Tools and Processes for Robotic Outfitting of Buildings Terrestrial And Space Construction Examples

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NATIONAL RENEWABLE ENERGY LABORATORY

Overview

Terrestrial Vs Extraterrestrial Construction

Multi System Assemblies

Traditional Construction

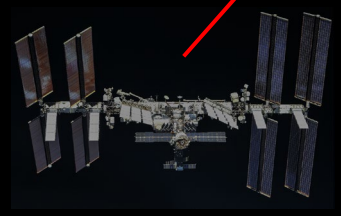
Systems Integration

NREL ICI – Robotics for Systems Integration

Terrestrial Vs Extraterrestrial Construction

Building on extra-terrestrial bodies

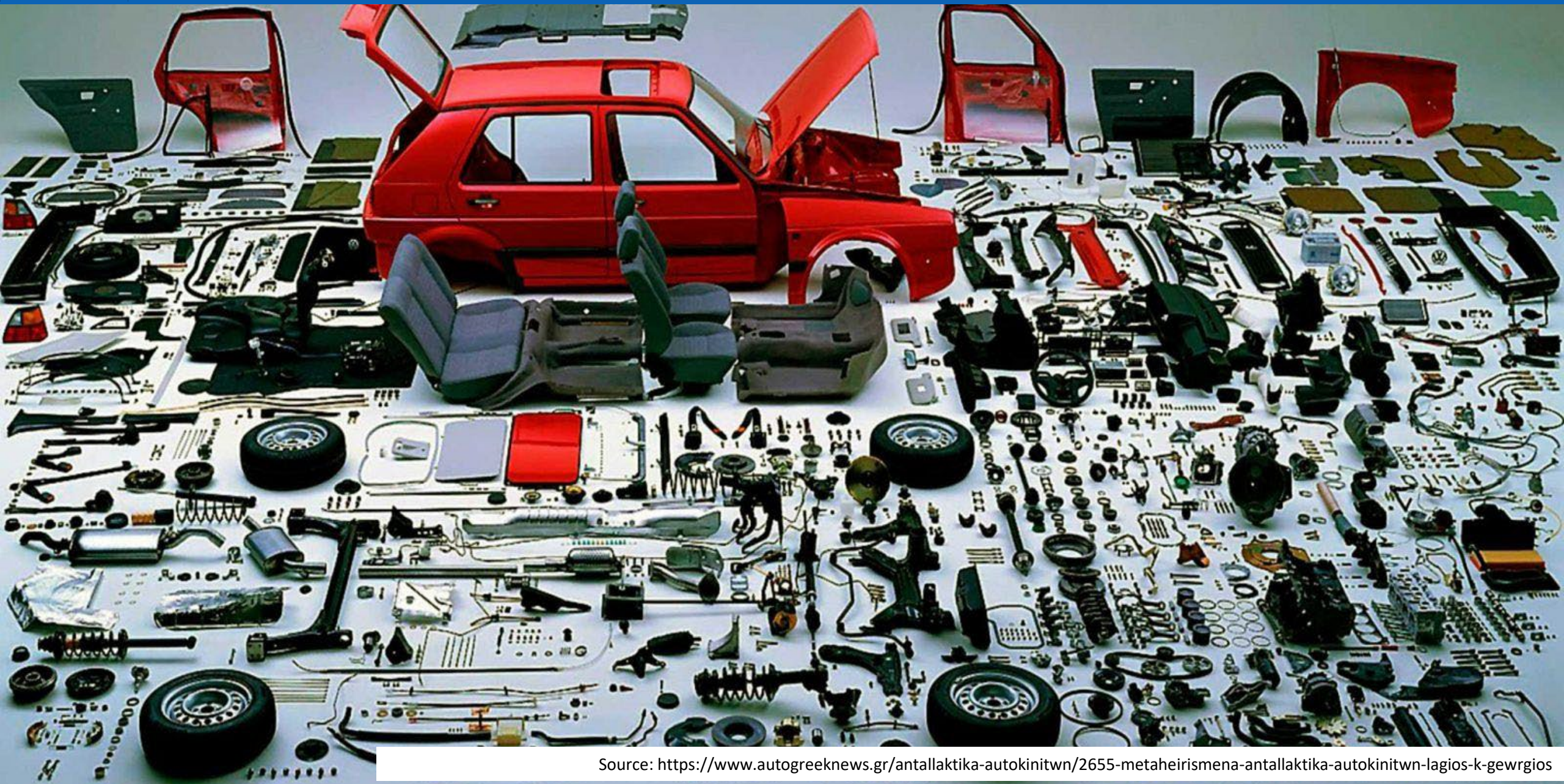
a system of systems that are functional
-structurally stable
-energy efficient
-thermally efficient
-habitable**
-remotely constructable
-easily deployable
-remotely controllable



Building in orbital space
a system of systems that are functional
-structurally stable
-energy efficient
-thermally efficient
-habitable**
-easily deployable (or assembly)
-remotely controllable

Building on Earth
a system of systems that are functional
-structurally stable
-energy efficient
-thermally efficient
-habitable**
-rapidly constructable

Multi System Assemblies

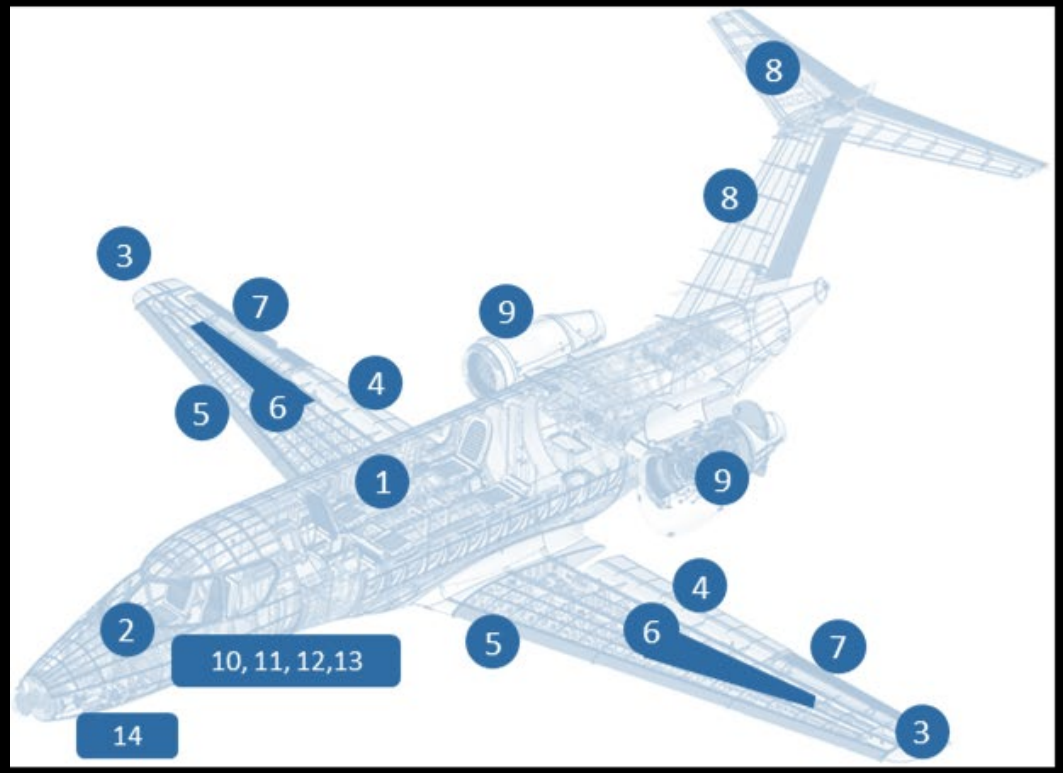


Source: https://www.autogreeknews.gr/antallaktika-autokinitwn/2655-metaheirismena-antallaktika-autokinitwn-lagios-k-gewrgios

Multi System Assemblies

Source: https://imageio.forbes.com/specials-images/imageserve/6123fd7c33703c8ccc0e9ba6/Automotive-production-line--Welding-car-body--Modern-car-Assembly-plant/960x0.jpg?format=jpg&width=960

Multi System Assemblies



STRUCTURES

1. Fuselage
2. Cockpit

AVIONICS

3. Winglet
4. Flaps
5. Slats
6. Spoiler
7. Aileron
8. Stabilizers

MECHANICAL

13. Landing Gear
14. Wheels

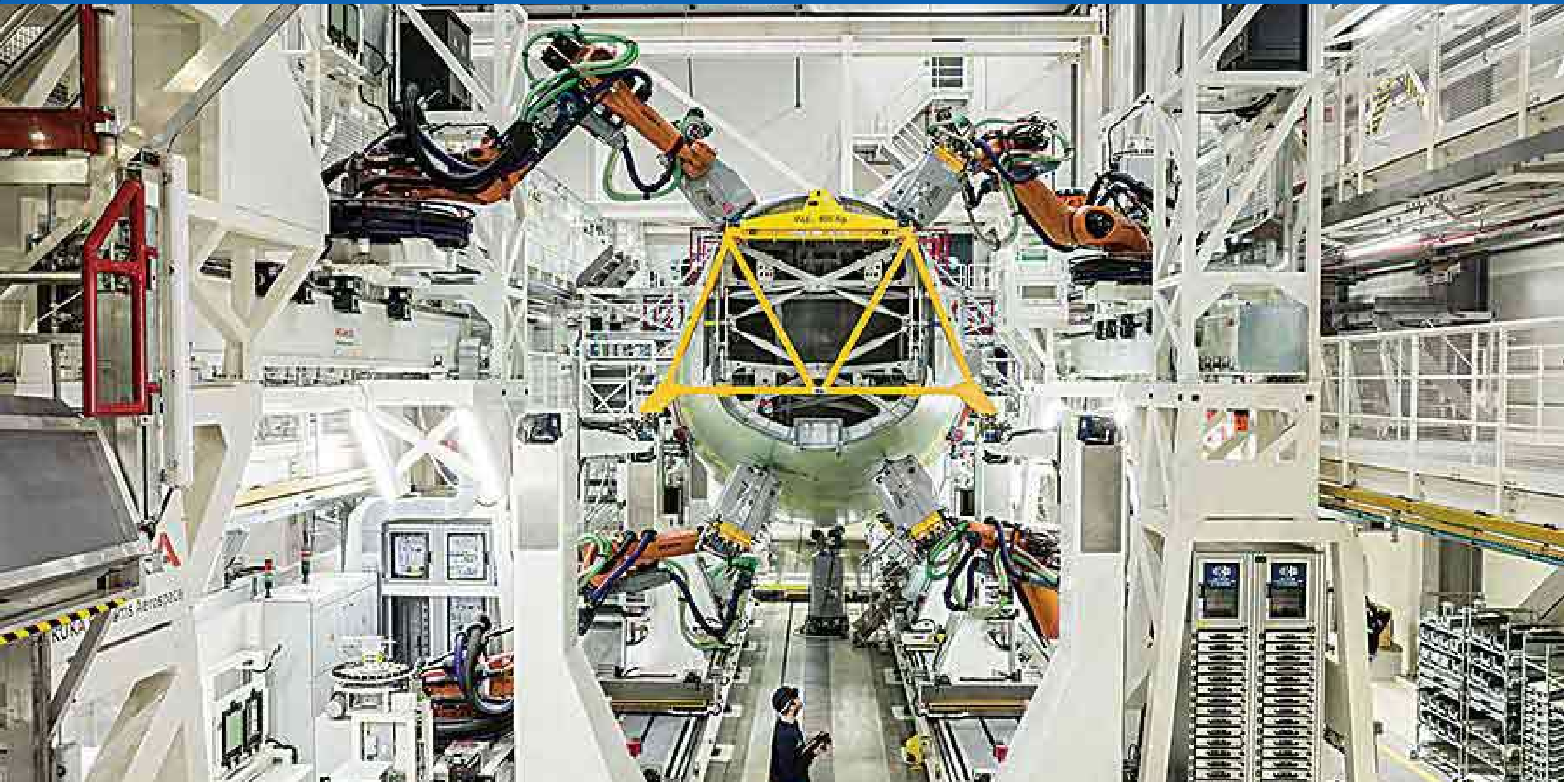
CONTROL SYSTEMS

10. Flap Control System
11. Aileron Control System
12. Spoiler Control System

ENGINES

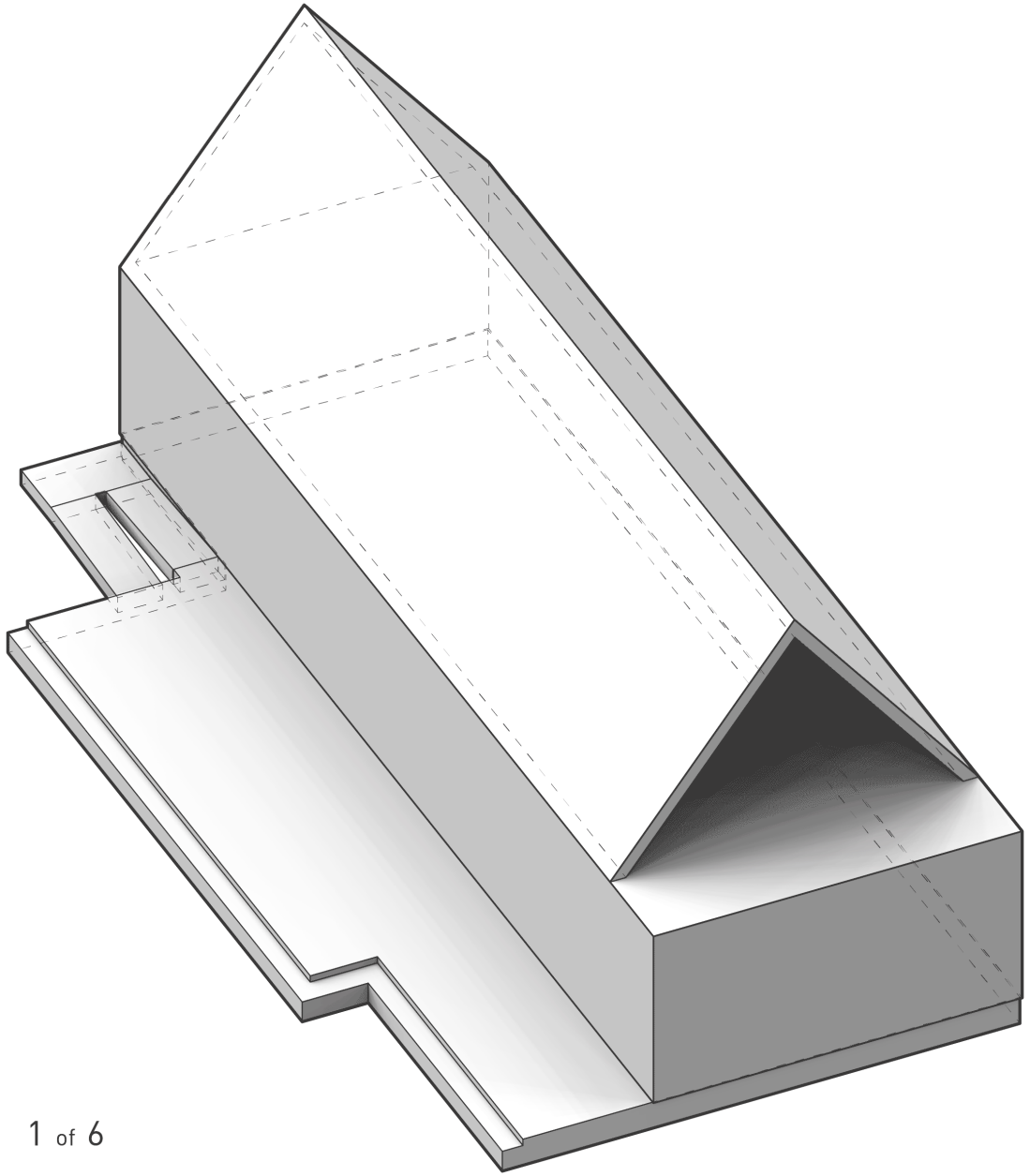
9. Turbine

Multi System Assemblies



Source: https://www.sme.org/smemedia/industry-reports/aerospace-and-defense-manufacturing-industry-report/aerospace-defense-2020/

Multi System Assemblies



1 of 6

~100+
Components

Multi System Assemblies

MECHANICAL

12. Boiler Plant
11. Chiller Plant
10. Air valves
9. Ducts

ELECTRICAL

16. Main board
15. Power supply
14. Conduits
13. Artificial Lighting

PLUMBING

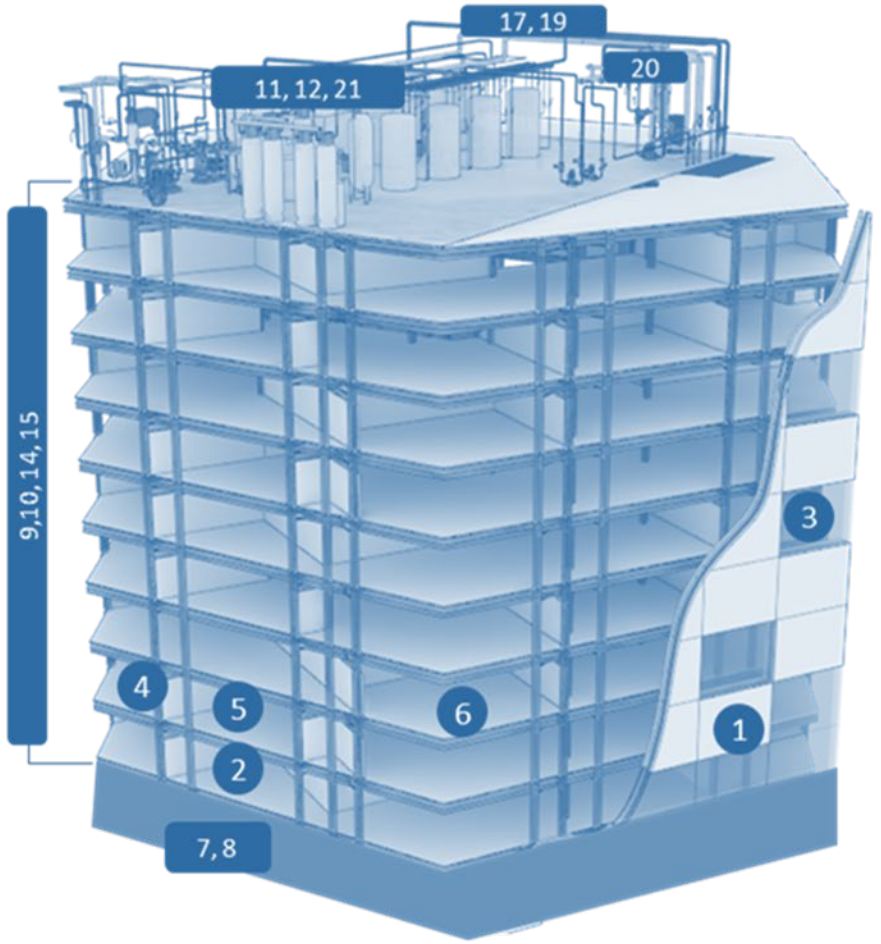
21. Water storage tank
20. Water supply pipes
19. Grey water return pipes
17. Drainpipes

STRUCTURAL

8. Footing
7. Foundation
6. Slabs
5. Beams
4. Columns

ARCHITECTURAL

3. Windows
2. Interior walls
1. Envelope assembly



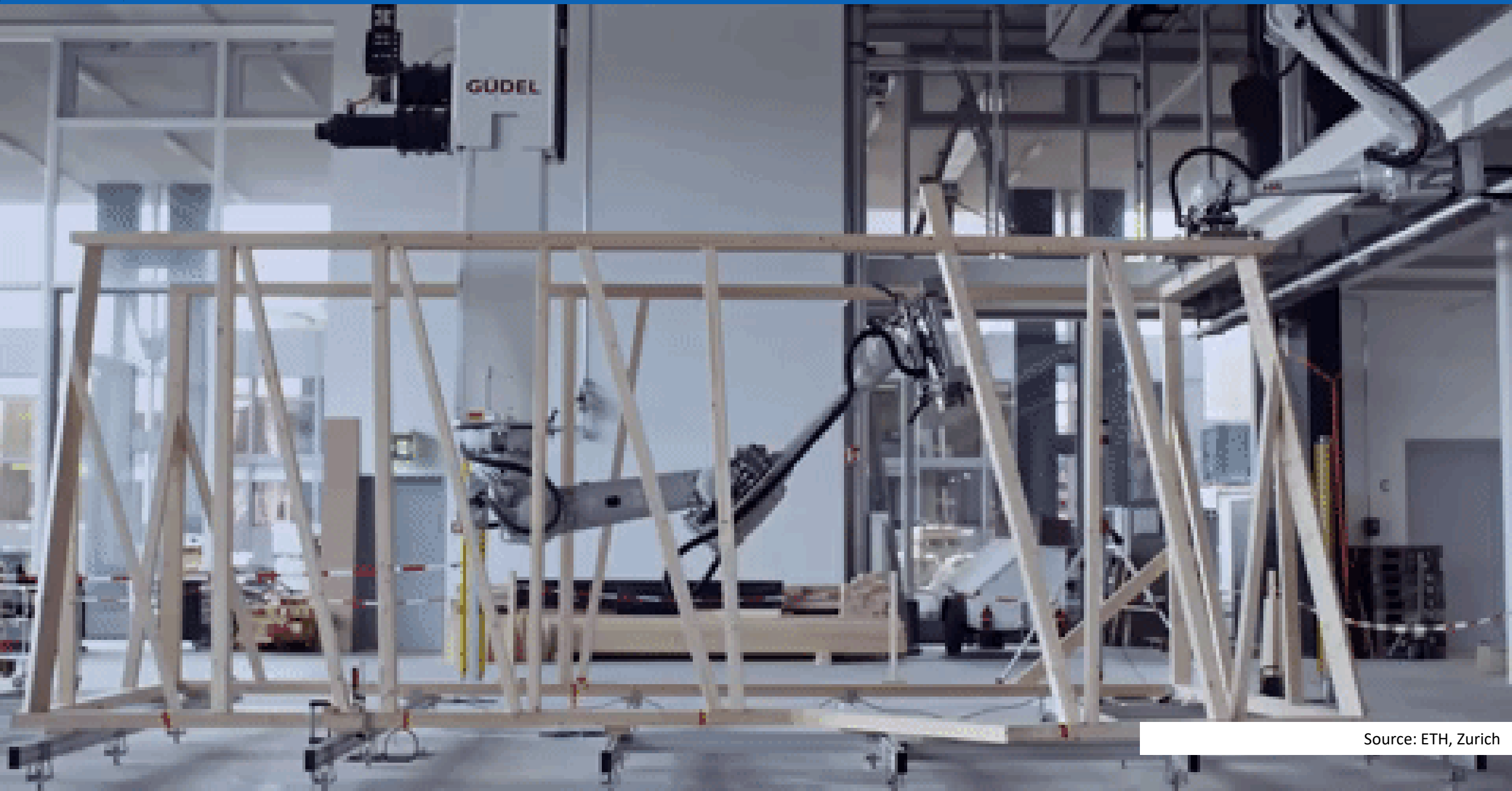
~1000+ Components

Multi System Assemblies

~10000+
Components

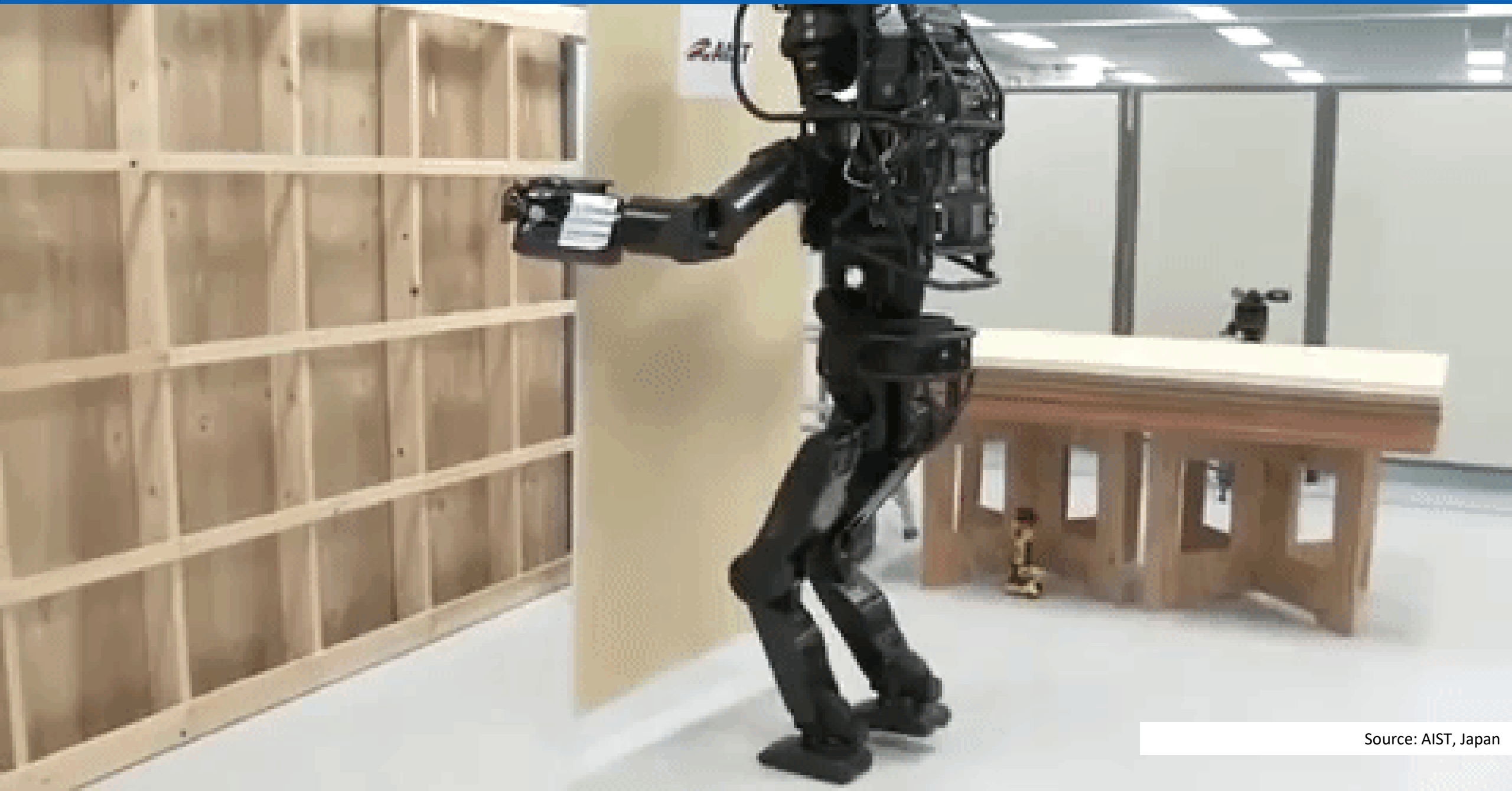
Traditional Construction

Trends in Robotic Construction – Timber Construction



Source: ETH, Zurich

Trends in Robotic Construction – Wall Assembly



Source: AIST, Japan

Trends in Robotic Construction – Brick Laying

Source: Semi Automated Mason (SAM)

Trends in Robotic Construction – Brick Laying

Source: Semi Automated Mason (SAM)

Trends in Robotic Construction – Wall Finishing

Source: Canvas Drywall Robot

Trends in Robotic Construction – Additive Concrete Construction

Source: Naveen Kumar Muthumanickam (Penn State at NASA 3D Printed Mars Habitat Challenge)

Trends in Robotic Construction

MECHANICAL

12. Boiler Plant
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9. Ducts

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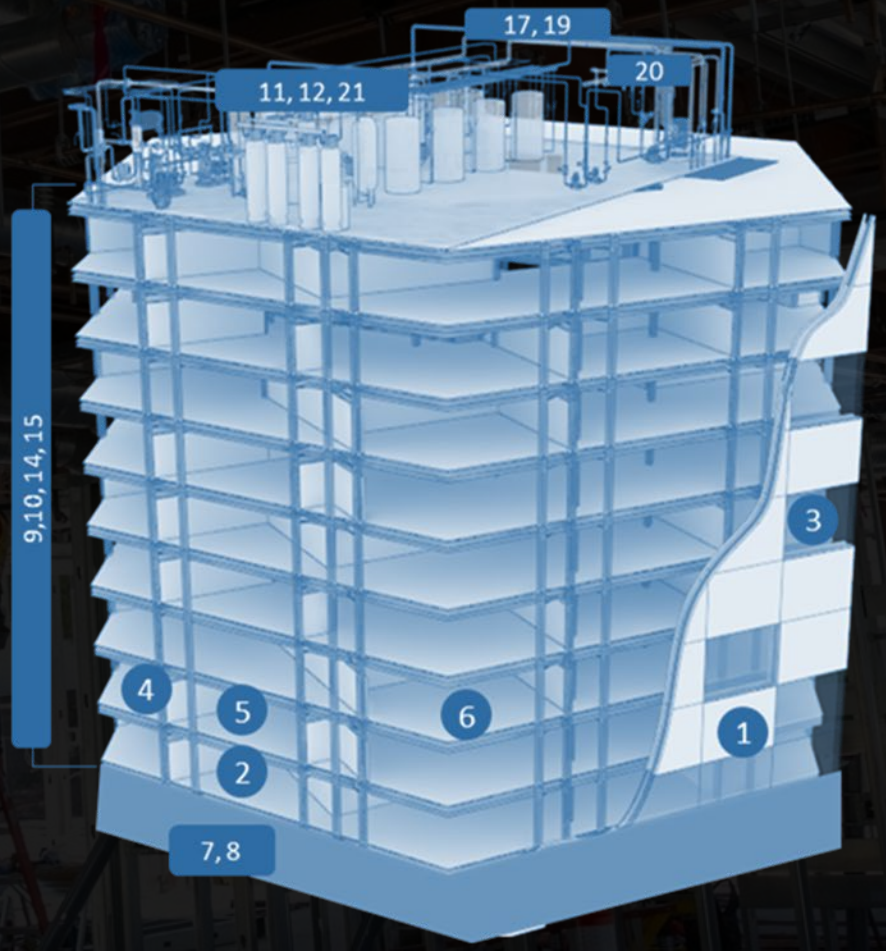

Systems Integration in Buildings

Source: The Architect's Newspaper

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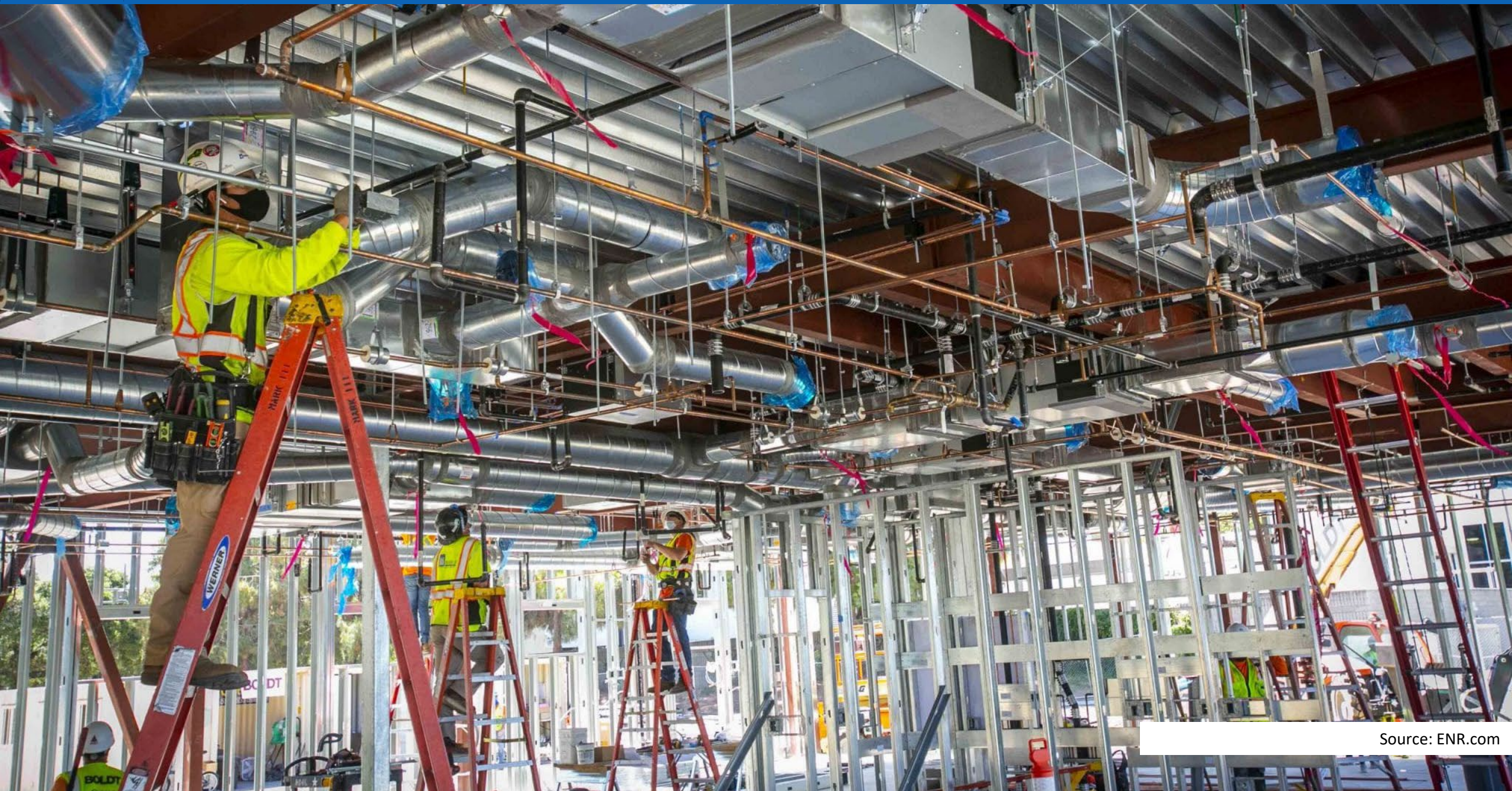
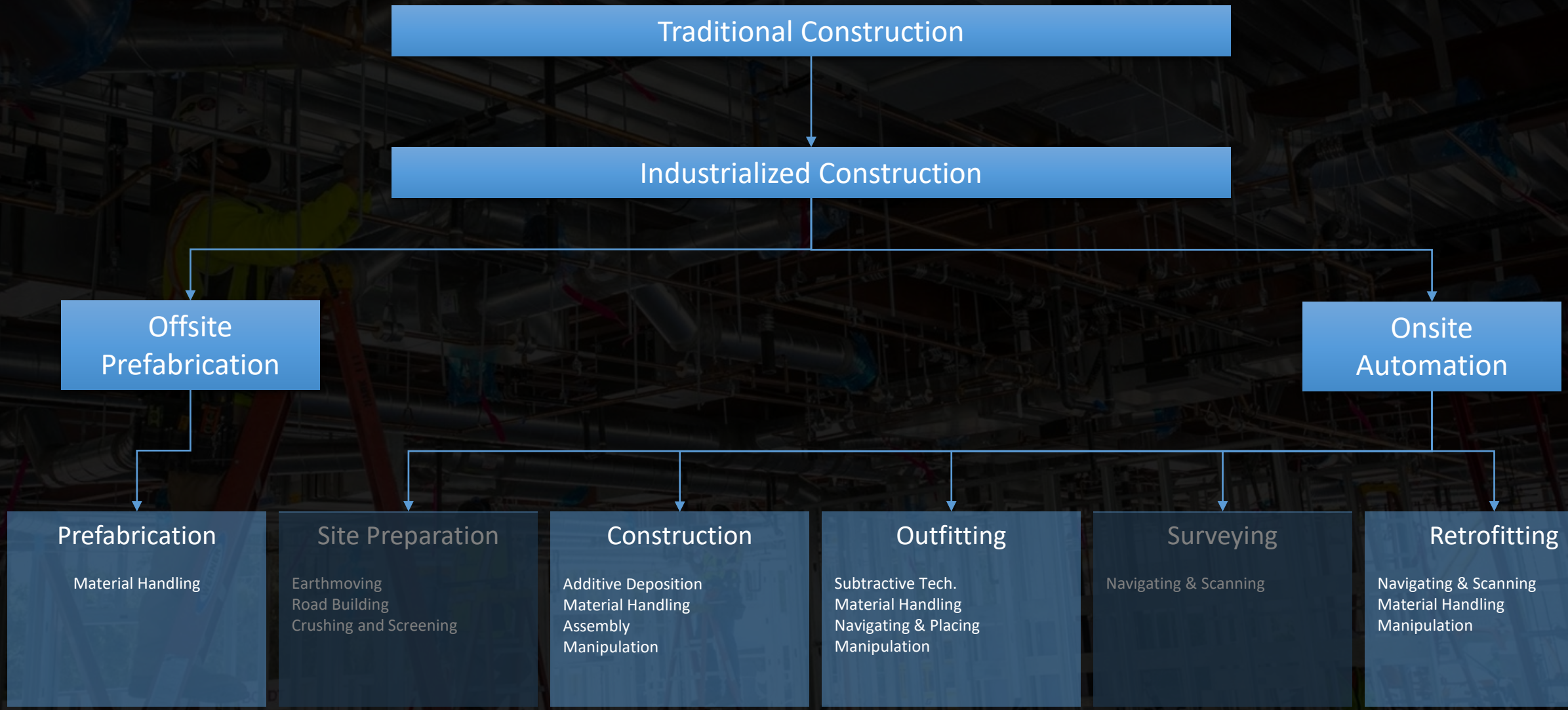
Systems Integration in Buildings



Source: ENR.com

NREL ICI Focus Areas – Robotics for Systems Integration in Buildings



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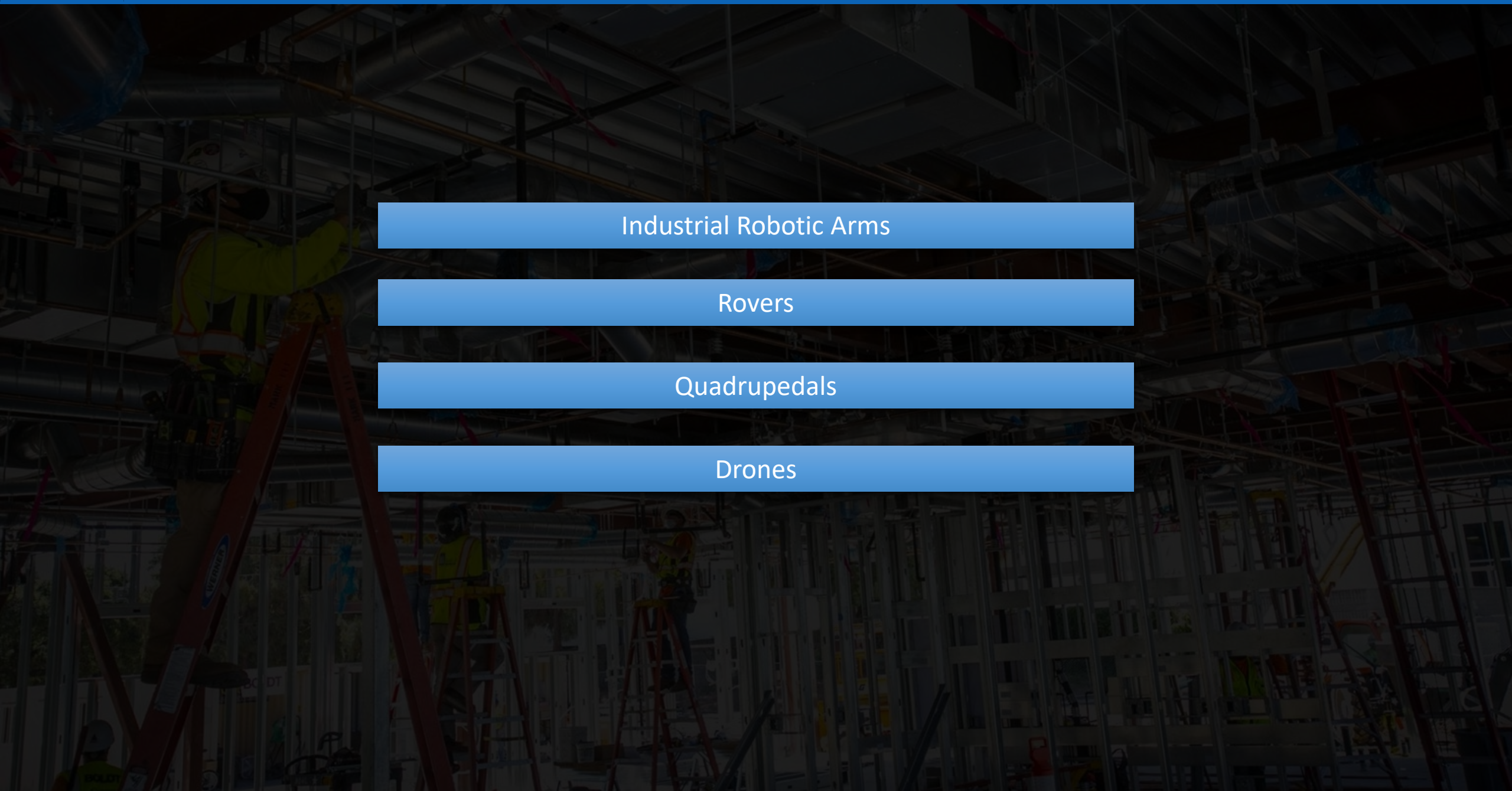


NREL ICI Focus Areas – Robotics for Systems Integration in Buildings

Robotic Outfitting

Virtual Simulation

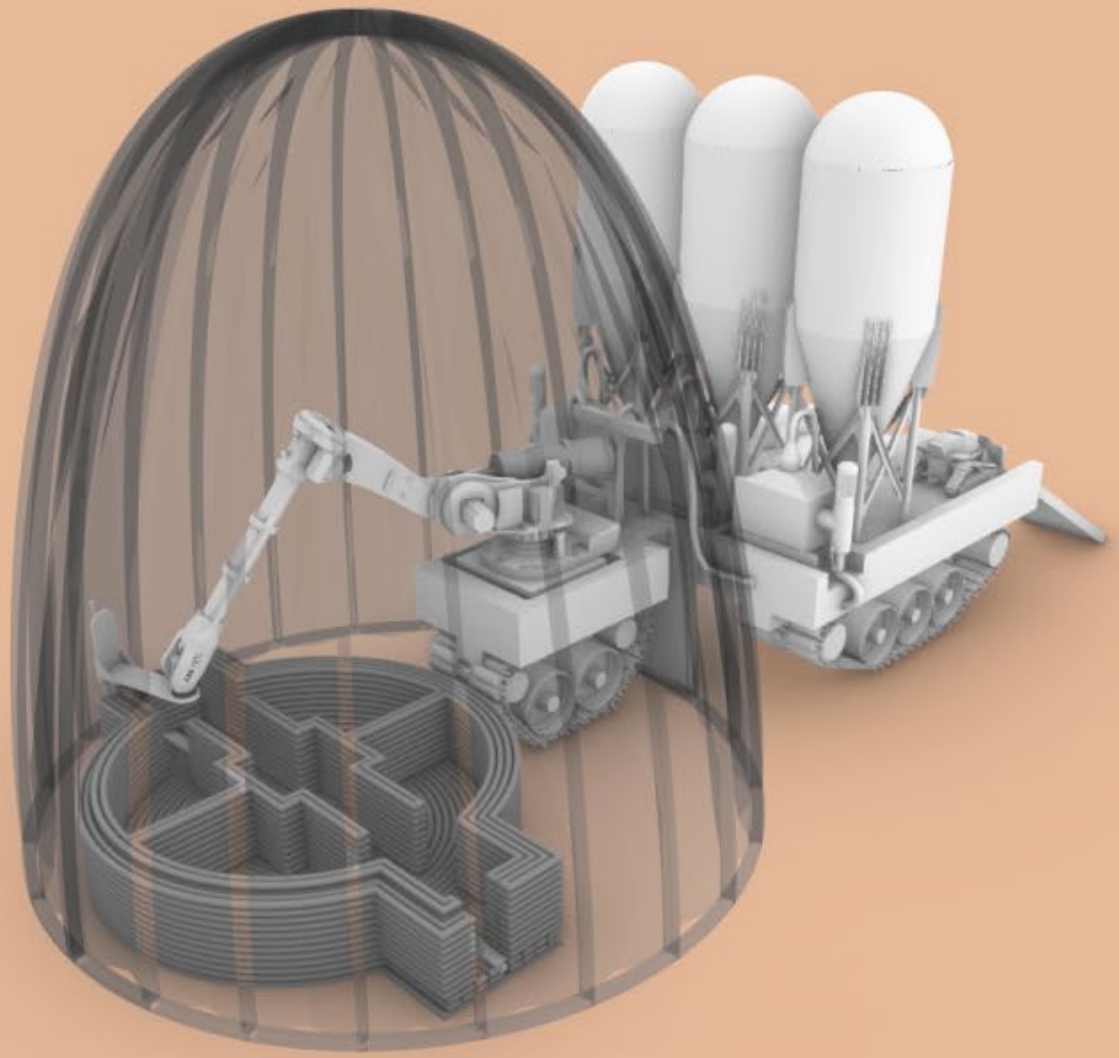
Semi-Autonomous Robotics

Computer Vision Based Sensing

Autonomous Robotics

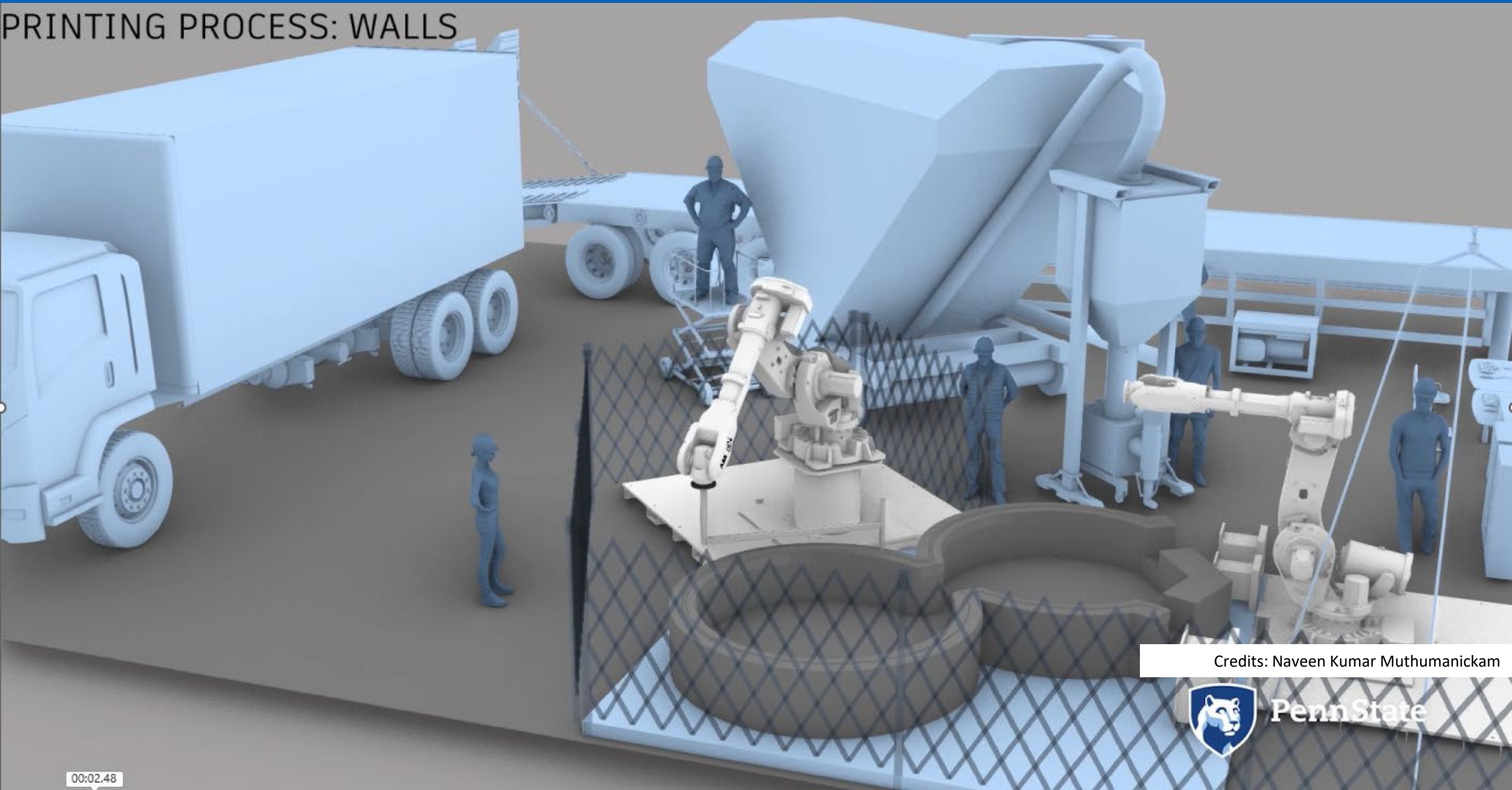
Digital Twin Visualization

Past Projects from Penn State – NASA 3D Printed Mars Habitat Challenge



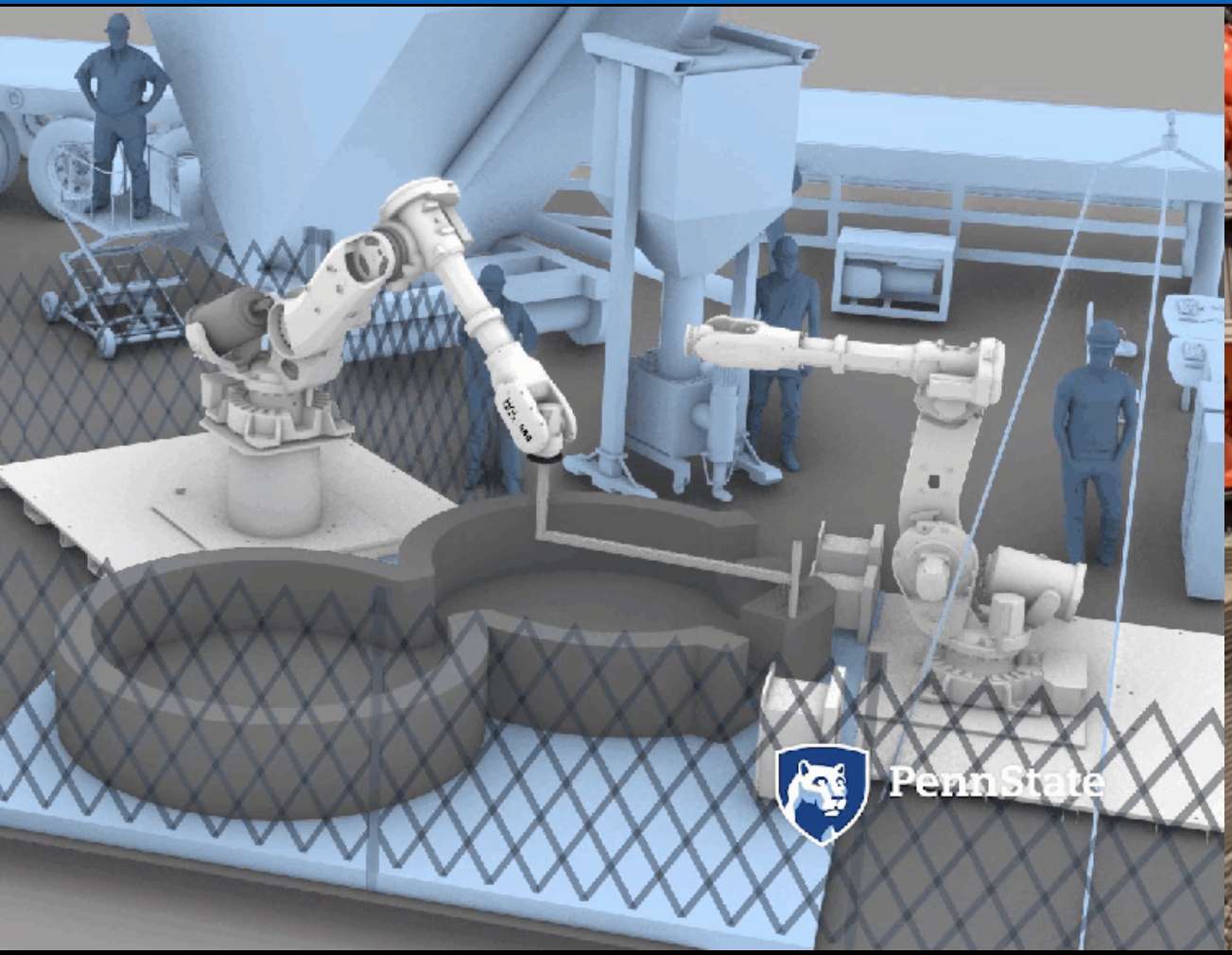
Credits: Naveen Kumar Muthumanickam/Eduardo Castro/Negar Ashrafe

Past Projects from Penn State – NASA 3D Printed Mars Habitat Challenge



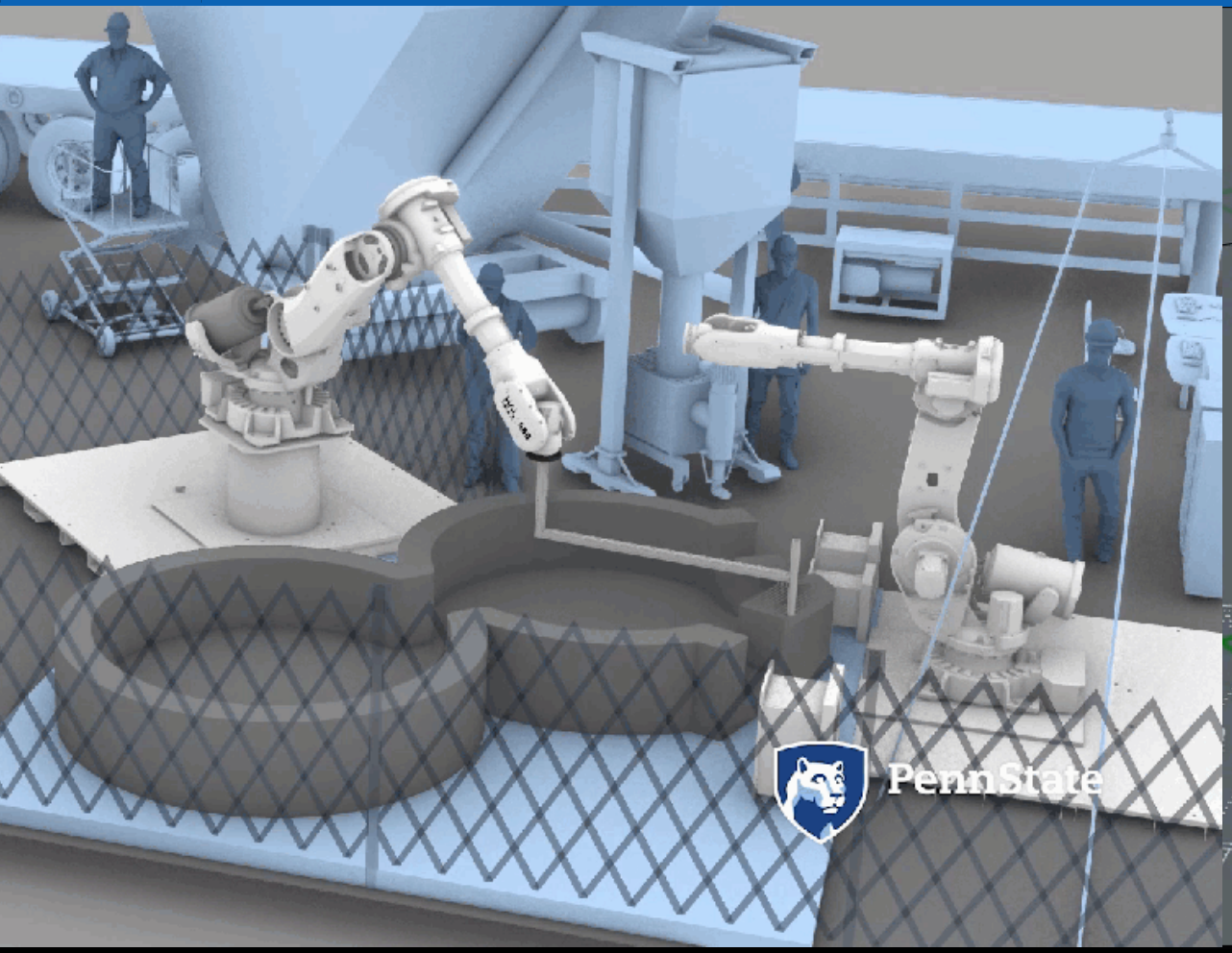
Credits: Naveen Kumar Muthumanickam

Past Projects from Penn State – NASA 3D Printed Mars Habitat Challenge

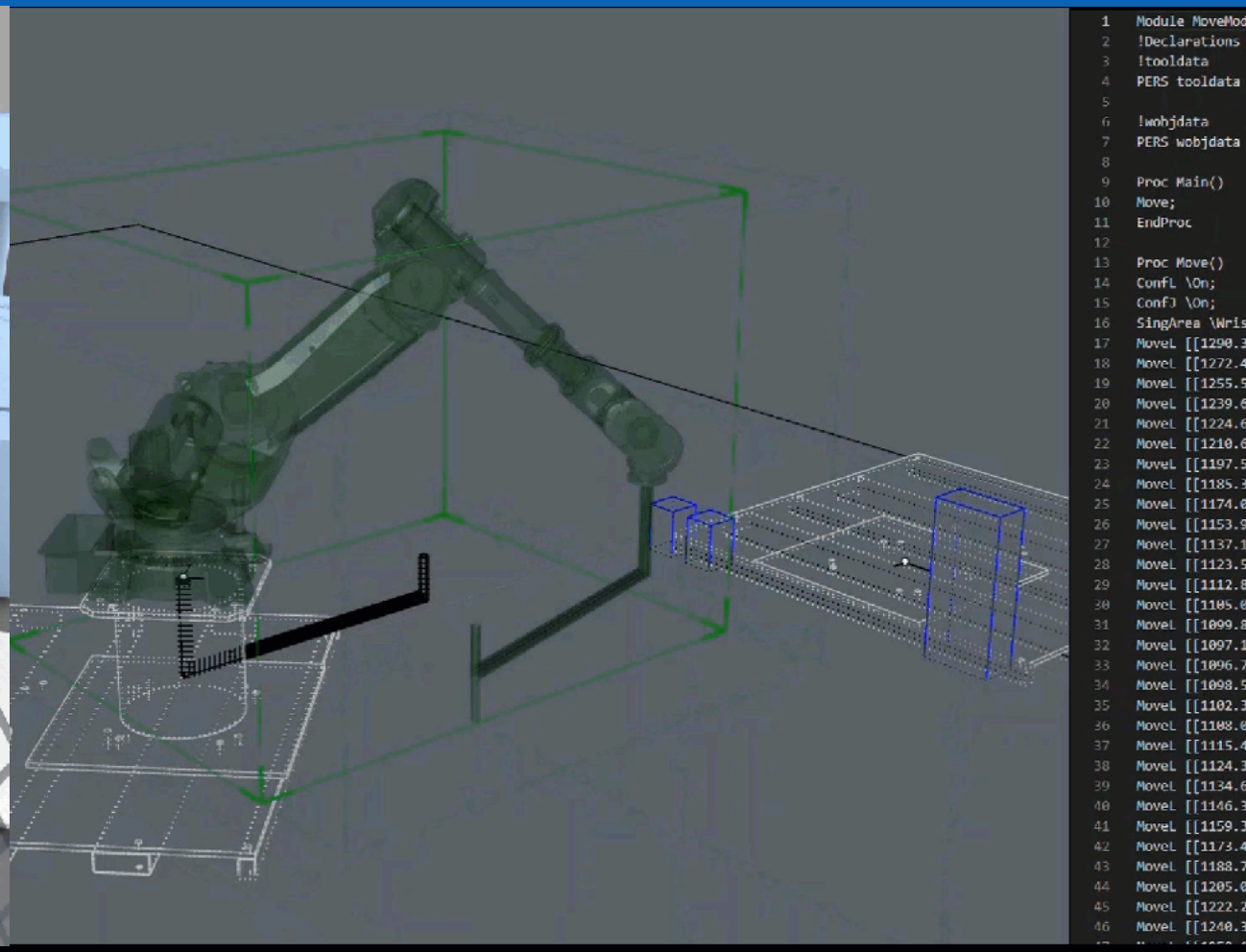


4D Simulations of robotic construction is computational graphics intensive

Past Projects from Penn State – NASA 3D Printed Mars Habitat Challenge



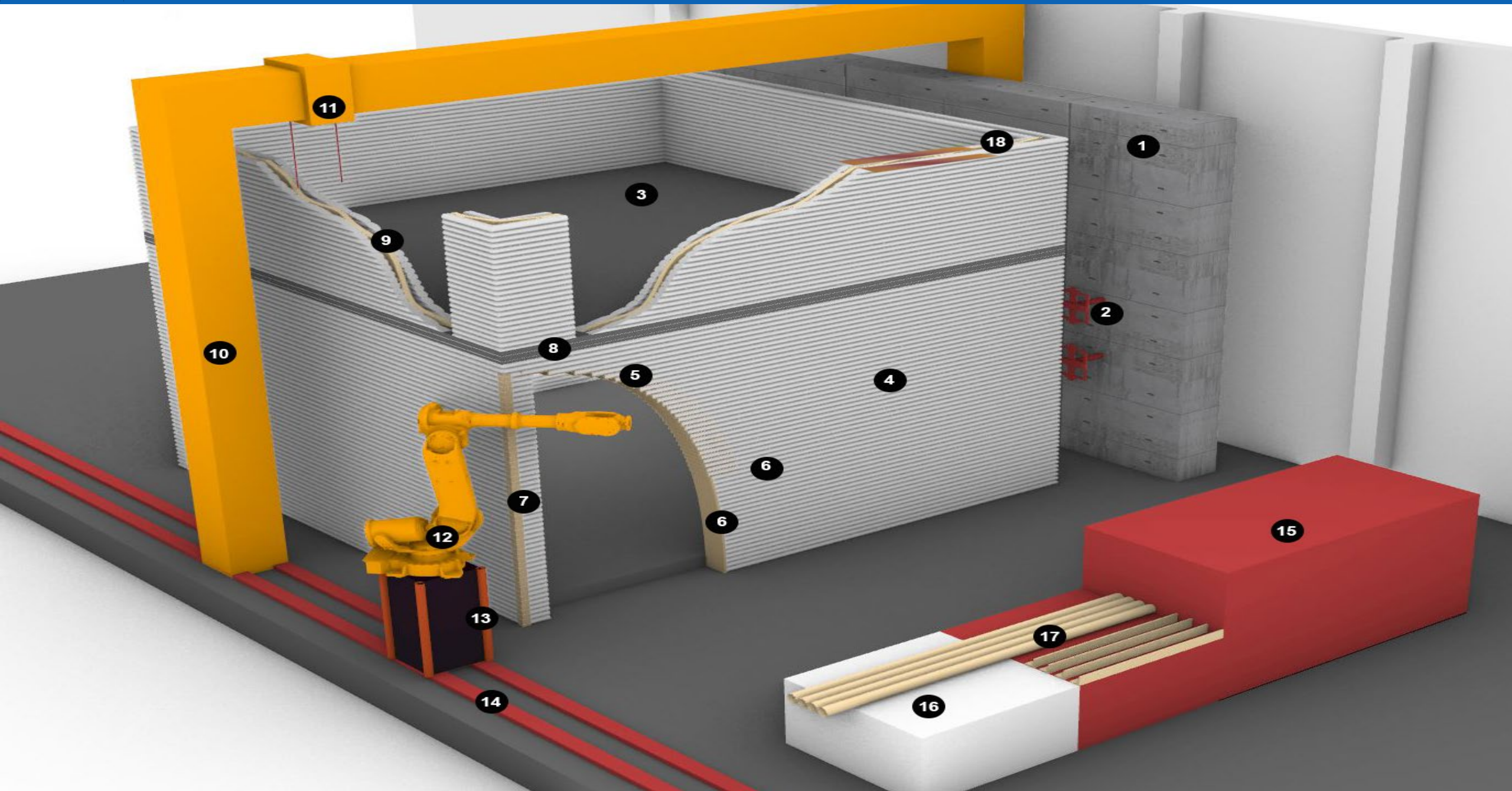
Detailed 4D Simulation



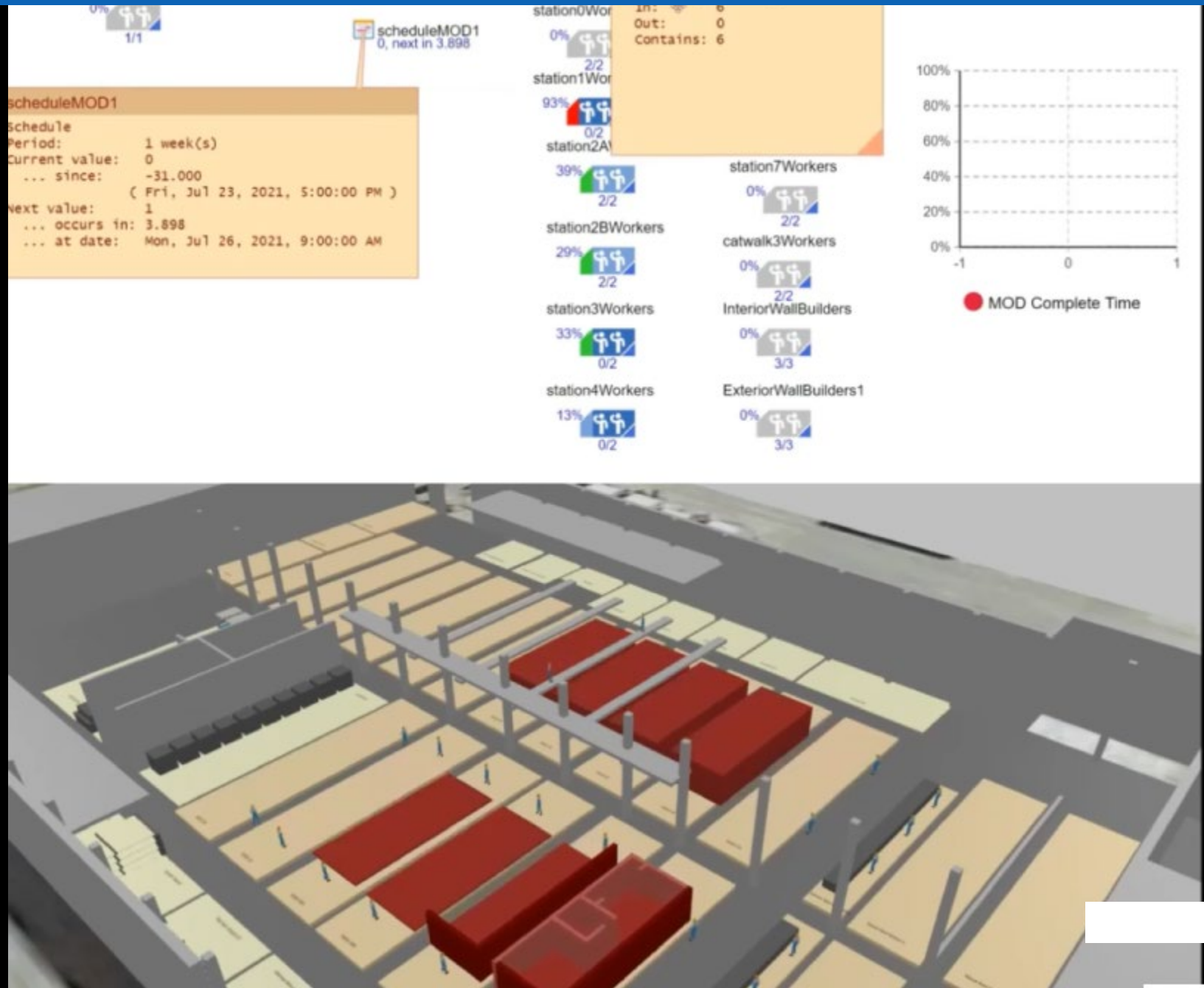
Robotic Box Collision metamodel (faster computation)

Metamodels for faster constructability analysis (Toolpath Clash Detection)

NREL ICI Focus Areas – Additive Concrete Construction + Energy Systems



NREL ICI – Process Modelling of Factories and Robotic Tasks

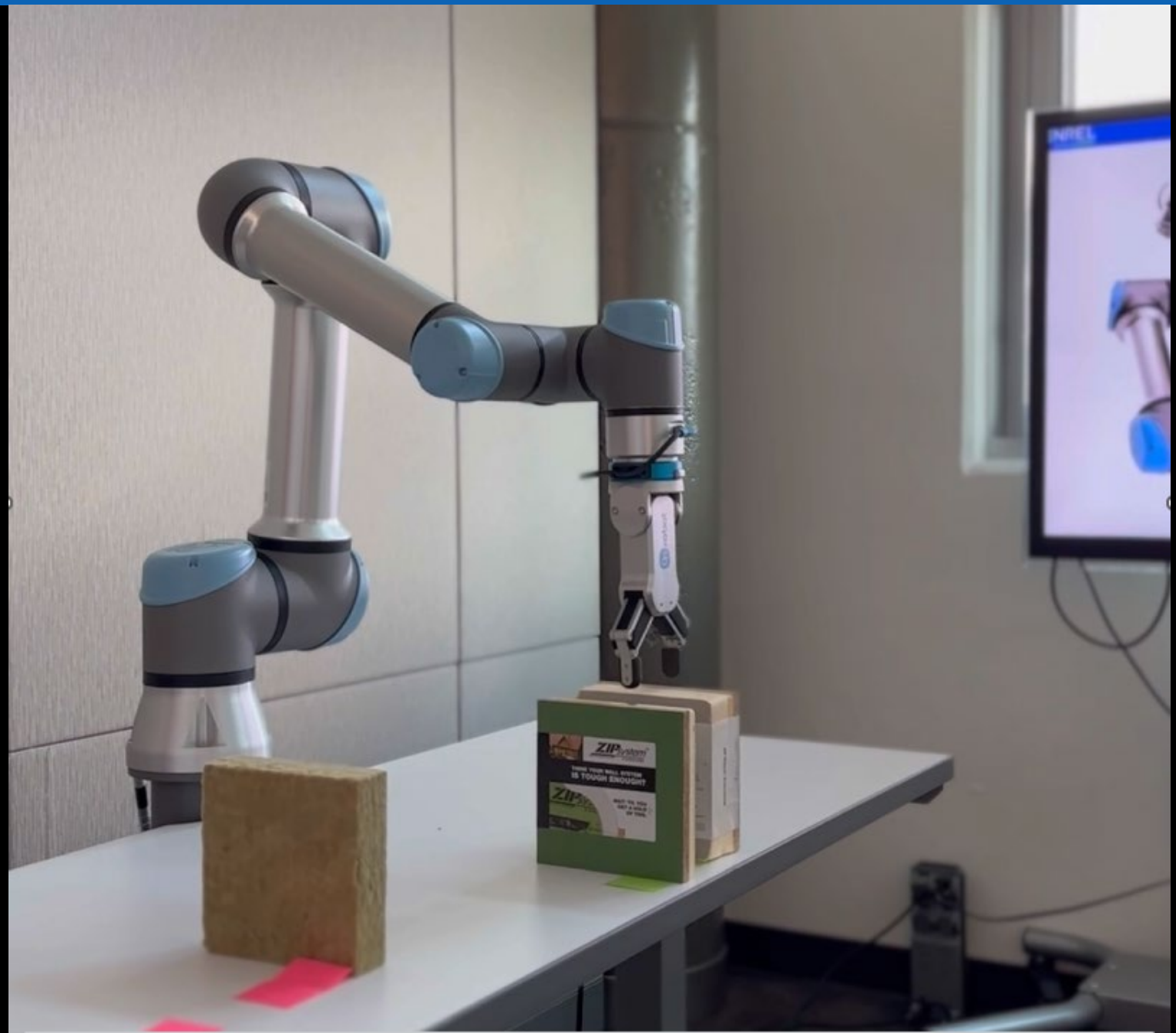


Credits: NREL (Ankur Podder)

NREL ICI – Factory Manufacturing Process Optimization

Source: BLOX

NREL ICI – Robotic Programming for Environmental Control Systems Integration



NREL ICI Focus Areas – Robotic End Effector Design (NREL CoMET Facility)

NREL ICI Focus Areas – Robotics for Renovation and Recycling

Source: Woodtech.events | Panel Handling Robots

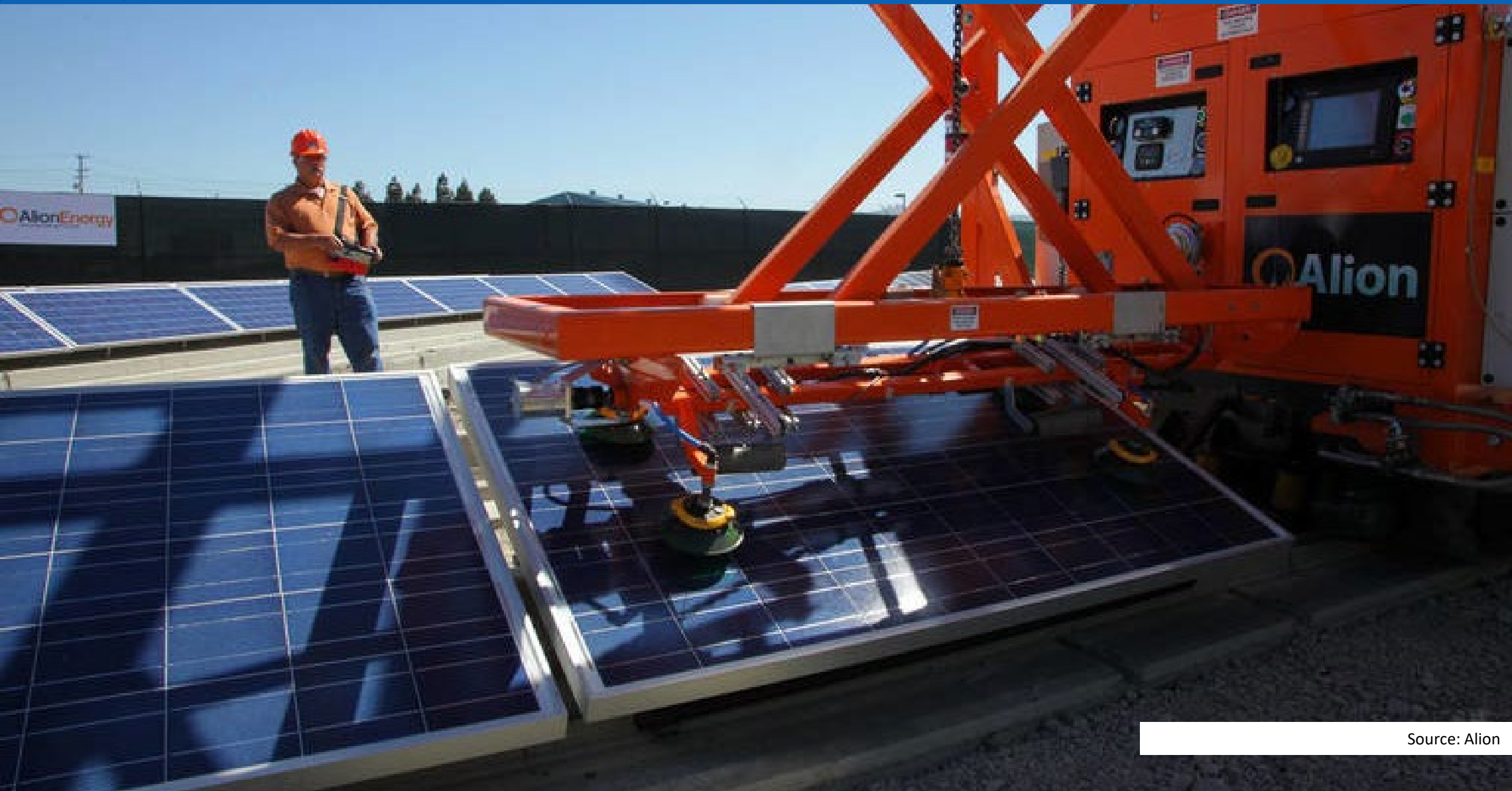
NREL ICI Focus Areas – Robotics for Hygrothermal Systems Integration in Buildings

Source: DOE/NREL E-Robot Challenge

NREL ICI Focus Areas – Robotics for Non-Destructive Testing in Buildings

Source: Entech Engineering, Inc

NREL ICI Focus Areas – Robotics for Power Generation Systems Integration



Source: Alion

NREL ICI Focus Areas – Computer Vision Guidance for Robotic Tasks

Thank you!

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