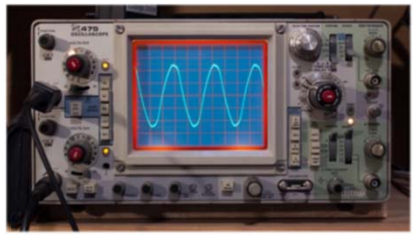
Company Overview

November 2019

Evolution of test & measurement solutions for scientists, engineers, and product developers (1960 – today)



Electro Rent Corporation

TestEquity

LIQUID INSTRUMENTS Moku:Lab

Late 1960's

- Mass production of test equipment boxes
- Rise of Tektronix's dominance in T&M hardware (>$1B revenue today)

Late 1980's

- Modular hardware instruments first introduced
- VXI/PXI enable physical, swappable modules by National Instruments (>$1B revenue today)

Early 2000's

- Companies become more sensitive to T&M capex
- ElectroRent, TestEquity, etc. expand rent/lease model

Next

- Modular software instruments first introduced
- Advances in FPGAs enable software-defined-hardware, swappable modules
- Ultra-flexible devices offer customizable and upgradable solutions with minimal capex

Moku:Lab reduces testing complexity and cost through its ultra-flexible and expandable instrument platform

Test & Measurement today

One instrument per box:

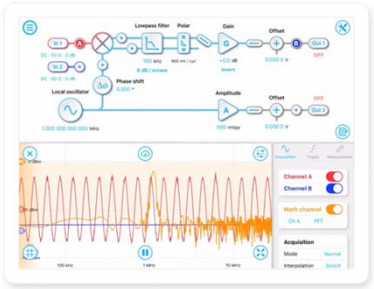
Many different devices to generate, record, and process electrical signals

Agilent Technologies Tektronix NATIONAL INSTRUMENTS

Sub-par workflow that hasn't changed in decades

Liquid Instruments couples the signal processing power and reconfigurability of an FPGA with high-speed analog inputs and outputs to pack multiple instruments, new functionality, and unlimited flexibility into a single device.

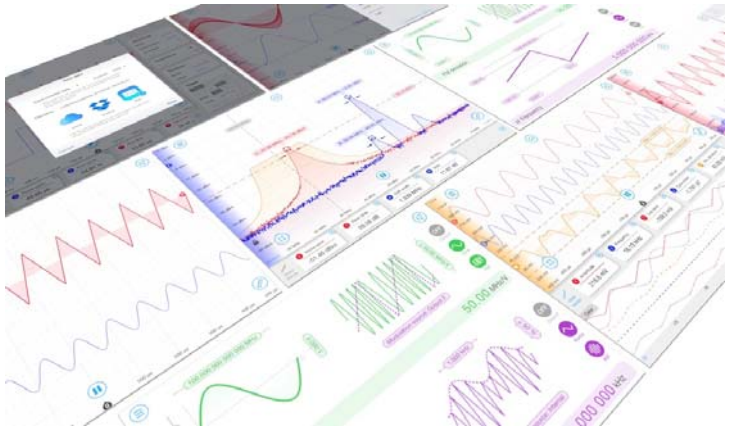
LIQUID INSTRUMENTS Moku:Lab



Launched with three instruments, now includes 12:

Our modular software instruments leverage recent advances in FPGAs, DSP, tablet hardware, and UI design

Moku:Lab's hardware and iPad App connect wirelessly, allowing users to record measurements and control experiments from anywhere in the lab.



Carefully designed interfaces streamline workflow and maximize productivity. Common elements and integrations between instruments translate into more familiar, intuitive and consistent experiences in the lab.

For even more control, use Moku:Lab through one of our supported APIs:

python™ MATLAB LabVIEW™ Windows (Coming soon)

Founded by a team of experimental physicists with a background in gravitational wave detection

Prof Daniel Shaddock,
Chief Executive Officer

Danielle Wuchenich, Ph.D.
Chief Strategy Officer

Timothy Lam, Ph.D.
Chief Technology Officer

Paul Altin, Ph.D.
Chief Scientist

Ben Coughlan, Ph.D.
VP Engineering - Software

David Rabeling, Ph.D.
VP Engineering - Hardware

Jet Propulsion Laboratory
California Institute of Technology

Caltech

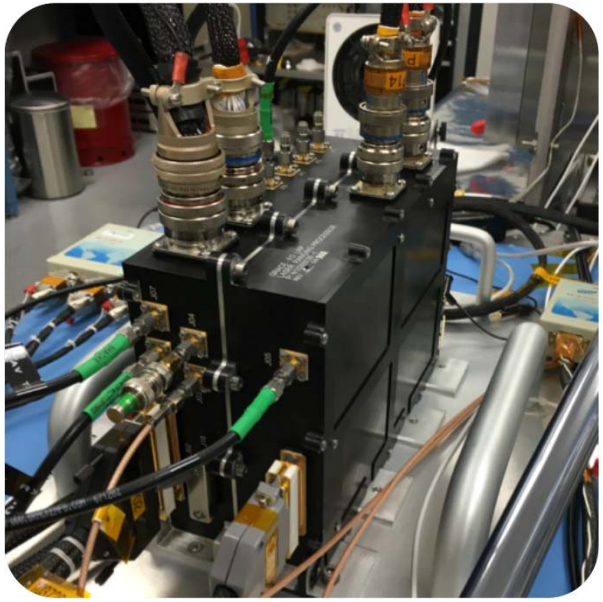
LOCKHEED MARTIN

MAX PLANCK INSTITUTE
for the science of light

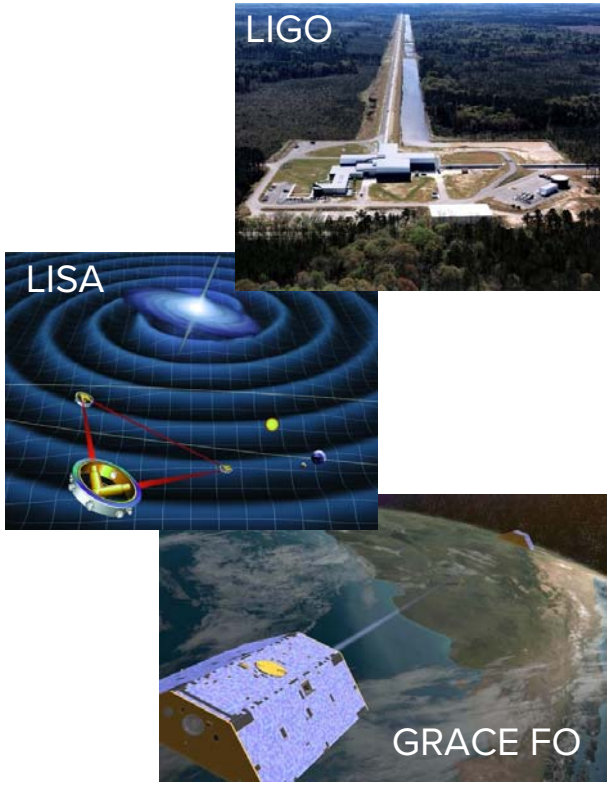
Australian National University

Moku:Lab technology evolved from research at NASA's Jet Propulsion Laboratory (JPL), and was further developed at the Australian National University (ANU) before spinning out into Liquid Instruments.

Moku:Lab was born out of the team's work on the LIGO, LISA, and GRACE Follow-on laser ranging interferometer projects



Flight-qualified FPGA hardware with algorithms designed by Liquid Instruments team members



GRACE Follow-on launched May 2018 and meets all performance requirements

Moku:Lab is optimized for high-end research applications

High fidelity signal analysis, agile signal generation, control systems, and advanced filtering.

Team's extensive experience in extreme LIDAR techniques

LIGO: matched template filtering for optimal signal extraction

LISA: precision phase measurements on flexible FPGA platform

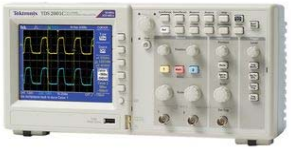
GRACE Follow-on: control systems, laser link acquisition (beam steering, FFT signal analysis), precision timing

Moku:Lab's family of instruments is the world's most compact suite of high-performance tools

Lock-in Amplifier	DC–200 MHz, >80 dB dynamic reserve, 20 nV/√Hz input noise
Laser Lock Box	Better than 0.1 Hz/√Hz @ 1 Hz frequency stability demonstrated
Digital Filter Box	Implement custom or preset IIR filters (e.g. 8th order Chebyshev) at 15 MS/s
Arbitrary Waveform Generator	2 channels, 1 GS/s with 300 MHz bandwidth, >8,000 points
Phasemeter	Zero-dead time phase measurements with better than 1 µcycle/√Hz precision
Waveform Generator	2 channels, DC–250 MHz, modulation, better than 300 ppb frequency accuracy
PID Controller	10 MS/s sample rate, 2 In/Out channels with MIMO blending
Oscilloscope	200 MHz, 12 bit ADC, 1 MΩ/50 Ω, measurement trends, cloud data saving
Data Logger	1 MS/s data logging to RAM or SD card, 10 Vpp, network controlled
Frequency Response Analyzer	10 mHz–120 MHz, 2 channels, advanced harmonic measurements
Spectrum Analyzer	DC–250 MHz, 1 Hz minimum RBW, integrated tracking generator
FIR Filter Builder	Design and implement custom filters at up to 15 MHz or 14,000 coefficients

How does Moku:Lab compare to other industry leaders?

One Moku:Lab provides the capabilities of:

Arbitrary Waveform Generator	KEYSIGHT TECHNOLOGIES		33622A	$7,000
Oscilloscope	Tektronix		TDS2022C	$2,640
Lock-in Amplifier	SRS Stanford Research Systems		SR844	$8,450
Frequency Response Analyzer	OMICRON LAB		Bode 100	$5,490

and more...

How does Moku:Lab compare to other industry leaders?

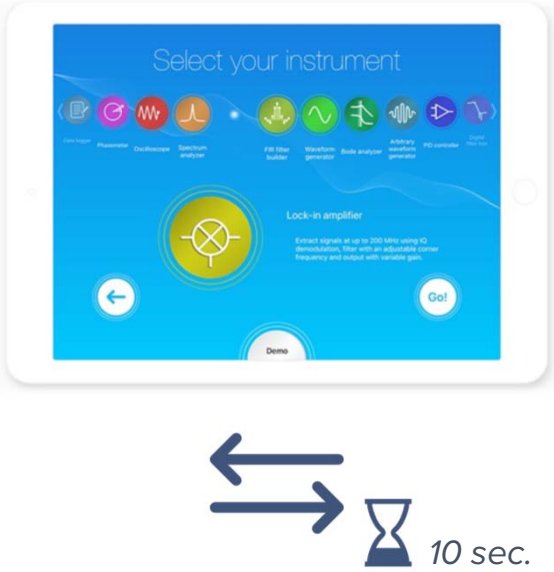
One Moku:Lab provides the capabilities of:

Laser Lock Box	TOPTICA PHOTONICS		PDD 100/F	$6,000
PID Controller	Newport		LB1005-S	$2,700
Phasemeter	Zurich Instructments		HF2LI-PLL	$25,000
Data Logger	KEYSIGHT TECHNOLOGIES		U2531A	$2,200

and more...

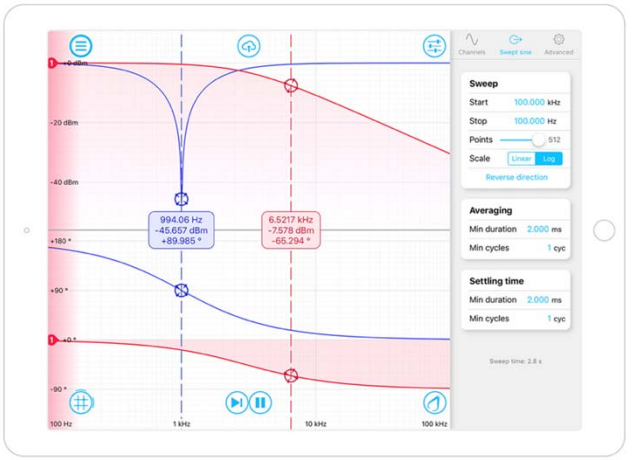
With our software-controlled hardware, switch instantly between instruments in seconds

Oscilloscope



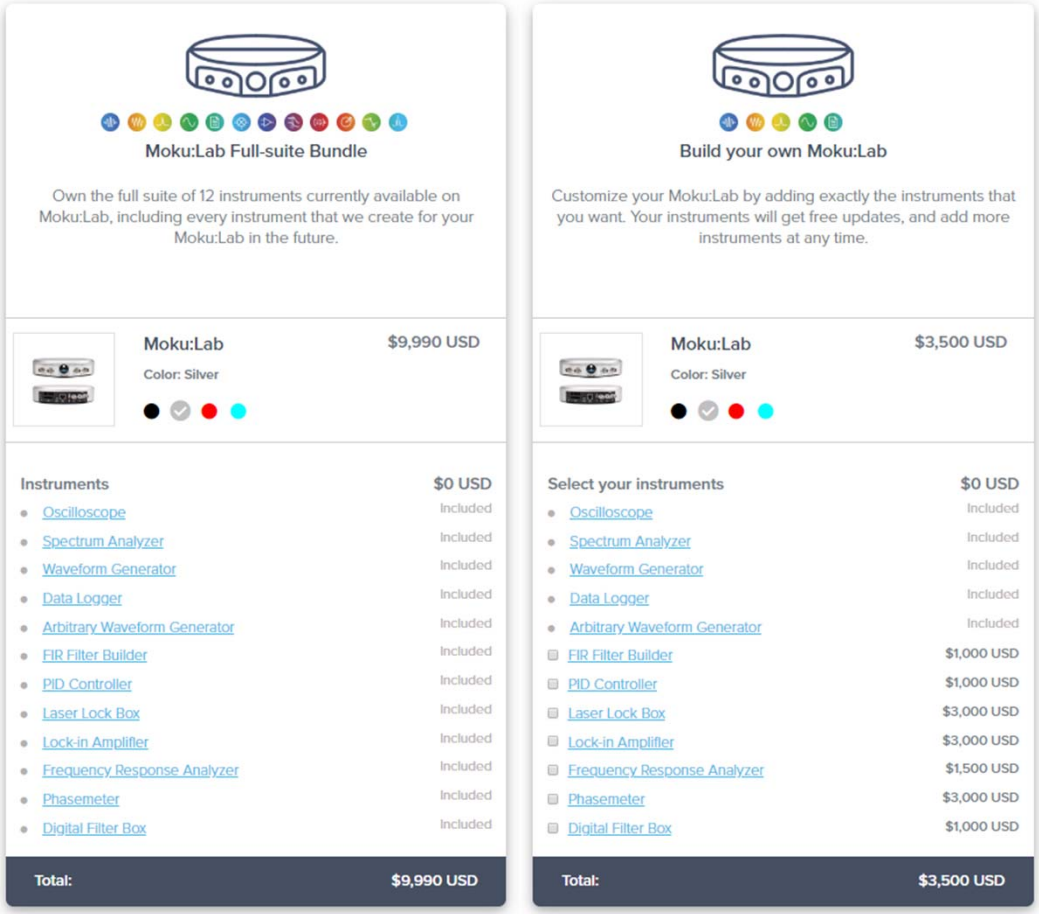
10 sec.

Frequency Response Analyzer



When an instrument is selected, Moku:Lab is rewired ‘on-the-fly’ to become the chosen tool, with all the hardware capabilities and features of the new instrument.

Build fit-for-purpose bundles of instruments and get measuring with less hassle



Build a customized suite of instrumentation in a few clicks online, with transparent pricing and fast lead times (< 48 hours).

Moku:Lab gets even better over time: users regularly receive over-the-air software updates that add new features and enhance existing ones.

Optimize size, weight, power, cooling, and cost (SWaP-C) of your test, measurement, and diagnostic equipment

Example: Field deployed demo of a motion sensing project at a conference. The Moku:Lab configuration results in ~25% savings on cost of equipment, and a huge reduction in volume and weight of equipment transported (>90%).

Standard Equipment Configuration

Instruments	Model	Price	Dimensions | Weight
Lock-in Amplifier	SRS SR830	$4950	17x6x20” | 23 lbs
Oscilloscope	Tektronix TBS1064	$1300	13x7x5” | 5 lbs
AWG	Keithley 3390	$2150	5x9x15” | 9 lbs
DAQ Board	Labjack U3-LV	$115	7x4x3” | 1 lbs
Total		**$8515**	**3250 in^3 | 38 lbs**

Power: 125 W

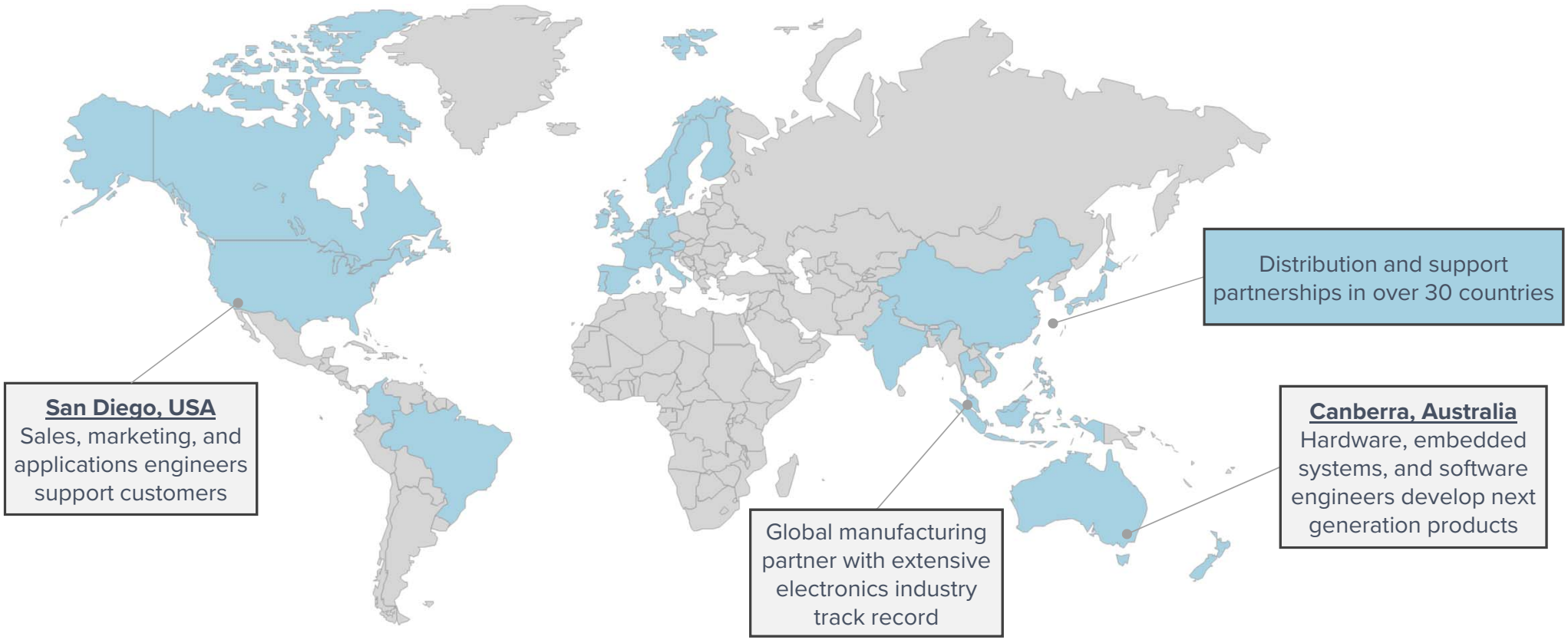
Moku:Lab Configuration

Instruments	Model	Price	Dimensions | Weight
Moku:Lab	Hardware	$3500	~8x8x2” | 4 lbs
	LIA Download	$3000	0x0x0” | 0 lbs
Total		**$6500**	**100 in^3 | 4 lbs**

Power: 20 W

Source: https://github.com/robinvanemden/Flappy-Kinect-Lock-in-Amplifier/blob/master/README.md

Our extended team and global partners are dedicated to innovative new products and customer success

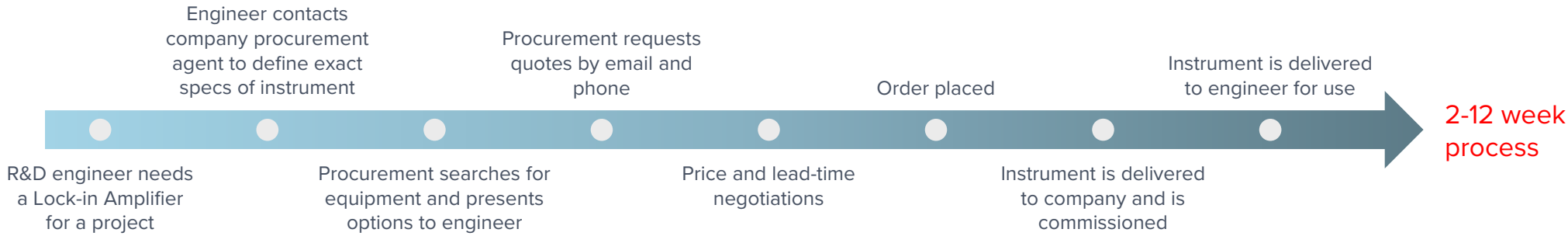


Liquid Instruments is invested in user success by providing the best service and support in the industry

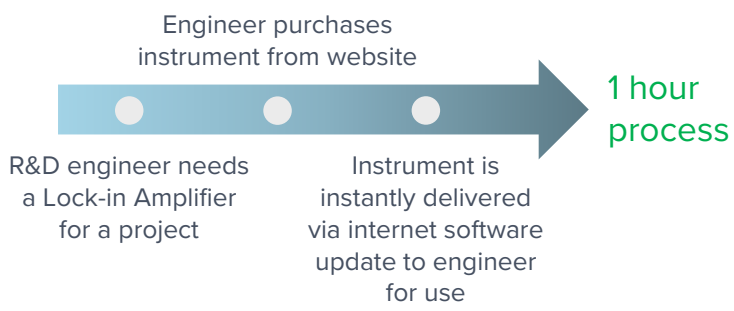
- 30-day return for any reason
- 1-year warranty included on all products
- 3-year extendable warranty and service plans available
- NIST traceable (ISO/IEC 17025) initial calibration and periodic re-calibration plans available
- 48-hour turnaround on product replacement (common hardware platform means we always have your system in stock)
- Average response time from an applications engineer or technical team member < 12 hours
- New feature requests from users can be implemented and deployed remotely

New instruments, updates, and upgrades are delivered the moment you need them, not 12 weeks later

Traditional workflow for new equipment acquisition



Liquid Instruments' workflow



Don't wait, just measure.

Hundreds of technology companies and R&D institutions already rely on Moku:Lab for their day-to-day measurements

A few of our customers

U.S. Air Force Academy
Oak Ridge National Laboratory
NIST National Institute of Standards and Technology
Texas Instruments
Indian Institute of Technology Madras
CERN
NPL National Physical Laboratory
JPL Jet Propulsion Laboratory California Institute of Technology
NVIDIA
The University Of Queensland Australia
Applied Materials
UF University of Florida
Yale
Micron
MIT Massachusetts Institute of Technology
SLAC National Accelerator Laboratory

Cool stuff they're doing

NASA Goddard Space Flight Center

Demonstration of high precision ranging measurements over high data-rate coherent optical communication links.
Moku:Lab Phasemeter used to measure the optical phase of a slave laser against a master in a 10 Gbps PSK modulated system.

G. Yang *et al.* IEEE Aerospace Conference, 2018, pp. 1-10.

Lockheed Martin

Development of compact interferometric imaging systems for space applications based on photonic integrated circuits.
Moku:Lab Arb. Waveform Generator used to control and drive fast-steering mirrors to scan through interferometric fringes.

K. Badham *et al.* Conference on Lasers and Electro-Optics, 2017, pp. 1-5.

University of Chinese Academy of Sciences

Engineering of vibration-insensitive optical fiber spools for laser stabilization.
Moku:Lab Frequency Response Analyzer used to drive a chirp modulation signal and measure vibration-induced phase noise.

J. Huang *et al.* Chinese Optics Letters, 2019, 17(8): 081403

Universities are teaming up with us through our Educational Partnership Program to bring Moku:Lab to their students

U.S. AIR FORCE ACADEMY

Moku:Lab deployed in USAFA EE teaching labs to increase cadet retention and improve time from concepts to applications

Center of Physics Experiments, Beijing Institute of Technology

Joint LI-BIT teaching lab for physics unveiled in mid-2019

Moku:Lab being used/evaluated for Physics & Engineering education:

United States Naval Academy Annapolis

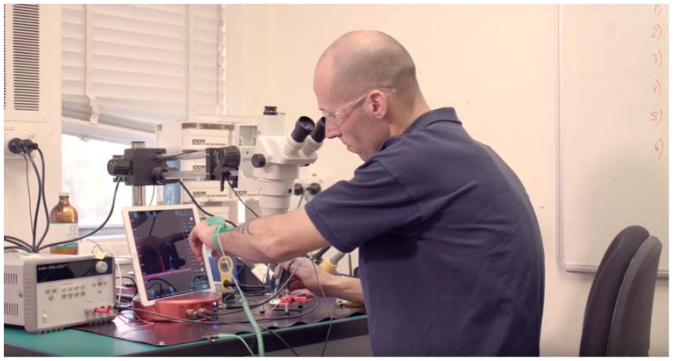
Australian National University

St Andrews University Spiritus Mens Corpus 1874

Rensselaer Polytechnic Institute 1824

Colorado School of Mines

Moku:Lab in action



Click to see Moku:Lab in use:

YouTube

Moku:Lab Videos

Application Notes


LIQUID
INSTRUMENTS