ASTM International – Committee E20 on Temperature Measurement

E20.96 Session

Newer Thermometers and Techniques

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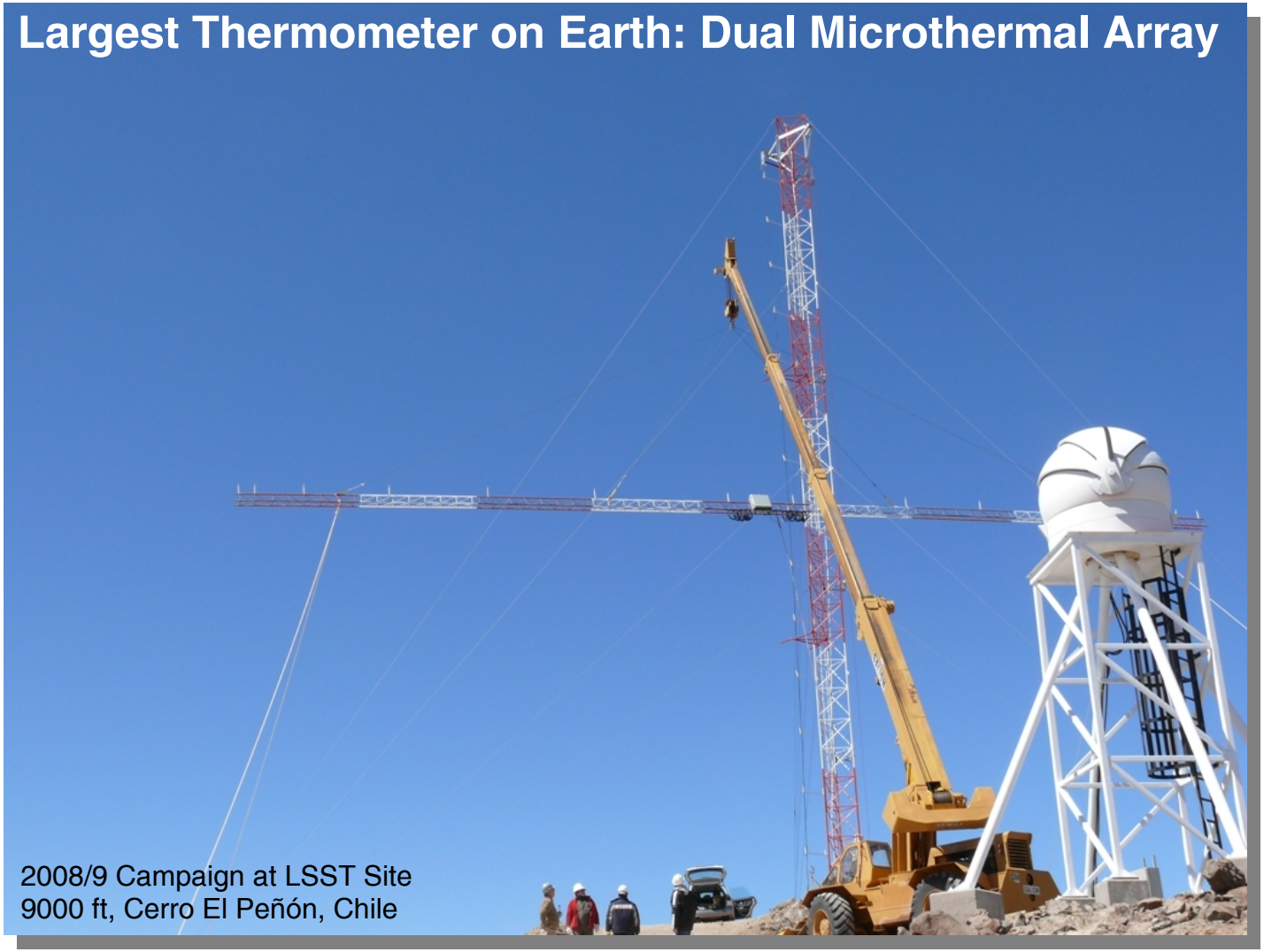
ASTM INTERNATIONAL
Helping our world work better

Metrology Grade Thermometers in the Mass Customization Era

Largest Thermometer on Earth: Dual Microthermal Array



2008/9 Campaign at LSST Site
9000 ft, Cerro El Peñón, Chile

Innovation in Metrology: Instrument Maker Perspective

- **New techniques:**
  - **new ways of using existing equipment and sensors.**
- **New technologies:**
  - **discovery of new phenomena (better physics or math).**
- **New materials:**
  - **lower noise and more stable components;**
  - **improved or new types of sensors.**
- **System optimization:**
  - **evolution of IT, modeling, design, manufacturing, and calibration tools, leading to enhanced performance;**
  - **often forgotten, seldom used for major improvements…**

Instrument Manufacturer Dilemma: Pleasing Greeks and Trojans

- Metrology field notorious for wide diversity of applications and requirements:
  - large variety of functional requirements;
  - procedural and regulatory prerequisites;
  - compatibility with other systems (interfaces);
  - different personal needs (human factors);
  - staying state of the art (utmost performance).
- Swiss army knife conundrum: functionality vs. cost.
- Achieving good results may require several players.
- Do it once: mass customize – avoid one-offs!
  - requires collecting and conciliating numerous use cases…

How to Mass Customize Metrology Grade Instruments?

- Design with sufficient interfaces to allow a viable range of configurations (customization):
  - consider multiple application environments, not just the lab.
- Focus on delivering measurement data:
  - smart phones also make calls paradigm – how much extra stuff?
  - connectivity to modern communications devices;
  - use off-the-shelf human-machine interfaces (HMIs).
- Allow for a variety of encapsulations:
  - instrument as part of the installation;
  - integrated electrical and mechanical design.
- Provide hardware and software modularity.
- Make devices easy to handle by system integrators.

Building a Better Mouse Trap: Reaching Device Design Excelence

- Complete top-down system specification including electronics, mechanics, software, and calibration.
- System optimization:
  - employ modeling and analysis extensively.
- Electronics design:
  - use advanced circuitry and board layout techniques;
  - account for EMI/EMC and electrical safety from the start;
  - aim for low noise and long term stability (low uncertainty).
- Improved calibration procedures and algorithms:
  - custom calibration curves with high order polynomials.

Universal Means Worldwide: Meeting International Standards

Specification Sheet for Customization of Electronic Instruments								
Operating Conditions								
Temperature Range								
Humidity Range								
Maximum Altitude								
Shock								
Vibration								
Marine Environment?								
Storage and Transport Conditions								
Temperature Range								
Humidity Range								
Maximum Altitude								Indicate AIR if air shipping is applicable.
Shock								
Vibration								
Marine Environment?								
Enclosure								
Size Limit								
Total Weight Limit								
Installation Type		flush panel mount		cutout panel mount		bench		DIN rail
Required Hardware		metric		imperial		either	yes / no	mix?
Preferred Materials								
Forbidden Materials								
Power Feed								
Supply Voltage and Frequency								
Power Plug or Connector								
Insulation Requirements [kV]								Indicate if DC or RMS.
Medical Application?								Indicate if antimicrobial coating is needed.
Max Power Consumption								
I/O Accidental Voltage Protection								
Describe Requirements								
Communication Standards and Protocols								
Serial		RS-232		RS-422		RS-485		
USB		2		3			yes / no	Power?
Ethernet		10 Mb/s		100 Mb/s		1 Gb/s	yes / no	PoE?
Wireless		Wi-Fi		Bluetooth		Zig-Bee		other
Protocols								
Error Detection?								
Other Specifications								
Agency Approvals								
Certifications		cUL		CE		CCC		cTick
EMI / EMC		FCC		IEC		IEEE		Conflict Materials
ROHS2	yes / no	Does not apply to durable items (more than 2 to 5 years) or specialty equipment.						
Is this unit part of a larger assembly (device, instrument, equipment or machine) seeking UL or CE certification?								yes / no
What's the operating environment? Check all applicable.					industrial/control panels			home/office

- **Electrical safety is paramount – insulation of medical devices >= 3 kV.**
- **MISRA C for firmware reliability – medical app.**
- **RoHS when requested:**
  - **use of led-free solder not recommended for longevity and wide room temperature.**
- **Special coatings for bio-medical (antimicrobial) and harsh environments.**

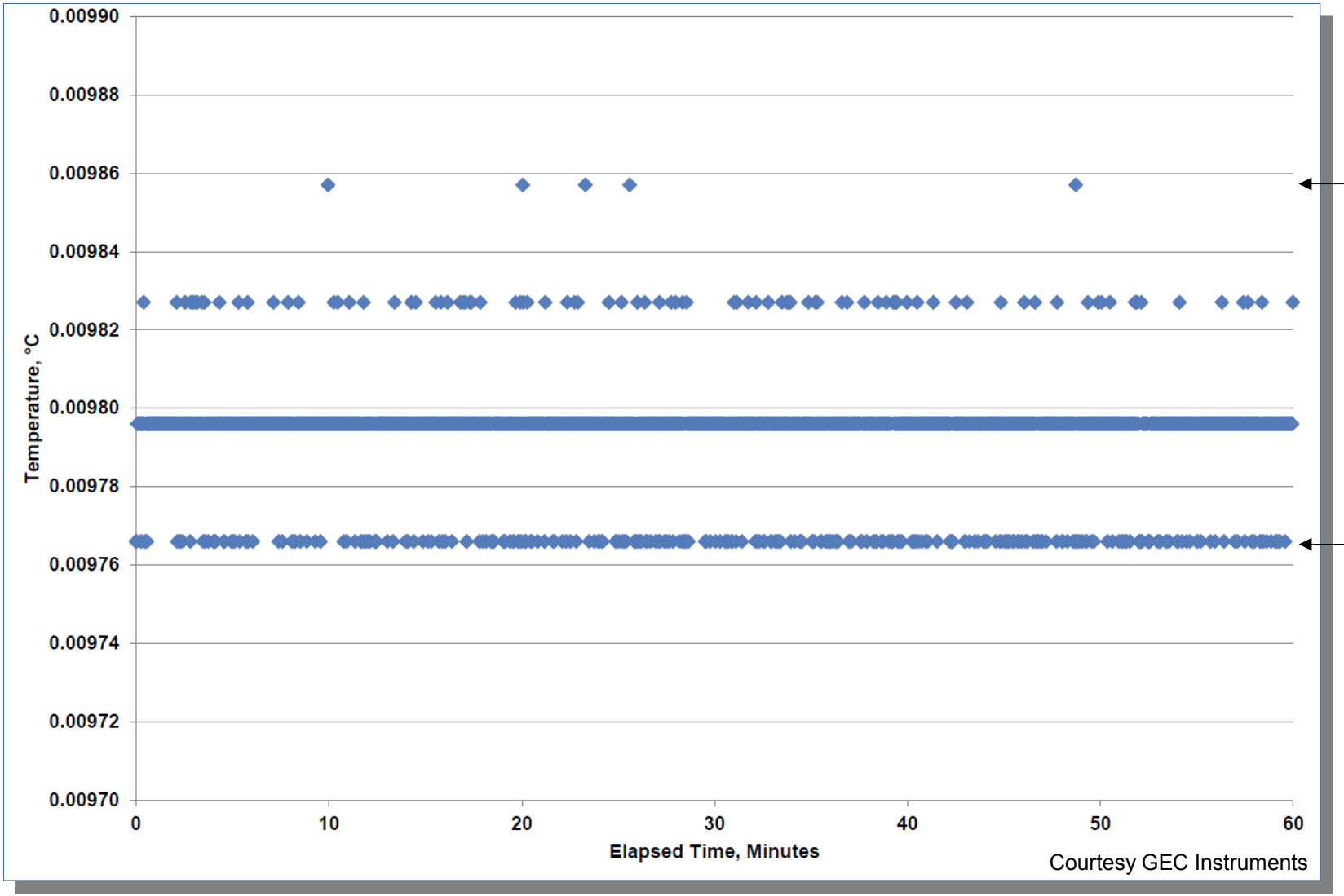
SEL1101 15-Channel Thermistor Scanner with TEDS and DSO™

Courtesy GEC Instruments

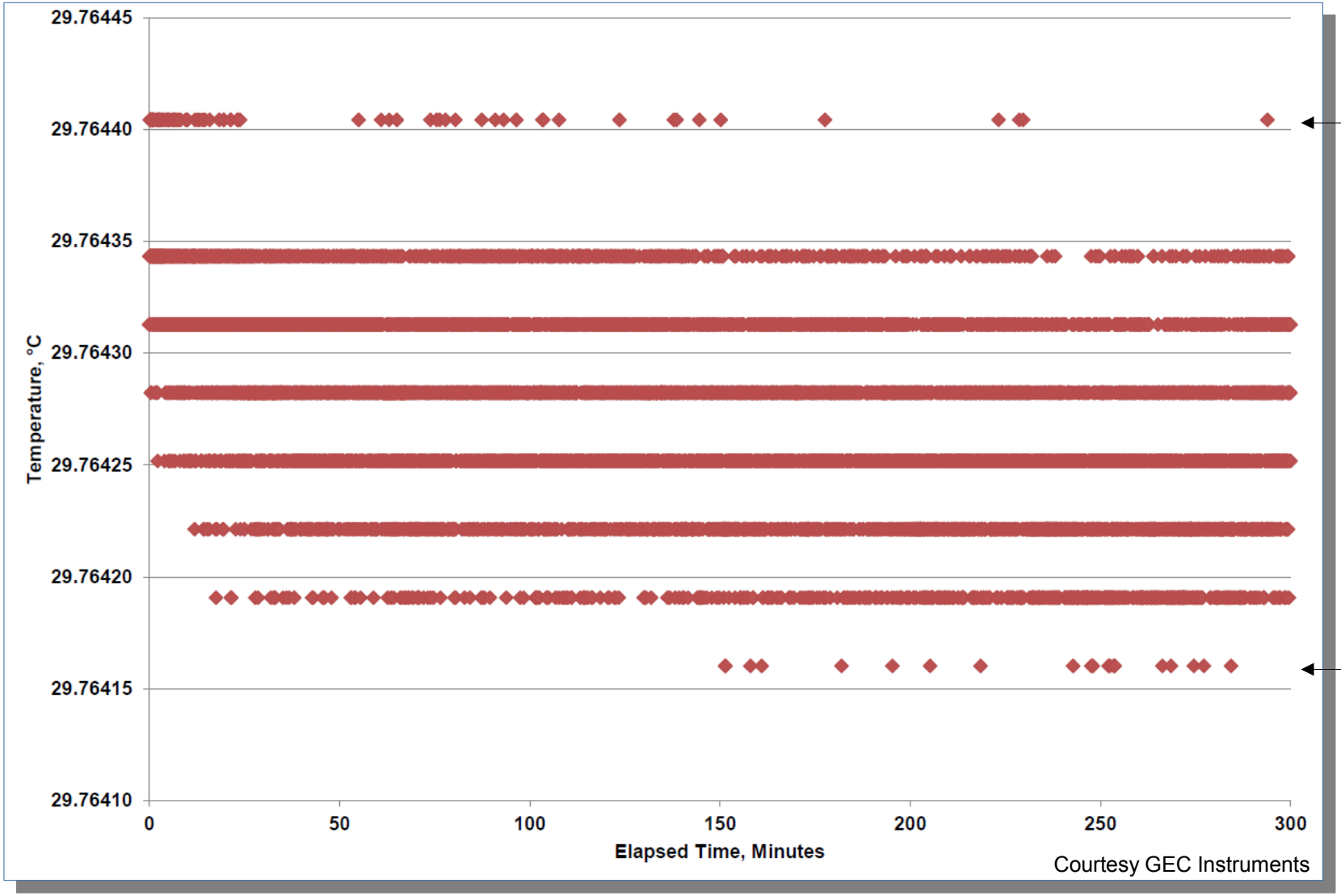
Once Upon a Time: SEL1101 Background

- Initially utilized for pilot installation of major CT scan manufacturer with 30 temperature sensors calibrated to < 10 mK.
- Instruments were part of the engineering test setup – packaging!
- Each temperature probe equipped with TEDS for interchangeability without loss of accuracy (only installed probes are scanned).
- Direct serial output (DSO™) for simple communications with inherent time stamping features (phase lag reduction).
- RS-232 serial port for maximum versatility using media converters.
- LCD, keypad, and PWM output for temperature control (optional).
- Easily reconfigurable for low uncertainty single thermistor readout to 1 mK class and double data rate.
- Adapted for industrial project using interchangeable thermocouples calibrated to < 0.1 °C.
- Engineering unit for many other configurations and topologies.

SEL1101 with Thermometics AS115 Thermistor Probe in TPW Cell



SEL1101 with Thermometrics AS115 Thermistor Probe in Gallium Cell



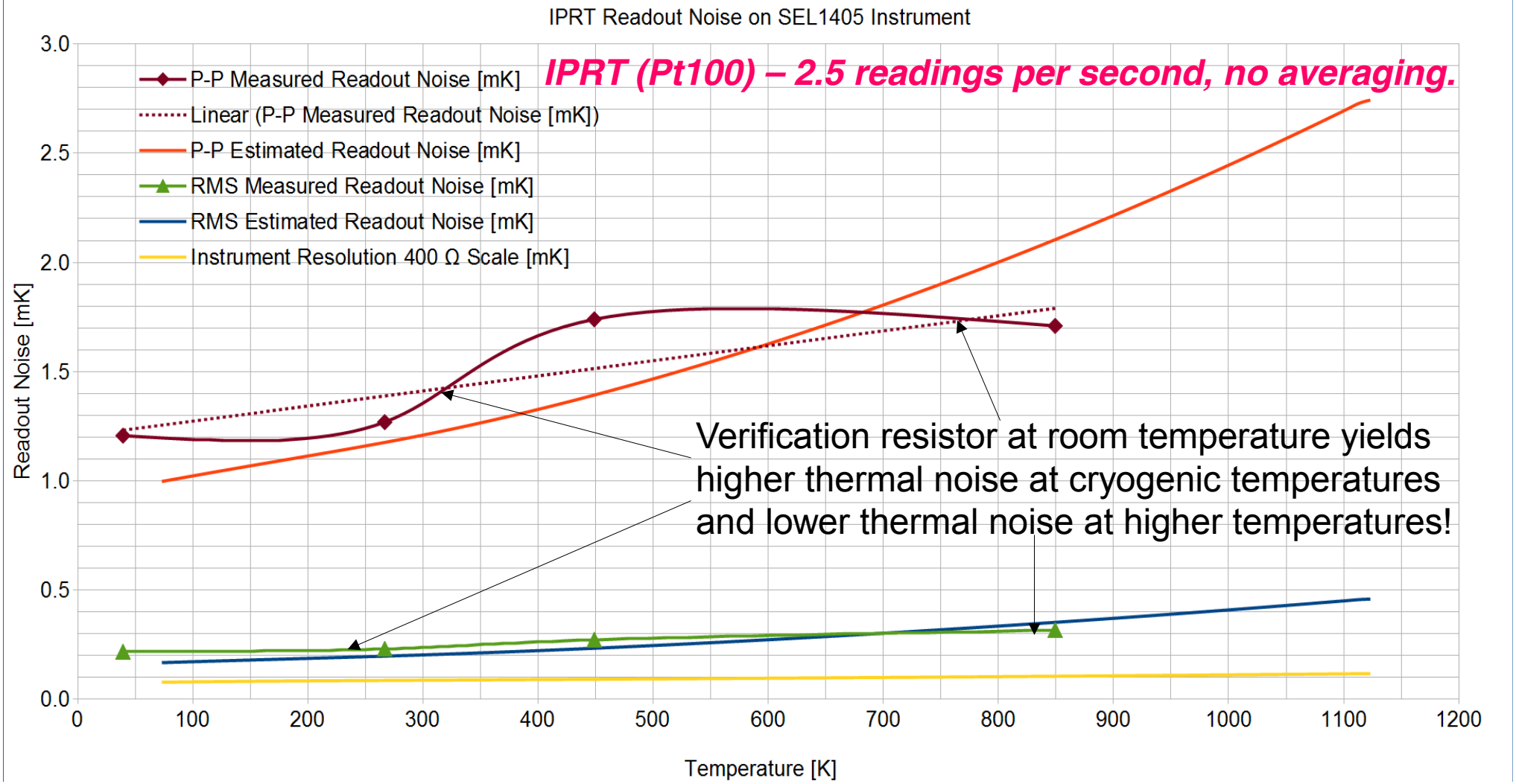
SEL1405 5-Channel Thermocouple Scanner & Resistance Thermometer

Note shorter enclosure!

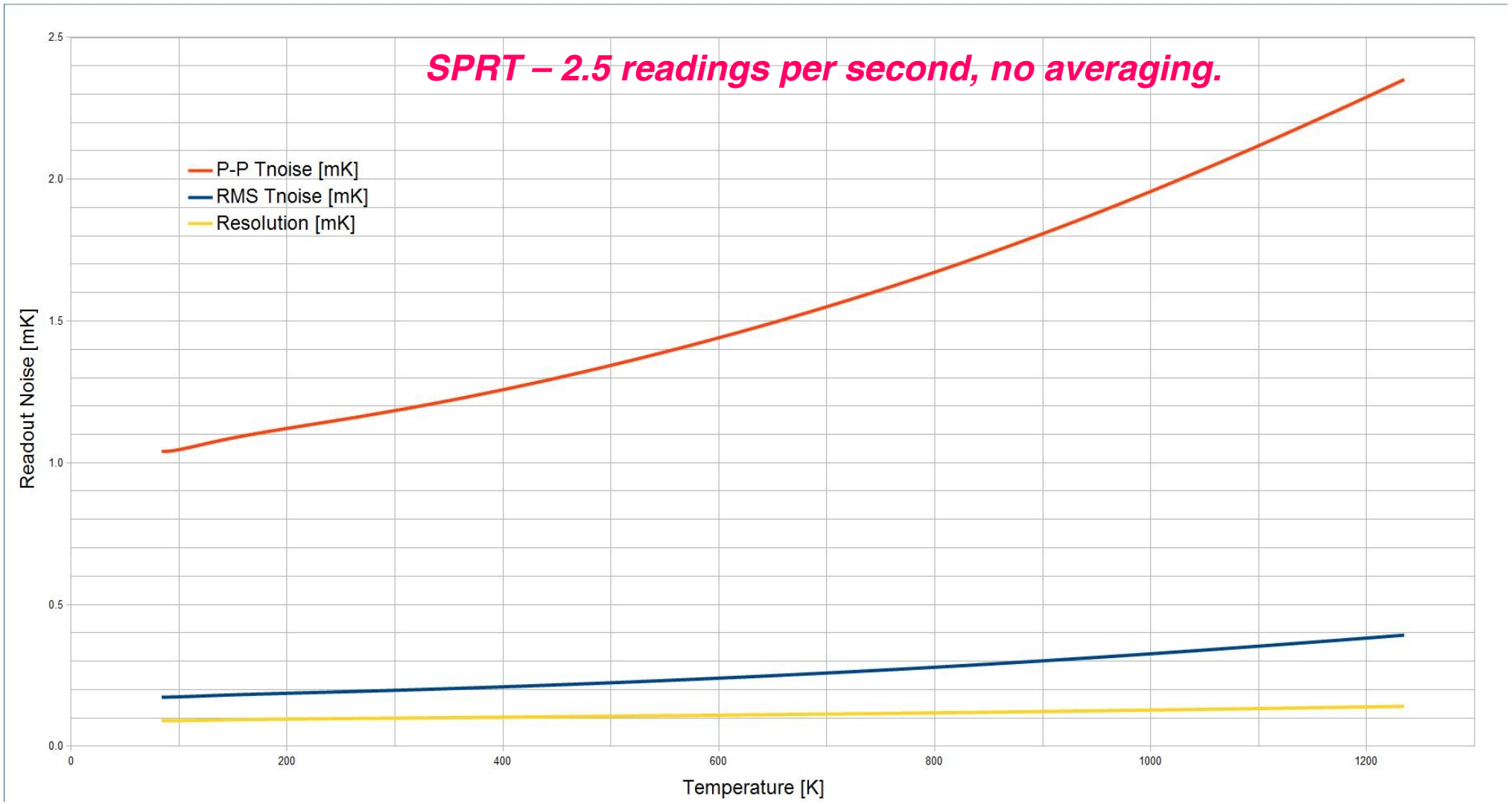
Low Cost, Versatile Configuration Options for Mass Customization

- True reference junction:
  - thermocouple with thermistor attached to isothermal block;
  - reference junction can be internal or external;
  - precision thermistor with CDS (correlated double sampling), 1 mK class.
- Custom calibration curves and system calibration; TC < 10 mK*
- Several packaging and power supply options:
  - universal wall adapter;
  - wide range industrial;
  - DIN rail mount bracket;
  - IPRT (Pt100) with TEDS;
  - thermistor with TEDS.
- Multiple protocols for communications in industrial applications.

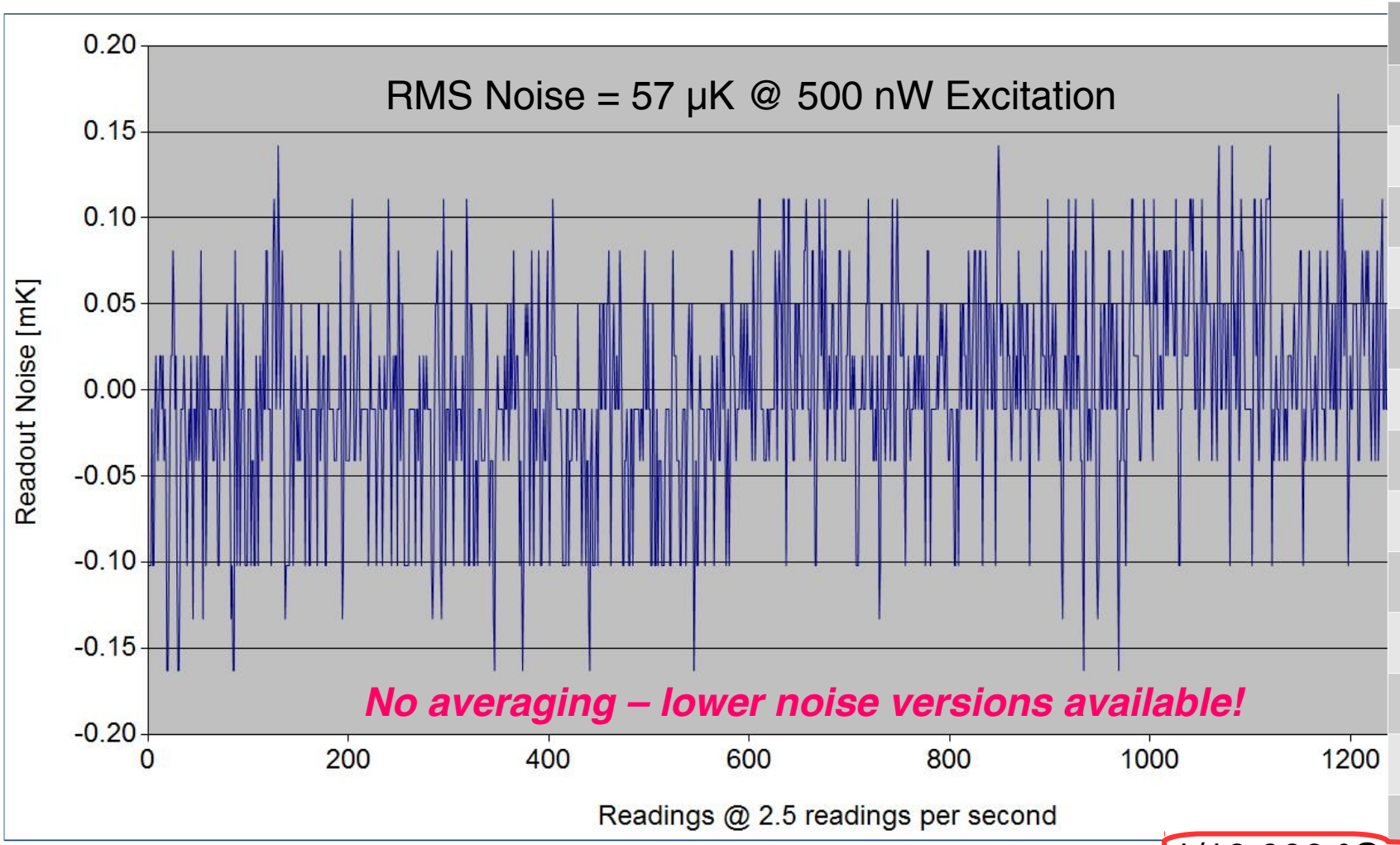
Model Based Engineering in Good Agreement with Measured Results



SEL1405 Configured for SPRT
Estimated Performance



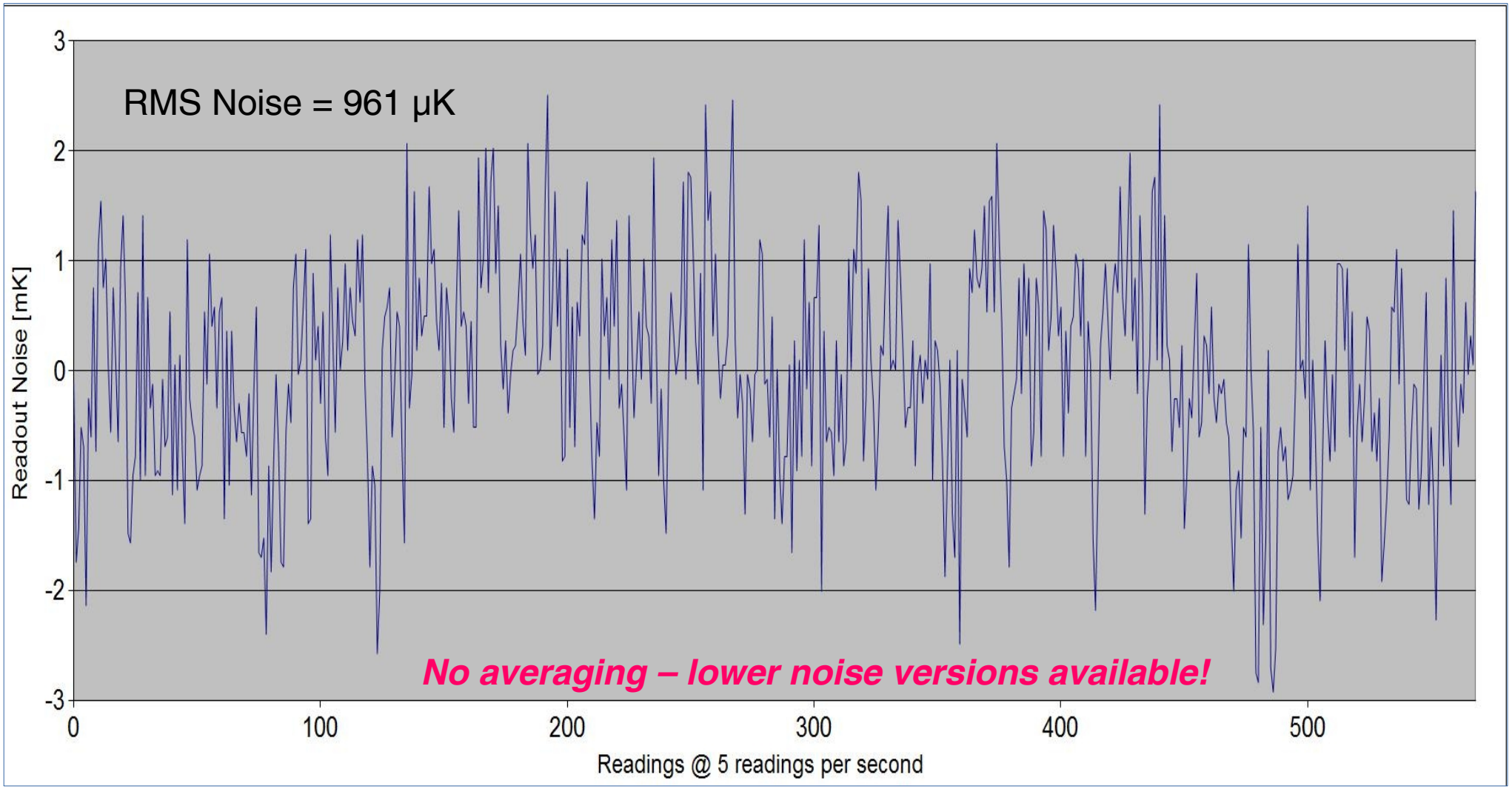
SEL1405 with Thermometrics AS115 Thermistor Probe Readout Noise



Temp [°C]
30.219269
30.219269
30.219269
30.219269
30.219360
30.219269
30.219269
30.219360
30.219391
30.219360
30.219330
30.219360
30.219391

1/10,000 °C

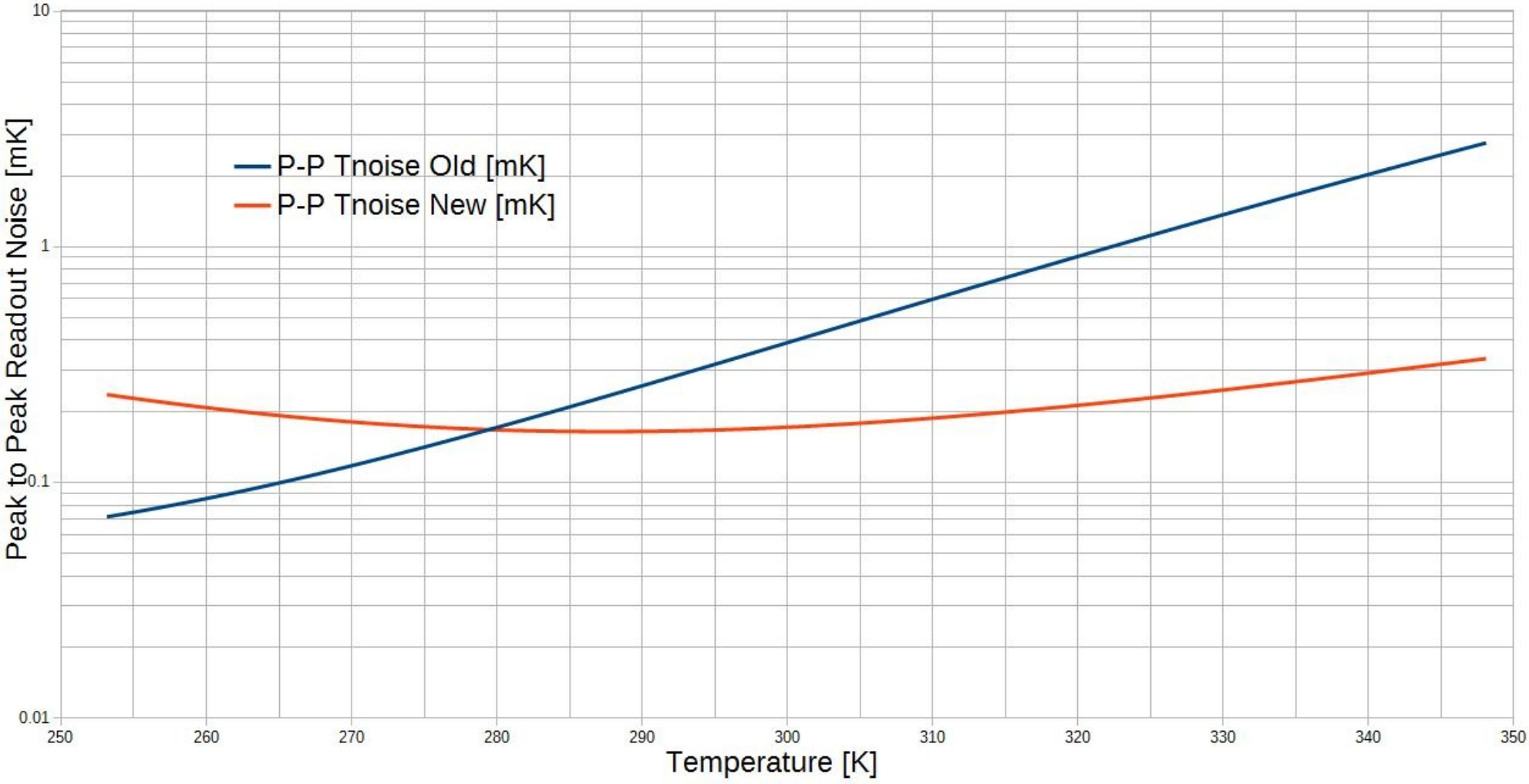
SEL1405 Readout Noise Configured for T-type Thermocouples @ 5 rdgs/s



New Techniques

- Solid state multiplexing with unlimited channel count at > 170 dB channel-channel separation:
  - no unused inputs paradigm, no cross-talking noise.
- Components for extended temperature range, vacuum compatible, and galvanically isolated.
  - long term stability: 30-year calibration interval?
  - instrumentation in astronomy applications;
  - metrology in inaccessible locations or equipment.
- Technologies seeking patent protection:
  - high temperature thermistor noise reduction;
  - thermocouple wire resistance compensation.

Noise Reduction Technique Example
US Sensor Corp. 10k Lab Thermistor

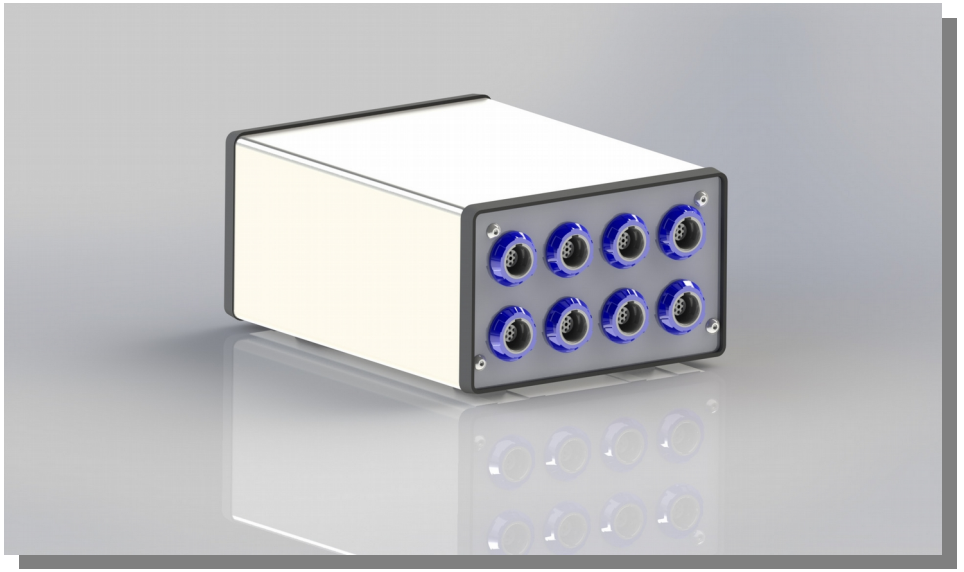


Thermometers with New Techniques

- SEL1501 USB powered, miniature, single resistance thermometer instrument with selectable Iref and LCD:
  - ideal for system calibration with self heating measurement functionality.
- SEL1504 4-channel resistance thermometer scanner.
- SEL1508 8-channel resistance thermometer scanner.
- SEL1506 6-channel thermocouple instrument with two reference junctions and three pulsed outputs:
  - for temperature control of calibration baths and three-zone furnaces in fixed-point temperature cell maintenance apparatus.
- SEL1524 24-channel thermocouple scanner for distributed systems with large channel count (synchronous sampling):
  - allows elimination of extension wires and other secondary thermocouples;
  - 3 voltage input ranges for maximum resolution and lowest noise (max 💣/$).
- 4 designs variants each with lower noise signature…

SEL1504 & SEL1508: 4/8-Channel Precision Resistance Thermometers

- Used in science, industrial, engineering, and (automated) calibration lab applications:
  - **extended burn-in option for long calibration intervals.**



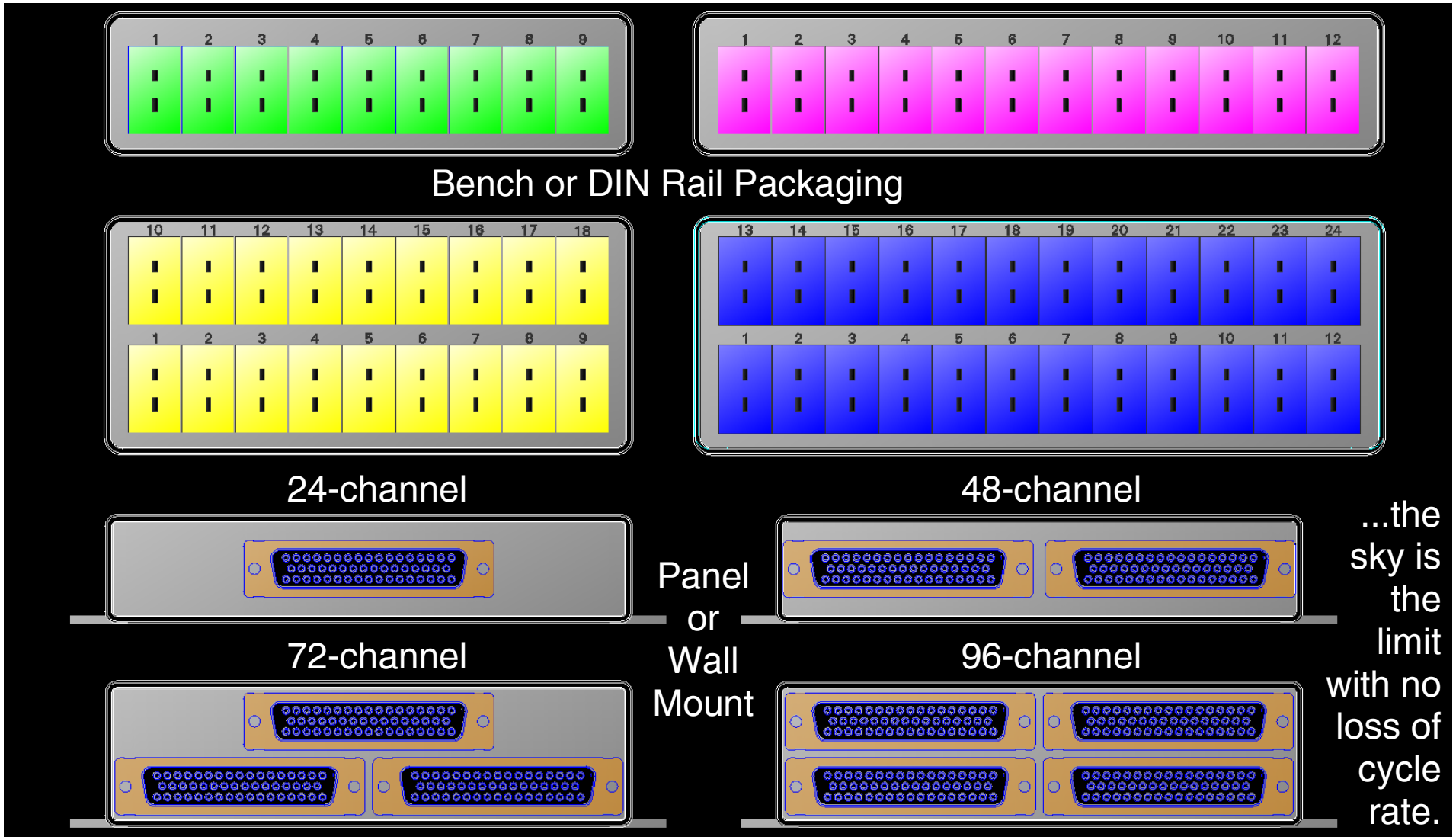
- Available with feature compensation for minimal uncertainty loss in extended room temperatures.

SEL1506: Ultra Precision RT and 6-Channel Thermocouple Instrument

- **Versatile platform for the use or study of thermocouples alone or aided by resistance thermometers (2 RJs).**
- **Potential applications include very precise temperature control.**
- **Design your very own configuration – if you can draw it, we'll do it!**

Many enclosure models and variants with different aesthetics to choose from!

SEL1524 Thermocouple Instrument Assembly Configuration Options



Questions?

Thank you for the opportunity!

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