Indy Autonomous Challenge
Indiana University-Purdue University Indianapolis
IUPUI Team

Round 1

The IUPUI Team

Indiana University-Purdue University (IUPUI) is a research public university located in Indianapolis, Indiana. IUPUI was founded in 1969 and today has over 21,000 undergraduate students and 8,000 graduate students. IUPUI is one of the seven campuses of Indiana University. It has sixteen Indiana University schools and two Purdue University schools, namely, Purdue School of Science and Purdue School of Engineering and Technology—the first one in the United States to offer a bachelor's degree in motorsports engineering.

The Purdue School of Engineering and Technology hosts various research centers, institutes, laboratories, and initiatives, including the Transportation & Autonomous Systems Institute (TASI), the Engineering Design Research Laboratory (EDRL), the Mechatronics & Automotive Research Laboratory (MARL), and the Autonomous Vehicle Initiative. The IUPUI Team for the Indy Autonomous Challenge is formed by researchers such institutes, laboratories, and initiatives.

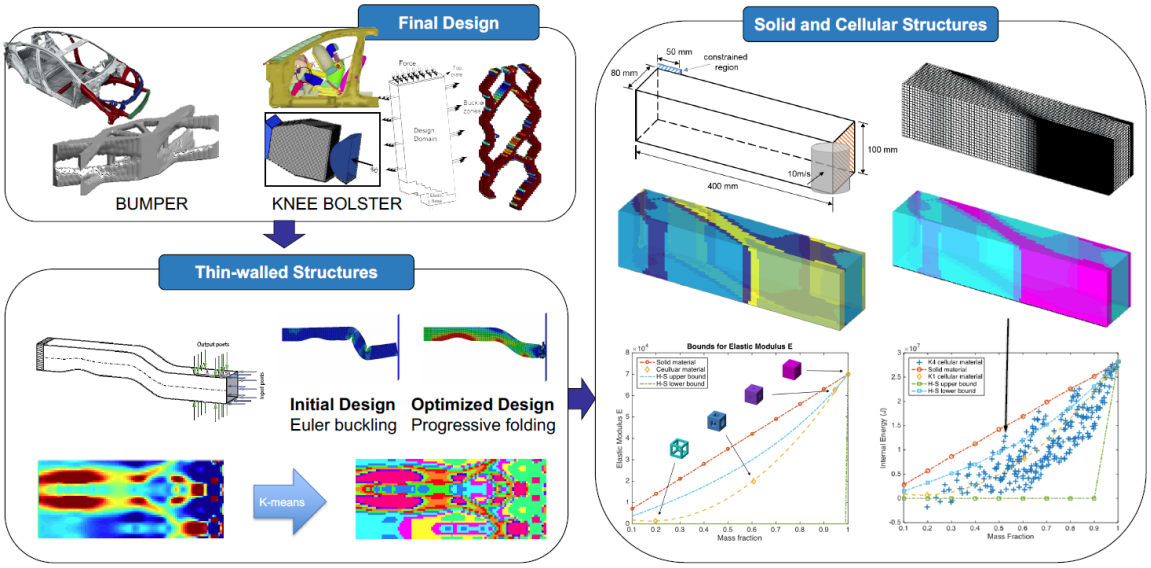
Transportation & Autonomous Systems Institute (TASI) (tasi.iupui.edu)—TASI is a collaborative University, Industry, and Government consortium to facilitate research, development, evaluation and assessment of transportation active safety and autonomous systems. As a cross-campus research center, faculty members from more than 10 departments and schools at IUPUI, Indiana University Bloomington, and Purdue University West Lafayette are involved in TASI's research activities. TASI's main activities include vehicle testing and evaluation, human factors in active safety systems, crash data analysis and risk benefit analysis, scientific research on automation of selected driving functions, crash prevention technologies, and connected vehicles.

TASI research areas include modeling and simulation, pedestrian/bicyclist safety, and vehicle dynamics and control

TASI faculty team has the expertise and technical skills to address research needs for these enabling technologies for connected vehicles and automated driving systems by collaborating with its academic and industry partners. Research

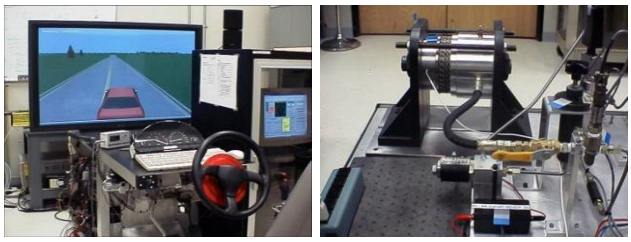
areas include pedestrian and bicyclist safety, human factors/HMI in automated driving, driver state sensing and performance evaluation, ADAS system performance test and evaluation, V2X communications for traffic safety, impaired and fatigue driving, NDD and crash data analytics, SAE/IEEE standards development for automated driving, modeling and simulation, and vehicle dynamics and control.

Engineering Design Research Laboratory (EDRL) (edrl.et.iupui.edu)—EDRL research focuses on engineering systems, structures, and material design optimization algorithms. Their work exploits and develops synergies among structural vehicle engineering, engineering mechanics, material science, and manufacturing to introduce new insights and capabilities to vehicle engineering design. Research topics include machine learning-assisted design (Bayesian optimization), topology optimization (mechanical and thermal-fluid structural optimization), and generative design (bio-inspired design). Applications include vehicle structural optimization (e.g., crashworthiness, ballistic penetration, and blast mitigation), materials for energy storage, and composite material optimization, and their integration in a multiscale material and structure design methodology



EDRL research includes vehicle lightweighting through multimaterial topology optimization and machine learning-assisted design.

Mechatronics & Automotive Research Laboratory (MARL) (www.iupui.edu/~meengr/mrl/)—MARL was established in 2005 to facilitate teaching and research in the areas of Mechatronics and Intelligent Systems, Diagnostics/Prognostics, Advanced Control Systems, Modeling and Simulation, Drive-By-Wire and Autonomous Systems, and Sensors & Algorithms. MARL is aimed at creating high-tech workforce in the area of automotive mechatronics and intelligent systems by providing appropriate training to the students in order to meet the needs of these rapidly changing technologies and provide services to industry for promoting new technologies.



MRL is equipped with state of the art rapid control prototyping hardware and software which are used to conduct fundamental research.

Team members

Andres Tovar
tovara@iupui.edu
Associate Professor
Department of Mechanical and Energy Engineering
Director of the Engineering Design Research Laboratory (EDRL)

Andres Tovar is an Associate Professor of Mechanical and Energy Engineering and an Adjunct Assistant Professor of Biomedical Engineering at Indiana University-Purdue University Indianapolis (IUPUI). He received his B.S. in Mechanical Engineering and M.S. in Industrial Automation from the National University of Colombia in 1995 and 2000, respectively. He earned his M.S. and Ph.D. in Mechanical Engineering from the University of Notre Dame in 2004 and 2005, respectively. At IUPUI, he has been the recipient of the 2015 Wisner-Stoelk Outstanding Faculty Award and the 2016 IU Trustees Teaching Award. He also received the 2014 SAE Ralph R. Teetor Educational Award, the First Place in the 2015 ARPA-E LITECAR Challenge, and the 2018 SHPE STAR Educator of the Year Award. At IUPUI, he teaches courses in design engineering including topology optimization, Bayesian optimization, and additive manufacturing. He is the director of the Engineering Design Research Laboratory (EDRL) and the Center for Additive Manufacturing Research at IUPUI. His research areas include machine learning-assisted design for of lightweight vehicle structures.

Sohel Anwar
soanwar@iupui.edu
Associate Professor and Graduate Chair
Department of Mechanical and Energy Engineering
Director of the Mechatronics Research Laboratory

Sohel Anwar is an Associate Professor in the department of Mechanical Engineering at Purdue School of Engineering and Technology, IUPUI. He is also the graduate program chair of the department and the director of Mechatronics and Automotive Research Lab (MARL). He has over 24 years of combined academic and industry R & D experience in the general area of mechatronics and controls. He received his Ph.D. from University of Arizona, Tucson, AZ in 1995. He worked as an R&D engineer at Caterpillar, Inc. between 1995 and 1999 where he focused on X-By-Wire systems design for Wheeled Loaders. He then joined Ford Motor Company / Visteon Corporation in 1999 as a Senior R&D engineer where he led the fault tolerant design of Drive-By-Wire systems. He joined Purdue School of Engineering and Technology at Indiana University Purdue University at Indianapolis (IUPUI) in 2004. Dr. Anwar has published over 135 papers in peer-reviewed journal and conference proceedings. He is also an inventor or co-inventor on 14 US patents. He is a member of ASME, IEEE, and a faculty advisor for SAE student chapter at IUPUI. He is on the editorial board of four international journals.

Yaobin Chen
ychen@iupui.edu
Professor
Department of Electrical and Computer Engineering
Director of the Transportation & Autonomous Systems Institute (TASI)

Lingxi Li
ll7@iupui.edu
Associate Professor
Department of Electrical and Computer Engineering
Core Member of the Transportation Active Safety Institute (TASI)

Clayton L. Nicholas
clnichol@iupui.edu
Industry Research Development Specialist
Associate Director, Transportation & Autonomous Systems Institute (TASI)
Purdue School of Engineering and Technology
IUPUI Office of the Vice Chancellor for Research

Cliff Campbell
clcampb@iupui.edu
Senior Consultant for Research and Partnership
Transportation & Autonomous Systems Institute (TASI)
Chair of the Dean's Industrial Advisory Board (DIAC)
Purdue School of Engineering and Technology, IUPUI

History with automation

The IUPUI team has been involved in many automation projects including the design and fabrication of autonomous vehicles for applications in precision agriculture since 2015. These vehicles are referred to as agricultural robots (agBOTs). The first agricultural robots was a small electric vehicle that participated in the agBOT Challenge in 2016. A second and a third robots have participated in the agBOT Challenges of 2017, 2018, and 2019. The IUPUI team placed in the top three for two consecutive years (2018 and 2019).

All agricultural robots have been capable of remote controlled and autonomous navigation. These last two robots (one electric and one powered by internal combustion engine) have been equipped with RGB depth cameras, 2D LIDAR or ultrasonic proximity sensors, GPS enhanced with a real-time kinematic (RTK) positioning system, and wifi antenna and router with a range of 10 miles. In addition, a deep neural network has been implemented to identify different weeds and crops and spray with precision either a specific weed agent or fertilizer. This technology can be utilized to detect obstacles and other objects and improve autonomy in environments other than agriculture.

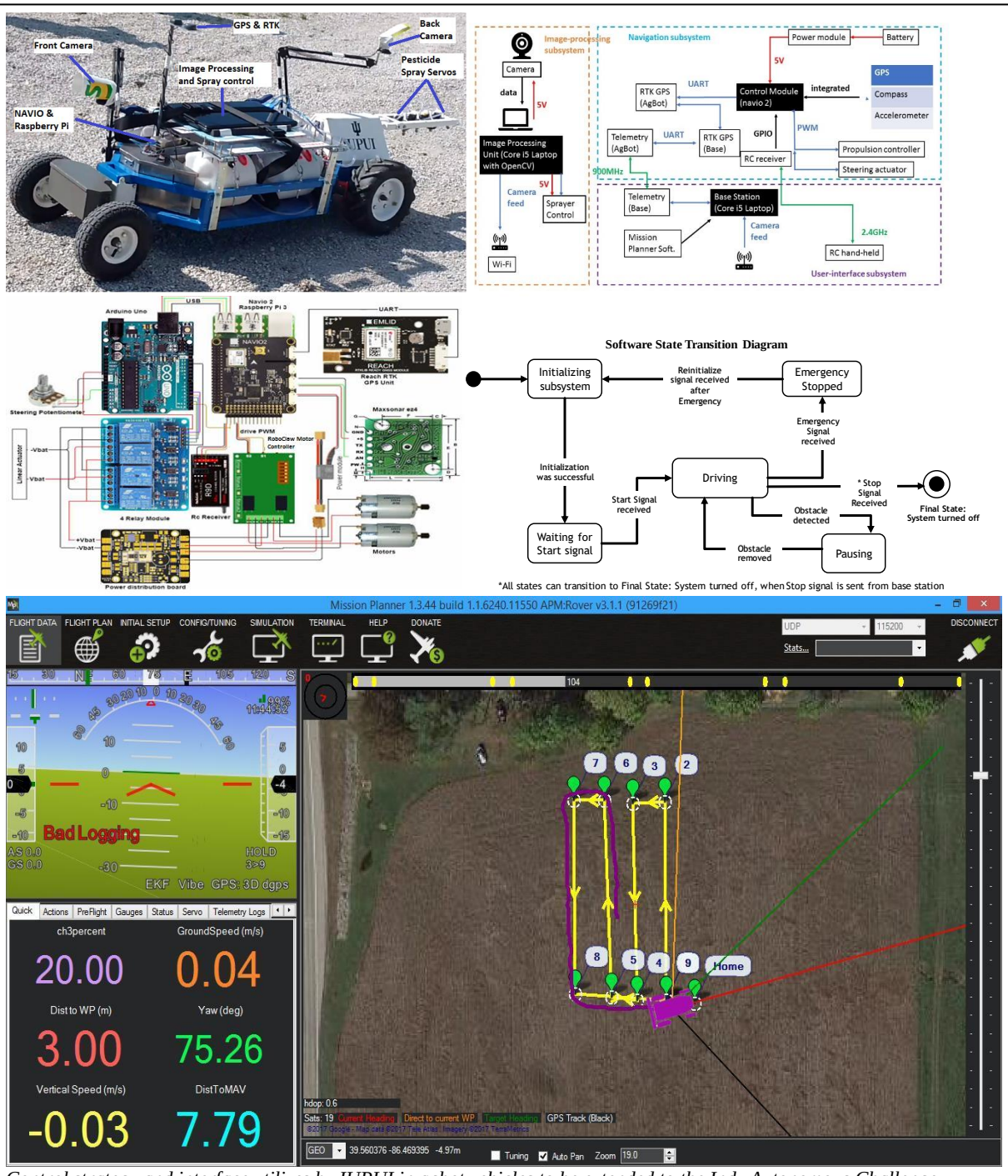
IUPUI agBOT ver 1.0 (2016): Seeding Competition (4th place)

IUPUI agBOT ver 2.0 (2017): Weed and Feed Competition (4th place)

IUPUI agBOT ver 3.0 (2018) and IUPUI agBOT ver 3.1 (2019): Weed and Feed Competition (2nd place in both years).

Plans for the competition

Proposed approach—This project will be executed in three phases: (1) Simulation Model and control software for an autonomous vehicle, (2) Autonomous electric go kart, (3) Autonomous control and communication software for Indy Light racecar. The simulation model and control software will be developed based on existing codes and expertise on our AgBot vehicles. A suitable simulation will be selected for modeling the vehicle, road, and implementing the control software. The hardware / software architecture of our AgBot 2.0 is shown in the following figure. The autonomous electric go cart will be equipped with RGB depth cameras, infrared cameras, 3D LIDAR, long range RADAR (77 GHz), and ultrasonic proximity sensors, GPS enhanced with a real-time kinematic (RTK) positioning system, and Wi-Fi antenna and router. The top speed reached by the go-cart is about 80 mph. Finally, the developed software technology will be transferred to the Indy Light racecar.



Control strategy and interface utilizes by IUPUI in agbot vehicles to be extended to the Indy Autonomous Challenge.

Testing— The autonomous control software will first be tested on the simulation model proposed above. Testing includes both virtual tests (simulation) and physical tests (lab and track). Virtual tests will be performed at IUPUI utilizing state-of-the-art models and software infrastructure from

EDRL. Lab physical tests will be done at IUPUI at TASI and MARL. Track physical tests will be done at the Indianapolis Motor speedway.

Project management— The leadership team will provide project management oversight, maintaining control over the scope, schedule and costs associated with the project. By making sure the strategy and goals of the project are visible and aligned, the true and valid outcomes of this project will be realized, that is the advancement of knowledge and understanding in the field of autonomous driving. Project management provides the framework and guidance that allows an effort such as this to maintain focus on these goals and to deliver value that transcends the end of the race, and the project. For this effort to have lasting value to the school and community, there must be residual benefit, which is the ultimate responsibility of project management.

Fundraising—The goal of the fundraiser is to tell the story in an engaging manner to companies that identify with the challenge. With a heavy regional presence of automotive, racing and automation related industry and the long and storied history of the Indianapolis Motor Speedway engrained in Indiana's very being, the story almost writes itself. Its an easy pitch to make our signature institute, TASI the hero in a story like this, with our very labs residing in the building where the Stutz Bearcat, that raced in the very first Indianapolis 500, was built. The story of the local team and the local track competing for Indiana pride is compelling and will be told well.

Plans for collaboration—While winning the race would be nice, if that is the end of the adventure, we haven't gained much. The true prize in this challenge is the advancement of the collective knowledge gained by more than twenty universities from around the word focusing on a shared task. The IUPUI team welcomes collaboration with industry and academic partners. With our close proximity to the track, our signature institute centered on autonomous systems (TASI), and the presence of the first Motorsports Engineering program in the United States to offer both Bachelor's and Master's degrees, we believe our school has a unique offering to teams wishing to collaborate.