keoscientific

Keo *Sentry* 4” Multispectral Imager

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Company Profile

Keo Scientific Ltd. designs and builds highly sensitive scientific instrumentation capable of wavelength-resolved imaging of sub-visual emissions from the upper atmosphere. Imaging systems can be designed to satisfy unique customer requirements, or one may choose from a wide range of highly flexible existing configurations that meet a wide range of strategic and tactical scientific objectives. In addition to CCD/EMCCD/sCMOS imagers, spectrographs, Fabry-Pérot Interferometers and photometers, Keo Scientific Ltd. has designed and built a next-generation RIOMETER.

Keo Scientific was founded in January 2004 by a group of Science and Engineering personnel from the University of Calgary. Collectively, this group has experience with the design and use of specialized scientific optical instrumentation going back to the 1960s. Keo Scientific's founders have expertise ranging from space and atmospheric research to mechanical engineering to the deployment and maintenance of distributed imaging arrays.

Keo Scientific was started by acquiring Keo Consultants of Brookline, MA, USA, from Dr. Robert Eather. Dr. Eather's expertise remains available through his current role as Keo Scientific's Senior Consultant. Keo Scientific have designed and built optical systems for customers such as NASA, UC Berkeley, as well as Japanese, Korean, Italian, Chinese, Indian, Brazilian, Norwegian, Swedish, and Finnish private and academic research groups.

Keo Scientific is based in Calgary, Alberta Canada. It has a modern optical laboratory facility that supports the design, assembly, testing, and calibration of a wide variety of imaging instrumentation. Equipped with a darkroom, ISO Class 3 Clean Room space, a NIST traceable integrating sphere, and with priority access to a CNC machine shop and a custom lens-grinding facility, Keo Scientific is capable of designing and manufacturing optical instruments of unmatched quality.

Multispectral Imaging Instrumentation for Aeronomy/Space Science

Modern scientific-grade backside-illuminated CCD cameras with deep-cooled detectors allow high precision low-light-level (LLL) imaging of atmospheric and ionospheric/thermospheric phenomena. It is in many cases desirable that such imaging be monochromatic, yielding spatiotemporal multi-spectral data suitable for qualitatively and quantitatively studying specific auroral atomic line and molecular band excitation processes.

For LLL imaging, it is highly desirable to operate at extremely low f-numbers. Lower f-numbers unfortunately imply steeper ray angles through filters, and thus generally require wide-band interference filters. ***Imaging instrumentation from Keo Scientific Ltd. are however designed to form monochromatic images of wide-angle fields – up to 180 degrees field of view – onto imaging detectors at effective f-numbers as low as F0.7 through interference filters having bandwidths as narrow as 1.8 nm. Keo Scientific Ltd. is currently the only existing off-the-shelf source for a range of such uniquely sensitive, truly multispectral all-sky imagers.*** Keo Scientific works intimately with a lens-grinding facility in order to design, manufacture and coat a variety of special lenses required to meet their stringent design goals. Keo Scientific has, through leveraging 40+ years of experience in the field, an understanding of the many subtle (and often non-intuitive) aspects of the design process, and can assist customers in planning an optimal system for their particular application.

In order to fully understand the electrodynamics of airglow and auroral processes, both microscopic and macroscopic plasma processes must be understood, as they both affect the electrodynamics and are coincident in time and space. In auroral physics, as in astronomy and particle physics, progress is closely tied to the development of better sensors, yielding higher sensitivity, higher resolution, larger statistical samples, and broader spectral response, as the observer effectively opens his eyes wider to the view offered by Nature. Keo Scientific offers a wide range of fields of views ranging from telescopic (2 degrees), for the highest spatial resolution, to all-sky (180 degrees), for mesoscale studies.

Keo Scientific Ltd. designs and builds custom scientific imagers with optics and filters carefully matched and coupled to CCDs and EMCCDs of any size, any field of view (enabling true multi-scale studies), any wavelength range including UV, Visible, NIR and IR. Keo Scientific provide carefully characterized and calibrated imagers with ephemerides-driven software suitable for reliable operations at remote, unmanned field-stations. Keo Scientific provide a **truly turn-key solution** for quantitative airglow and auroral studies.

Keo Scientific Ltd. stocks a wide range of custom manufactured image-quality narrow-band interference filters targeted at airglow and auroral work. Keo orders custom designed filters suitable for aurora/airglow observations in significant quantities from the manufacturer, and can thus offer them to customers at highly advantageous prices. Keo also stocks a wide range of compound, singlet and achromatic lenses, suitable for customers' own home-made projects.

Keo *Sentry* Imaging Systems

A complete Keo Scientific *Sentry* Imaging System is typically comprised of the following:

- Fast all-sky (fish-eye) primary lens with additional proprietary telecentric optics
- Optional field of view modules (e.g., 15, 30, 60, and 90 degrees field of view, in the case of Keo *Sentry* 4)
- A highly reliable capping shutter (rather for more than 1,000,000 cycles)
- Bright-light protection sensor
- Filter wheel with 6 or 8 filter slots, for 3-inch filters (Keo *Sentry* 3) or 4-inch filters (Keo *Sentry* 4). Filter temperature is carefully stabilized, due to the fact that filter transmission characteristics change with ambient temperature. Single-filter slot (no filter-wheel) versions of all Keo Scientific imagers are also available
- Non-vignetting re-imaging optics, consisting of custom made achromat field lenses, achromat close-up lenses, and a special high-speed compound final imaging lens to the detector.
- Detector, typically a cooled thinned backside-illuminated CCD sensor head, such as offered by Princeton Instruments, with an e2v Grade 1+ CCD or EMCCD, hand-picked for Keo Scientific by the manufacturer
- A rack mount box with filter-wheel temperature controller, digital control electronics, and power supplies
- Keo *Synopticx* ephemerides-driven image acquisition software (MS Windows)
- Computer system for imager sequencing control, data acquisition, and data storage. Many customers choose to provide their own computer hardware; note that PCI slots, USB2 ports, and and RS-232 ports may be required – please inquire for details about your particular system.

Keo *Sentry* Low Light-Level Multispectral Imagers

Keo Scientific currently carry two different models of Keo *Sentry* imagers: The Keo *Sentry* 3 (which uses 3-inch diameter filters) and the Keo *Sentry* 4 (which uses 4-inch diameter filters). The sensitivity of an imager is proportional to the filter area (and the CCD area has to be sufficiently large to make sure of the available photons at the filter). **Shown in following figure is a Keo *Sentry* 4 all-sky imaging system** with horizon-to-horizon (180°) field of view. It comes complete with a low-noise backside-illuminated charge-coupled device (CCD), deep-cooled down to -70°C, high speed telecentric optical column, and 6-position filter wheel. This is the world's most sensitive airglow imager, capable of imaging sub-visual emissions associated with a variety of airglow phenomena. Through Keo Scientific's unique re-imaging concept, imaging through narrow band filters (1.8-2.0 nm FWHM) at extremely low f-number is possible. The

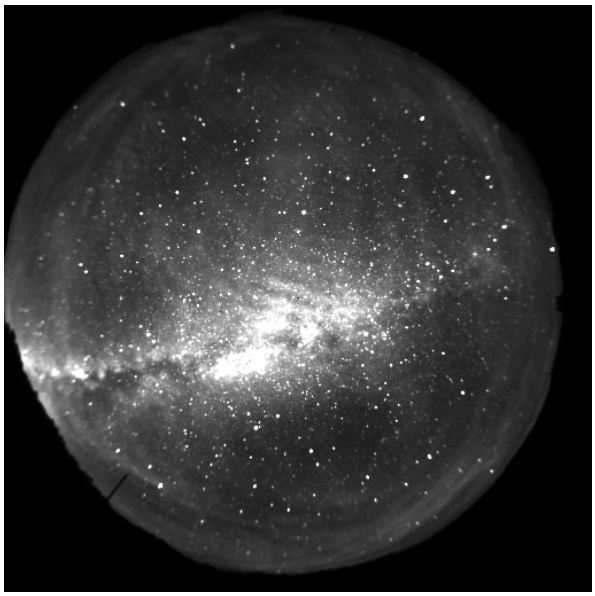
allsky lens is telecentrically imaged onto a 6-position filter-wheel (8-position also available) containing ~2-nm narrow-band interference filters. A single-filter-slot (no wheel) version is available as well.

As the actual passband of interference filters is temperature dependent – on the order of one Ångstrom per five degrees C – a dedicated temperature controller is used to carefully stabilize filter wheel temperature. A specially customized high-reliability mechanical shutter is used to protect filters from prolonged exposure to sunlight.

Further contributing to enhanced imaging performance is the large-diameter optics with 4-inch diameter, high-transmittance interference filters. The filter-wheel will accommodate filters with passbands centered on (for example) 557.7 nm (OI), 630.0 nm (OI), 750-920 nm (OH), 589.3 nm (Na), plus a background filter (572.5 nm) and/or a selection of neutral density filters (for operation during sunlit conditions).

High sensitivity and corresponding high low-light-level spatial resolution – less than a kilometer at 100 km altitude – are achieved by adopting a 27.6 mm x 27.6 mm CCD, thermoelectrically cooled (-70 C, lifetime vacuum guarantee) back-illuminated scientific Grade-1+ CCD chip (2048x2048 pixels). The maintenance free forced-air TE cooling provides decreased dark-noise accumulation, allowing longer integration times and higher sensitivity.

The final image is digitized at 16 bits per pixel, yielding a dynamic range sufficient for the simultaneous detection of both faint airglow emissions (such as gravity waves) as well as more intense green/red-line auroral features (whether natural or artificially generated). The CCD can be read out at 100kHz or 2MHz digitization for either high speed or high dynamic range (low noise) imaging. Shutter operation, filter-wheel position, filter-wheel temperature, CCD gain/binning, image integration and acquisition can be managed from any external computer, via industry-standard USB 2.0 and RS-232 interfaces. The optical system design is based on the proven and time-tested, refined over 20 years, concept of Dr. Bob Eather, and is now in use by academic and government institutions around the world.



Gravity waves and Milky Way observed using Keo Sentry 3 camera with allsky field of view module. Image courtesy of KOPRI, Korea (Dr. Young-In Won).

Keo *Sentry* 4 Technical Specifications

The Keo *Sentry* is a proven, custom designed scientific imaging system with an all-sky (180 degree, fisheye) field of view, for studying weak emissions from upper atmosphere through a series of filter-wheel mounted narrow-band filters. The final sensor is a back-illuminated 2048 x 2048 pixels Charge-Couple Device (CCD). CCD and filter wheel operation is computer controllable via USB2 port. Optional narrow field-of-view "drop-in" modules are also available. Assuming an all-sky field of view module, and a P.I. Acton Pixis 2048B_eXcelon sensor head, some typical specifications are:

- Field of View: 180 degrees (optional drop-in narrow-field modules also available)
- Angular resolution: better than 0.2 deg center, 1 deg edge of field
- Spatial resolution: better than 0.5 km at 100 km alt. (zenith)
- Focal length for primary image at filter: 37 mm
- Optics: Ultra-fast f/1.2 imaging onto large-area CCD via proprietary reimaging concept
- Filter Diameter: 4 inches, for the highest sensitivity
- Filter Wheel: 6 positions, temperature stabilized
- Minimum filter bandwidth (FWHM): 1.8 nm (3-cavity, "imaging quality" filters)
- Filter Thickness: 0.25 inches
- Shutter: high-reliability, rated for greater than 1,000,000 open/close cycles
- Sensitivity: 10 rayleighs (630.0 nm) or better, depending on CCD exposure settings
- CCD Head: PI Acton Pixis:2048B_eXcelon Scientific CCD Camera System
- CCD Array: e2v CCD42-40 scientific grade 1, enhanced UV process, back-illuminated, NIMO
- CCD Coating: *eXcelon*, for high-QE in VIS and reduced etaloning in NIR
- CCD Active Area: 27.6 mm x 27.6 mm
- CCD Format: 2048 x 2048 pixels
- CCD Pixel Size: 13.5 um x 13.5 um, 100% fill factor
- CCD Cooling: -60 C, Thermoelectric Peltier Cooled, forced air,
- CCD readout: 2 MHz and 100 kHz dual speed (selectable)
- Deep Depletion or eXcelon technology used to reduce etaloning in NIR
- Quantum Efficiency: 97% at 557.7 nm
- AD Conversion: 16 bits per pixel
- Dynamic Range: 0 to 65,535
- CCD Camera Interface: USB2
- Exposure time: 1 usec to > 30 minutes
- Environmental: 0 C to +25 C, non condensing
- Voltage Requirements: 110VAC or 220VAC (customer must specify)
- Power Consumption: 500 mA max
- Instrument Mass: 50 lbs (with filters installed)
- Physical Size: 38 inches x 16 inches x 16 inches max.
- Mounting: 1/4x20 helicoil-reinforced mounting holes provided for vertical mounting.
- Software: Keo *Synopticx* real-time acquisition, display, ephemerides driven, for automatic operations
- Computer requirements: Shutter operation, filter-wheel position, filter wheel temperature, CCD gain/binning is managed from any computer via 1 x industry standard USB2 and 2 x RS232 interfaces.
- Assembly and Testing: At KEO facilities in Calgary
- Calibration: full absolute and zonal (flat field) calibration available

Filter Specifications

Spectral

- Center Wavelength (CWL) Tolerance: +/- 0.15 x FWHM across clear aperture
- Full Width Half Maximum (FWHM) Tolerance: +/-0.20 x FWHM across clear aperture
- Blocking Range and Density: 200 to 1000 nm, OD 5.0 « 0.001% maximum)
- Peak Transmittance: Dependent on CWL and FWHM

Cosmetics

- Fringes: No visible fringes when viewed in a black box with a 40 watt frosted incandescent bulb
- Scratch/Dig: 60/40 per MIL-PRF-13830B
- Pinholes: Maximum of one 0.004" pinhole per 20 mrn area. Maximum of 3 pinholes < 0.004" per 20 mm
- Bubbles: Treated as digs
- Stains: Combined area of stains < 10% of clear aperture

Dimensional

- Outside Diameter Tolerance: +0.000/-0.010", including out of round
- Thickness: 0.250 +/- 0.030"
- Substrate Thickness; 0.230 +/- 0.030"
- Clear Aperture: 90% of OD

Optical

- A.R. Coating: None unless specified
- Transmitted Wavefront: Unspecified
- Parallelism: Unspecified

Keo Scientific Warranty Statement (Keo *Sentry* Imagers)

All internal Keo Scientific electronics (including Filterwheel Control, Shutter Driver, Light Sensor, and Filterwheel Environmental Control Electronics): 3 years Keo Scientific Warranty. The product is warranted to meet published specifications and to be free of defects in materials and workmanship as defined in the specifications for three (3) years from the date of original shipment from Keo. During this time, Keo will arrange to have the product repaired or replaced without charge to you. You must return the entire instrument to Keo Scientific for inspection and assessment. You are only responsible for shipping costs to return the product.

Keo Scientific machined mechanical housings and all included optics (excluding filters): 3 years Keo Scientific Warranty. The product is warranted to meet published specifications and to be free of defects in materials and workmanship as defined in the specifications for three (3) years from the date of original shipment from Keo. During this time, Keo will arrange to have the product repaired or replaced without charge to you. You must deliver the defective part(s) to Keo Scientific. You are only responsible for shipping costs to return the product.

Keo Scientific filterwheel mechanics, including Animatics SmartMotor, Gear Box and rest of drivetrain: 3 years Keo Scientific Warranty. The product is warranted to meet published specifications and to be free of defects in materials and workmanship as defined in the specifications for three (3) years from the date of original shipment from Keo. During this time, Keo will arrange to have the product repaired or replaced without charge to you. You must deliver the defective part(s) to Keo Scientific. You are only responsible for shipping costs to return the product. Some filterwheel

related problems can be easily fixed via SmartMotor firmware. Please inquire about firmware upgrades from Keo Scientific. Firmware upgrades will be sent by email, at no charge. Custom firmware for special operational needs can be designed by Keo upon request.

CCD Camera Head: Camera manufacturer's own warranty applies. Details vary from manufacturer to manufacturer. Warranty period commences when CCD camera is delivered to Keo Scientific for integration with the rest of the optical system. Most CCD camera heads now come with lifetime vacuum guarantee.

Normal Wear Item Disclaimer: Keo Scientific does not warrant certain items against defect due to normal wear and tear. These items include cables and connectors, as well as anti-reflection coatings on lenses. Lens integrity may be compromised by prolonged exposure to solar UV – lenses should be capped during extended times of no imaging operations. Also note that it is normal for the external anodization black color of the machined housings to fade over time, if exposed to solar UV for prolonged periods of time (on the order of 3 years), but this will often not affect instrument operation – it is often a cosmetic issue only.

Shipping damage: Any damage occurring to the instrument while in transit from Keo to customer must be reported to the shipping company or courier company immediately upon receipt of goods. Shipments are separately insured, and such damage is covered by said insurance. Please inspect instrument thoroughly upon arrival.

Installation, Application and Technical Support

We, Keo Scientific Ltd., stand by each and every one of our high-performance imagers throughout the entire lifetime of the system. Whether you require technical assistance or have an installation-related or application-related issue, please feel free to contact us at trondsen@keoscientific.com. **We are pleased to provide you with free lifetime installation, application and technical support via email, fax, and telephone.**

Contact Us

Do not hesitate to contact us for further information. We are here to serve you.

Email: trondsen@keoscientific.com

Phone: 1.403.383.7192 (Dr. Trondsen)

Fax.: 1.403.206.7680

Keo Scientific Key Personnel

DR. TROND S. TRONDSEN started his career in the field of scientific imaging at the University of Tromsø, Norway in 1988. There, he designed, implemented, and characterized a computer controlled digital all-sky camera system (Ramfjordmoen All-Sky Imager) for autonomous observation of the aurora borealis. He wrote the real-time control and acquisition software as well as a complete image processing suite at a time when no such program suite was commercially available. He took part in the design of the European Space Agency's AURIO visible and ultra-violet auroral satellite-based CCD imagers. He participated in the design of the far ultra-violet (FUV) auroral imagers on the Swedish satellite Freja, successfully launched in October 1992. He assisted in the design of the Polar Camera (PoCa), a set of two weatherproof imager pods for dual-wavelength observations of the aurora from Eureka, Ellesmere Island. This work included research into weather-proof enclosures, portable and robust data-loggers, image compression algorithms, writing low-level software handling data communication between computer and camera controllers, writing an ephemerides software package, as well as performing the complete mechanical design of the camera units. He was a Participating Scientist on the NASA IMAGE mission (the first MIDEX mission) and assisted with the design of the

Wideband UV Imaging Camera (WIC). Dr. Trondsen graduated in 1998 from the University of Tromsø, Norway with a PhD in Cosmic Geophysics, after having conducted all his PhD related research at the Institute for Space Research, University of Calgary. For his PhD dissertation, he developed (optics, electronics, hardware, software) a highly portable intensified imaging system — The U of Calgary Portable Auroral Imager — and applied it to outdoor-based high-resolution (narrow-field) auroral studies in the Canadian north and Norwegian arctic, publishing numerous findings in refereed scientific journals. From 1998 to 2010, Dr. Trondsen worked as an Imaging Specialist at the University of Calgary's Institute for Space Research, designing the NORSTAR (CGSM) multispectral all-sky imaging system (based around Keo Consultants' all-sky cameras), including writing all control and real-time monitoring software. He was Principal Investigator of the Enhanced Polar Outflow Probe (ePOP) mission's Fast Auroral Imager (to be launched 2011), where he spearheaded the optical design, sensor and filter selection, and design of low-noise readout and processing electronics. He was also a member of the U of Calgary-led ground-based segment for the NASA THEMIS mission, which involved deploying and networking an array of 20 all-sky cameras spread out across northern regions. Dr. Trondsen has been a licensed ham radio operator (Advanced Class) since 1983, and studied signal-losses in waveguides at the European Incoherent Scatter Scientific Association (EISCAT) during his MSc days. As well, he worked with riometers, ionosondes, and partial reflection experiment (PRE) radars. Dr. Trondsen is a Norwegian citizen who holds permanent residency status in Canada and has a NATO security clearance. He is President of Keo Scientific Ltd.

DR. ROBERT H. EATHER, the founder of the original Keo Consultants, has designed and developed low-light level (LLL) imagers for auroral and airglow research for almost 40 years. Dr. Eather specializes in LLL optical problems. Research and developmental work has been primarily in the fields of LLL spectrophotometric, photometric, television and camera systems, and associated special-purpose optics. His products range from custom lens systems to complete turnkey imaging and recording systems, including customized software development. Dr. Eather has also conducted basic research into various aspects of the physics of the low-, mid- and high-latitude ionosphere, including correlated experiments using rocket and satellite data. In addition, work has been carried out on optical calibration standards, color image intensification, lidar systems, space debris detection, and Imax/Omnimax cameras and filming. Dr. Eather was the Director of Photography on the IMAX movie Solar Max and he was the recipient of the first AGU Athelstan Spilhaus Award. He was made a Member of the Order of Australia in 2009. Publications: 70 publications in refereed scientific and technical journals on auroral and magnetospheric physics, and LLL optical topics as well as numerous publications in commercial magazines on auroral topics. Dr. Eather is the author of the popular book Majestic Lights: The Aurora in Science, History and the Arts (ISBN 0875902154), and the classic Review Paper on proton aurora, Auroral proton precipitation and hydrogen emissions, Rev. Geophys., 5, 207, 1967.

MR. KEVIN RASMUSSEN manages Keo's business operations. His education as a Mechanical Engineer (BSc from U of C) and an MBA (U of A, 1993) provides him with a unique combination of technical and business skills. This, combined with his experience in the manufacturing, high tech. and professional services sectors, allows him to bring a broad and seasoned perspective to Keo's business and operations. Although the cornerstone of Keo's success is the scientific knowledge and experience that goes into the design and construction of the instruments, Kevin feels that an efficient operational structure is necessary to allow Keo to maintain top-notch quality, reliable delivery schedules, and highly responsive customer service. It is his goal to ensure that Keo's customers are provided with the best possible experience every time they interact with the company - from the initial inquiry to the order, delivery, installation and ongoing support.

DR. SANDY MURPHREE has a PhD from Rice University (1975). His background is in experimental space physics working with datasets obtained from several satellite borne low-light level imagers. Dr. Murphree, a founding partner of Keo Scientific Ltd., has been the lead investigator of auroral imager instrumentation on several recent satellite missions. For example, in 1986 the Swedish Viking satellite carried a new generation ultraviolet imager utilizing advanced image acquisition technology. Global auroral images were acquired as fast as every 20 seconds for the first time opening up the

possibility of doing large scale dynamic studies. This was followed by an improved UV imager flown on the Swedish Freja satellite in 1992. Images were acquired every 6 seconds in this mission, allowing high temporal and spatial resolution studies. The datasets acquired represent one of the finest set of two-dimensional auroral images in the world and today provide a unique database for understanding the magnetospheric processes which result in the aurora. He is a founding partner of Keo Scientific Ltd.

DR. LEROY COGGER has a PhD from the University of Saskatchewan(1968). Dr. Cogger retired from the University of Calgary in 1997 and was awarded the honorary titles of Professor Emeritus and Faculty Professor (a designation that recognizes the expertise and continuing high calibre of research being done by some retired Professors). In this capacity, he continues an active research program. Dr. Cogger has for years been the leader of an active research group under the auspices of the Institute for Space Research at the University of Calgary. The research involves ground-based and space-borne measurements of the aurora and upper atmosphere. As part of the Canadian Space Agency's CANOPUS network of ground based instruments, Dr. Cogger was the Principal Investigator of an automated all-sky imager in northern Manitoba from which short-term spatial and temporal variations of the aurora in the auroral oval were studied from 1986 to 1998. This imager was the seed of what later was to become the NORSTAR network of all-sky imagers. Dr. Cogger was the Director of the Institute for Space Research from 1989 to 2002. He is a founding partner of Keo Scientific Ltd.

A list of some of Keo Scientific's worldwide customers

The following is a very incomplete, alphabetical list of Keo Scientific Ltd. customers and clients. Keo Scientific Ltd. is the only off-the-shelf source of such uniquely sensitive multispectral all-sky imagers in the world today.

- Air Force Office of Scientific Research (AFOSR), Arlington, VA, U.S.A.
- Air Force Research Laboratory (AFRL), Hanscom Air Force base, MA, U.S.A.
- Arecibo Observatory, Arecibo, Puerto Rico
- Athabasca University Geophysical Observatory, Athabasca, Canada
- Australian Antarctic Division, Australia
- Boston College, Department of Physics, Boston, MA, U.S.A.
- Boston University, Center for Space Physics, MA, U.S.A
- Clemson University, Department of Physics and Astronomy, Clemson, SC, U.S.A.
- Colorado Research Associates, Boulder, CO
- Colorado State University, Department of Physics, Boulder, CO
- Communications Research Laboratory (CRL), Tokyo, Japan
- Cornell University, Department of Electrical Engineering, Ithaca, NY, U.S.A.
- Cornell University, Space Plasma Physics Group, Ithaca, NY, U.S.A.
- Embry-Riddle Aeronautical University, Space Physics Research Lab (SPRL), FL, U.S.A.
- Finnish Meteorological Institute, Space Physics Department, Finland
- Indian Institute of Geomagnetism, Equatorial Geophysical Research Lab., Tirunelveli, India
- Indian Institute of Geomagnetism, Upper Atmospheric Sciences Division, Navi Mumbai , India
- Instituto Nacional de Pesquisas Espaciais (INPE), São José dos Campos, Brazil
- Istituto di Fisica dello Spazio Interplanetario (INAF –IFSI), Rome, Italy
- Johns Hopkins University, Applied Physics Laboratory, MD, U.S.A.
- Korea Polar Research Institute (KORDI/KOPRI), Ansan, Korea
- Lancaster University, Department of Communication Systems, Lancaster, U.K.
- MITRE Corporation, Bedford, MA, U.S.A.

- Massachusetts Institute of Technology, MA, U.S.A.
- Muskingum College, Department of Physics, New Concord, OH, U.S.A.
- Nagoya University, The Solar-Terrestrial Environment Laboratory (STELab), Nagoya, Japan
- National Aeronautics and Space Administration (NASA), Greenbelt, Maryland, U.S.A.
- National Science Foundation (NSF), Arlington, VA, U.S.A.
- NorthWest Research Associates, Inc., Tucson, AZ, U.S.A.
- Northern Michigan University, Department of Physics, MI, U.S.A.
- Penn State University, CSSL, University Park, PA, U.S.A.
- Physical Research Laboratory, Ahmedabad, India
- SRI International, Menlo Park, CA, USA
- Scion Associates, Inc., Port Townsend, WA, U.S.A.
- The Aerospace Corporation, Space Sciences Department, Los Angeles, U.S.A.
- United States Department of Defense, Pentagon, Washington D.C., U.S.A.
- United States Department of Defense, U.S. Air Force, Hanscom Air Force Base, M.A., U.S.A.
- Universidade do Vale do Paraiba, Brazil
- University Centre in Svalbard (UNIS), Institute of Arctic Geophysics, Norway
- University of Alaska, Geophysical Institute, Fairbanks, AK, U.S.A.
- University of Calgary, Institute for Space Research, Calgary, Canada,
- University of California Berkeley, Space Science Laboratory (SSL), Berkeley, CA, U.S.A.
- University of Illinois at Urbana-Champaign, Urbana, IL, U.S.A.
- University of Illinois, Department of Electrical and Computer Engineering, Urbana, IL, U.S.A.
- University of Massachusetts, Amherst, MA, U.S.A.
- University of New Brunswick, Dept. of Physics, Fredericton, NB, Canada
- University of Newcastle, Space Physics Group, New South Wales, Australia
- University of Oslo, Institute of Physics, Norway
- University of Tromso, Department of Physics and Technology, Tromso, Norway
- Utah State University, Department of Physics, UT, U.S.A.
- Williams College, Williamstown, MA, U.S.A.

Recent Customer Testimonials

TO WHOM IT MAY CONCERN:

We , SRI International, verify that Keo Scientific Ltd was the supplier of two sets of custom-made fast-imaging optics with the quality required.

Elizabeth Kendall, Ph.D.

June 08, 2009

SRI International
333 Ravenswood Avenue • Menlo Park, California 94025-3493 • 650.859.2000

Recent Customer Testimonials (continued)

University of New Brunswick Fredericton
8 Bailey Drive PO Box 4400 Fredericton, NB Canada E3B 5A3
Tel 506 447-3257 Fax 506 453-4581 wward@unb.ca www.unb.ca/physics
Department of Physics
Professor William E. Ward

June 5, 2009

TO WHOM IT MAY CONCERN

We (Department of Physics, University of New Brunswick) certify that Keo Scientific Ltd was the supplier of an All Sky Imager, which included a fish-eye lens and appropriate components (filters, imaging optics, CCD detector) suitable for imaging wave signatures in airglow. The instrument has been operating for two years in the Canadian High Arctic without problem and we have generated data of good scientific quality with it.

University of New Brunswick, Fredericton

Sincerely,

William Ward

Recent Customer Testimonials (continued)

From: Kirsti.Kauristie@fmi.fi
Subject: Re: Keo Scientific Ltd.

Dear Dr. Trondsen,

Thousand thanks for your many generous offers to help us. Your flexible attitude is highly appreciated!

As you may have heard, I will start in new organization at the beginning of next year. This means that my role in the technical maintenance issues will become smaller and consequently the communication between Keo Scientific and FMI will become someone else's pleasure. Thus I hereby want to express once again my sincere thanks to you for fluent collaboration. You have done business with us according to very high principles and with honest style.

With kind regards,

Kirsti Kauristie, Professor

Finnish Meteorological Institute
P.O.B. 503
FIN-00101, Helsinki, Finland

phone: +358-9-1929 4637
fax: +358-9-1929 4603

From: narayananvlwins@gmail.com
Date: March 5, 2009 10:22:20 PM MST (CA)

Dear Dr. Trondsen,

Kindly recall that we procured a CCD-based all-sky airglow imager from Keo Scientific about two years ago. We have been operating the instrument at two locations, namely, Tirunelveli and Kolhapur. Between January and March 2008, the imager was operated at Kolhapur, a field station located about

800 km north of Tirunelveli, whereas during rest of the times, it was operated at Tirunelveli. We are satisfied with the results obtained so far as two papers were accepted for publication in scientific journals, one in the Journal of Geophysical Research and the other one in the Indian Journal of Radio and Space Physics.

[...]

With warm regards,
Sincerely,
V. Lakshmi Narayanan.

References

We are pleased to provide the following references, constituting some of our most recent customers:

1.
Professor Kirsti Kauristie
Finnish Meteorological Institute
P.O.B. 503
FIN-00101, Helsinki, Finland
Email: Kirsti.Kauristie@fmi.fi
Phone: +358-9-1929 4637
Fax: +358-9-1929 4603

2.
Dr. Elizabeth Kendall (née Gerken)
SRI International
333 Ravenswood Avenue, Menlo Park CA 94025 USA
Email: elizabeth.kendall@sri.com
Phone: 1-650-859-4906
Fax: 1-650-322-2318

3.
Professor S. Gurubaran
Equatorial Geophysical Research Laboratory
Indian Institute of Geomagnetism
Krishnapuram
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