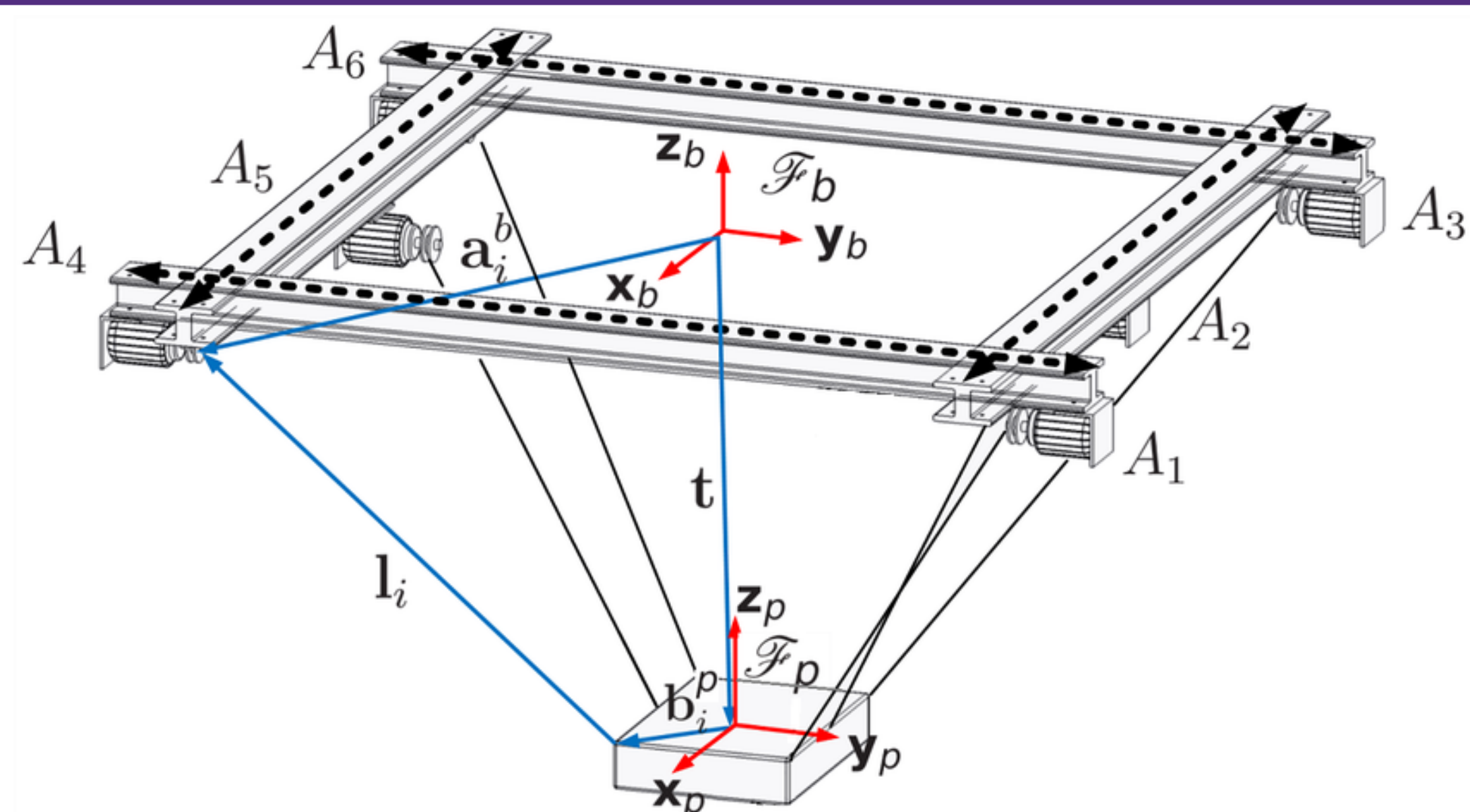


NRI:FND: 3D Concrete Printing with Macro-Micro Robots

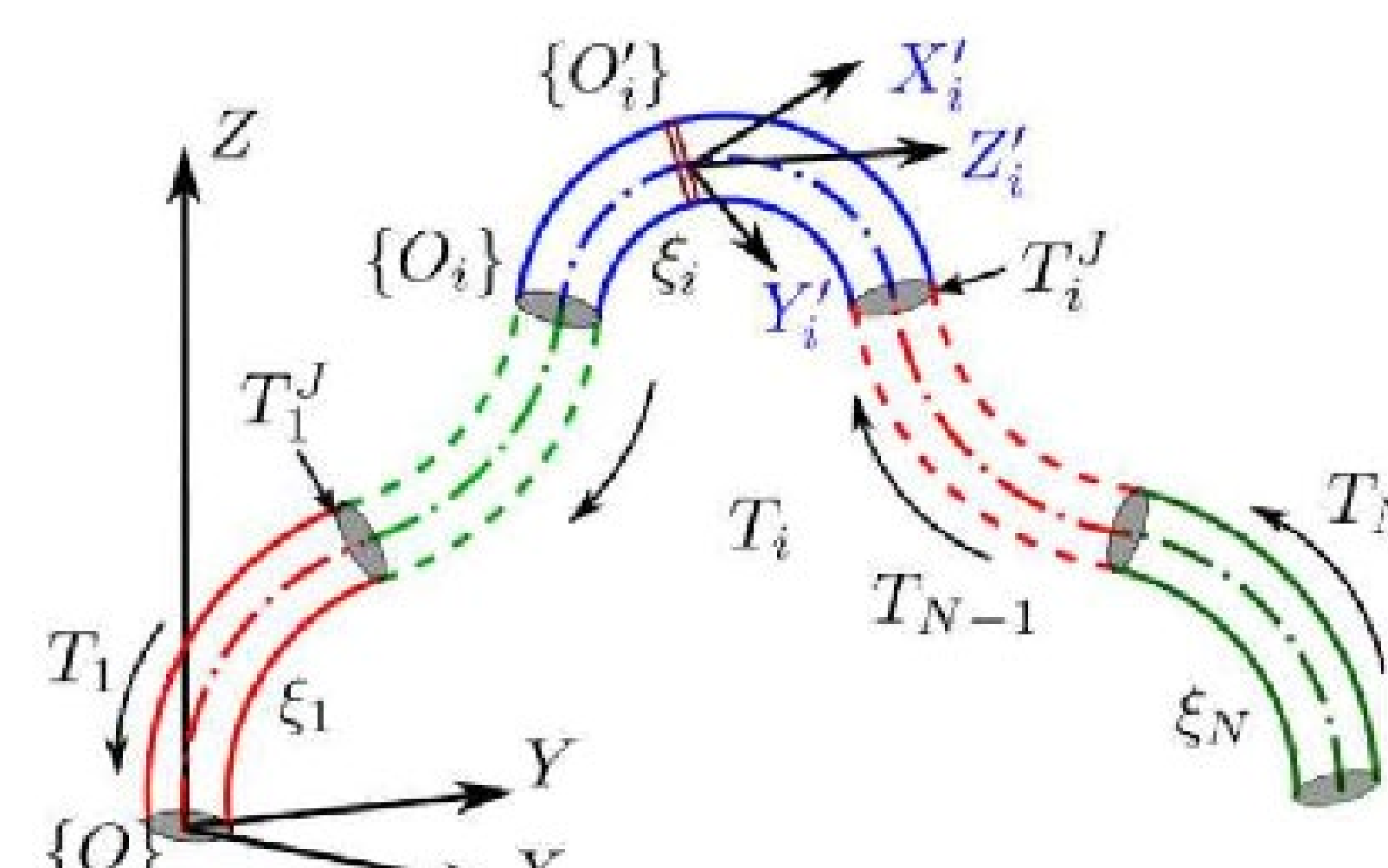
Ian D. Walker, Venkat N. Krovi, Prasad Rangaraju, and Matthias J. Schmid, Clemson University



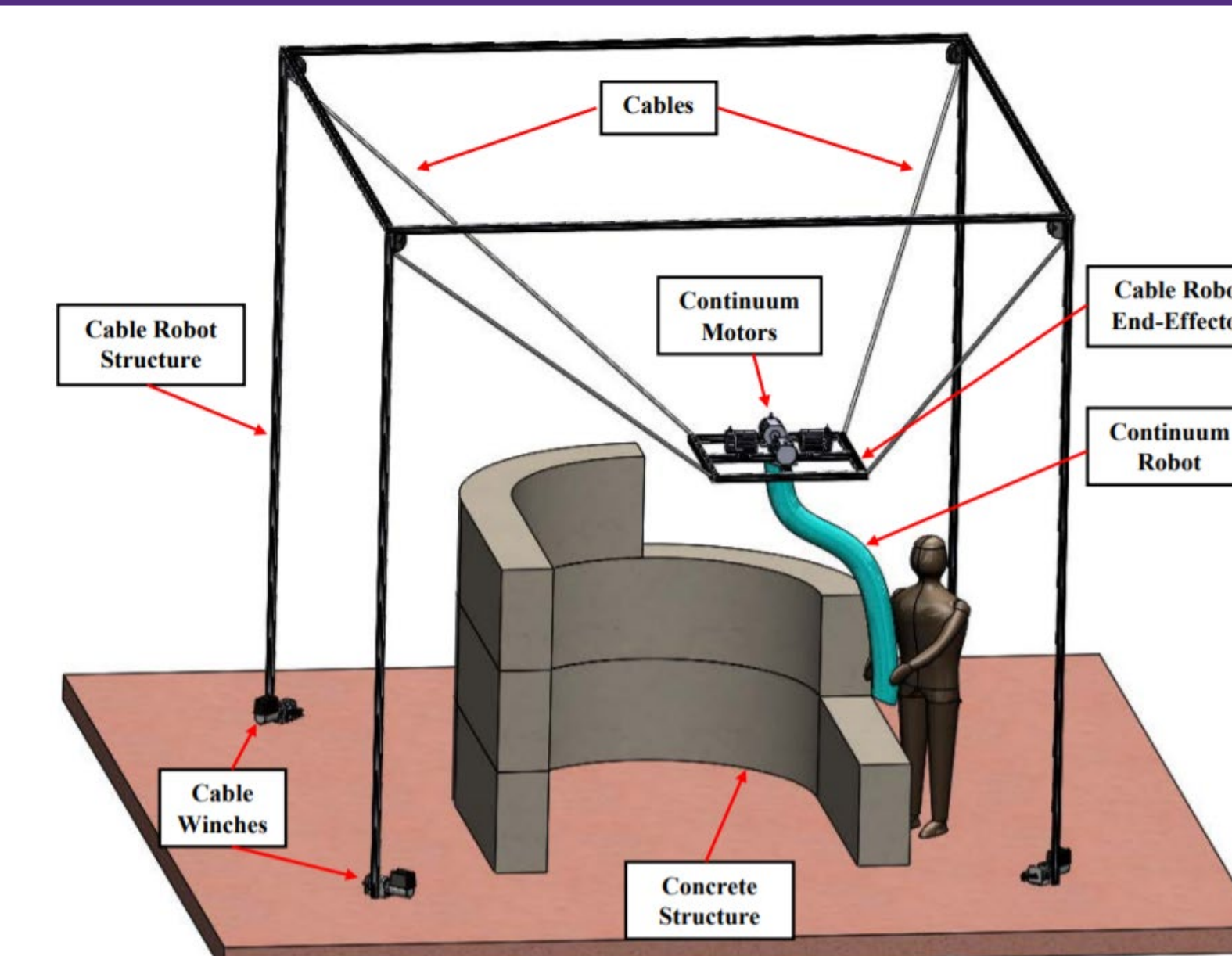
Project URL: https://cecas.clemson.edu/armlab-cuicar/research_1/cavs-in-manufacturing



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Challenge

Interactively assist construction workers to dexterously deploy concrete-delivery hoses in congested spaces for 3D printing of concrete

Background

Construction industry is vital for national economy:

- ~ 5% of US Gross Domestic Product (GDP)
- 1.463 trillion, 6.7 M workforce (in 2017)
- Construction is one of the least automated industries in the world
- Productivity hindered by lack of automation tools
- Within construction, concrete operations are a foundational element

Proposed solution

Intelligent co-robot: Novel cable-driven macro/micro design:

- Cable-robot acts as the macro-base
- Cable-driven continuum robot (integrated with concrete delivery hose) serves as micro-unit
- Field Intelligence: Situational awareness and physical-assist
- Field-deployable with large workspace/load carrying capability

Impact of solution

- Fundamental research in rheology of 3D-printable concrete
- New generalizable modeling of coupled cable-driven macro-micro robot systems
- Intelligent assist for concrete delivery in construction industry

Broader impacts

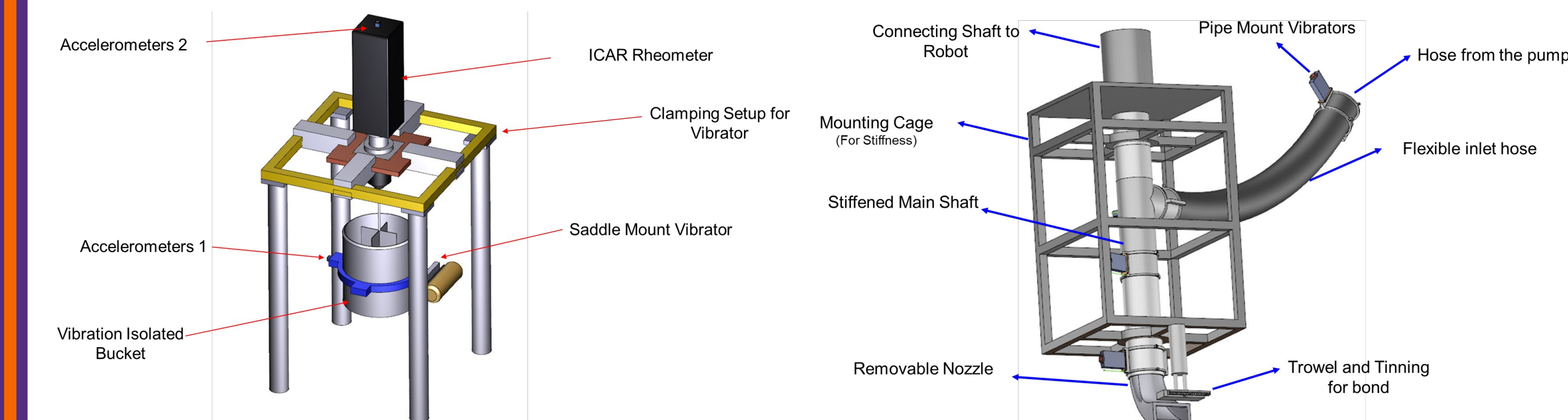
4 Ph.D. Students (2 female) and 2 REU students hired; Industry and conference (ASME IMECE, ACI, IEEE, ACeRS, TRB) presentations; Summer outreach seminars to high-schools and industry

Process Video



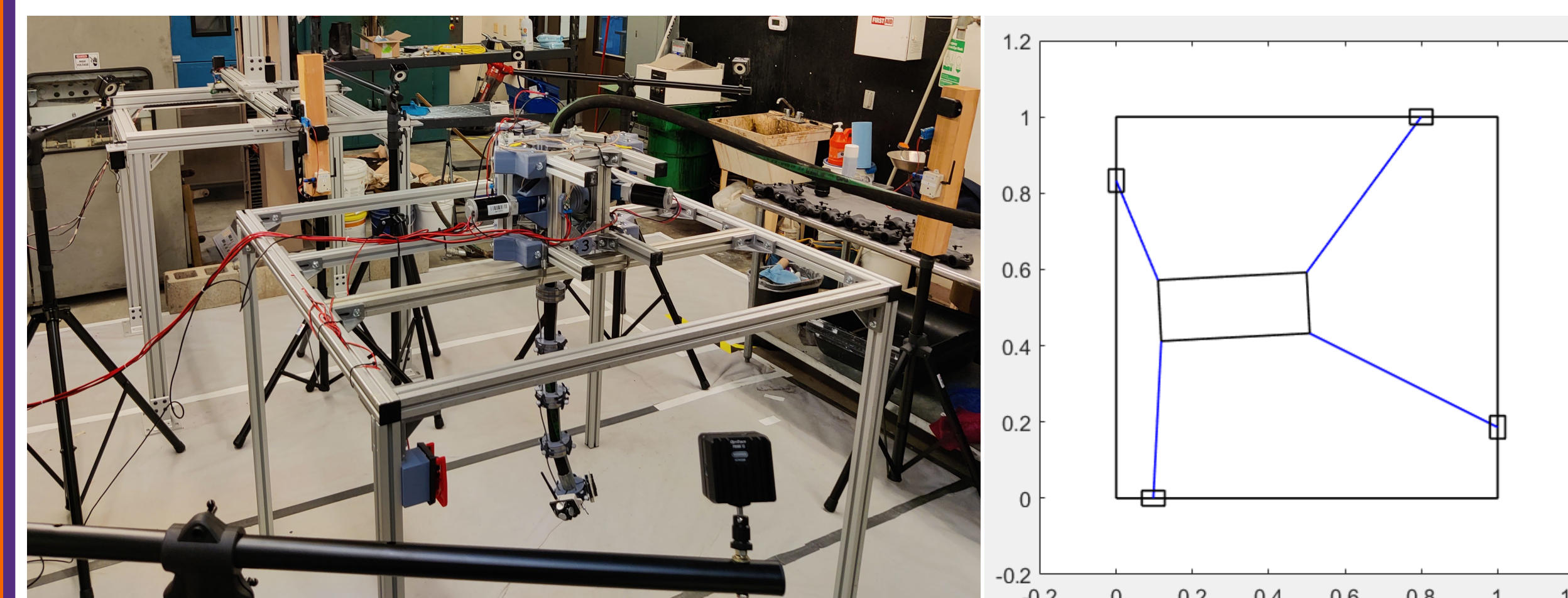
Materials Research Results

- Developed 3D printable mixtures of Portland cement with slag and metakaolin (ASTM Publication submitted)
- Investigated influence of aggregate shape characteristics on the rheological behavior of 3D printable mixtures (ACI Publication submitted)
- Developing dynamic rheology controlled cementitious materials for 3D printing
- Preliminary work on shrinkage, mechanical and transport behavior of 3D printable mixtures



Macro Cable Robot Results

- Modelled a reconfigurable m-CDPR in 2D
- Implemented task and joint space control
- Developed redundancy resolution scheme for directional disturbance rejection (IEEE publication)
- Preliminary results in joint state estimation given partial sensor data
- Preliminary work in robot construction



Continuum Robot Hose Results

- Single section prototype
- Initial pumping tests
- Dynamic modeling conducted (ASME publication)
- Preliminary work in situational awareness

