UNIVERSITY OF SURREY

STAR LAB

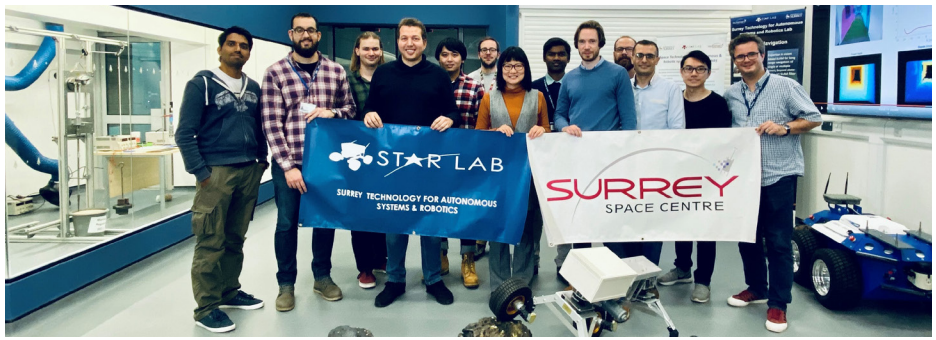
SPACE TECHNOLOGY FOR AUTONOMOUS & ROBOTIC SYSTEMS LABORATORY

Widening the horizon of space exploration & exploitation

surrey.ac.uk/ssc

SPACE TECHNOLOGY FOR AUTONOMOUS & ROBOTIC SYSTEMS LABORATORY

The University of Surrey's STAR LAB (Space Technology for Autonomous & Robotic systems Laboratory) was established in 2007 and has hosted over 50 Postdoctoral and PhD researchers since then.



We are a team of academic scholars, engineers and roboticists whose mission is to build on over three decades of heritage in small spacecraft engineering and extend this philosophy to advance autonomous systems and robotics for space.

We are also focused on transferring our technologies to other non-space domains, enabling our research output to make a valuable impact here on Earth.

KEY STRENGTHS & ACHIEVEMENTS

- Offering lab facilities and research testbeds (capital value of over £3m) to support R&D on autonomous vehicles for extreme and hazardous environments such as space, nuclear, oil and gas
- Established as a leading academic group in several niche research topics including low-computational visual navigation, reconfigurable autonomy, energy-optimised mobility mechanisms, and underactuated locomotion or attitude control
- A steady R&D funding portfilio obtained from over 10 national and international funding bodies and industrial companies
- An international R&D collaboration profile with over 30 universities, research institutes, space agencies and industrial companies
- Numerous R&D esteem factors obtained by the academics and researchers within the Lab, including top ranked publications, leadership & fellowships within prestigious international professional institutions (such as the IET, RAeS, IEEE and RS), awards and prizes in international competitions (such as IAC, COSPAR, UKSEDS, IEEE/ASME and ESA)
- Active involvement and championship in national and internationally teamed space missions including ESA's ExoMars, Proba3 and VMMO, UK's MoonLITE/Moonraker, and CNSA's Chang'E3.

R&D FACILITIES & TESTBEDS

SURFACE ROBOTICS TESTBED

- Surrey autonoMous software And Rover hardware Testbed (SMART) – reconfigurable and customisable in terms of the rover chassis options including Mecanum wheels, normal wheels, tracks and the payload options including mono, stereo or panoramic cameras, 2D or 3D LIDAR. The testbed operates on standardised mid-ware ROS for testing of modular autonomy functions and applications, and employs a full range of control, data acquisition and analysis, and adjustable gravity effect
- Commercial robotic platforms for algorithmic validation and software testing, including Pioneer 3AT, Seekur Jr, Pepper and MIRO
- ESA PANGU Simulator of planetary surface topology, appearance and texture and potential environmental parameters (e.g. lighting, dusts) affecting visual sensing, perception and navigation performance of the rovers
- ESA APCI Framework for testing autonomy algorithms or decision-making software
- High performance computing servers/clouds supporting system verification & validation against ground truth and bench marks.

SUBSURFACE ROBOTICS TESTBED

- Soil characterisation and preparation to simulate Martian and lunar (icy and non-icy) regolith for lab-based testing and experiments
- Subsurface drilling and sampling test rigs with force control, data acquisition and analysis, and adjustable gravity effect

- Motion capture system with infra-red motion cameras and 3D motion tracking (sub-mm accuracy)
- Numerical modelling capability based on DEM and FEM for design simulation and analysis of drills and samplers.

ORBITAL ROBOTICS TESTBED

- Physical simulation testbed of 6DoF orbital dynamics and motion of cooperative or non-cooperative target objects in free space, provided by air bearing table and multiple robotic arms
- Physical simulation testbed of 6DoF manipulation and > 6DOF grasping mechanisms in a complete range of control modes from tele-operation to full autonomy, under disturbances and uncertainties caused by orbital dynamics, occlusion and sensor noise affecting precision and accuracy of the manipulation and capturing systems
- In-house developed Unreal Rendered Spacecraft On-orbit (URSO) photorealistic simulator of environmental parameters (such as lighting, occlusion and sensor noise) affecting sensing and perception in orbit
- System V&V against ground truth and benchmarks for proximity guidance, navigation, control and autonomy.

RESEARCH EXPERTISE

Over the past 10 years, the STAR LAB has secured over £10m in research grants from the European Commission; European Space Agency (ESA); major UK national funding bodies such as UK Space Agency (UKSA), UK Research Innovation (UKRI) – (the Engineering and Physical Sciences Research Council, Science and Technology Facilities Council, and InnovateUK), National Decommissioning Authority, UK Atomic Energy Authority and Royal Academy of Engineering; as well as industrial companies like Airbus, NEPTEC, OHB and Sellafield. This has led to collaborative research with over 30 national and international partners.

With academics who are international leaders in their fields, and close links with partners and collaborators leading the industry sector, the STAR LAB offers the ideal education and research environment for the next generation of space professionals, engineers and roboticists.

Our research is focused on the following topics:

SENSING, PERCEPTION & VISUAL GNC

- Our research leads to technologies for low-computation, high-accuracy 3D mapping and perception, resource-aware computation, and data assimilation for parameter tuning in order to address challenges imposed by the extreme environments and design constraints of spacecraft and space missions
- Visual sensing using optical monocular/stereo cameras, 2D/3D LIDAR, and RGB-D sensors for visual odometry or pose estimation. (Our technique is ranked 2nd place for real-world dataset and 3rd place for synthetic dataset in the ESA/Stanford Pose Estimation Challenge 2019)
- Visual perception based on cognitive vision and saliency techniques for thematic feature extraction, sinkage prediction, and terrain classification
- Planetary Monocular SLAM (PM-SLAM) for long range navigation of surface rovers (IAF's 3AF Edmond Brun Silver Medal 2013)
- Major funded research projects and contributions to real-world space missions: ESA ExoMars mission's PanCam payload and Phase A study; ESA Proba3 mission's FLLS payload; UKSA funded CREST-1, NSTP2, and CREST-3 projects; Airbus funded OOA project; CNSA Chang'E3 mission's PanCam data analytics; UKRI/UKSA funded Future AI & Robotics for Space (FAIR-SPACE) project.

RECONFIGURABLE AUTONOMY

- Our research leads to technologies for hardware/software reconfiguration and self-verification in real time
- Autonomous software architecture, domain-independent, generic and reconfigurable, based on rational agents for complex space systems such as multi-satellite and multi-rover scenario

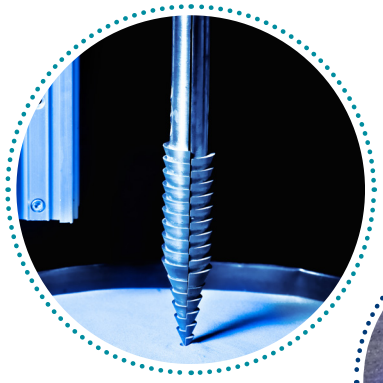
- Advanced software agents for learning and planning capabilities
- Ontology-based complex system modeling through SysML
- Major UKRI-EPSRC funded research projects: FAIR-SPACE RAI hub grant; Industrial 6th Sense grant; Autonomous & Intelligent Systems Programme; Impact Acceleration Account; Strategic Collaboration Award; Capital Equipment Grant

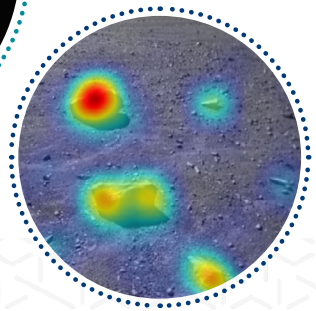
UNDERACTUATED ATTITUDE CONTROL

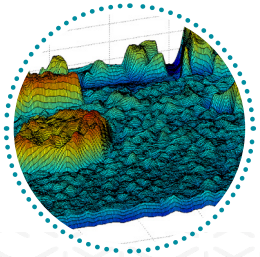
- Low-cost attitude control for spinning space vehicles (such as kinetic penetrators or multi-U CubeSat) using minimum one actuator
- State-of-the-art slew algorithms including Extended Half Cone, Dual Cone, Sector Arc, and Spin Synch
- Major funded research projects and contributions to real-world space mission: Airbus funded R&D on software and hardware testbed for underactuated slew control; Surrey led Strand-1 CubeSat mission's slew control experiment.

BIO-INSPIRED LOCOMOTION & MECHANISM

- Our research leads to technologies for energy-optimised locomotion mechanisms and control
- Pioneering bio-inspired Dual Reciprocating Drilling (DRD) technology - also known as the 'wasp drill' - allowing deep drilling with flexible deployment mechanism in low-gravity environments, and low-mass sampling tool suitable for small space vehicles. (COSPAR Outstanding Paper Award 2016; Finalist of IEEE/ASME's AIM Best Paper Award 2019; Exhibition at National Science Museum 'Antenna' gallery)
- Innovative surface Mobile Active Rover Chassis for Enhanced Locomotion (MARCEL), capable of negotiating with loose soil and rugged terrains using minimal actuation
- Rigorous and systematic preparation methodologies for planetary soil simulants, ranging from Martian compressible soil to icy lunar regolith
- Vision based techniques for soil characterisation and physical property estimation
- Major funded research projects and contributions to real-world space missions: ESA ExoMars mission's sampling payload testing; ESA Lunar Polar Sample Return (LPSR) mission's L-GRASP payload testing; CNSA's Chang'E3 mission terrain image analytics; ESA's ACT grant on Bionics and Space Systems; NPI/OHB grant on innovative deep drilling; RAEng project on low-cost sampling; UKRI/UKSA funded FAIR-SPACE project.

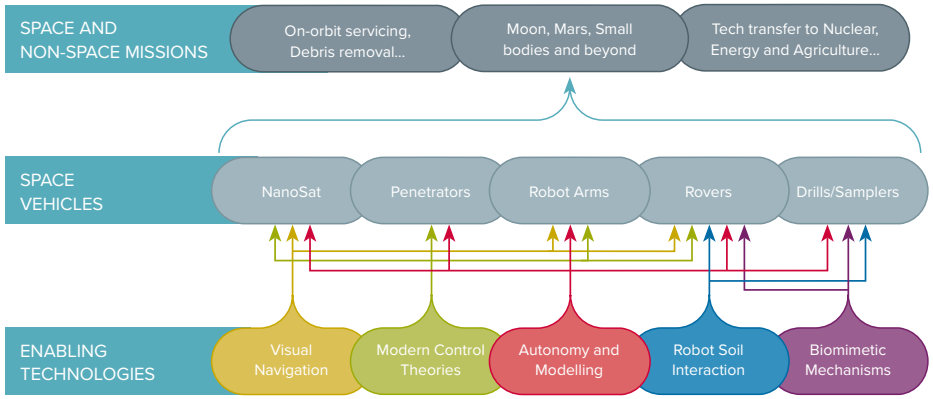






KEY SPACE SYSTEMS

Technology developed in the STAR LAB is enabling the next generation of spacecraft and vehicles, including rovers, robotic arms, drills and penetrators.



OVERVIEW OF VEHICLES DEVELOPED IN THE STAR LAB

Surrey autonoMous software And Rover hardware Testbed (SMART)

- Multiple small to medium-sized rovers with different chassis, e.g. Mecanum wheeled, normal wheeled, tracked (ranging from 20 to 100kg each)
- **Robotic payloads:** multi-DoF robotic arm, gripper, drill sampler
- **Sensors:** monocular and stereo camera, 2D and 3D LIDAR, IMU, differential GPS
- Operating standardised mid-ware ROS for testing of modular autonomy functions and/or applications.

Mobile Active Rover Chassis for Enhanced Locomotion (MARCEL)

- Active suspension design to allow crawling and climbing behaviours
- 4- wheeled active rover chassis to improve crossing capabilities over rough terrain and loose soil with a minimal amount of actuation (or comparable to rocker-bogie design with passive suspension)
- Deep reinforcement learning-enabled GNC algorithms that can learn traversability features and automatically tune the GNC parameters.

Wasp drill/sampler

- Planetary drill inspired by wood wasp ovipositor mechanism
- Based on Dual Reciprocating Drilling (DRD) which does not rely on overhead force to operate
- Lighter weight, higher power efficiency than conventional drills such as rotary and percussive
- Advantageous for low-gravity mission scenarios such as the Moon, asteroids and comets.

Micro-penetrator

- The probe (~10kg) free falls and penetrates into target planetary bodies at hundreds of metres per second, and a small angle of attack (less than 8 degrees) is permitted
- Fully instrumented with engineering and scientific payload
- Involved in MoonLITE, LunarEX/NET missions and the UK Penetrator Consortium.

STUDENTS

The University of Surrey offers undergraduate and MSc degree programmes in space and aerospace engineering across several schools/ departments, which each draw on research expertise and STAR LAB. Students on these courses are often able to benefit from working on a three to twelve-month project within the STAR LAB. In addition, we offer a summer internship programme and host several project students each academic year.

RESEARCHERS

The STAR LAB has an impressive heritage of first-class research in multi-disciplinary scientific fields for cross-sector applications. Both Postdoctoral and PhD researchers will benefit from our extensive lab facilities and our long-standing collaborations with internationally-renowned partners and funding bodies.

INDUSTRY

The STAR LAB has many years of experience working with industry in R&D for different Technology Readiness Levels through collaborations and industrial contracts.
We also offer professional training, bespoke short courses, and academic consultancy services to the space, nuclear, energy and agriculture sectors.

CONTACT DETAILS

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