SPARCS: Star-Planet Activity Research CubeSat

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On behalf of the SPARCS Team:

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ASU School of Earth and Space Exploration
Arizona State University

NASA

JPL Jet Propulsion Laboratory

The University of Arizona

University of Washington

SwRI

MIT

Lowell Observatory

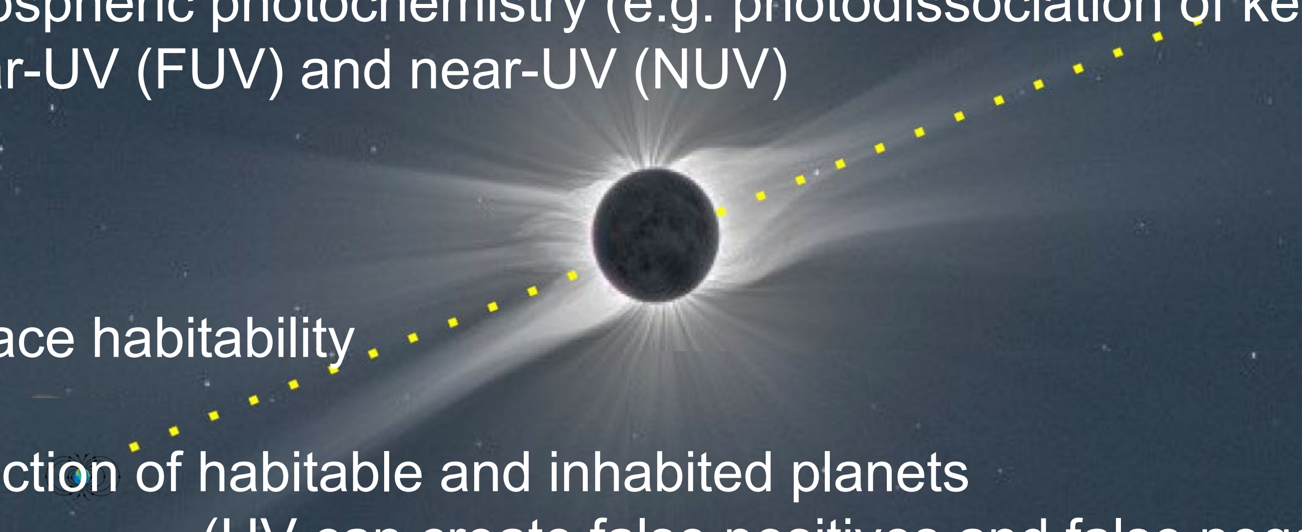
Goddard

Blue Canyon Technologies

Planetary Consequences of High-Energy Radiation at close distances.

- Atmospheric heating/escape by extreme-UV (EUV) photons

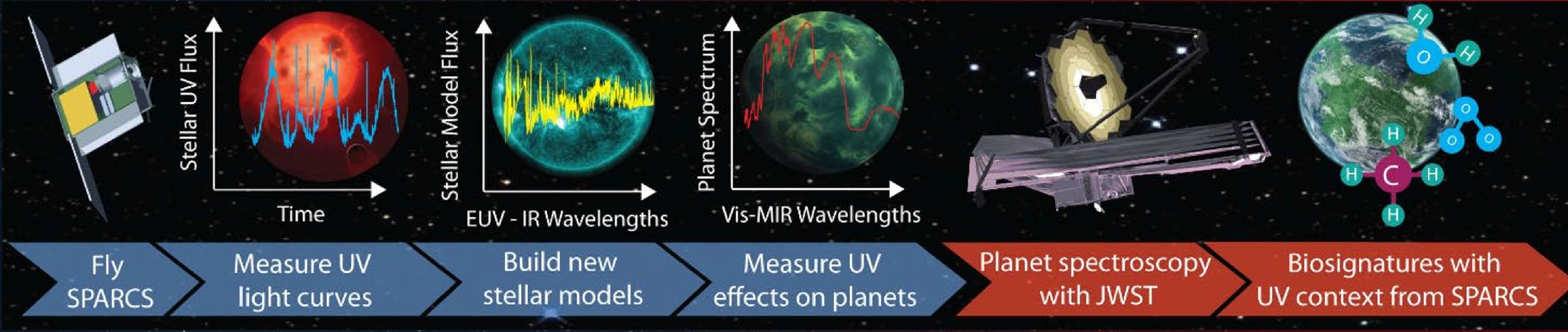
- Atmospheric photochemistry (e.g. photodissociation of key molecules) by far-UV (FUV) and near-UV (NUV)



- Surface habitability

- Detection of habitable and inhabited planets
  (UV can create false positives and false negatives.)

SPARCS Science Flow



Fly SPARCS

Measure UV light curves

Build new stellar models

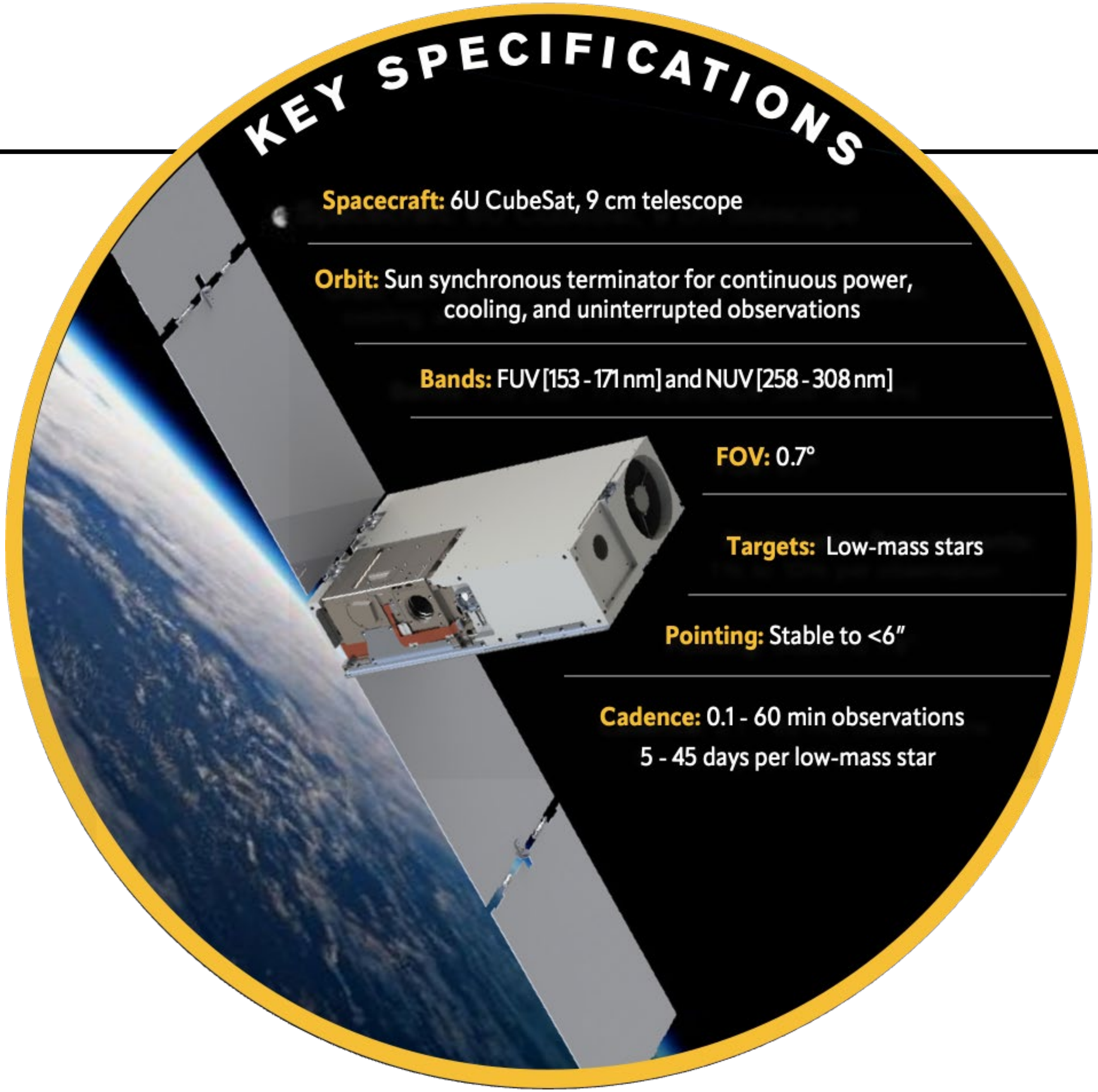
Measure UV effects on planets

Planet spectroscopy with JWST

Biosignatures with UV context from SPARCS

Baseline Design

NUV & FUV photometry of 20 low-mass stars, young and old.



KEY SPECIFICATIONS

Spacecraft: 6U CubeSat, 9 cm telescope

Orbit: Sun synchronous terminator for continuous power, cooling, and uninterrupted observations

Bands: FUV [153 - 171 nm] and NUV [258 - 308 nm]

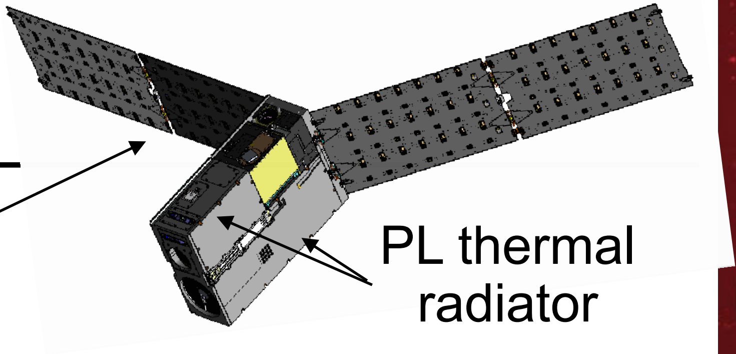
FOV: 0.7°

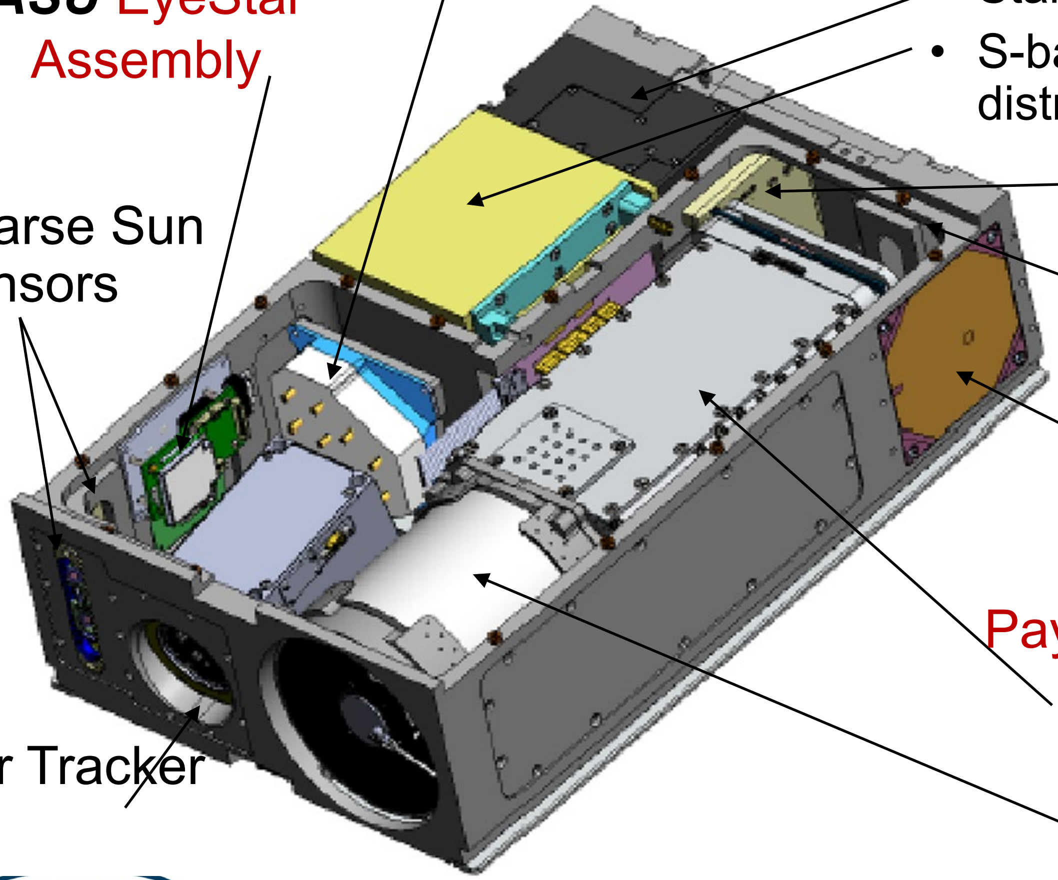
Targets: Low-mass stars

Pointing: Stable to <6″

Cadence: 0.1 - 60 min observations
5 - 45 days per low-mass star

SPARCS Flight System





Solar Arrays

PL thermal
radiator

Diplexer

XB1 Avionics
- Star tracker, torque rods, reaction wheels
- S-band radio, avionics control and power distribution, GPS receiver, & battery

ASU EyeStar
Assembly

Deployment Switches

Coarse Sun
Sensors

Coarse Sun Sensor

S-Band Antenna

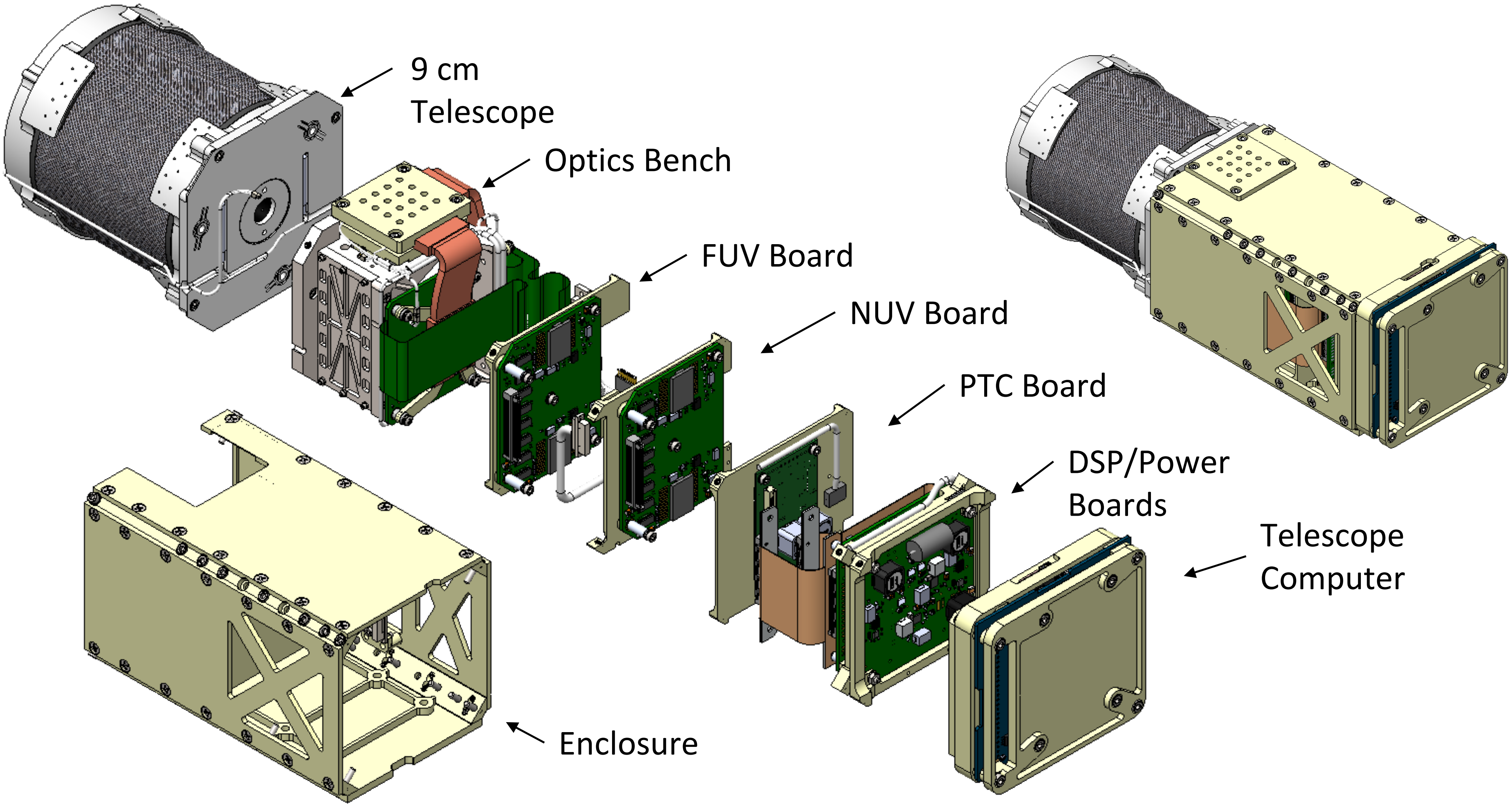
Payload
- ***JPL*** Camera (Detectors & Electronics)
- ***ASU*** Structure/Optical Bench/Thermal/PLP
- ***Hexagon*** Telescope

Star Tracker

BLUE CANYON
TECHNOLOGIES

SPARCS

Instrument Overview



9 cm
Telescope

Optics Bench

FUV Board

NUV Board

PTC Board

DSP/Power
Boards

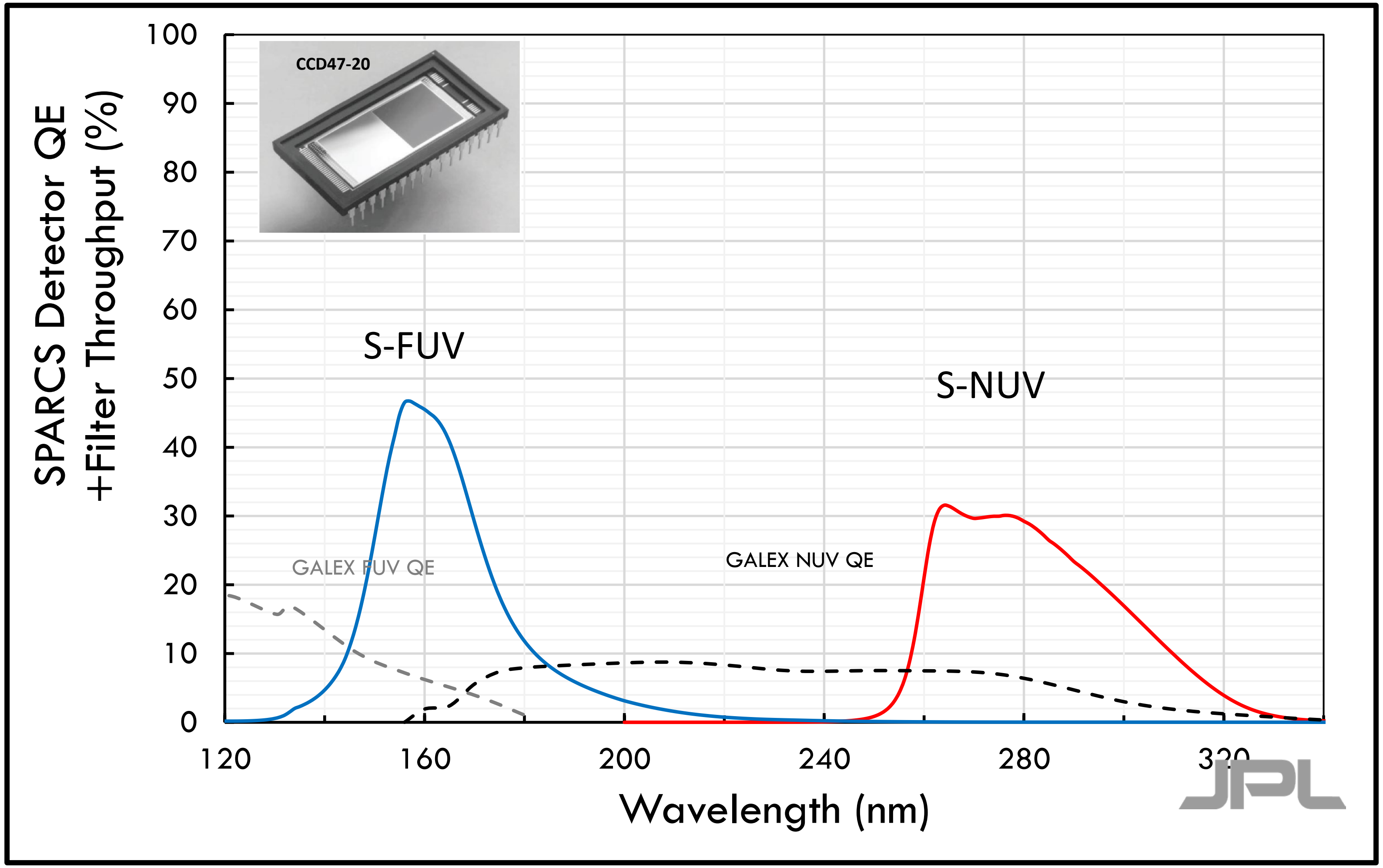
Telescope
Computer

Enclosure

SPARCS' technology mission:
Fly high-quantum efficiency, 2D-doped detectors (SPARCam)

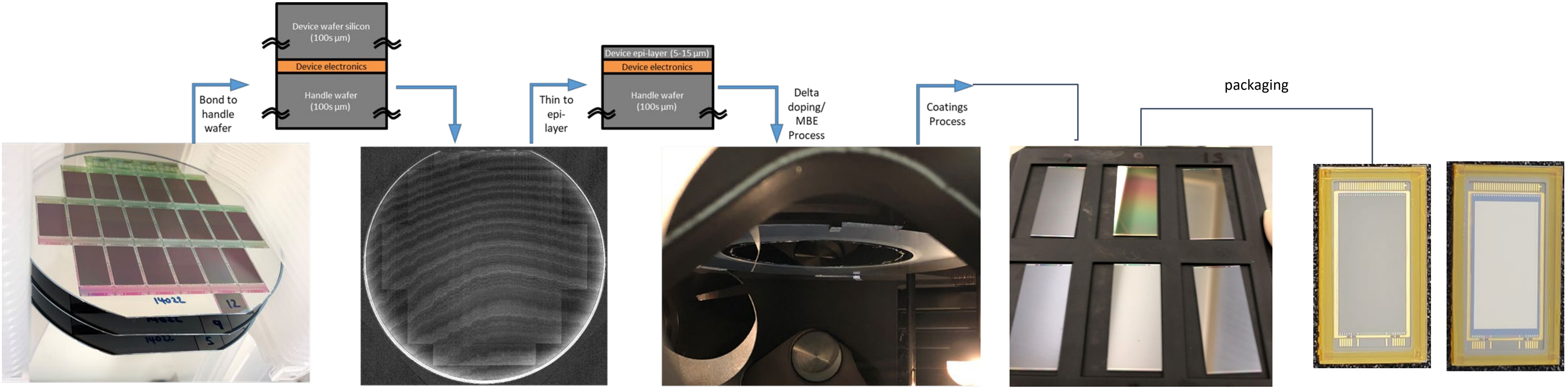
Science-grade CCDs are modified for UV enhancement using JPL's 2D-doping process, in which a highly-doped layer of silicon is deposited on the photon incident surface of detector.

Nikzad et al. 2012
Jewell et al. 2019



Detector UV Optimization

- CCD47-20 wafers procured from Teledyne-e2v
- JPL performs backside processing, including bonding, thinning, delta-doping (2D doping), pad opening, dicing, application of SPARCS coatings followed by packaging (below)

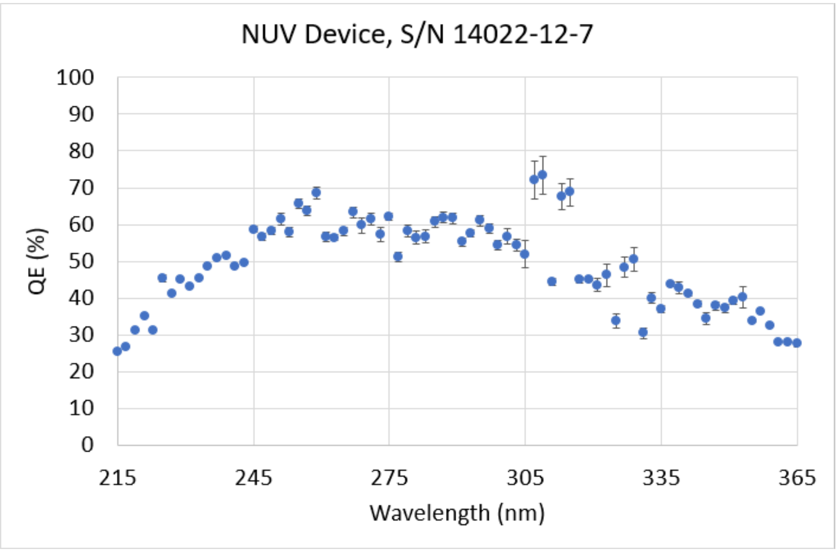


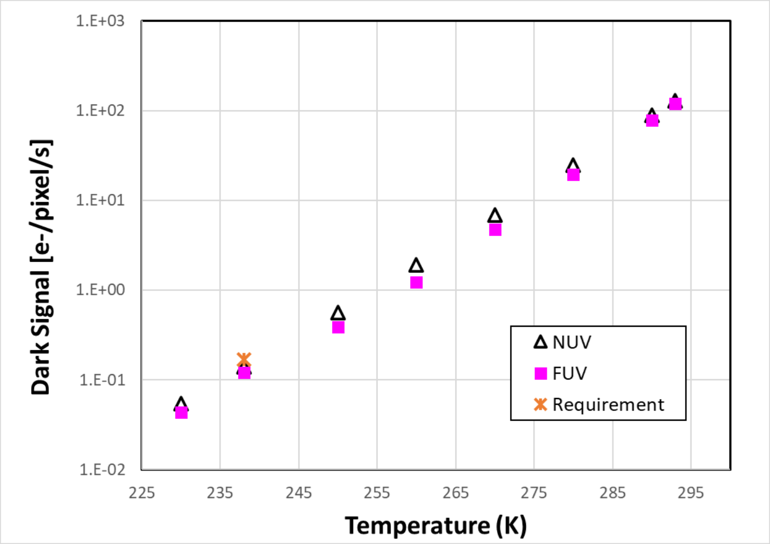
As received SPARCS wafers

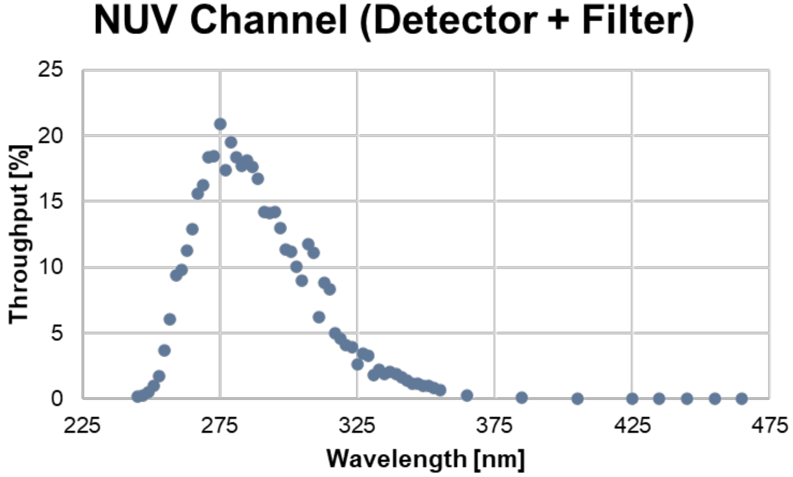
Bonded SPARCS wafer (C-SAM)

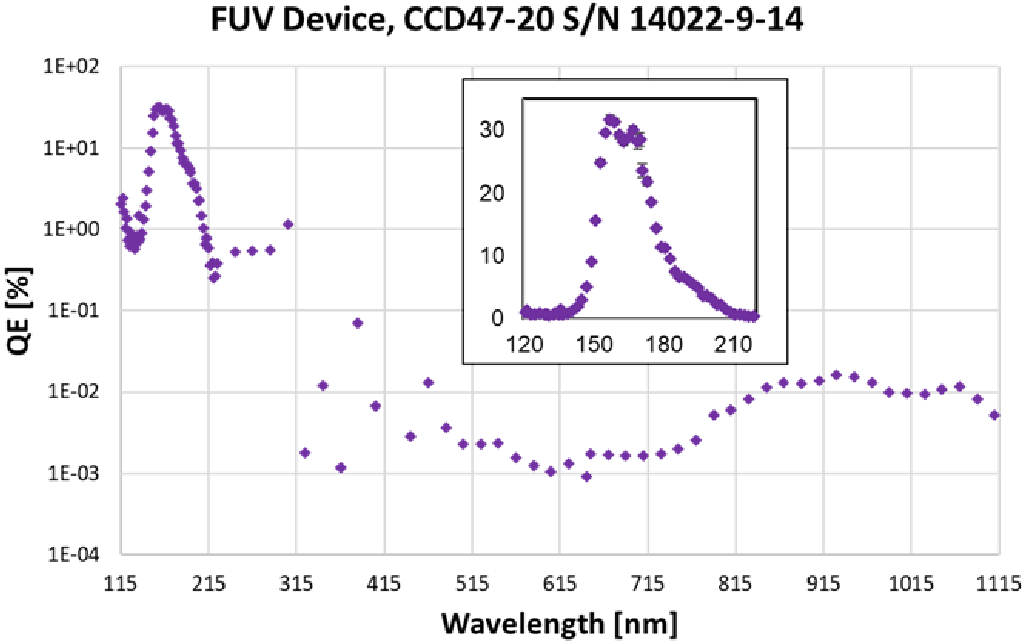
SPARCS wafer during delta doping (in MBE)

Detector + Filter Characterization

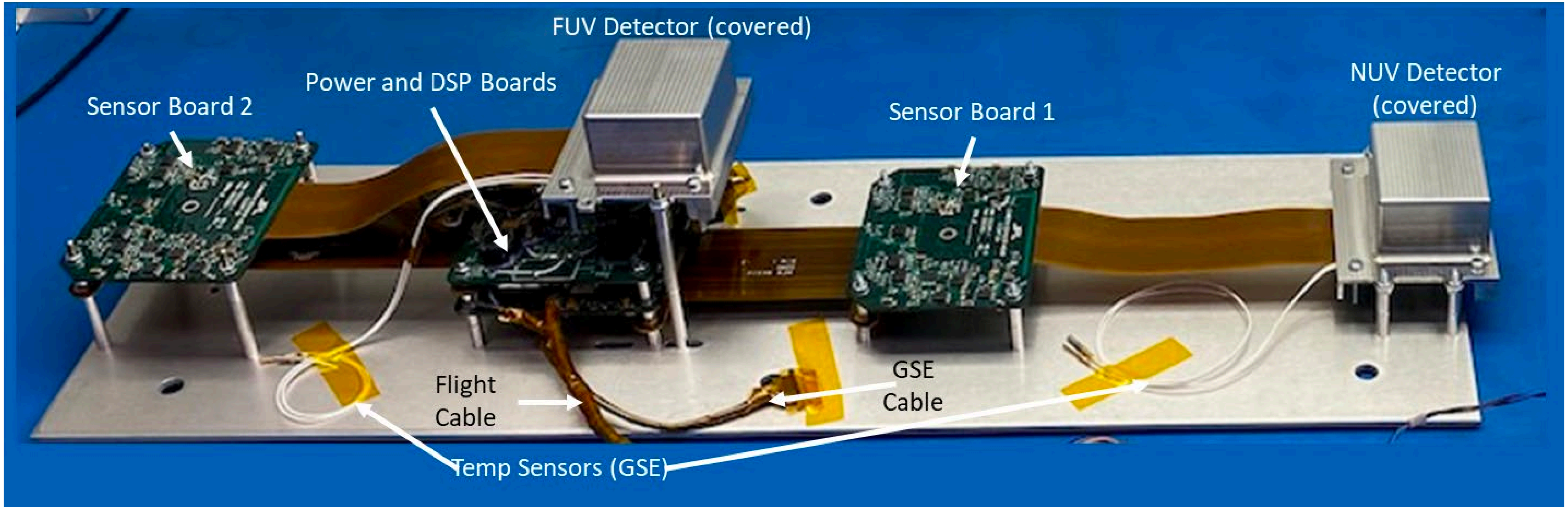

NUV Device, S/N 14022-12-7




NUV Channel (Detector + Filter)


FUV Device, CCD47-20 S/N 14022-9-14

SPARCam Flight Hardware:



SPARCam at JPL in the “flatsat” configuration for benchtop testing. The detectors are covered for shipping and storage

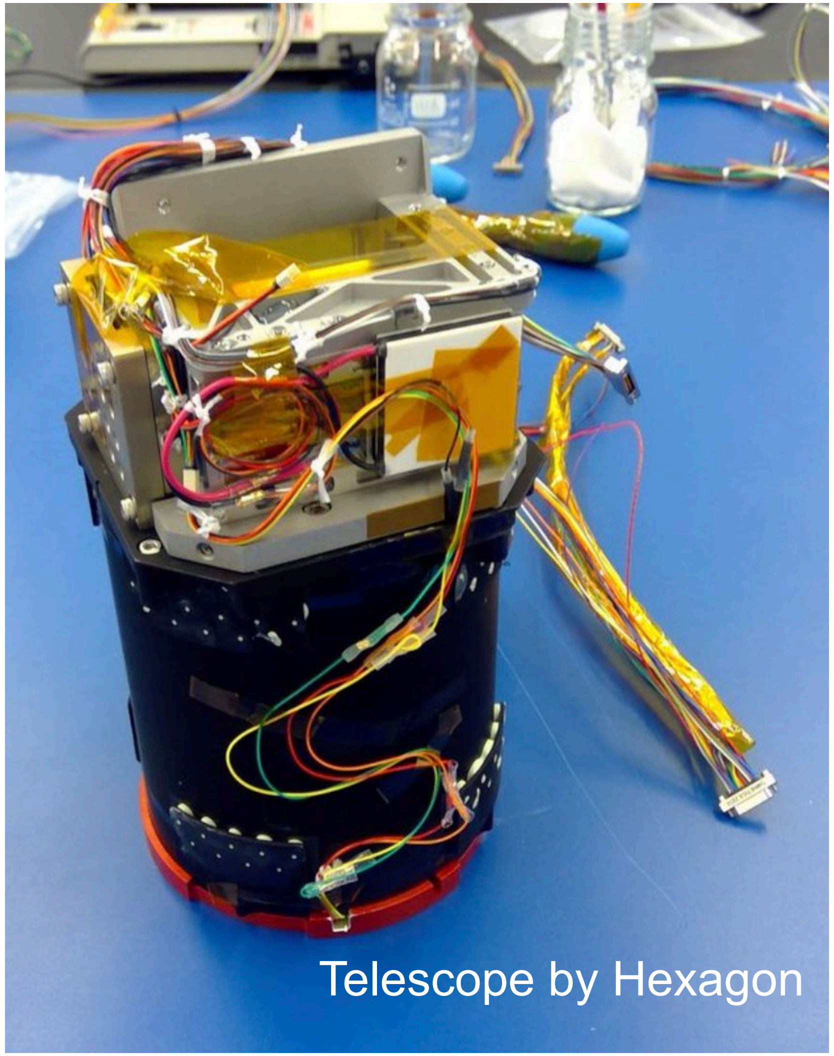
- SWaP
  - Size:
    Power and DSP Boards: 70 × 70 mm;
    Sensor Board: 80 × 63 mm w/ Detector HeadBoard: 67 × 52 mm
  - Mass: 253 g
  - Power: 14 W
- Processing Elements
  - FPGA – Microsemi ProASIC 3E A3PE3000

- Memory
  - 2× 512 Mbit SDRAM
- Interfaces
  - 1× Ethernet (data)
  - 1× SPI (data backup)
  - 1× JTAG (EGSE)
  - 12 V input (power)

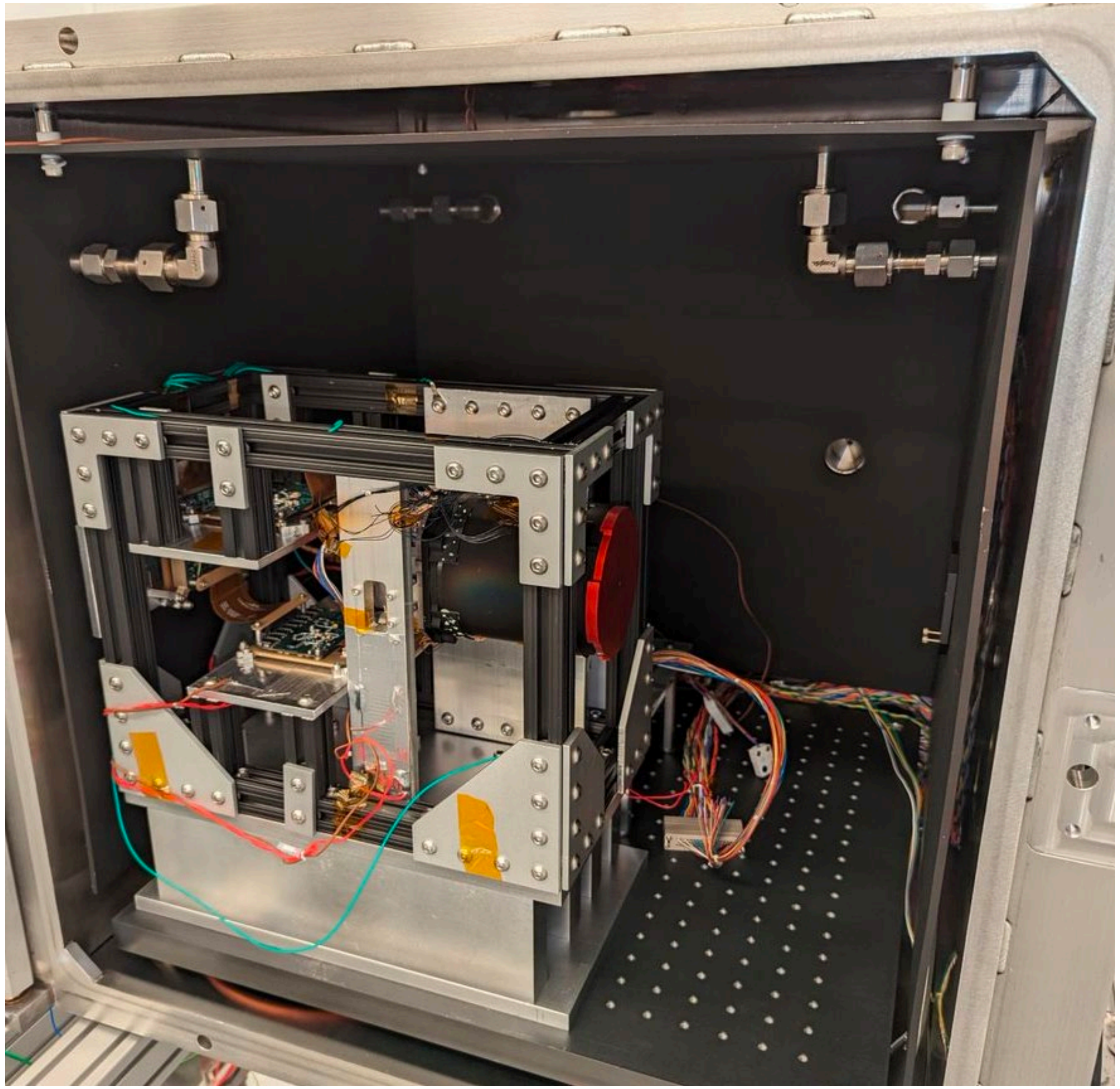
SPARCam Flight Hardware Checkout

The JPL Team (blue) demonstrates SPARCam operation to the ASU team (white) during delivery on October 5, 2023. All flight hardware testing at ASU taking place in the SPARCS cleanroom.

Payload Assembly, Integration, and Test (AIT)



Optical bench installed on telescope



Status: Where we are today

Telescope Delivered
Spacecraft CDR done
Payload CDR done
Mission PDR done
SPARCam Delivered

KSAT Contract done
Mission CDR done
BCT bus to arrive Feb 2024
Payload AI&T at ASU underway

Ready for launch early 2025
CSLI launch is TBD
Science!

The SPARCS Team:

Principal Investigator
Evgenya Shkolnik (ASU)

Engineering
Dawn Gregory (AZST)
Daniel Jacobs (ASU)
Nathaniel Strobel (AZST)

Payload Scientist
David Ardila (JPL)

Science
Travis Barman (UA)
Joe Llama (Lowell)
Victoria Meadows (UW)
Sarah Peacock, (GSFC)
Mark Swain (JPL)

Camera/Detector
Shouleh Nikzad (JPL)
April Jewell (JPL)
Christophe Basset (JPL)

Operations/Software
Judd Bowman (ASU)
Tahina Ramiaramanantsoa (ASU)
Matt Kolopanis (ASU)

Project Manager
Cristy Ladwig (ASU)

CubeSat, Telescope and I&T
Paul Scowen (GSFC/ASU)
Matt Beasley (SWRI)
BCT/Ratheon
Mary Knapp (MIT)
Logan Jensen (ASU)
Jonathan Gamaunt (ASU)
+ 4 Undergrad Interns

For more details, see papers
by Jewell et al. 2018, Scowen et al. 2018, Ramiaramanantsoa et al. 2021, Ardila et al., 2022

SPARCS

Star-Planet Activity Research Cubesat

OVERVIEW

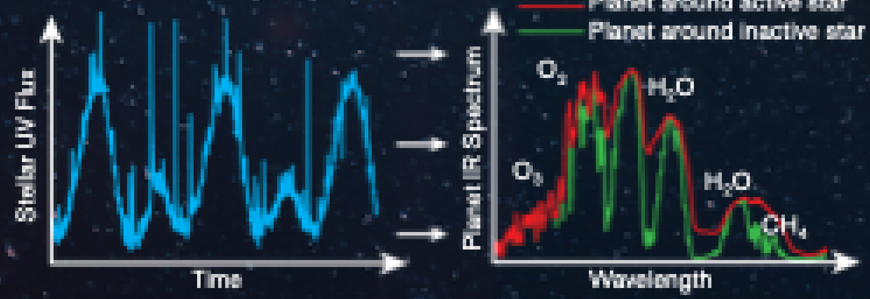
Mission SPARCS is the first ever mission dedicated to monitoring the high-energy radiation environments of exoplanets throughout their lifetimes by continuously and simultaneously measuring the FUV and NUV emission of low-mass stars from young to old.

Technology SPARCS advances UV detector technology by flying state of the art delta-doped detectors and metal dielectric filters.

Education SPARCS trains the next generation of scientists and engineers in mission development, operations, and data analysis.

DELIVERABLE SCIENCE

SPARCS determines the high-energy radiation environment around the most common types of exoplanet hosts. By measuring month-long light curves in two UV bands, SPARCS maps stellar activity due to flares and stellar rotation. These data are crucial to understand the evolution and habitability of planets and for interpreting their spectra and atmospheres.



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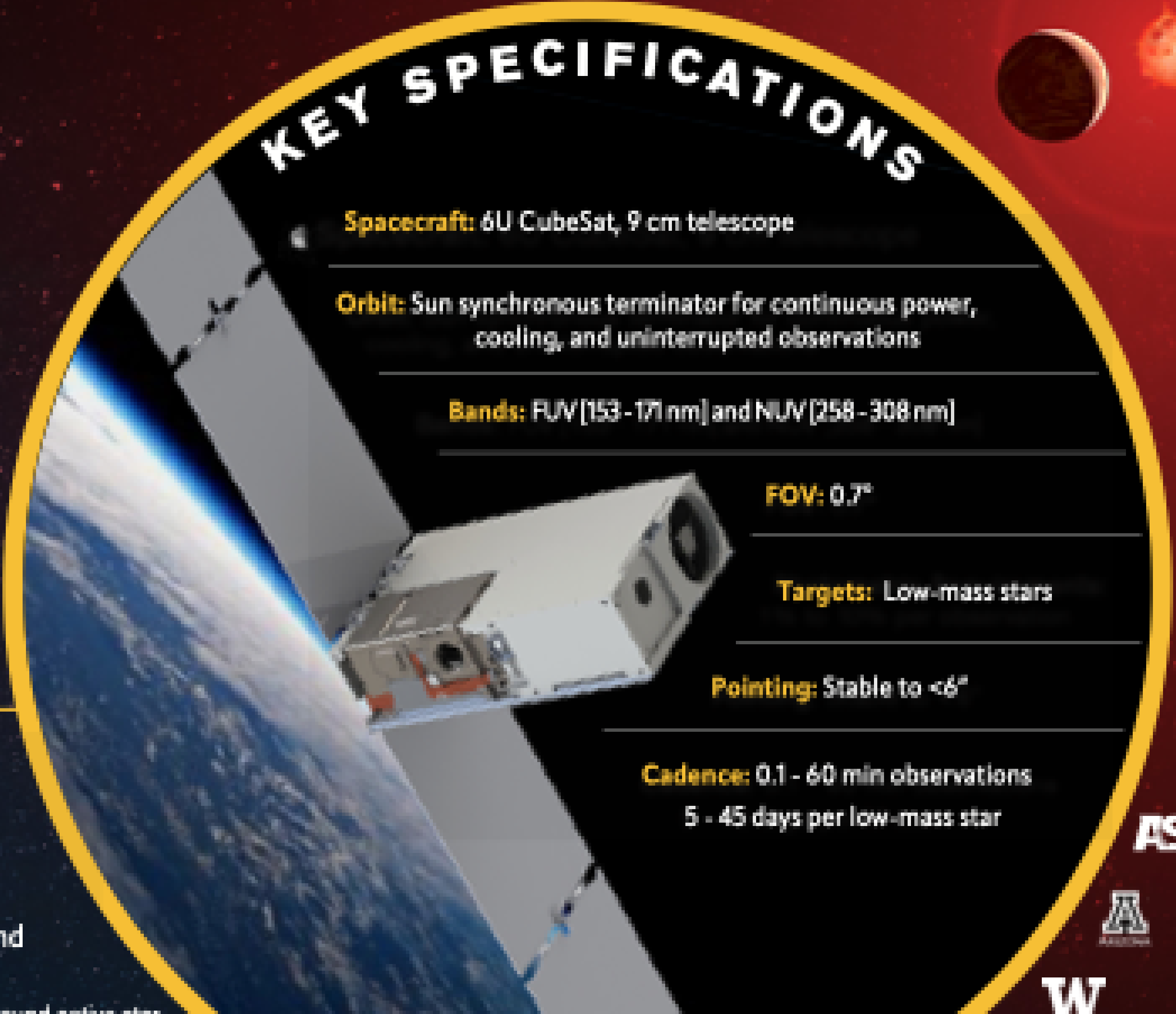

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ASU
W
SwRI
NASA
Goddard
MIT
JPL

Announcing Upcoming UV Science and Spectroscopy Workshop

When: Late Spring
Where: JPL, Pasadena
Who: You

More information Coming soon!

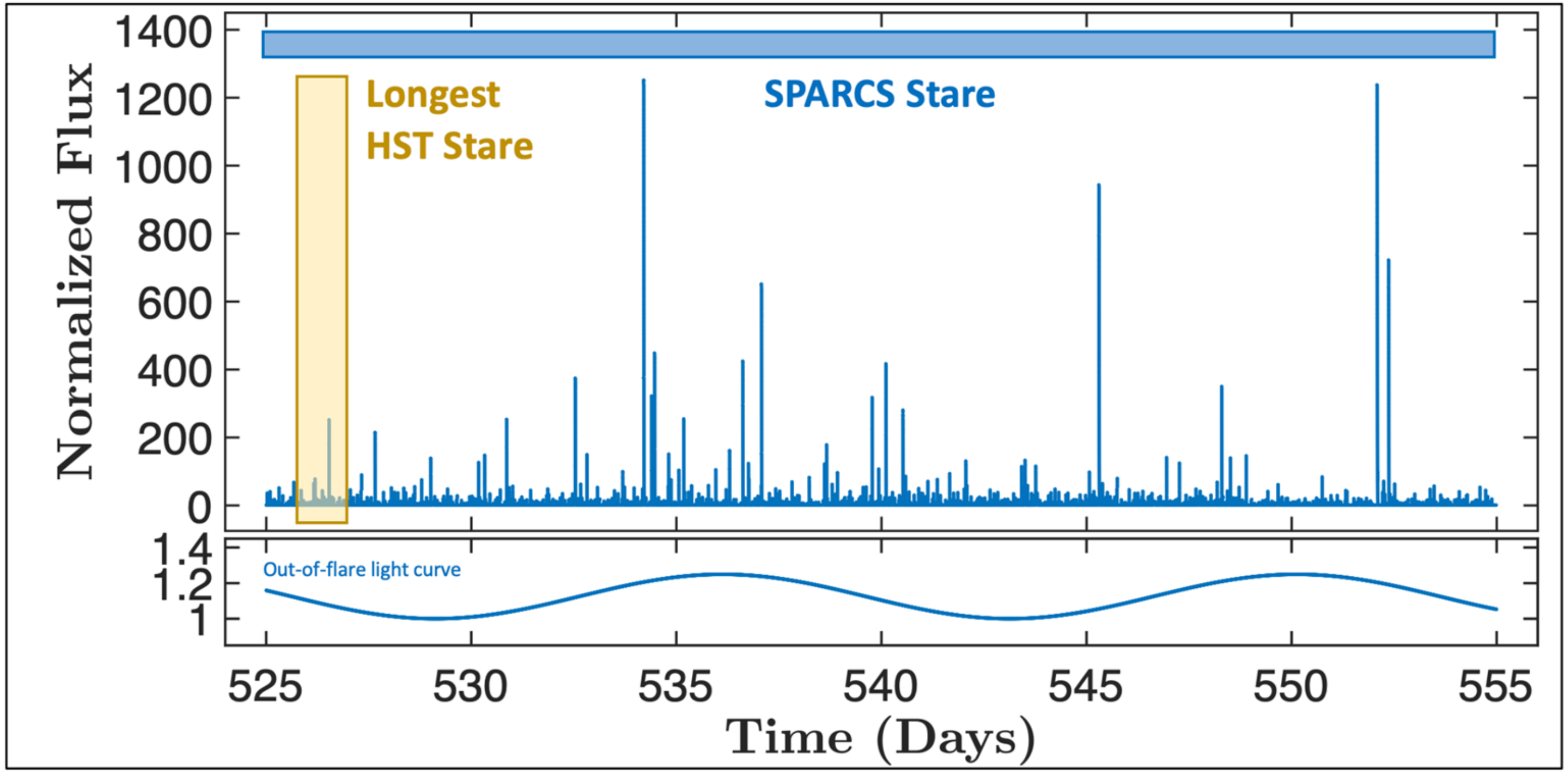
Shouleh.Nikzad@jpl.nasa.gov

Backup Slildes

SPARCS Continuous and Simultaneous NUV+FUV Monitoring

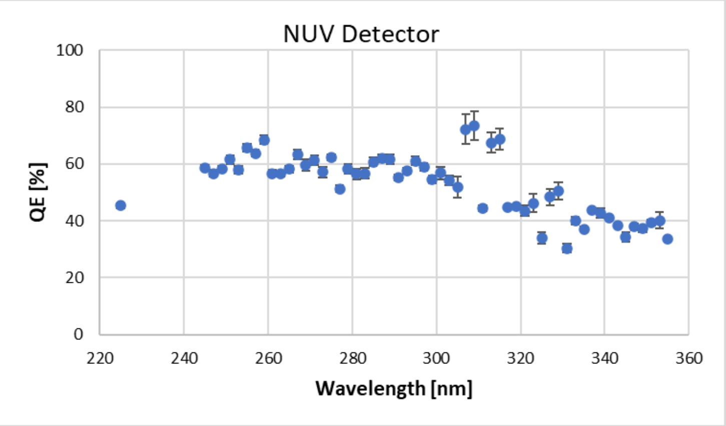
Simulated stellar flares

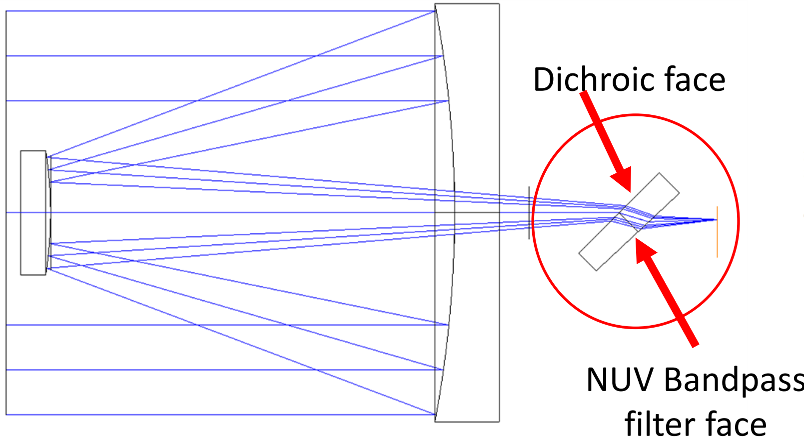
Simulated stellar rotation



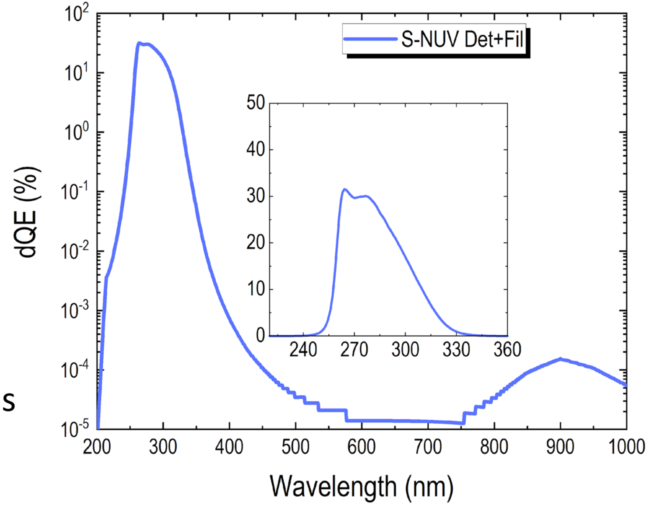
NUV Bandpass Filter

- SPARCS NUV Detector has high QE throughout the UV and visible wavelength range
- Out-of-band rejection achieved with stand-alone NUV Bandpass filter

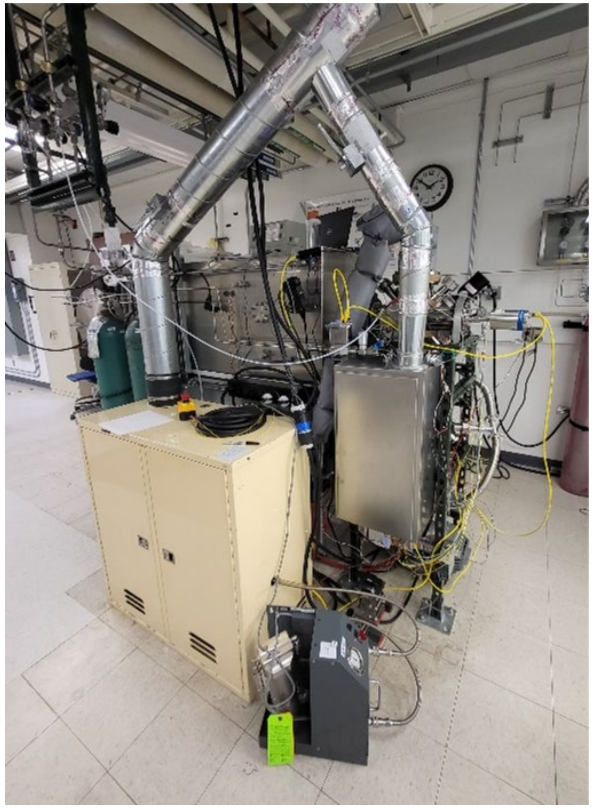



Dichroic face

NUV Bandpass filter face



ALD/PVD System for UV Bandpass Filters



- In the first FUV detector production run, electron-beam evaporation of Al in the detector-integrated UV bandpass filter caused damage to the detector leading to high dark current (2-3 orders of magnitude higher than expected)
- Standard thermal evaporation lacked good base vacuum & deposition rate causing oxide formation and low quantum efficiency (QE)
- New custom reactor designed and built at JPL combines ALD w/ thermally-evaporated Al *in vacuo*
- Critical for implementing multilayer UV bandpass filters with high solar-rejection required for SPARCS

JPL's new ALD/PVD system critical to achieving SPARCS mission goals

Contamination Budgets

- Contamination cannot be wholly prevented but it can be mitigated
- Degradation analysis performed by Jim Austin defined budgets for payload contamination during AI&T (90% End-of-life budget)
- IEST STD-1246D defines settled particle levels

Maximum allowable contaminant quantities any time prior to launch

Surfaces	Particles	Molecular Contaminates
Telescope, dichroic & detectors	Level 350	175 ng/cm^2 ~ 1.75 nm avg thickness
Spacecraft structure , electronics, batteries, solar panels, star tracker	Level 450	320 ng/cm^2 ~ 3.2 nm avg thickness