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Collecting micro-sized minerals is a difficult hobby to engage the public. The traditional approach has been to set up one or several stereo microscopes, pre-focused on an eye-catching crystal. A more elaborate approach added a specimen carousel—most successful when a collector stood by to coach the viewer. The advent of digital cameras has dramatically changed the micro-mineral hobby. This talk introduces a system built around a Hayear 41 MP camera whose large working distance—approximately 9 cm versus one to two cm typical of high-magnification setups—leaving room for the mechanical automation that turned a simple scope into a fully interactive robotic microscope. The presentation relates the design's evolution through three generations and the father-son engineering tradeoffs at each stage.

Version 1 employed an eight-specimen platter using a discarded twelve-inch vinyl LP. Notches filed onto the perimeter engaged a V-shaped spring to define stop points aligned with the lens. Mounted on a six-dollar lazy Susan, it required the user to manually rotate the platter, adjust focus, and set magnification for each specimen. Public reaction was very positive on the first outing, but when left unattended, the alignment drifted, the spring became distorted, and despite my instructive signage, users had difficulty operating the scope.

I reviewed these frustrations with my son Kevin, also an electrical engineer. He said, "Dad, we need to motorize—computerize—this." Version 2 added NEMA stepper motors, a Raspberry Pi 4 micro-computer, and pushbutton control of the carousel, focus, and magnification. Its first public demonstration was at the Capital Mineral Club show, Concord, NH, August 23–24, 2025. It was pleasing to see how quickly juniors engaged in the interactive experience. But the lens-to-specimen alignment remained a bit "fiddly," especially at high magnification.

The father-son "engineer mode" kicked in and we embarked on version 3. Kevin suggested a low-cost CNC frame as the mechanical base, contributing his large-format 3D printer and programming skills to the build. The CNC provides true 4-axis motion—X, Y positioning plus independent Z-focus and optical zoom—driven by a Teensy 4.1 microcontroller acting as a motion appliance under Raspberry Pi control.

The resulting system holds a tray of 28 mineral specimens. For each unique tray, the operator uses a calibration GUI to jog (translate) to each specimen, define its X-Y position, focus, and zoom, and save the result as a simple configuration file containing the name, locality, coordinates, and optical settings for the specimen. Loading another tray is just loading a different file. Once deployed, the system is hands-off: it auto-sequences through all specimens, overlaying each with its mineral name, locality, collector, and a dynamically calibrated scale ruler computed from the actual field of view. Public users can select any specimen to explore manually; after thirty seconds of inactivity, auto-cycling quietly resumes. A 24-LED ring provides adjustable illumination with rainbow transitions between specimens.

A unique feature is computational focus stacking: the system automatically captures ten images at progressive focus depths, then merges them into a single sharpened photograph using open-source stacking software running on the Pi micro-computer. Taking this further, a "Giga Crystal Clear" mode tiles a 3×3 grid of overlapping positions—each independently focus-stacked—and stitches the nine results into a single high-resolution composite with a 3X field of view. The result is a detailed, annotated, image with calibrated scale bars, suitable for research documentation or public display.

This talk will present the mechanical evolution, the engineering tradeoffs at each stage, and live demonstrations of the system's imaging capabilities.


The Mineral Microscope
HAYEAR
Explore Tiny Crystals
INTERACTIVE MICROSCOPE
Mouse control of Microscope Features
• Scope auto-runs until mouse activation
• Select specimen from list on screen left side (use vertical slider)
• Use screen toolbar controls (functional when view is static)
• X – Y fine position "JOG" controls to adjust view
• JOG control step amount is adjustable – 0.1 mm to 5.0 mm
• Adjust focus and magnification-zoom with mouse.
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