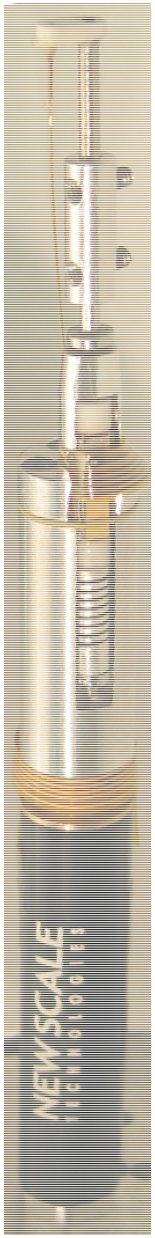
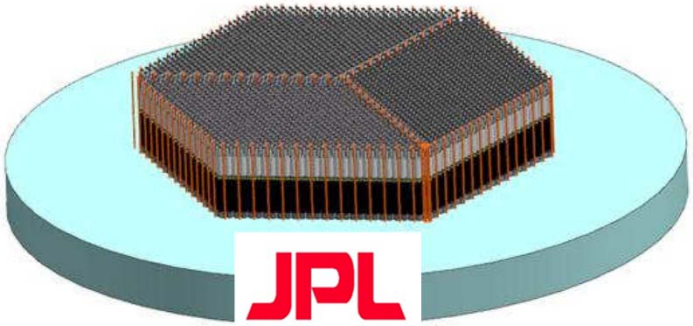
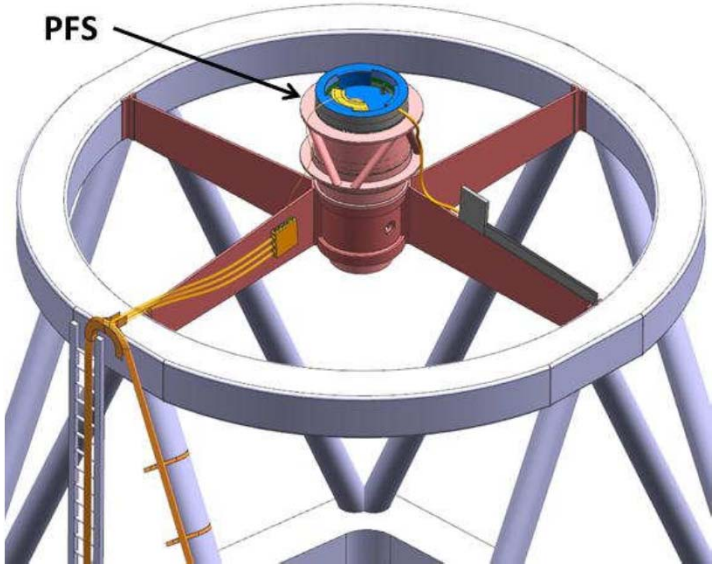


Cobra, 2-Degree of Freedom Fiber Optic Positioner for the Subaru Prime Focus Spectrograph



David Henderson
co-CEO and CTO



NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems

New Scale Technologies, Inc.
121 Victor Heights Parkway
Victor NY 14564
www.newscaletech.com

Outline

NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems

- About New Scale
- Background and Acknowledgements
- System Requirements – PFS
- Selection of Piezo Motor Technology
- 2-Axis Positioner Module
- Future Work

About New Scale Technologies

NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems

- Founded in 2002 by David Henderson
- Innovation in Tiny Piezo Motors and Micro Motion Systems
- Manufacturing and System Integration
- New Scale Delivers Motion Systems:
  - Small……*fits in mobile phone*
  - Precise……*micrometer movements*
  - Smart……fully integrated, “plug and play”

Victor, NY (near Rochester, NY)

Strategic business partner	amUn	**Investment, ASIC’s, Sales Support**

Licensed manufacturing partners	TDK-EPC (EPCOS) **UTAF Actuator Motor and Modules** **SQUIGGLE Advanced piezo ceramics**	**Tier 1 Camera Module Companies** **UTAF Actuator Modules**	TAMRON Perfecting the Art of Electronics ALPS **SQUIGGLE motors**

About New Scale ...Miniaturization

NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems

1/100 Squiggle

2.8 volts
0.35 Watts

1/5
UTAF

2.8 volts
0.15 Watts

1/500 Smaller Motor
1/10,000 Smaller Drive
1/100 Lower Voltage
1/100 Lower Power

Background and Acknowledgements

NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems

Developments in high-density Cobra fiber positioners for the Subaru Telescope's Prime Focus Spectrometer

Charles D. Fisher*[a], David F. Braun[a], Joel V. Kaluzny[a], Michael D. Seiffert[a], Richard G. Dekany[b], Richard S. Ellis[c], Roger M. Smith[c]
[a]Jet Propulsion Laboratory/California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109 USA; [b]Caltech Optical Observatories, 1201 East California Blvd., Pasadena, CA 91125 USA; [c]California Institute of Technology, 1201 E. California Blvd., Pasadena, CA 91125 USA

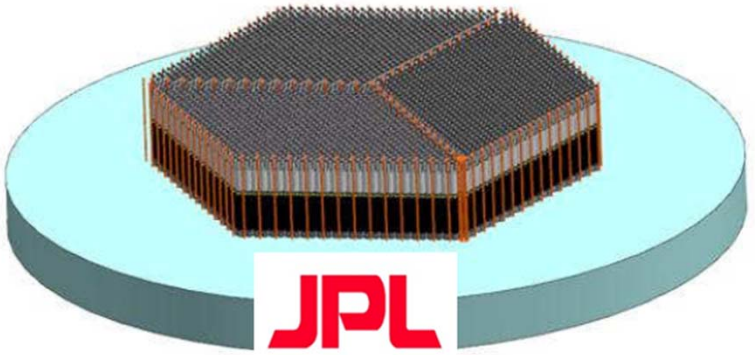
Presented this month in Amsterdam at SPIE Astronomical Telescopes + Instrumentation

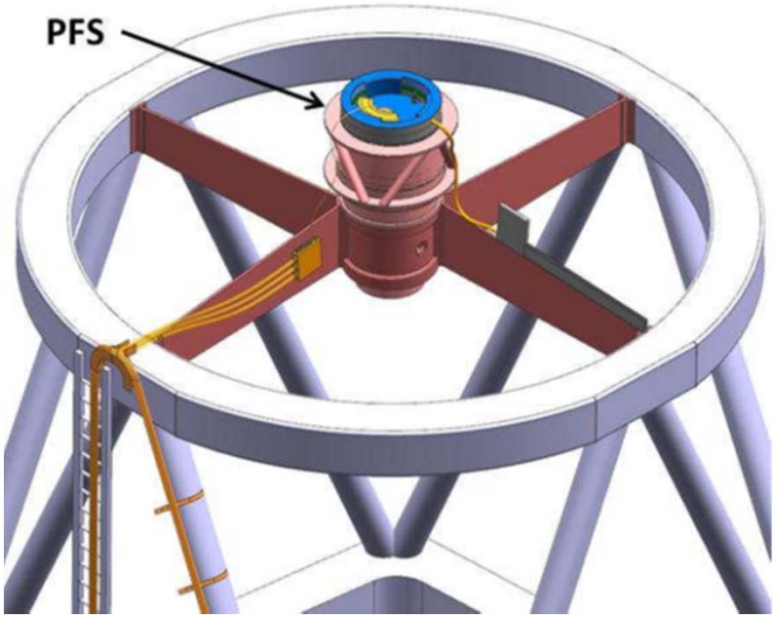
- This program started in 2008. Gen 1 positioners delivered in 2009.
  Fisher, C., Braun D., Kaluzny, J., Haran, T., "Cobra – a Two-Degree of Freedom Fiber Optic Positioning Mechanism," IEEE Aerospace Conference paper #1185, Version 5 (2009).
- Gen 1A positioners delivered to JPL at the start of 2012.
- New Scale work is funded by the Jet Propulsion Laboratory, California Institute of Technology.
- JPL has received some funding from the Funding Program for World-Leading Innovative R&D on Science and Technology(FIRST) "Subaru Measurements of Images and Redshifts (SuMIRe)", CSTP, Japan.
- The New Scale Team: Justin Vacca, Rob Culhane, Conrad Hoffman, Dan Viggiano, Mat Wrona

System Requirements - PFS

NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems

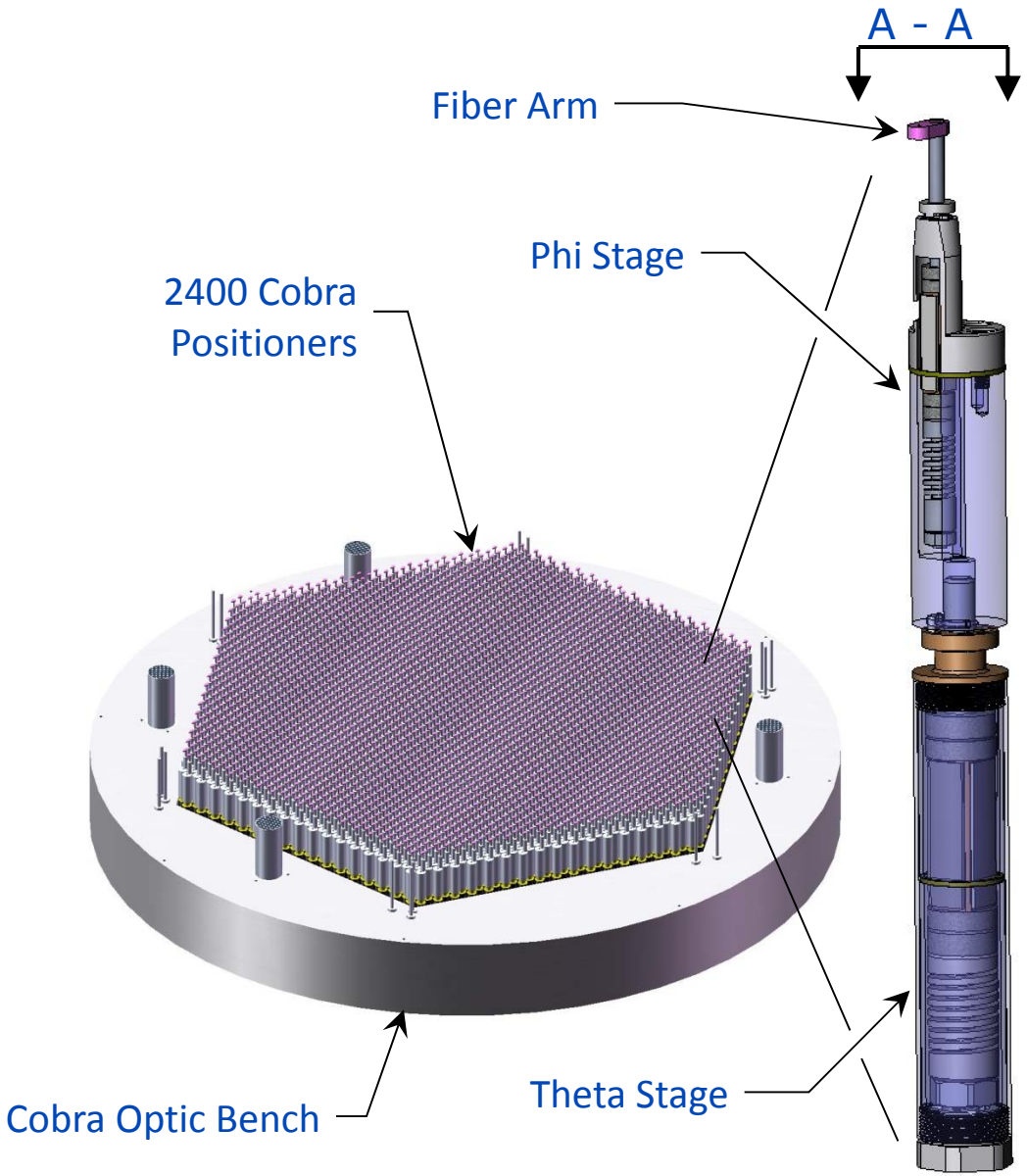
- The Prime Focus Spectrograph (PFS) for the Subaru Telescope.
- Hex shaped array of 2394 fiber positioners in a 1.38 degree field of view at the prime focus of the telescope.
- Each 50 meter fiber is connected to a remote spectrograph
- Operating target:
  - 1 min to move the telescope
  - Reacquire new field of targets in 15 min
  - 45 fields to be observed per night.

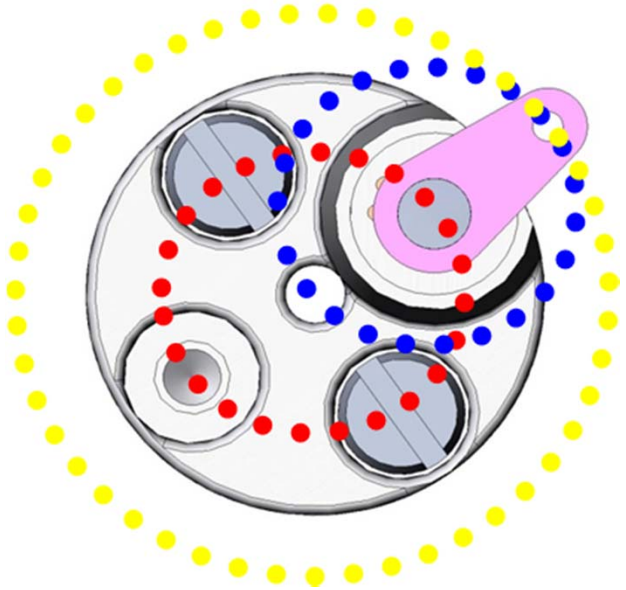




System Requirements - PFS

NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems





Motion From View A - A

System Requirements - PFS

NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems

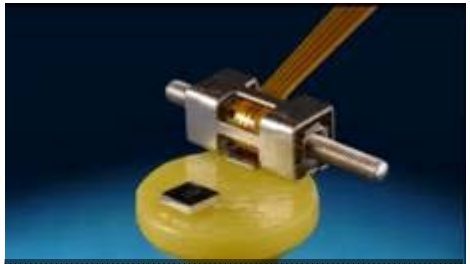
Requirement	Value	Units
Positioner External Diameter	≤ 7.7	mm
1st Stage Internal Diameter	≥ 1.2	mm
2nd Stage Offset	2.375	mm
1st Stage Hard Stop	≥ 360	deg
2nd Stage Hard Stop	≥ 180, < 360	deg

Requirement	1st Stage	2nd Stage	Units
Step Size	≤ .084	≤ .167	deg
Stall Torque	≥ 346	≥ 337	μN-m
Speed	≥ 1.0	≥ 0.5	rev/sec

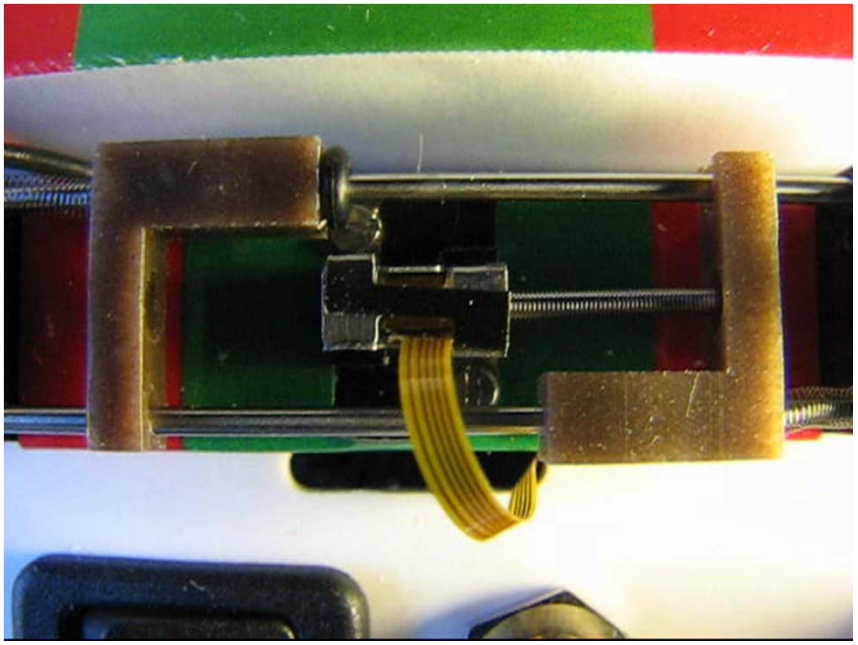
JPL has demonstrated moving a fiber within 5μm of an astronomical target using six move iterations with a success rate of 95%.

Motor Selection…Commercial Linear Motor

NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems


SQL-RV-1.8 Motor and NSD-2101 IC

squiggle® RV MOTORS



- PZT: multi-layer
- Voltage: 2.3-5.5 V
- No boost required
- Smart drive IC
- 5x smaller circuit
- Push: 30 g push
- Speed: 7 mm/sec
- Power: < 0.5 W

US Patents (6,940,209), (7,170,214), (7,309,943) & (7,339,306)

"Hula Hoop" vibrations are directly converted to linear movement

Motor Selection…Ultrasonic Rotary Motor

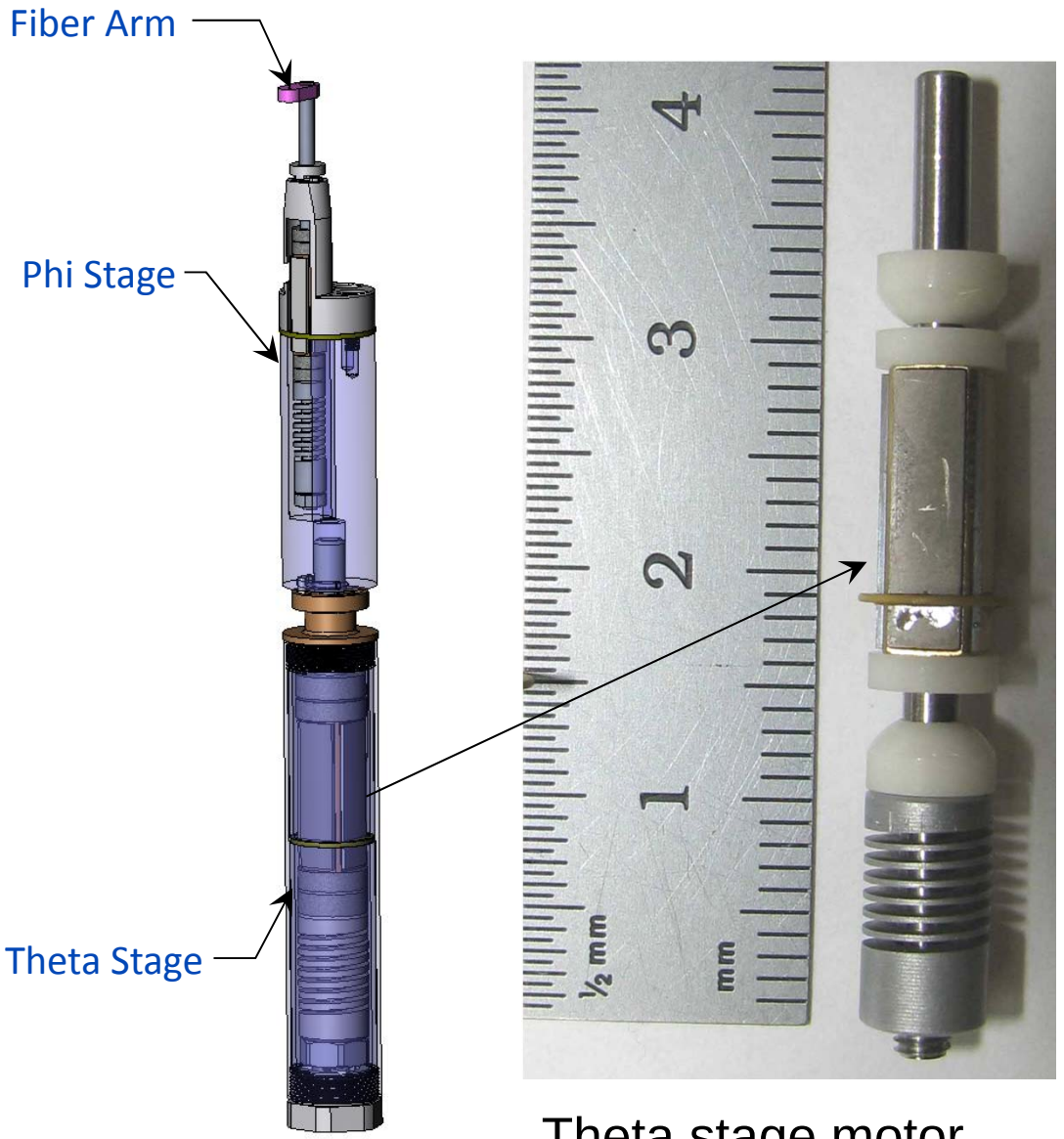
NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems

With thanks to:

W. Williams and W.J. Brown, "Piezoelectric Motor", US Patent, 2439499, April 1948.

T. Morita et al, "An Ultrasonic Micro Motor using a bending transducer based on PZT thin film", Sensors and Actuators A, Vol. 50, pp. 75-80, 1995.

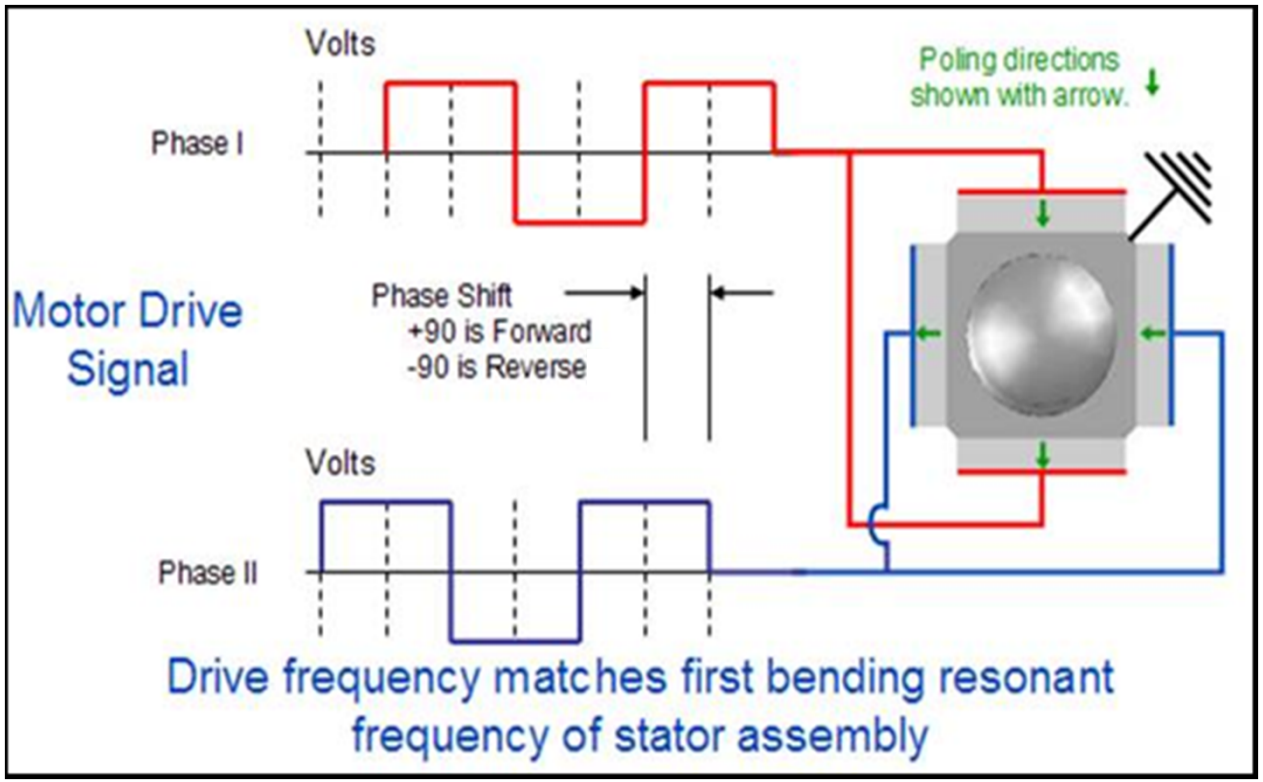
B. Koc, S. Cagatay, K. Uchino, "A piezoelectric motor using two orthogonal bending modes of a hollow cylinder", IEEE Trans. Ultrasonic Ferroelectric Freq. Cont. 49, 495-500, 2002.



Theta stage motor

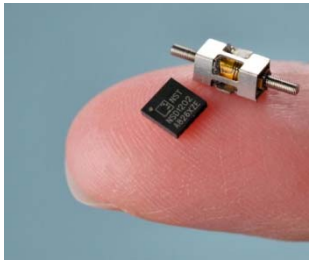
Motor Selection…Drive Details

NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems



MC-1100 (Today)
Size of Credit Card

Multi-Chip PCB (2013)



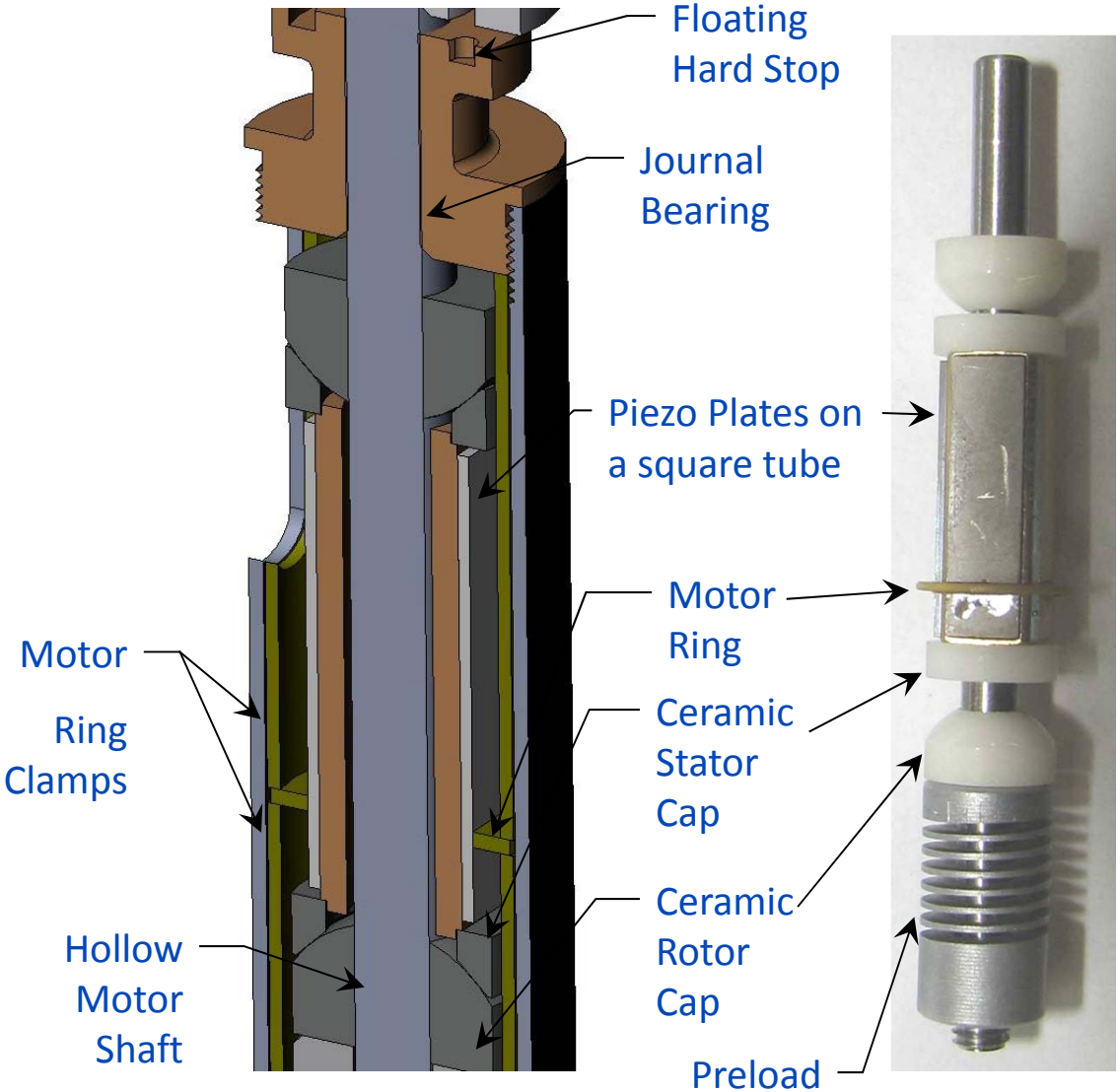
NSD2101 (> 2013)
Single-Chip Driver

Motor Selection….Details

NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems

- High torque without gears.
- High resolution with zero backlash
- No lubrication.
- Hold position without power.
- Back-driveable without damage
- Journal bearing limits motor side loads
- Hard stops limit fiber twisting
- Motor step repeatability is sufficient to eliminate need for angle sensors.

All fiber positions are measured using backlit fibers and CCD camera.

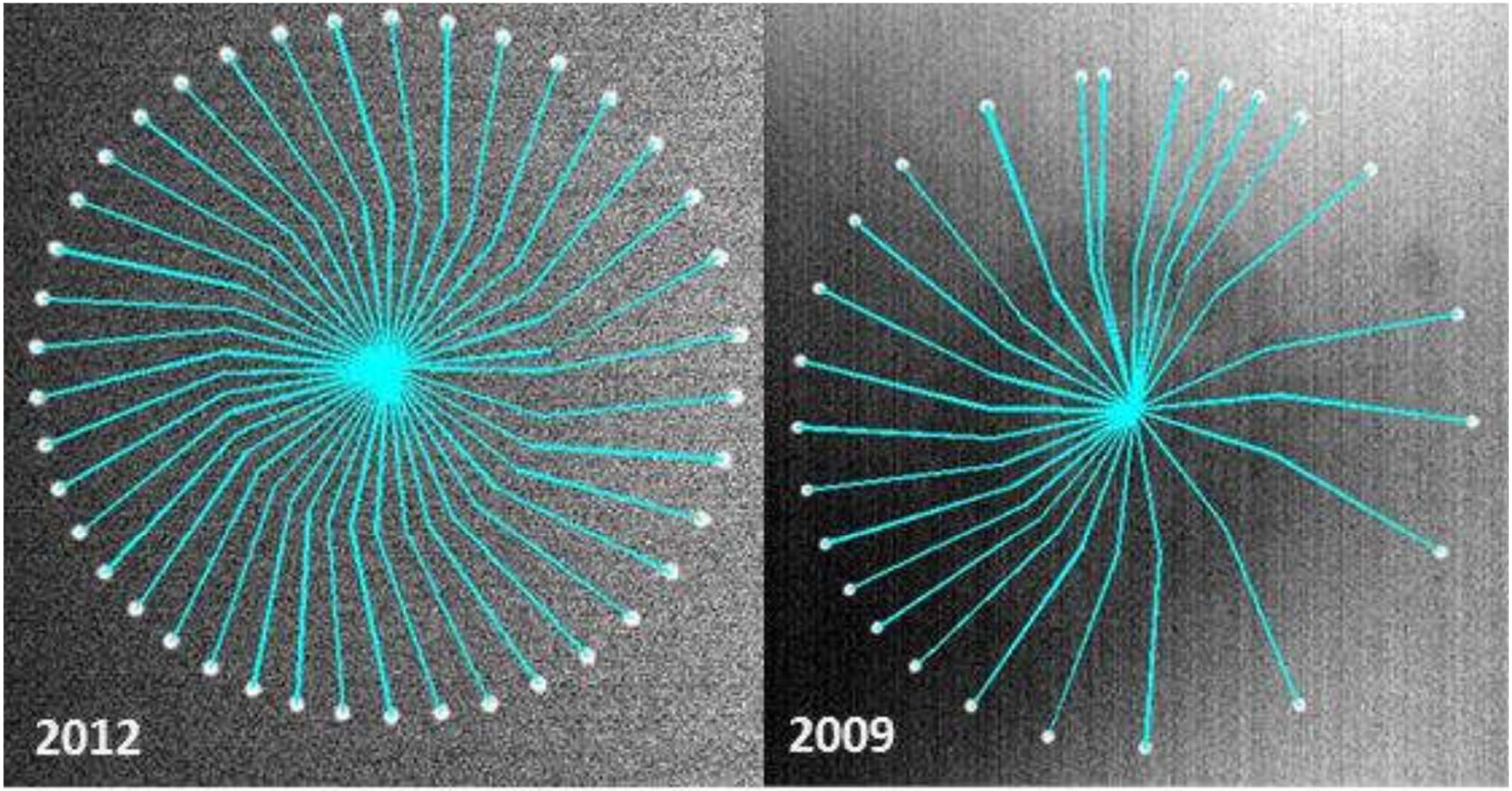


2-Axis Positioner

NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems

2-Axis Positioner

NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems



JPL test results showing improvement in step precision and repeatability from Gen1 (2009) to Gen1A (2012)

Next Steps …Cobra Positioner

NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems

1. Additional design improvements
    - Further improve angular step repeatability.
    - Keep the fiber aperture in the focal plane (+/- 50 μm) for all angles and positions.
        - Axes orthogonality and parallelism
        - Structural stiffness and bearing clearance
    - To further reduce manufacturing cost.
2. Reduce size of drive electronics more than 70%
3. Deliver 60 positioners to JPL
4. Deliver > 2400 positioners to JPL.

NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems

Thank You

David Henderson, DHenderson@newscaletech.com