

Technology Infusions

Space Missions



Implemented

Directly deposited optical blocking filters flying on OSIRIS-REx/OSIRIS-APEX • High-precision mirror-shell alignment and mounting used for IXPE • Si-thermistor/HgTe microcalorimeter array flew on Hitomi and flying on XRISM • Phasemeter flying on GRACE Follow-On • UV coatings flying on GOLD and ICON • High-Energy Replicated Optics contributed to IXPE and SRG (ART-XC) optics • Adiabatic Demagnetization Refrigerator (ADR) flew on Hitomi and flying on XRISM • APD-funded MCPs flying on ICON, GOLD, Juno, JUICE, and Solar Orbiter • X-Ray test processes and techniques used for IXPE and SRG (ART-XC) • Slumped-glass X-ray mirrors flying on NuSTAR

Upcoming

Multi-star Wavefront Sensing and Control to fly on RST • Charge Management Device developed as NASA contribution for LISA • Protected enhanced LiF (eLiF) mirror coatings and MCP anti-coincidence shielding to fly on SPRITE • Electron-beam-lithography-ruled gratings to be flown on MANTIS • ALD UV coatings to fly on SPRITE, Aspera, and UVEX • Multilayer Al dielectric filters for UV detectors to fly on SPARCS • Delta-doped SRI 4kx4k CMOS image sensors to fly on UVEX • Wavefront Control with two DMs baselined for RST • TES Microcalorimeter arrays and Time-Domain Multiplexing (TDM) baselined for ATHENA X-IFU • End-to-end Coronagraph models baselined for RST • CMB detectors baselined for LiteBIRD • Telescope developed as NASA contribution for LISA • Advanced CCD detectors baselined by SPARCS • Physical Vapor Deposition in support of ALD UV Coatings to fly on SPRITE and Aspera • H4RG IR detectors baselined for RST • Radiation-Tolerant, Photon-Counting, Visible/near-IR Detectors to fly on DarkNESS and DAVINCI • MCPs planned to fly on SPRITE, Aspera, Europa Clipper, GLIDE, Galileo, and MANTIS • Hybrid Lyot Coronagraph baselined for RST • Timepix2 ASICs to fly on PADRE • Feedhorn-coupled symmetric-OMT architectures adopted by LiteBIRD • Laser technology developed as NASA contribution for LISA

Strategic Concept

Directly deposited optical blocking filters baselined for Lynx • Advanced CCD detector baselined by AXIS and Star-X • Multi-star Wavefront Sensing and Control for HabEx and LUVOIR • PIAACMC Coronagraph for HabEx and LUVOIR • MEMS DMs are baselined for HabEx and LUVOIR • CMB detectors and antenna-coupled detectors baselined for PICO • MCP Anti-coincidence shielding baselined for LUVOIR • Next-gen microshutter arrays baselined for HabEx, LUVOIR, and CETUS • Linear wavefront control for HabEx and LUVOIR • Predictive wavefront control and sensor fusion for HabEx and LUVOIR • Avalanche Photodiode HgCdTe near-IR detectors baselined for HabEx and LUVOIR • Delta-doped SRI 4kx4k CMOS image sensors baselined by CASTOR • Starshade technologies baselined for Starshade-RST Rendezvous Probe • CMB detectors baselined for PICO • FPGA-based readout electronics for superconducting arrays baselined for PICO, Origins, GEP, and Cosmic Dawn • Low-blaze-angle grating baselined by ESCAPE • Delta-doped EMCCDs baselined for HabEx • Delta-doped CMOS detector arrays baselined for LUVOIR • Critical-Angle-Transmission (CAT) X-ray gratings baselined for Lynx • Thermal oxide coating-stress compensation for Lynx, AXIS, and TAP mirrors • Vortex Coronagraph baselined for HabEx and LUVOIR • Cross-strip MCP detector systems baselined for HabEx, LUVOIR, and CETUS • MCP detectors baselined for HabEx, LUVOIR, CETUS, ESCAPE, and MAGIC • Electroforming Process Modeling used for MIXO for CubeX • Apodized Pupil Lyot Coronagraph baselined for LUVOIR • Superconducting kilo-pixel far-IR detector architecture baselined for Origins • PTC as pathfinder for zonal thermal control in HabEx • X-Ray test processes and techniques used for MIXO for CubeX • CADR is baselined for Lynx, Origins, PICO, and GEP • Microwave SQUID multiplexers baselined for Lynx and Origins • Time-division SQUID multiplexers baselined for PICO • Single-crystal-silicon X-ray mirrors baselined for Lynx, AXIS, TAP, and STAR-X • Micro-Newton thrusters are baselined for HabEx fine pointing and jitter suppression

Infusion-Ready (TRL 5)

Ultrasensitive Far-IR KID Arrays • Fast X-ray Event Recognition • Single-photon-sensing and photon-number-resolving detector

Sounding Rockets



Implemented

Electroformed X-ray mirror shells flew on FOXSI-4 • High-precision mirror shell alignment and mounting used by FOXSI-4 • Electroformed X-ray mirror shells flew on MaGIXS-2 • Image Slicer flew on INFUSE • Next-gen microshutter arrays flew on FORTIS • Single and multilayer coating techniques used by FOXSI-4 • Si-thermistor/HgTe microcalorimeter array flew on XQC • X-ray reflection grating flew on WRXR and tREXS • ALD mirror coating flew on SISTINE • Superlattice-doped detector flew on SHIELDS • Blazed soft-X-ray reflection grating flew on MaGIXS • MCPs flew on FIRE, SLICE, EUNIS, FORTIS, VeSpR, CHESS, SISTINE, INFUSE, and DEUCE • Electroforming Process Modeling used by FOXSI-4 • X-Ray test processes and techniques used by FOXSI-4 • TES microcalorimeters and Time-division SQUID multiplexers flew on Micro-X • Tpx3 CdTe detector flew on FOXSI-4 • DMDs flew on INFUSE

Upcoming

Electroformed X-ray mirror shells to fly on REDSoX • Electron-beam-lithography-ruled gratings to fly on OAxFORTIS and MOBIUS • Multilayer Al dielectric filters for UV detectors and ALD UV coatings to fly on FLUID • X-ray reflection gratings to be flown on OGRE • Far-UV coatings to fly on FORTIS • X-ray CAT grating baselined for REDSoX • Next-gen microshutter arrays to fly on OAxFORTIS • MCP detectors to fly on MOBIUS, FORTIS, and FLUID • Single-crystal silicon X-ray mirrors to be flown on OGRE

Balloons



Implemented

Antenna-coupled detectors flew on SPIDER • 4.7 THz local oscillator flew on STO-2 and GUSTO • Heterodyne detectors flew on STO-2 • Heterodyne-detector-related C&DH and ASIC flew on HASP • Advanced CCD detectors flew on FIREBall 2 • Broadband Light Rejection with Optical Vortex Coronagraph flew on PICTURE-C • Far-IR large-format detectors flew on PIPER • Time-division SQUID multiplexers flew on SPIDER and PIPER • TiN KIDs were integrated into BLAST-TNG

Upcoming

Microwave SQUID multiplexer firmware and parameters baselined for DR. TES • Setup for Ultra-Sensitive Bolometers to fly on TIM • Far-IR heterodyne technology to fly on ASTHROS • RFSoc readout baselined for EXCLAIM, PUEO, and TIM • Low-loss transmission lines and micromachined packaging and Absorptive mixtures and glint reduction coatings to be implemented on EXCLAIM

Airborne



Implemented

TES Bolometers for the HAWC+ flew on SOFIA • Time-division SQUID multiplexers for the HAWC+ flew on SOFIA • Absorptive mixtures and glint reduction coatings for HAWC+ flew on SOFIA

Upcoming

IF Board to be flown in ONR airborne KID instrument

Ground-Based



Implemented

Microwave SQUID multiplexer crosstalk avoidance implemented at Simons Observatory • Antenna-coupled detectors were deployed on BICEP2, BICEP3/Keck, and BICEP Array • Near-IR LmAPD implemented in U Hawaii 2.2m telescope ULBCam • Ultra-Sensitive Bolometers were deployed at Kitt's Peak • Linear Wavefront Control deployed to Subaru Observatory • Mandrel used to form NIF X-ray microscope optic • RFSoc readout used in Toltec camera at LMT • Spectrograph and Wavefront Control Architectures were deployed on Keck Planet Imager and Characterizer • Delta-doped CCDs placed at Palomar-WaSP and ZTF as permanent facilities • DMDs were deployed on the 4.1-m SOAR Telescope • Electroformed X-ray mirror shell techniques used for NIST Neutron Microscope optics • Vortex coronagraph deployed to Palomar, Keck, and Subaru Observatories • TES bolometers used in the IRAM bolometer camera at the IRAM 30m Telescope • Microwave SQUID multiplexers deployed on GBT MUSTANG2 and Simons Observatory • OMT-coupled TES bolometers deployed on ABS, ACTPol, AdvancedACT, ALI-CPT, GBT MUSTANG2, SPTPol, and Simons Observatory • TES bolometers deployed on JCMT SCUBA2 • Time-division SQUID multiplexers deployed on ABS, ACT, ACTPol, AdvancedACT, BICEP2, BICEP3/Keck, and JCMT SCUBA2 • TiN KIDs were deployed on Toltec Camera at LMT • Feedhorn-coupled symmetric-OMT architectures implemented on ABS, ACTPol, Advanced ACTPol, CLASS, and Simons Observatory • Feedhorn-coupled symmetric-OMT focal planes and absorptive mixtures and glint reduction coatings deployed on CLASS

Upcoming

Next generation Near-IR LmAPD implemented in Subaru Observatory • AstroPix CMOS Monolithic Active Pixel Sensors to be implemented at the Electron-Proton/Ion Collider (ePIC) at BNL • RFSoc readout to be used in Toltec camera at CCAT-prime • GISMO to be deployed to GLT • OMT-coupled TES bolometers baselined for CMB-S4 • EPRV etalon to be deployed on Keck Planet Finder • Feedhorn-coupled symmetric-OMT architectures adopted by CMB-S4

APD's technology development investments have advanced TRLs of dozens of technologies, and led to 160 infusions and over 60 potential infusions into space, suborbital, and ground-based missions and projects.