# The Safe Robotics Lab

## at Georgia Tech

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## Mission

The **SRL** is a new research group at Georgia Tech that is focused on building robotic systems that are not only **safe**, but also SAFE: Smart, Agile, Flexible, and Engaging

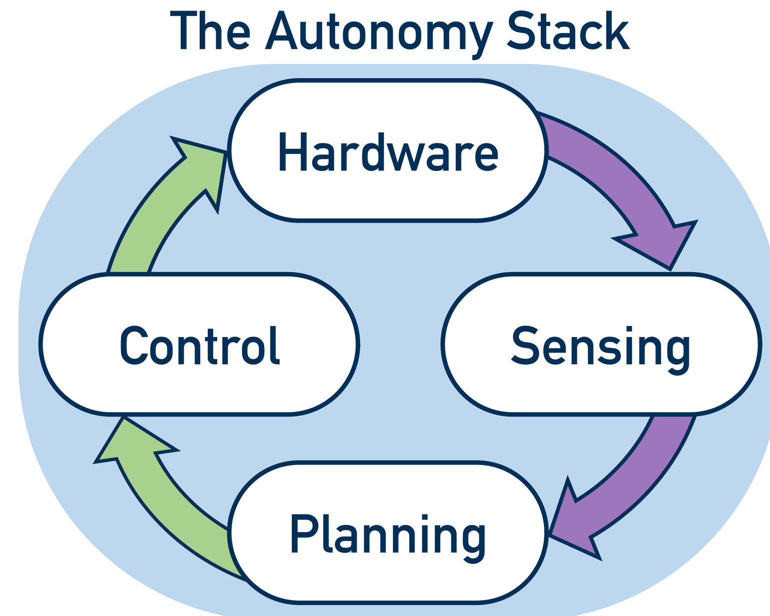
## Core Technical Challenge

Theoretical definitions of robot safety typically translate in a lossy way into numerical and hardware implementation. We seek to model and overcome this gap in each part of the autonomy stack. **The key challenge is thus to create tractable models of uncertainty within and across autonomy components.**

## Research Overview

We plan to explore, develop, and implement safety and performance in the **full autonomy stack**.

The Autonomy Stack



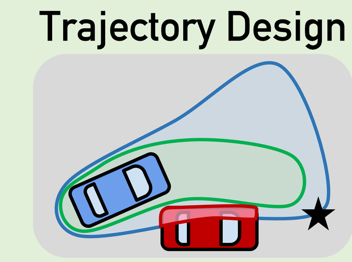

- 1 - 3 years: 1. Learning to Plan Safe Motion
- 2 - 5 years: 2. Robust Robot Perception
- 3 - 10 years: 3. Automated and Safe Co-Design

Long-term vision: we seek to model uncertainty to enable robots to teach themselves to be safe

## Prior Scientific Impact

Previous work focused on ensuring safety and performance in planning, control, and learning:

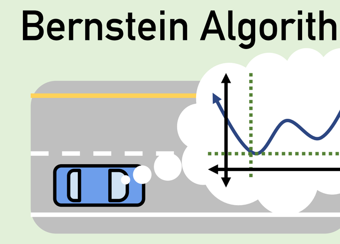
RTD
Reachability-based Trajectory Design



safety

Reachability-based Trajectory Design (RTD) is a method for provably-safe, real-time motion planning for robots including cars, drones, arms.

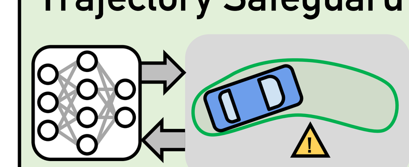
PCBA
Parallel Constrained Bernstein Algorithm



performance

RTD on its own doesn't enable performance guarantees, so we created PCBA to prove optimal performance.

RTS
Reachability-based Trajectory Safeguard



learning

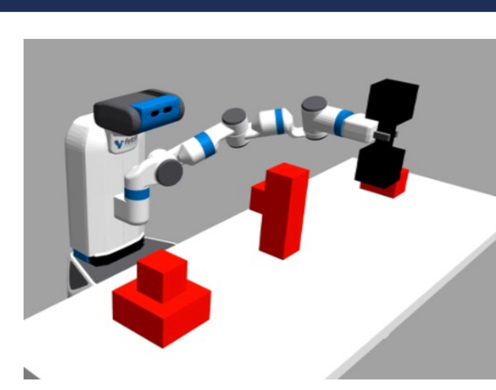
Reachability enables strong safety guarantees on a reinforcement learning agent, fusing formal control and learning.

## Planned Technical Objectives and Contributions

### 1. Learning to Plan Safe Motion

→ Reachable sets for complex robot dynamics to ensure safety during contact-rich motion

→ Fast online adaptation of dynamic model uncertainty to enable self-correcting, safe learning for control

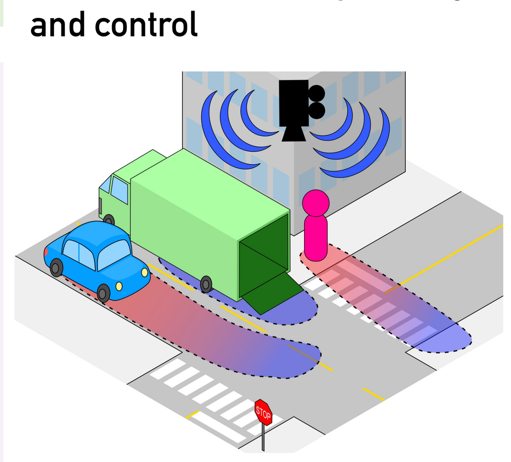


A manipulator arm maneuvers an uncertain payload around obstacles via robust planning and control

### 2. Robust Robot Perception

→ Numerically-tractable perception uncertainty models that leverage temporal effects to enable guarantees

→ Planning of active perception to increase likelihood of detecting task-relevant parts of the environment

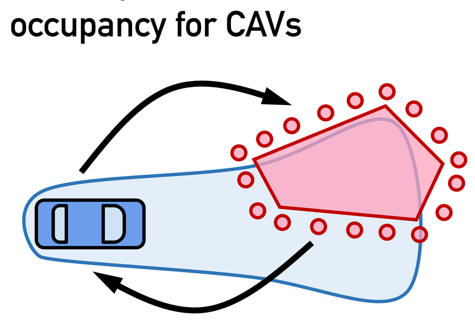


Smart urban sensor networks can output future uncertain occupancy for CAVs

### 3. Automated and Safe Co-Design

→ Coupled perception-planning-control uncertainty models for end-to-end uncertainty mitigation

→ Semantic mapping and planning to reduce uncertainty and increase legibility of robot motion



Co-design of perception and planning representations (e.g., obstacles and reachable sets) can mitigate uncertainty in both components of the stack

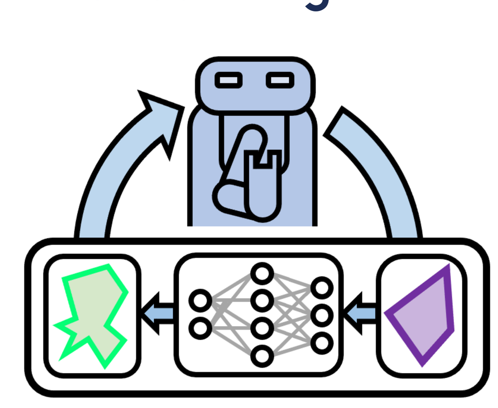
## Broader Impact in CPS

Theoretical and numerical methods for robot safety can be adapted to safety and performance guarantees for other cyber-physical systems

→ We develop fundamental methods for **verification of general dynamical systems**

→ Our past insights are on how to **generate safe trajectory plans**, whereas most methods seek safe trajectory tracking

→ Safety in robotics requires studying **safety in learning-enabled components**; we are considering the fundamental perspective of verification of machine learning



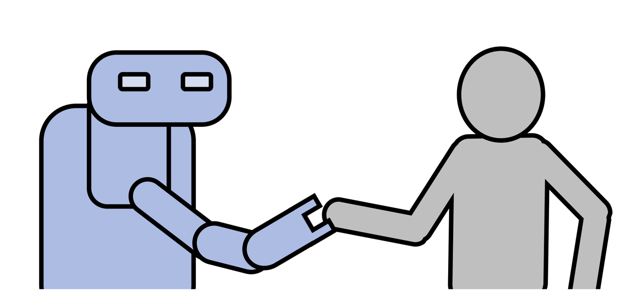
## Broader Impact in Society

We seek to enable studying the social impact of widespread robot deployment by creating practical robot safety guarantees.

→ The **legal framework around robot failure** can potentially be based on strict algorithmic guarantees

→ Societal trust may be increased by robots that can clearly **communicate intent and safety** efficiently and reliably

→ It remains open to establish a **"language" of robot movement and gestures** near and around people while avoiding misleading signals by accidental robot anthropomorphization



## Hardware and "Robot Playground" Plan

We are in the process of building a 50'x25'x25' (LxWxH) shared testing facility with full motion capture coverage.

Parrot Drones

Unitree B1

F1Tenth

Kinova Jaco

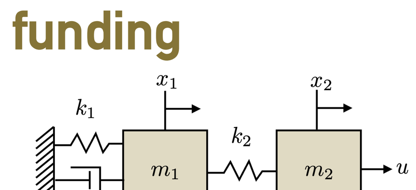
allotted 1500 sq. ft high bay space

## Education and Outreach Plan

→ Developing **in-classroom robotics exercises** and curricula for K-12 classrooms

→ Developing undergraduate system dynamics curriculum with robotics examples and **safety/convergence proofs**

→ Connecting with Atlanta HBCUs and MSIs to **co-develop projects and seek shared funding**



undergrads will learn to relate math models to real robot dynamics

the Edison V2.0 platform enables K-12 classrooms to explore mobile robotics

## References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**NSF FRR 2023 Aspiring Pi Workshop**