

A Dual-Pin Tool Coupler for Robotic Excavation. O.S. Lawlor¹, ¹U. Alaska Fairbanks, Duckering Building, Suite 527, 1760 Tanana Loop, Fairbanks, Alaska 99775. (Contact: lawlor@alaska.edu)

Introduction: Excavation and construction on planetary surfaces would benefit from a dust-tolerant tool *coupler*, to let a robot easily swap out robust end-of-arm *tools* such as a heavy excavation bucket, rock ripper, material extruder, gripper, or powered rock breaker. We built and robotically tested several approaches for robot-to-tool couplers, and recommend a dual-pin coupler for standard use on robots and tools.

Prior Work: On the International Space Station (ISS), robot arms use derivatives of the Flight Releasable Grapple Fixture (FRGF), a long mating pin with a three-lobed mechanical contact surface [1]. This is sturdy and flight-proven in orbit for decades, but it is heavy, and not shown to be dust tolerant for surface operations.

A lighter coupler is the ISS-derived wedge mating interface (WMI), although the wedges may jam or bind if covered in dust.

Robotic tool changers [2] are often low force but also low mass (<1kg) and low stack height.

Our dual-pin system is scaled down from the Cat® Pin Grabber [3], Yanmar Quick Coupler, or Miller PowerLatch excavator attachment systems. These field-proven designs use large clearances (>3mm) to allow reliable operation even when covered in dust, and thick steel parts make them robust to years of jobsite use with 100 kN forces.

Coupler Requirements: Flight hardware should be minimal mass. Surface mining and construction operations require a robust tool coupler, capable of handling large forces and moments. Robotic operation requires simple rapid attaching and detaching in dusty environments. Alignment precision is less important, due to the inherently low precision of excavation operations.

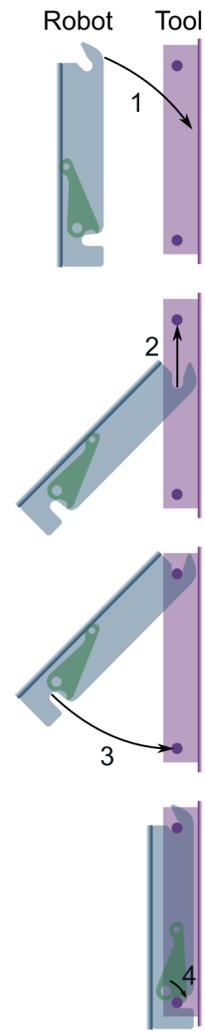
Tool Coupler	Mass / tool	Dust Tolerance	Ease of Coupling	Force
Dual-pin	0.4 kg	Field derived	Good, one pin at a time	>500 N
ISS WMI	4 kg	Wedge may jam	Wedge self-aligns	500 N
FRGF	8 kg	LEO design	Proven automation	667 N

Dual-pin Coupler: We propose putting two parallel pins on the tool. On the robot a static top hook self-aligns the coupler and tool, and a powered locking lug clamps the other pin in the bottom slot, to securely lock the tool to the robot. This puts all the active parts on the robot, and minimizes the mass of the tool. Four degrees of

freedom are constrained by direct contact, and the tool pitch is constrained by the locking lug, leaving only minimal sliding motion along the pins.

Coupling: To attach to a tool, the robot's end effector approaches the tool tilted down (1) so the robot's top hook enters the tool between the pins. After making contact the robot then lifts up until the top pin is captured (2) by the top hook. The robot then tilts the coupler until its bottom slot captures the tool's bottom pin (3), optionally using gravity to align the tool to the top hook. The robot can then clamp the tool's bottom pin (4) by tilting the locking lug. Detaching is in the reverse order.

Dimensions: For robot or tool around 100kg, 8mm diameter pins of length 75mm, mounted 125mm apart and 15mm from the face of the tool, works well. We tested this with a robot and a variety of tools: buckets, fluid tank, powered rockbreaker, robot deployment hanger. Upside down mating also works. Built from steel, the tool side masses under 400g and handles forces over 500N. Electrical connections could be made centrally or below the bottom pin. Computer vision markers for automated coupling could be applied above the top pin or at either side. A double-size version with hollow 16mm pins allows tools to also be lifted by human hands in gloves, which could allow shared robotic or human manipulation of tools or containers.



References: [1] ISS MCB, [International External Robotic Interoperability Standards \(IERIS\)](#), Feb. 2018. [2] Gyimothy D. and Toth A. (2011) [IEEE/ASME Advanced Intelligent Mechatronics \(AIM\)](#) pp. 1046-1051. [3] Caterpillar [Tech. Spec. for Cat Pin Grabber Excavator Couplers](#), GEJQ9387.