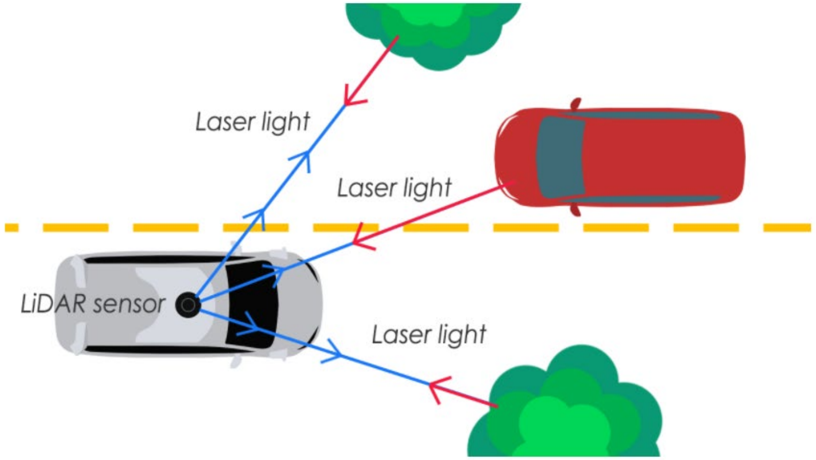


Credits: Google, Waymo, youngwonks.com

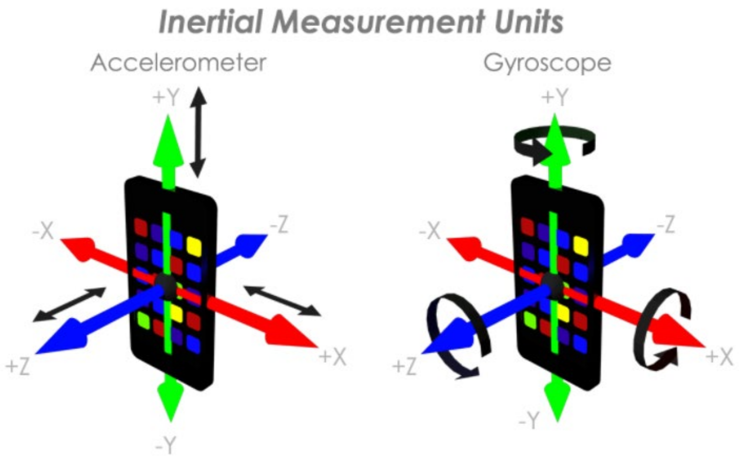
Important components of Visual Sensing

- **Cameras**

- **LiDAR:** Light Detection and Ranging



- **IMUs**



- **RADAR:** short for Radio Detection and Ranging
- **Ultrasonic and Thermal Sensors**

Credits: youngwonks.com

Transportation of Fission Batteries

Transportation loads (and not Natural Hazards) are likely to govern the design basis.

- Vibrations

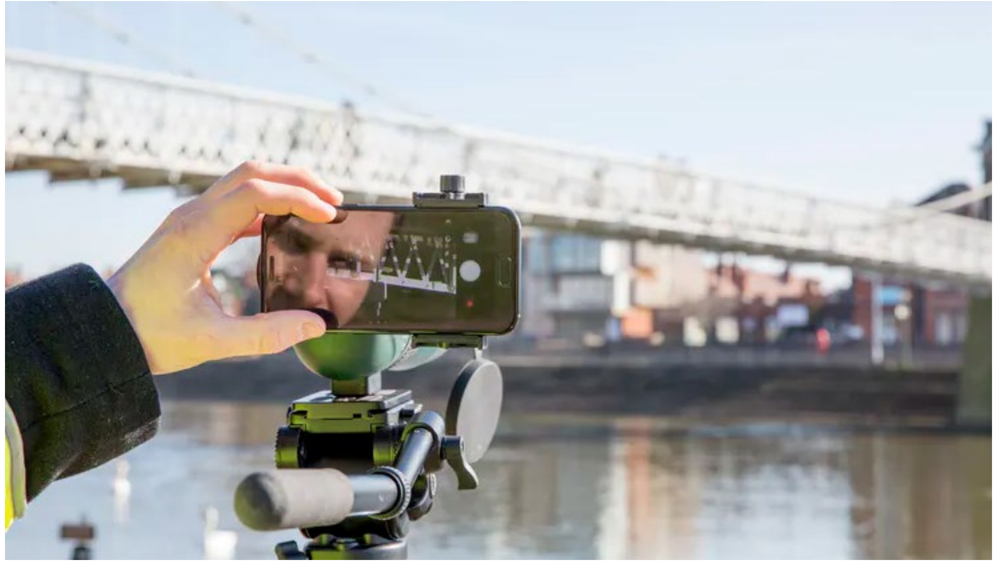
- Impact

Illustration: NuScale Power Module on a truck

Credits: cbc.ca

Visual Sensing for Transportation Loads

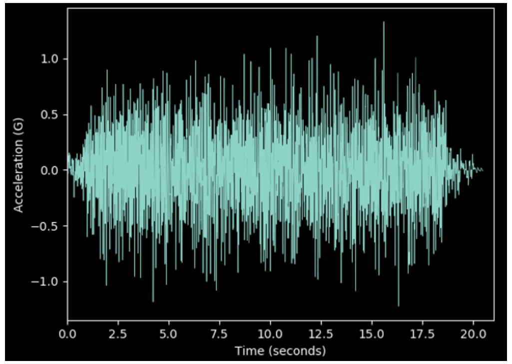
- Discrete Visual Sensing for analyzing Transportation Loads



- Visual Cameras: Extract sensor data

Thermal and High Speed Cameras

- Video Sensors: Extract acceleration data

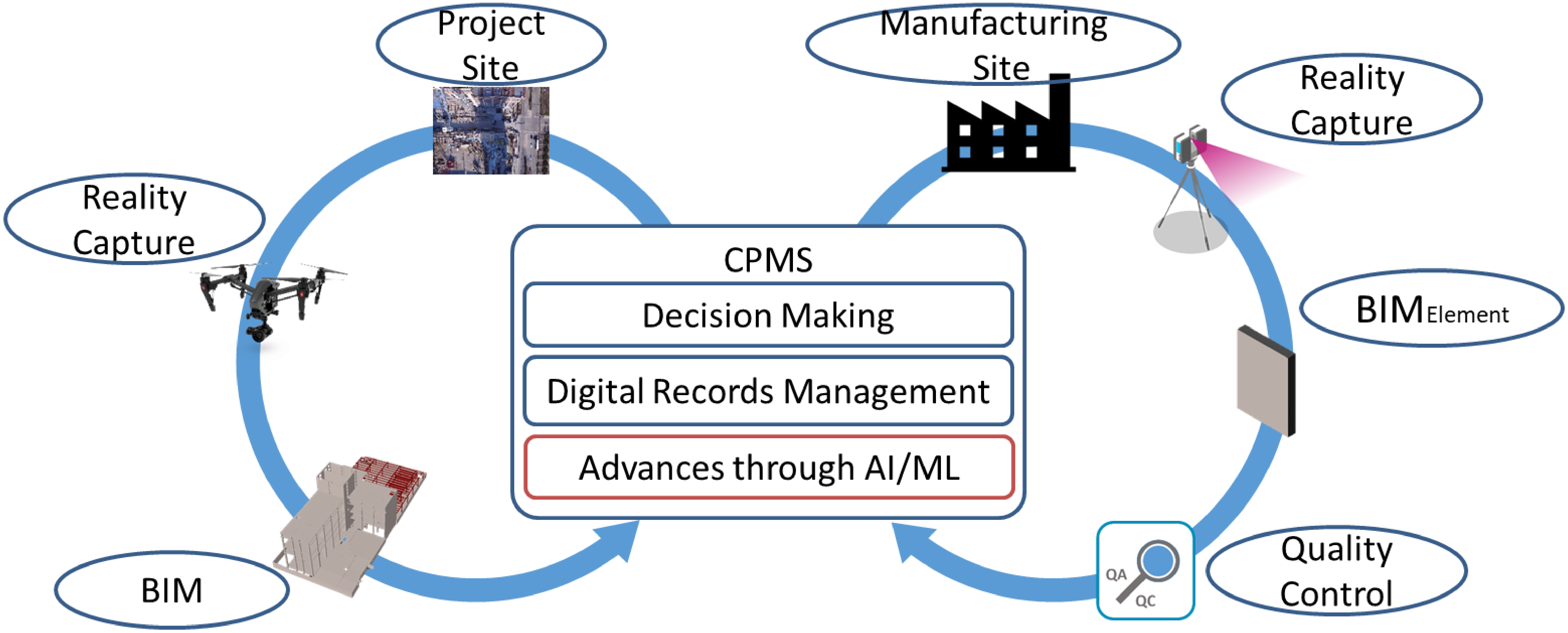


Visual Sensing: Multiple Cameras and Computer Vision

Preliminary study on monitoring of a suspension bridge using multiple camera positions using different cameras and fields of view

R. Kromanis and P. Kripakaran, "A multiple camera position approach for accurate displacement measurement using computer vision," Journal of Civil Structural Health Monitoring, Mar. 2021, doi: 10.1007/s13349-021-00473-0.

Visual Sensing in Construction Performance Assessment



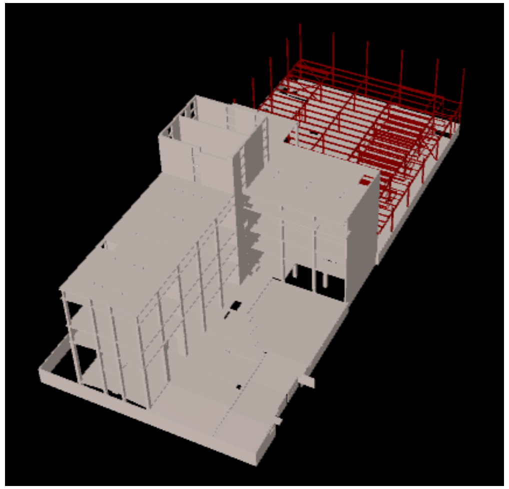
Augmented-Reality / Virtual-Reality Platform

- Visualize construction and manufacturing performance
  - Performance vs plan
- Support modular construction

Reality Capture (drone+laser scanner)

+

4D BIM



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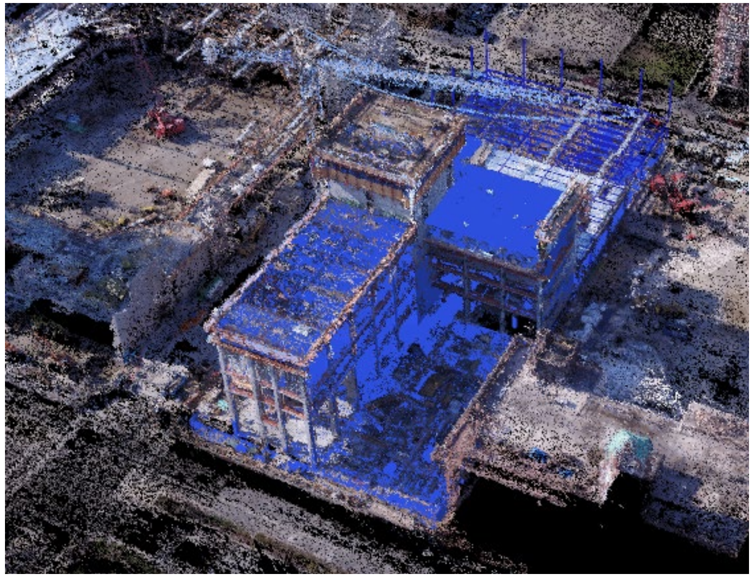
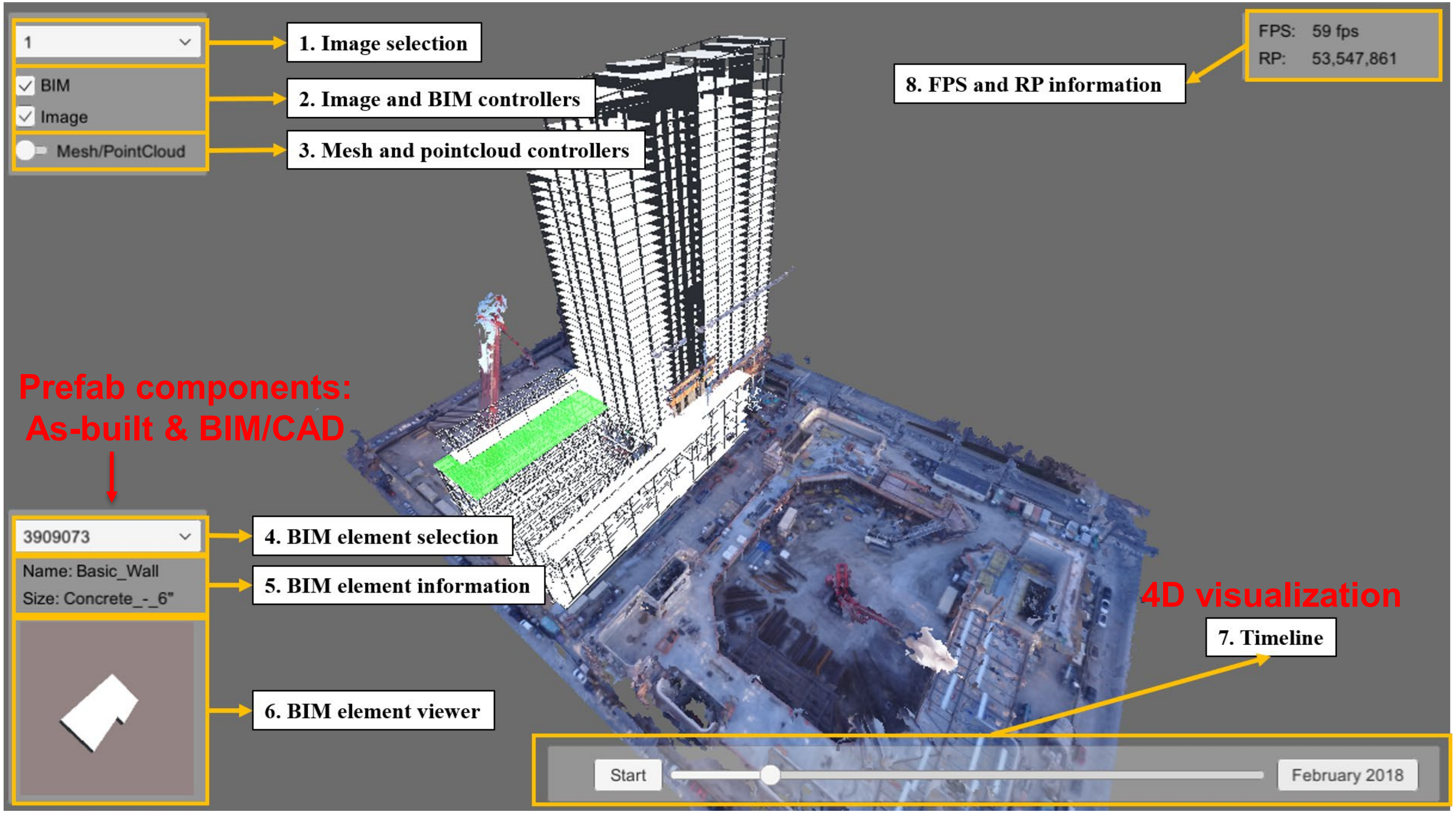
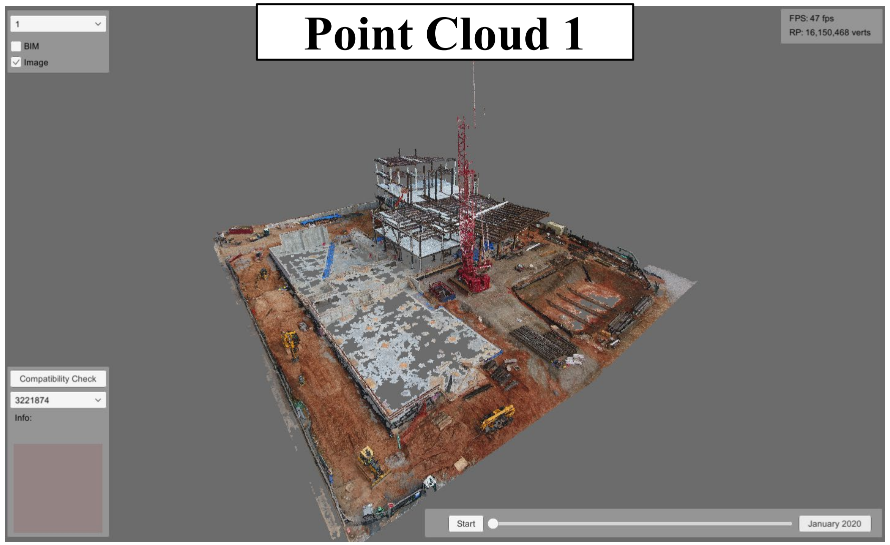
Integrated Project Site Model



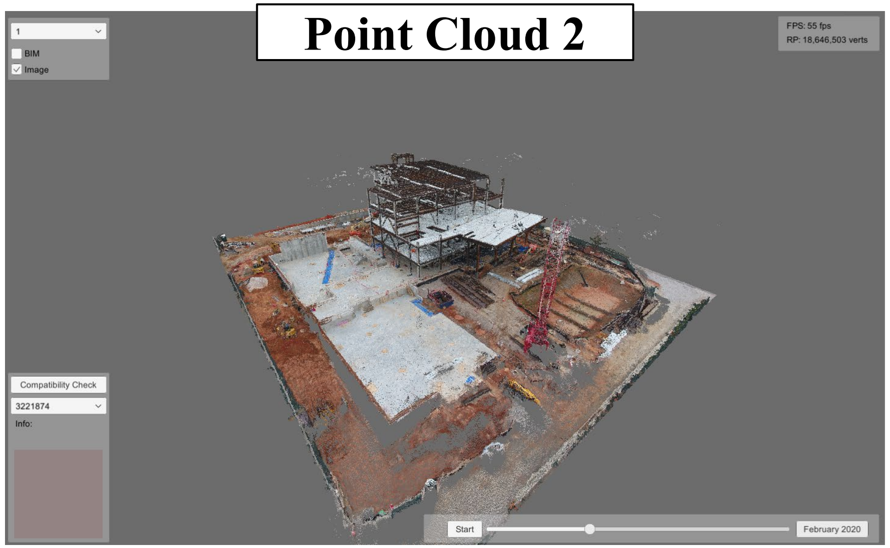
Prototype – Virtual Environment for Performance Monitoring



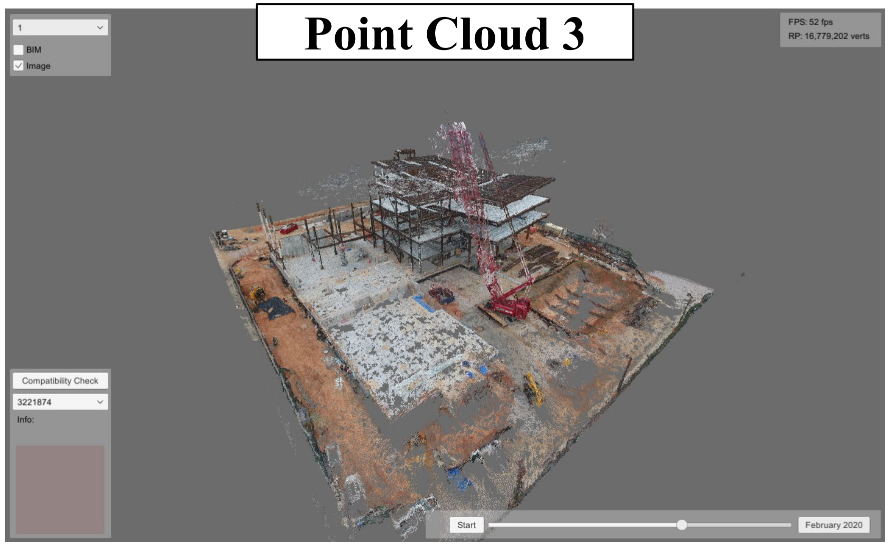
Prototype – 4D as-built model for capturing progress



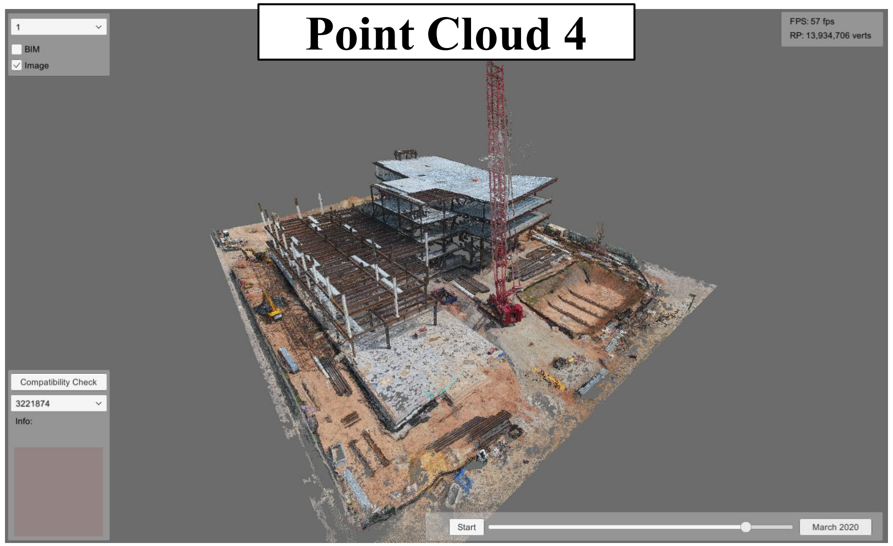
Point Cloud 1



Point Cloud 2

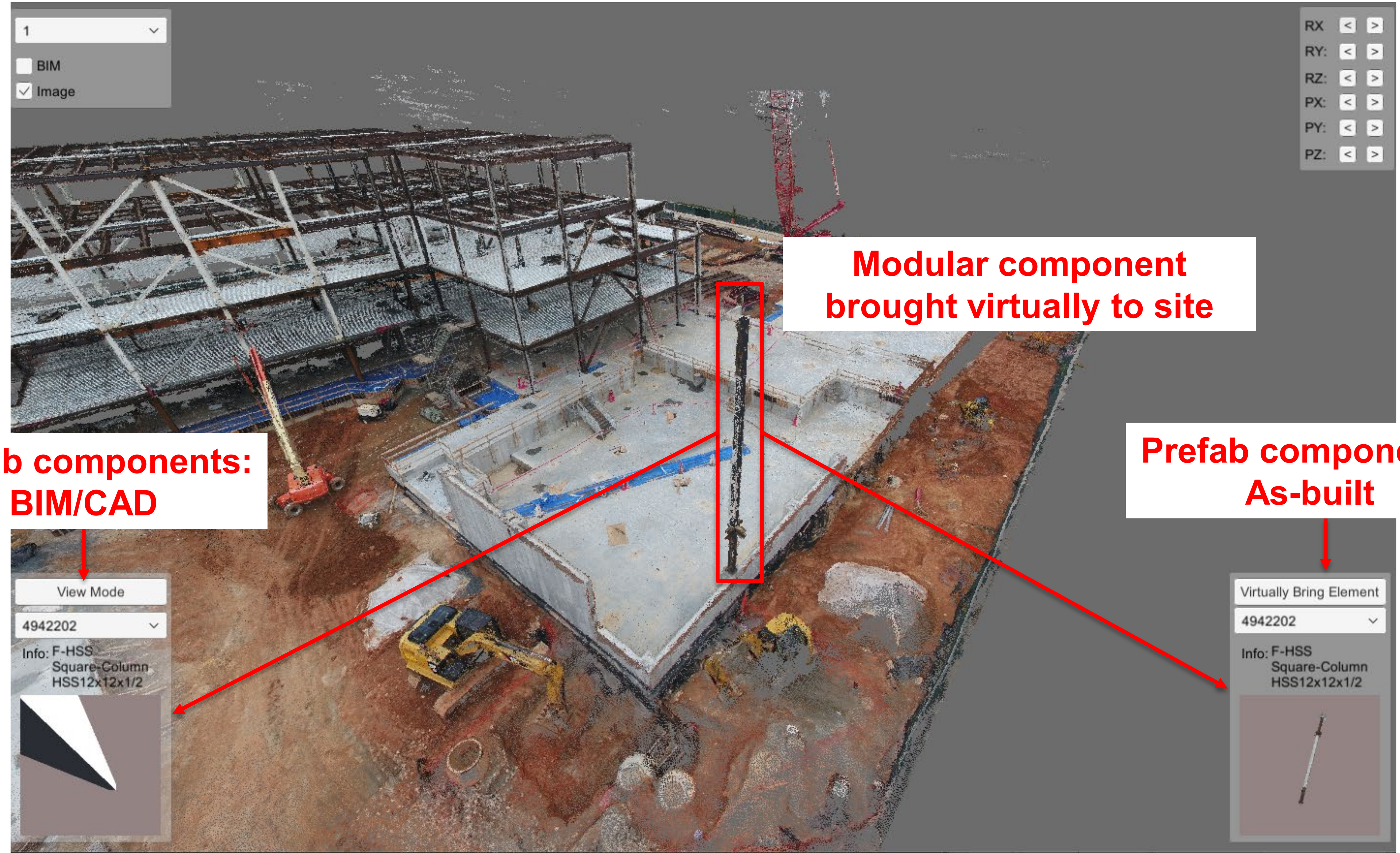


Point Cloud 3

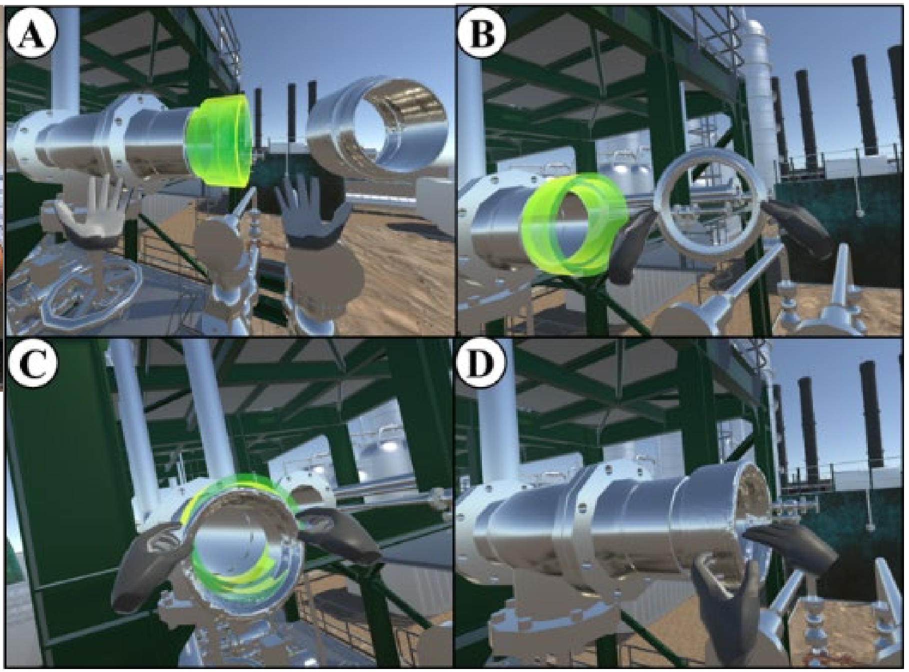


Point Cloud 4

Prototype – Virtually bring modular component to assess

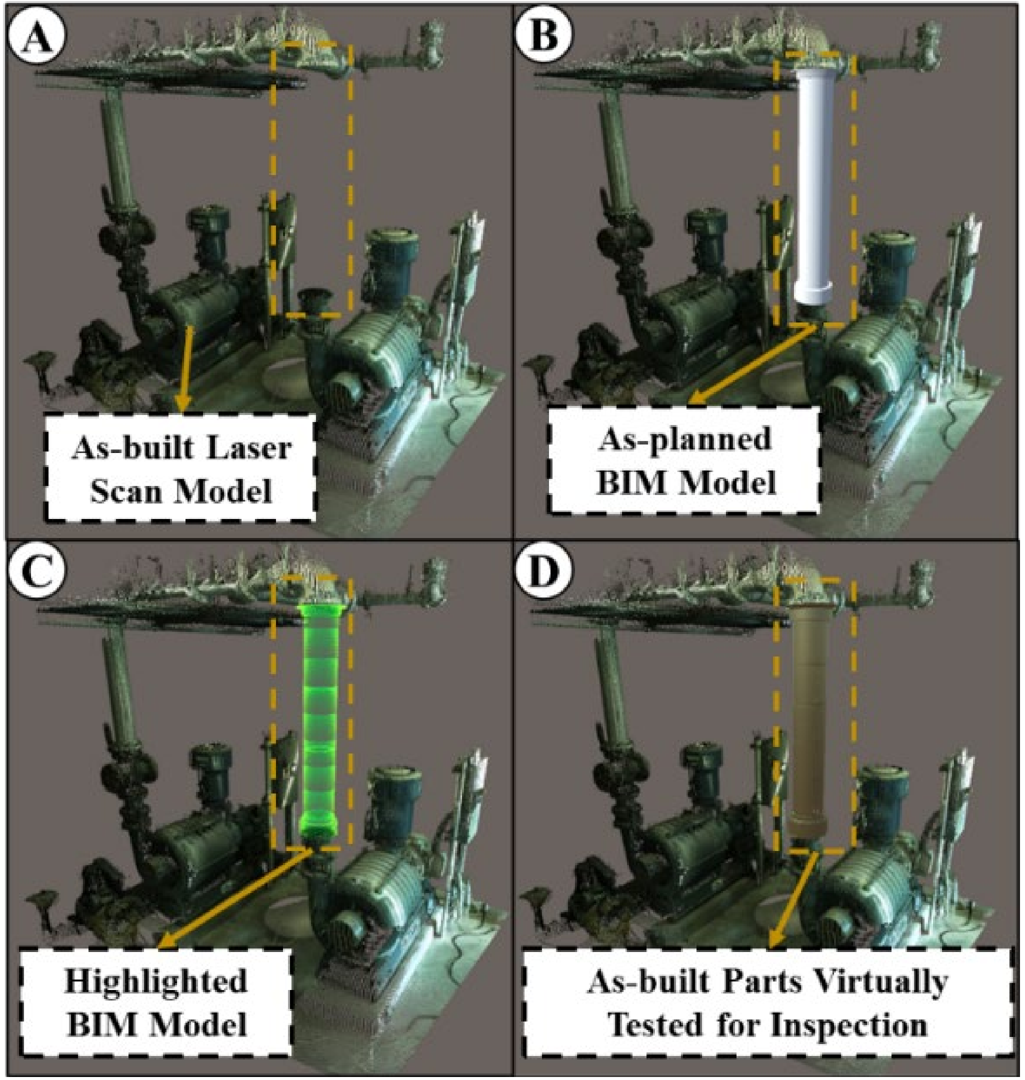


Virtual Reality for Managing QA/QC in Supply Chain



Manual Virtual Inspection

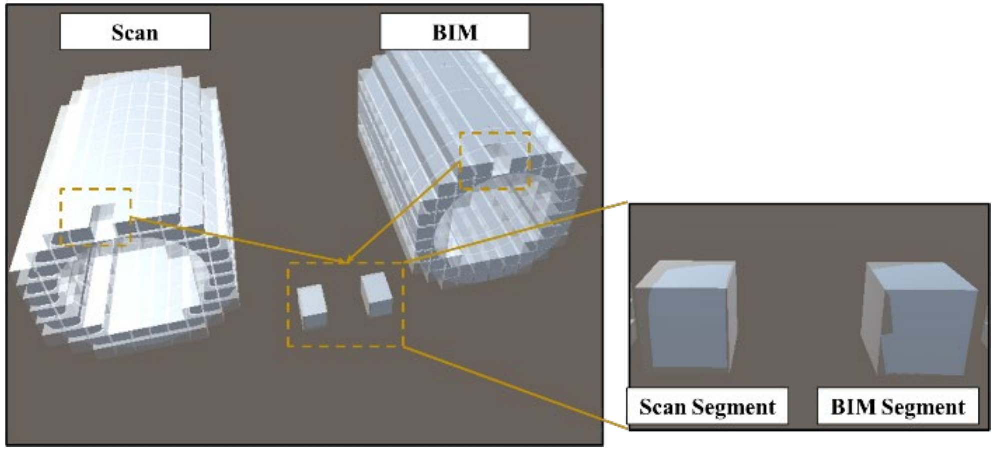
Automatic Virtual Inspection



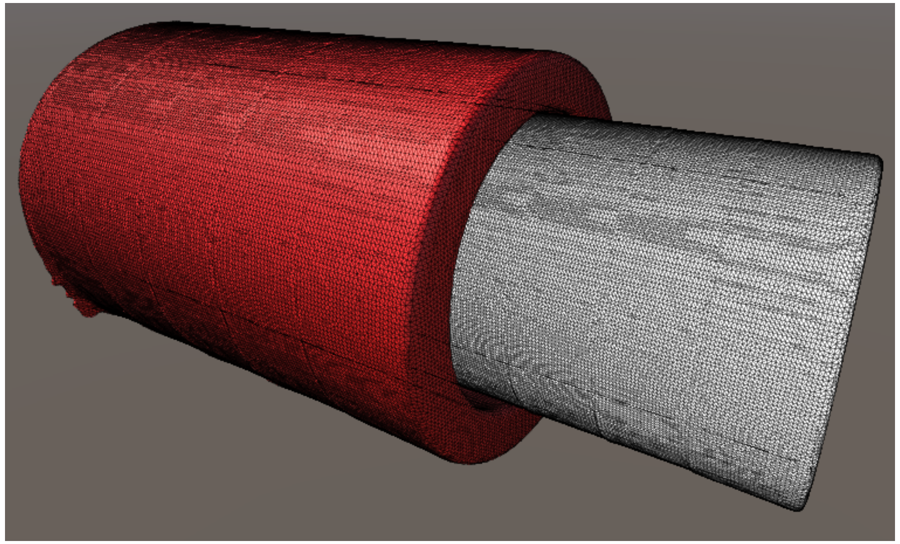
Compatibility check

- Compatibility check will present the percentage difference using a ratio

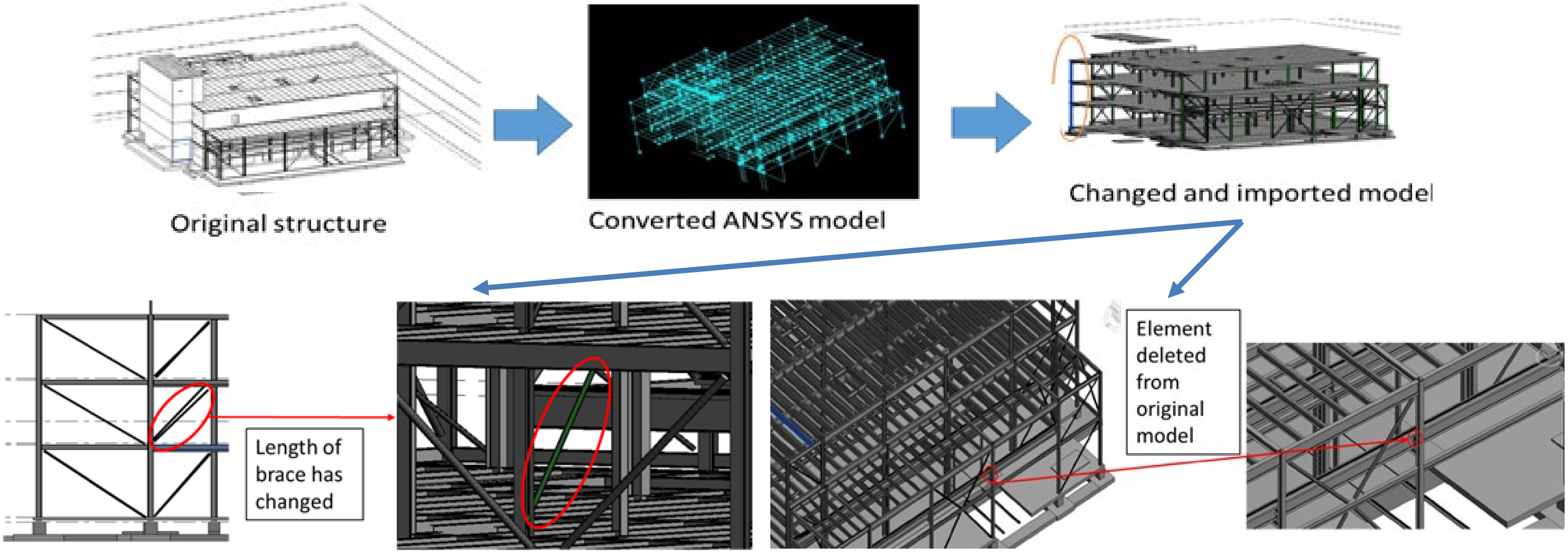
As-built to as-planned comparison



As-built to as-built comparison

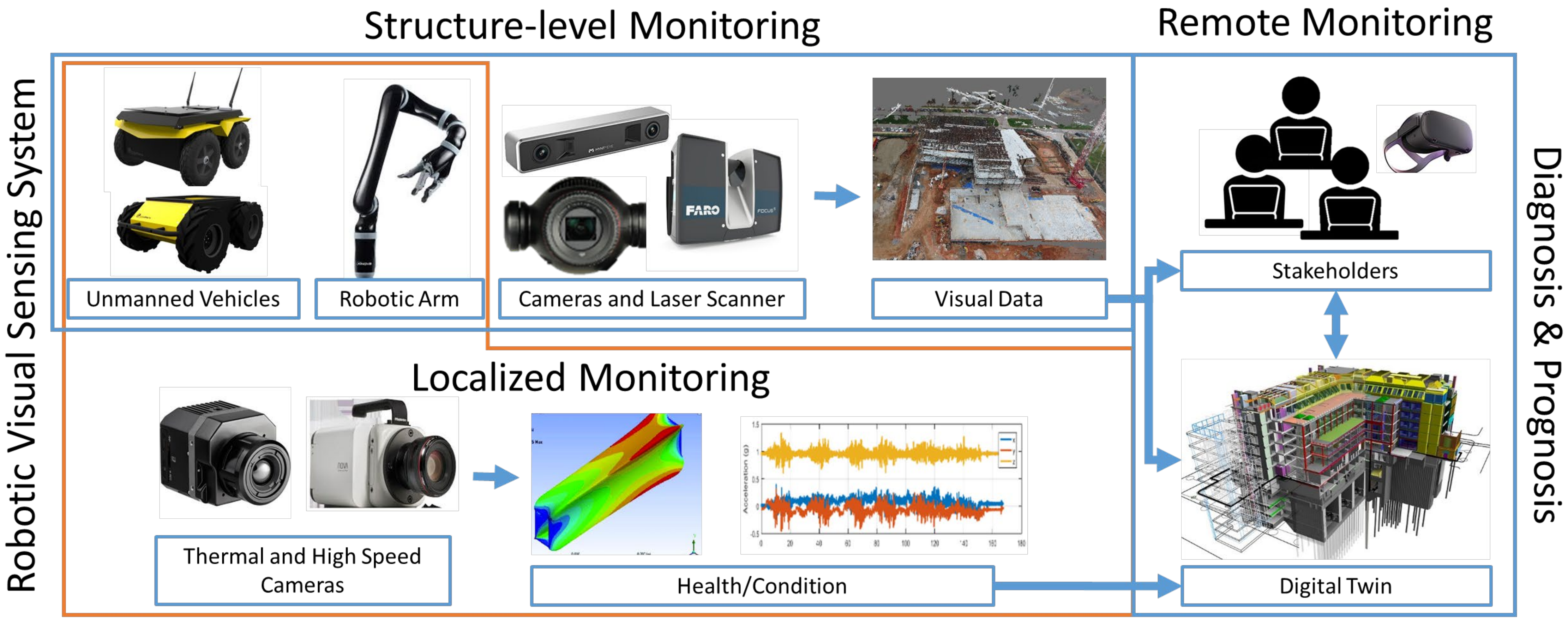


Interoperability of 3D BIM Models & Structural Models



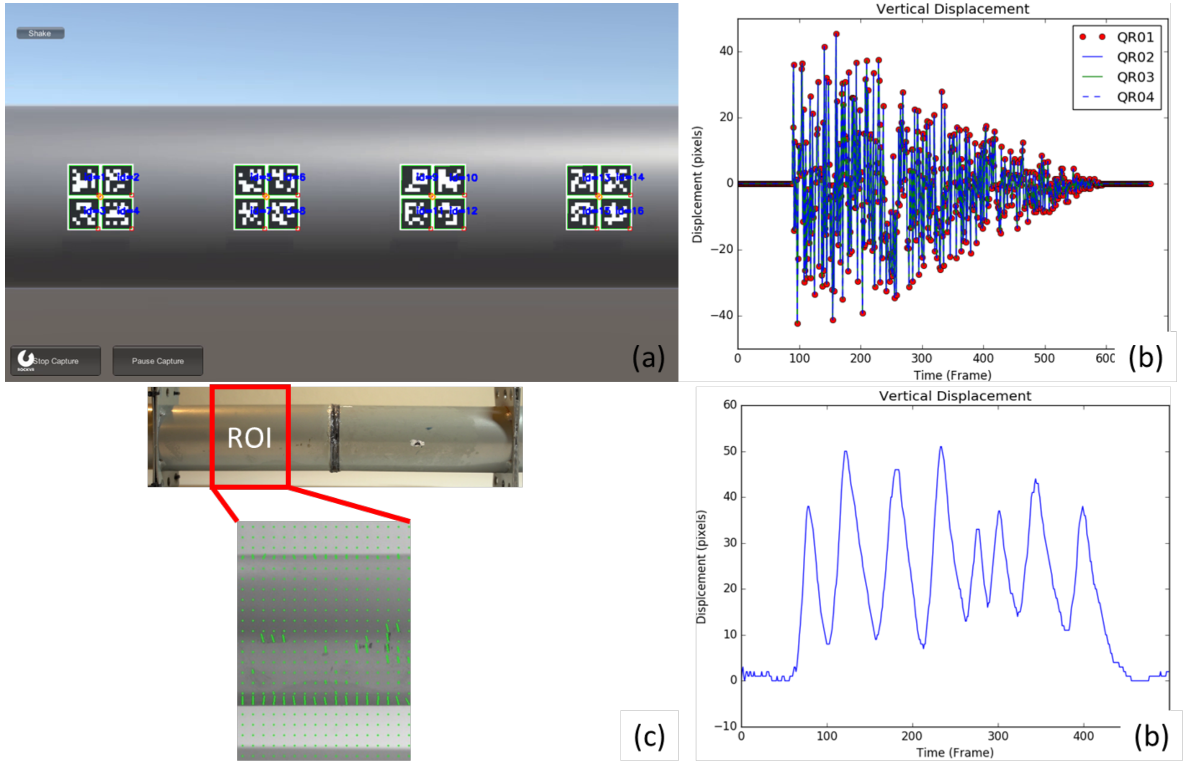
Visual Sensing for Transportation of Fission Battery

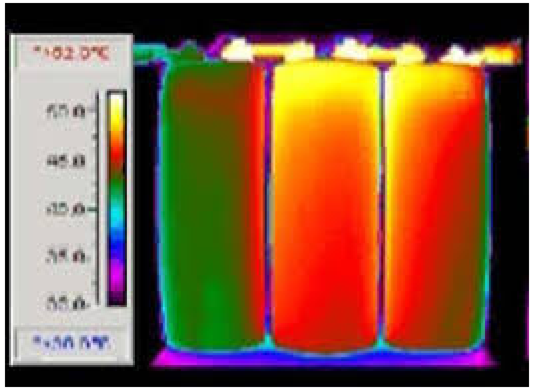
- Continuous monitoring during transportation using multi-sensory system & integration with "Construction" and "Design" models



Continuous Monitoring during Transportation

- Target-based (and also target-less for less accuracy) sensing for vibration
- Automated object recognition to detect any movement
  - Integrated sensing system (high-speed and thermal cameras and accelerometers)

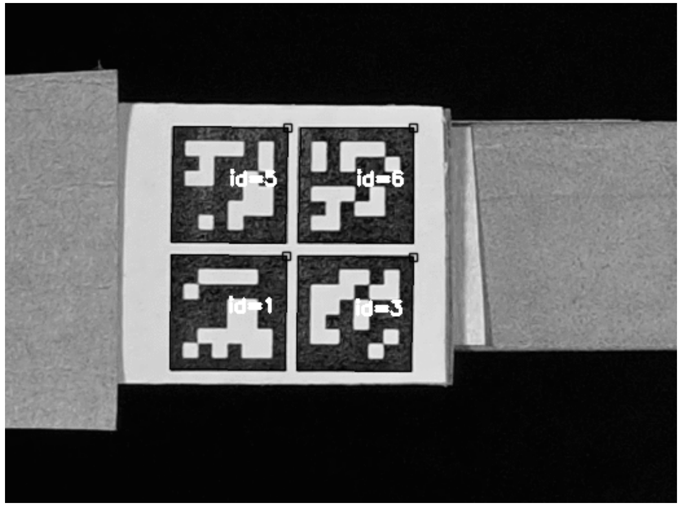




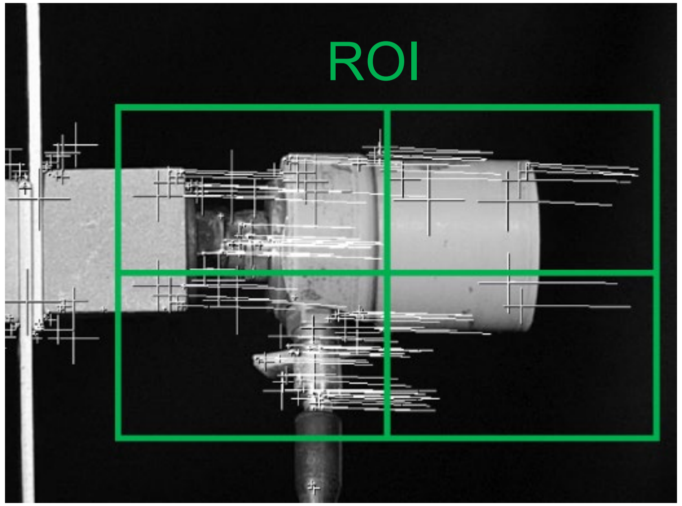
https://www.nrel.gov/docs/fy16osti/66960.pdf

Computer Vision based Vibration Measurement

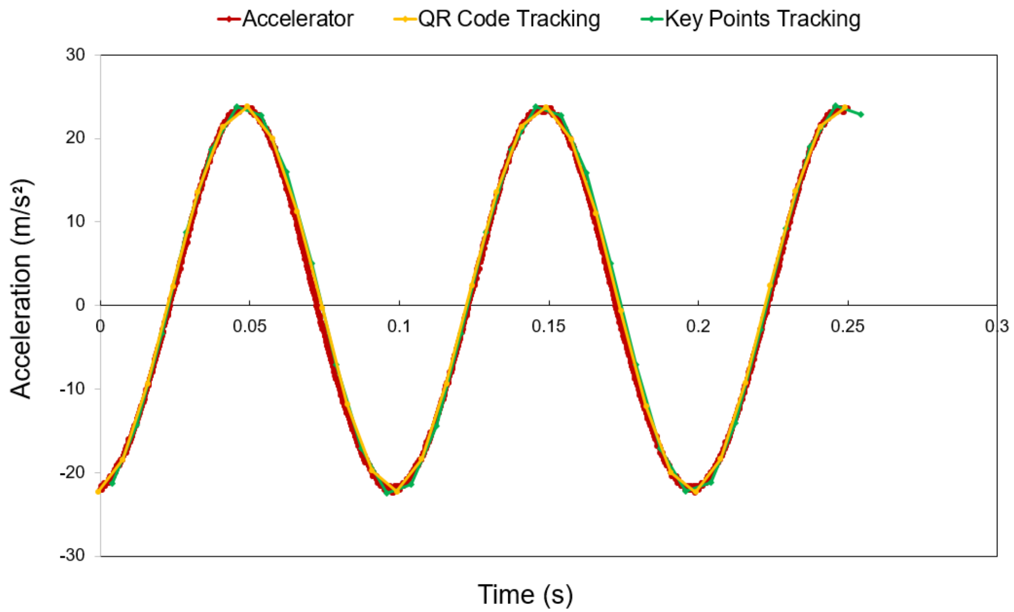
- Target-based (and also target-less) sensing for vibration
  - QR Code recognition and tracking
  - Key Points detection and tracking



QR Code Tracking



Key Points Tracking



Results Comparison

Questions?

Issues in Commercial Reactor

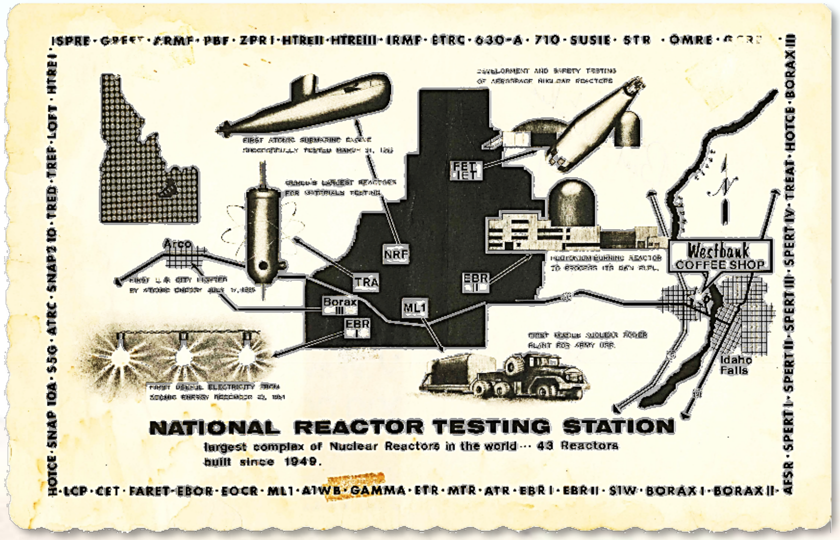
March 2021

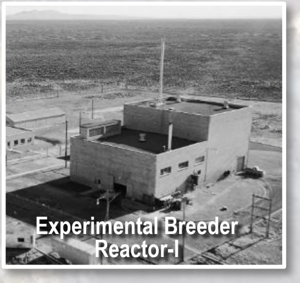
PRS/MIS-21-01066

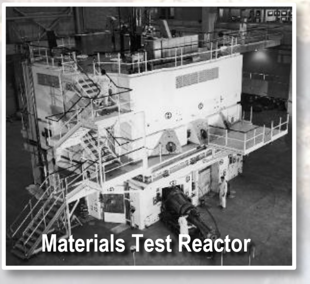
Idaho National Laboratory

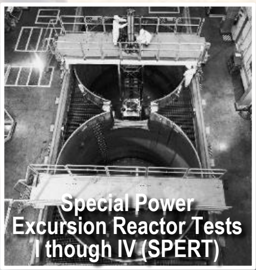
The National Reactor Testing Station drove nuclear innovation in the U.S. and around the world

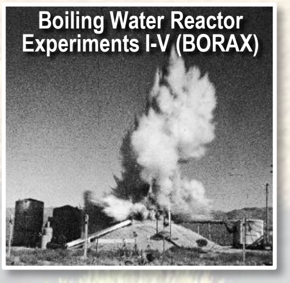
- First nuclear power plant
- First U.S. city to be powered by nuclear energy
- First submarine reactor tested; training of nearly 40,000 reactor operators until mid-90s
- First mobile nuclear power plant for the army
- Demonstration of self-sustaining fuel cycle
- Basis for LWR reactor safety
- Aircraft and aerospace reactor testing
- Materials testing reactors




Experimental Breeder Reactor-I


Materials Test Reactor


Special Power Excursion Reactor Tests I though IV (SPERT)


Boiling Water Reactor Experiments I-V (BORAX)


S1W (aka Submarine Thermal Reactor (STR)

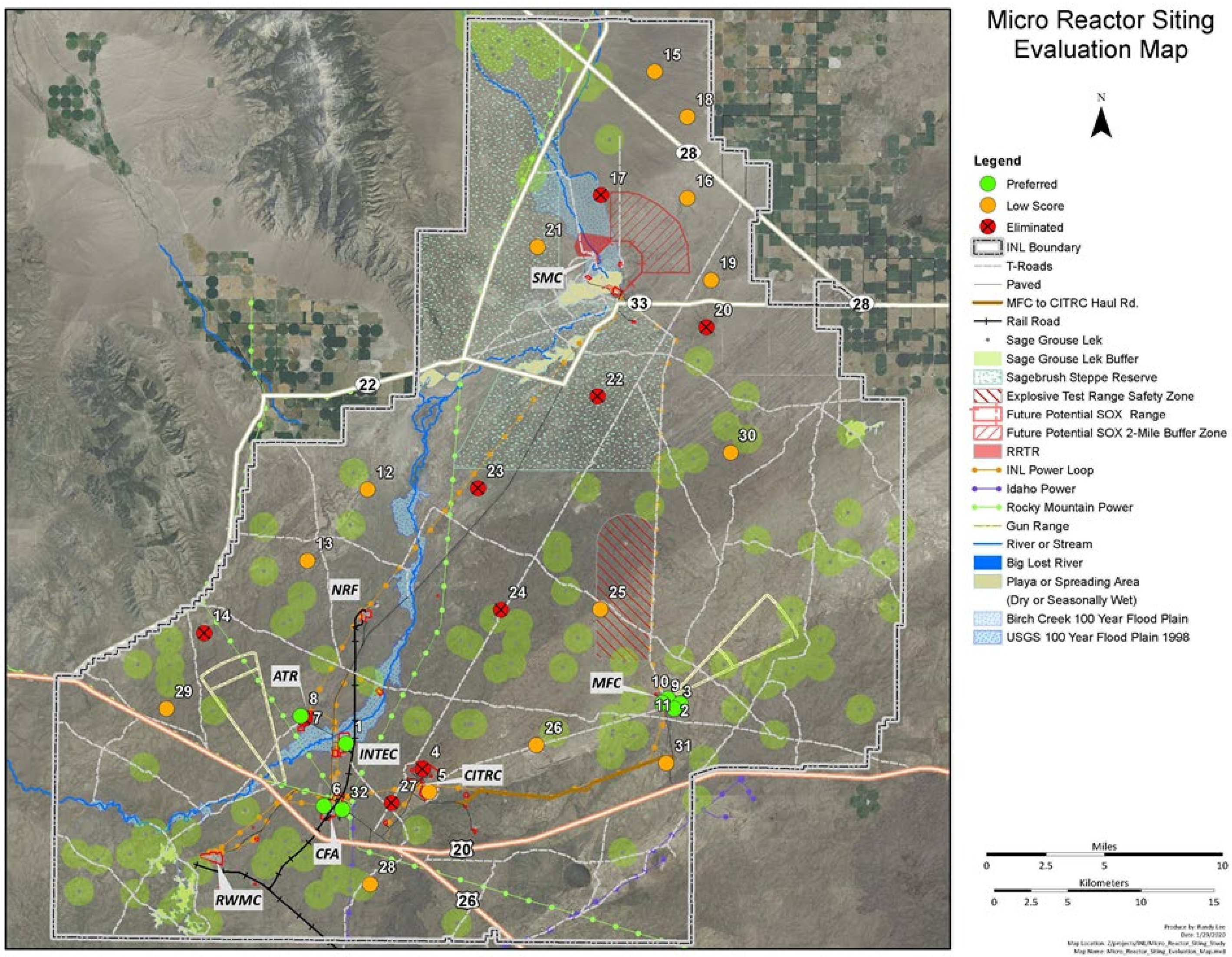

Loss Of Fluid Test Facility (LOFT)

Siting Process has been Established and Used

- INL and DOE have an established Site Use Permit.
  - A 99 year camping permit to access and develop a site
  - Provides separation of DOE and NRC regulation
  - Access to INL services as desired
- INL is the only DOE site to grant site use permits
  - NuScale (2017)
  - Oklo (2019)
- INL is developing the site to assist vendors

Candidate Sites

- Nine sites failed “Must” criteria
- Twenty-three sites evaluated by team of INL subject matter experts using “Want” criteria



Integration with INL Site

- INL is initiating a site wide NEPA analysis.
  - Supports NRC EIS submittals
- DOE is supporting multiple site upgrades
  - SSHAC Seismic Study started in 2019
    - 3 year/$10m Study to provide probabilistic seismic hazard assessment + multiple test bore holes ($1M/bore hole)
  - SSHAC Volcanic Study to start in 2021
    - 3 year/$10m Study to provide probabilistic volcanic hazard assessment
  - LIDAR Study of INL site and surrounding area
  - Flooding, volcanic, seismic and cultural information
- Supporting multiple commercial siting activities are planned or started
  - Services established
  - Unique local studies on-going
  - Meteorology studies
  - Volcanology to support draft NRC methodology
- Electrical Grid Upgrades
  - 345kV upgrades
  - Commercial grid access

Administrative Requirements

- U.S Ownership Section, 103d of the Atomic Energy Act of 1954, states that companies owning nuclear plants are required to be free of foreign influence. Effectively, this requires that owners of nuclear reactors be companies owned and controlled domestically.
- Regulations found in 10 CFR 50.33(f) demand that the owner demonstrate sufficient funds or access to the funding necessary to complete activities that support the license. The funding should demonstrate the capability to support each stage of reactor operation, including funding for licensing, construction, operation, and decommissioning will be needed.

Project Information

The required information includes:

- The power level of the reactor
- The inventory of required and generated radioactive materials
- A list of accepted engineering standards used to design the reactor
- A list of reactor features that affect the potential and magnitude of radioactive material released from the reactor in an accident
- A list of safety features and barriers, included in the reactor design, that limit the potential release of radioactive material
- A description of the local population distribution and how it intersects with necessary exclusion areas
- A list of man-made hazards that may affect the plant
- A description of the site's relevant seismology, meteorology, geology and hydrology
- A description of the local environment, including historic and current cultural features
- the environmental-effects analysis needs to eventually support an NRC NEPA decision.

Preferred Site Characteristics

- The 2011 NRC Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations," Per NRC guidance, an acceptable site must have or, in some cases, would be favorably viewed for having attributes, including:
- Located more than 10 miles from an airport [NUREG-0800 3.5.1.6]
- Located in an area of less than 0.5 G peak ground acceleration [NUREG/CR-4482]
- Located more than 5 miles from surface faults and capable tectonic structures [Appendix A to 10 CFR100, "Seismic and Geologic Siting Criteria for Nuclear Power Plants"]
- Located away from population centers of more than 25,000 people [Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," revision 3 (1978), Section 2.1.3.5]
- Located more than 5 miles from a hazardous site [NUREG-0800, Section 13.6.1 and 13.6.3]
- Located more than 1 mile from any commercial rail line [10 CFR 100.21(a), NRC, Reg Guide 1.91]
- Located outside a wetland area [NUREG-1555 and Reg Guide 4.11]
- Located outside of a 100-year floodplain [Reg Guide 1.59 and Reg Guide 1.206]
- Meets minimum reactor design requirements [NUREG-0800].

Additional Requirements

Environmental Standard Review Plan

- The NRC environmental review is guided by the ESRP, as described in NUREG-1555.The ESRP specifies methods used to review environmental impacts, provide details on required analyses, and indicate a way to describe significance of environmental impacts.

NRC NEPA Requirements

- The NRC assesses environmental impacts of licensing decisions to satisfy federal NEPA requirements. An environmental assessment (EA) is a lower level of assessment that can be used when environmental impacts are relatively low. Categorical exclusions can be used when no significant effect is anticipated from a decision [10 CFR 51.22]. An EA is a more-detailed review that can result in a **finding of no significant impact when the impacts are evaluated to be insignificant [10 CFR 51.30] The highest level of review results in an EIS, followed by a formal record of decision [10 CFR 51.102].**
- **The NRC reviews the nuclear plant-deployment impacts on, at minimum, the direct environment, air quality, geology, water, ecology, human environment, cultural and historic resources, economics, logistics, waste processes, visual effects, and environmental justice. Evaluation of other deployment options are also considered.**

Additional Coordination

- Beyond the NRC environmental requirements, the licensing can be evaluated against the National Historic Preservation Act, the Endangered Species Act, the Magnuson-Stevens Act, and additional federal regulations. The consultations add information to the EA or EIS.
- National Historic Preservation Act consultation involves working with local and state historic preservation offices, tribal preservation offices, and other federal and local offices.
- Endangered Species Act consultation occurs with the Fish and Wildlife Service and the Fisheries Service on critical habitats and endangered species that might be affected. Magnuson–Stevens Act consultation centers on potential effects on fish habitats.

Radiological Emergency-Response Plan

- An emergency-response plan will be required as part of NRC licensing. Even extremely safe plants need an established emergency plan that describes how a nuclear power plant’s emergency response will be performed. Events that trigger emergency response can be natural or man-made. Plants with unique capabilities have the potential to require new evaluation methods and planning.

External Hazards

- Basic environmental hazards are seismic, weather, volcanology, and flooding. Each hazard has an evaluation process specified in the standard review plan [NUREG-0800].

- **Seismic Analysis**

The NRC-required probabilistic seismic-hazard analysis (PSHA) evaluation is performed using an NRC recommended Senior Seismic Hazard Analysis Committee (SSHAC) analysis. [NUREG-2117, "Practical Implementation. Guidelines for SSHAC Level 3 and 4 Hazard Studies," Revision 1].

- **Volcanology**

Methods for analysis of volcanology hazards are being revised by the NRC (DRAFT Reg Guide DG-4028). A proposed analysis method based on the SSHAC process is publicly available and being established as the standard process. The probabilistic volcanic-hazard analysis (PVHA) will require detailed surface topology and understanding the historic volcanic behavior.

- **Weather**

To evaluate the effects of weather, all atmospheric conditions at the site are evaluated. High winds, tornadoes, hurricanes, and snow are all evaluated (Reg Guide 1.23]. The evaluation of the risk from weather events is largely based on historic weather conditions.

- **Flooding**

The effects of flooding are calculated based on previous conditions and the worst potential conditions. Local topology and historic events are used to evaluate the risk from flooding. Hurricanes, storms, dam breaks, ice dams, and tsunamis are all evaluated, as necessary.

- **Man-Made Hazards**

The reactor design should account for local man-made hazards that can affect the site.

ADDITIONAL NON-SAFETY STUDIES

- Electric Grid Commercial access into the correct market
- Ultimate Heat Sink access to water heat sink, air cooling or other thermal sinks

March 15, 2021
Virtual Format

Panel Discussion

Fission Battery – Siting and Transportation

Moderator: C. Bolisetti

Idaho National Laboratory

Overview

- Introduction of the speakers (5 mins):
  - Alan Wells (Private Consultant)
  - Emma Redfoot (Oklo)
  - Bernie White (U.S. NRC)
  - George Griffith (INL)
- Moderator: Chandu Bolisetti (INL)
- Format: Six questions (8-10 mins each)
- Q&A session from the audience (15 mins)

Question #1

What are the regulatory challenges that need to be addressed for fission battery transportation?

Question #2

What are the technical challenges that need to be addressed for fission battery transportation?

Question #3

What are the regulatory challenges for fission battery flexible siting?

Question #4

What are the technical challenges for fission battery flexible siting?

Question #5

What role can INL and NUC play in making fission batteries a reality?

Question #6

What are your key takeaways from this workshop?

Q&A Session – 15 Minutes

Questions from the audience