TELEDYNE IMAGING
Everywhereyoulook™

High TRL Space Imaging
Detectors Catalogue

The Space Imaging Group

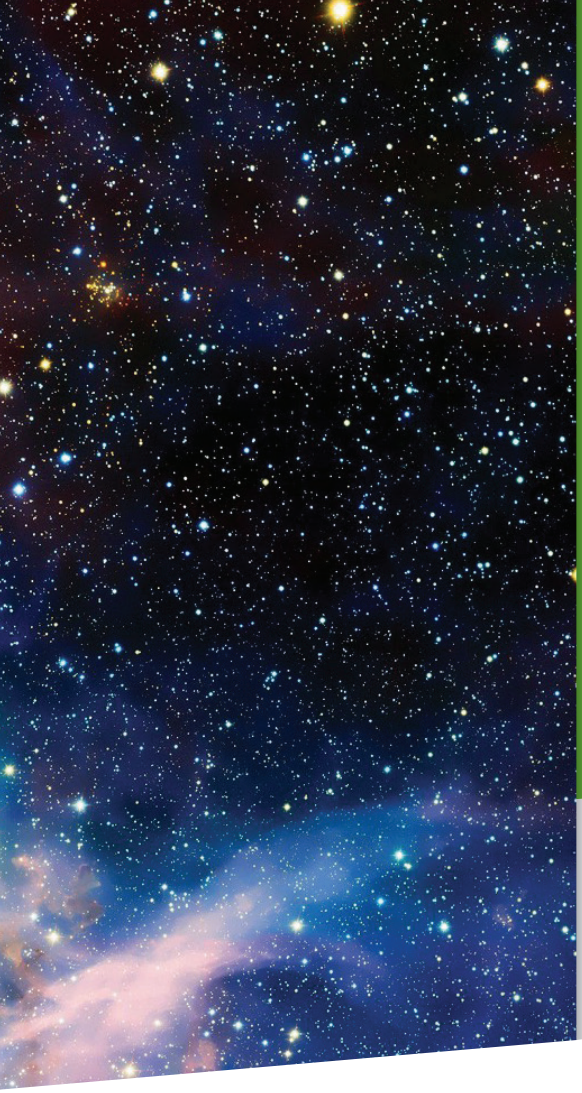
Teledyne Imaging has a long and enviable history of technical and scientific innovation and one of the most impressive space imaging heritage lists in the industry.

Our products observe the Earth from space, enable the discovery of distant worlds, provide the improved understanding of life sciences that we enjoy today, and make measurements at the quantum level.

The Space Imaging group is a global leader in specialised imaging devices, components, subsystems, manufacturing and engineering services, and an engineering consultancy for innovative solutions in space, defence, scientific and industrial applications.

Our capabilities and heritage span custom and standard CMOS, infrared, COTS+ and CCD imaging sensors and sub-systems used for Earth observation and the largest space telescopes, through to ground and space based communications systems.

With an eye always to the future, we are leading in the commercialisation of quantum timing and sensing technologies for space, defence and industrial applications.



Contents

High TRL Space Imaging

This catalogue presents Teledyne Imaging's detectors with a high space technology readiness level (TRL) that are available for consideration in instrument designs for future space missions. An overview of each detector is given, along with key parameters and a description of the relevant space heritage.

Space Heritage

Teledyne Imaging has been at the forefront of image sensor and detector manufacture for space for over 25 years. Having been involved in the charge coupled device (CCD) space industry from the onset in the late 80's and early 90's, major missions such as XMM-Newton and Envisat established the excellence in performance and reliability of Teledyne produced CCDs.

Specifically Teledyne e2v, Teledyne Imaging Sensors and Teledyne DALSA (collectively known as Teledyne Imaging and are part of the Teledyne Imaging Group) work with all of the major space agencies and space contractors across the globe. This has resulted in many CCD designs for flagship missions such as the Hubble Space Telescope WFC3 camera (CCD43), Kepler planet finder (CCD90), GAIA Milky Way mapper (CCD91) and many others.

The CCDs for these and other missions were designed for the specific custom configuration of the relevant instrument and whilst they qualify as high TRL detectors, they are not likely to be relevant for future missions. The detectors outlined in this document result from multipurpose designs that continue to be manufactured and are easily foreseen to be useful for a variety of future applications without modifications. Customers enquiring about reuse of any other mission specific CCD detectors not listed here are advised to contact Teledyne Imaging who will consider all proposals for a full assessment of the best solution.

TECHNOLOGY READINESS LEVEL (TRL)

The technical maturity of instruments and spacecraft sub-systems with respect to a specific space application are classified according to a "Technology Readiness Level" (TRL) on a scale of 1 to 9. The European Space Agency (ESA) uses the ISO standard 16290 Space systems – Definition of the Technology Readiness Levels (TRLs) and their criteria assessment. The high TRL levels considered within this document are TRL 8 and 9, defined by the ISO standard as:

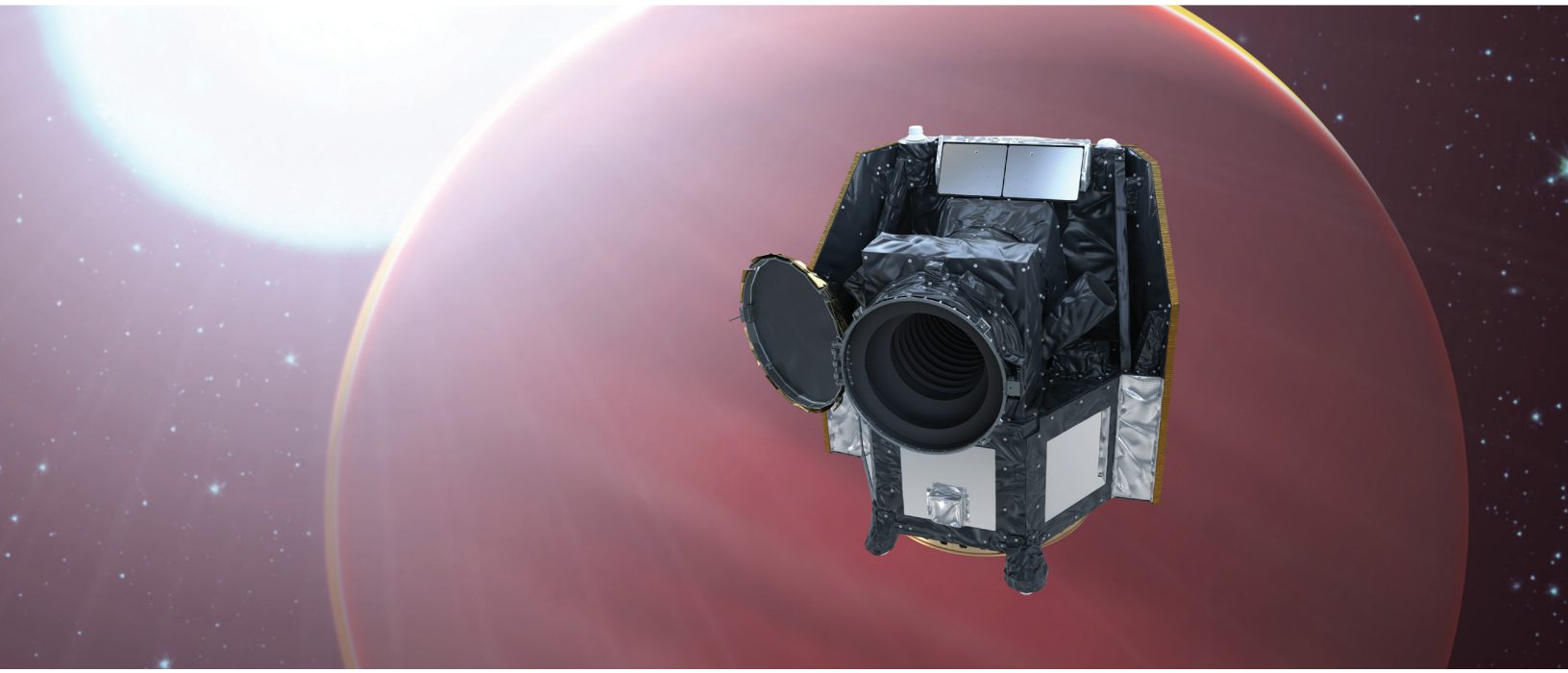
TRL: 9

Actual system "flight proven" through successful mission operations

TRL: 8

Actual system completed and accepted for flight ("flight qualified")

CCD47-20 (TRL9)

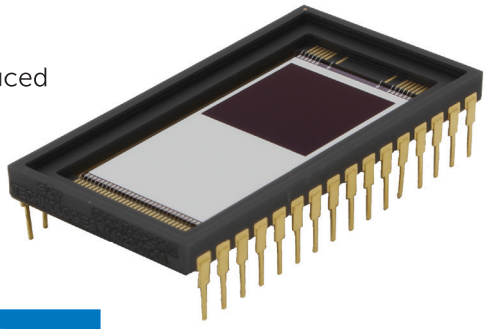


An artist's impression of ESA's CHaracterising ExOPlanet Satellite (CHEOPS 16) space observatory. Credit: © ESA / ATG medialab and NASA/Goddard Space Flight Center Scientific Visualization Studio

DETECTOR OVERVIEW

The CCD47-20 is a mid-sized, frame-transfer, area array, low noise CCD with a compact package footprint. Its format is suited to a host of different applications, from star trackers to imaging systems and scientific instruments.

The CCD47-20 has been produced for space applications for over 20-years and is one of the most numerous CCDs in space today.



CCD47-20 KEY FEATURES	PERFORMANCE PARAMETER	TYPICAL VALUE
• 1024 (H) x 1024 (V) nominal image pixels • 13.3 (H) x 13.3 (V) mm image area • 1056 (H) x 2060 (V) total pixels • Dark reference columns/rows • Bi-directional readout register with 2 outputs • NIMO or AIMO operation • Optional anti-blooming capability • Open ceramic package or with window option	Pixel size	13 µm
	Output Amplifier Responsivity	4.5 µV/e-
	Read Noise (at 20 kHz)	2 rms e-
	Peak Charge Storage (without binning)	120 ke- (NIMO) 100 ke- (AIMO)
	Pixel Readout Frequency	1 MHz Typical, 5 MHz maximum

Space Heritage

The use of CCD47-20 detectors on satellites and spacecraft is far too numerous for an exhaustive list. Some of the major missions are listed below and a full list can be found at https://www.teledyneimaging.com/en/aerospace-and-defense/products/sensors-overview/ccd/ccd47-20/

INTEGRAL

The CCD47-20 was supplied for the OMC (Optical Monitoring Camera) on board ESA's INTErnational Gamma-Ray Astrophysics Laboratory (INTEGRAL). The spacecraft, launched in 2002, is dedicated to spectroscopy and imaging of gamma-ray sources. INTEGRAL is still in operation and orbits the Earth every 3 days with an orbit whereby the spacecraft spends most of its time well outside the Earth's radiation belts.

ROSETTA

The ESA Rosetta mission launched on 2 March 2004 on a 10-year journey towards comet 67P/Churyumov-Gerasimenko, which it then studied for more than two years before a controlled impact onto the comet in 2016. The CCD47-20 was the detector for the NavCam instrument that provided stunning images of the comet throughout the approach, study and decent phases.

NEW HORIZONS

The Long Range Reconnaissance Imager (LORRI) is a telescopic panchromatic imager on board the NASA New Horizons spacecraft. Launched in 2006, the CCD47-20 detector of LORRI was used to image Jupiter and its moons on the way to the rendezvous with Pluto and its system of moons in 2015. Having completed its flyby of Pluto, New Horizons then maneuvered for a flyby of the Kuiper belt object known as "Arrokoth" in January 2019 when it was 43.4 AU from the Sun.

SELENE

SELENE, better known in Japan by its nickname Kaguya, was a lunar orbiter spacecraft. Produced by the Institute of Space and Astronautical Science and the National Space Development Agency, the spacecraft was launched on September 14, 2007 and was deliberately impacted on the south-east of near side of the Moon on June 10, 2009.

ATV

The ATV (Automated Transfer Vehicle) was an expendable cargo spacecraft developed by ESA and used for space cargo transport to the International Space Station (ISS) from 2008 to 2014. There were 5 ATVs each of which had CCD47-20 detectors supplied for the docking system videometers.

CHEOPS

CHEOPS is an ESA Small-class mission launched on 18 December 2019. The telescope is dedicated to searching for exoplanet transits using a CCD47-20 for performing ultra-high precision photometry on bright stars known to host planets.

STAR TRACKERS

Start trackers measure the positions of the stars for space craft attitude control. For over 20 years multiple manufacturers have supplied the CCD47-20 for use in hundreds of star trackers.

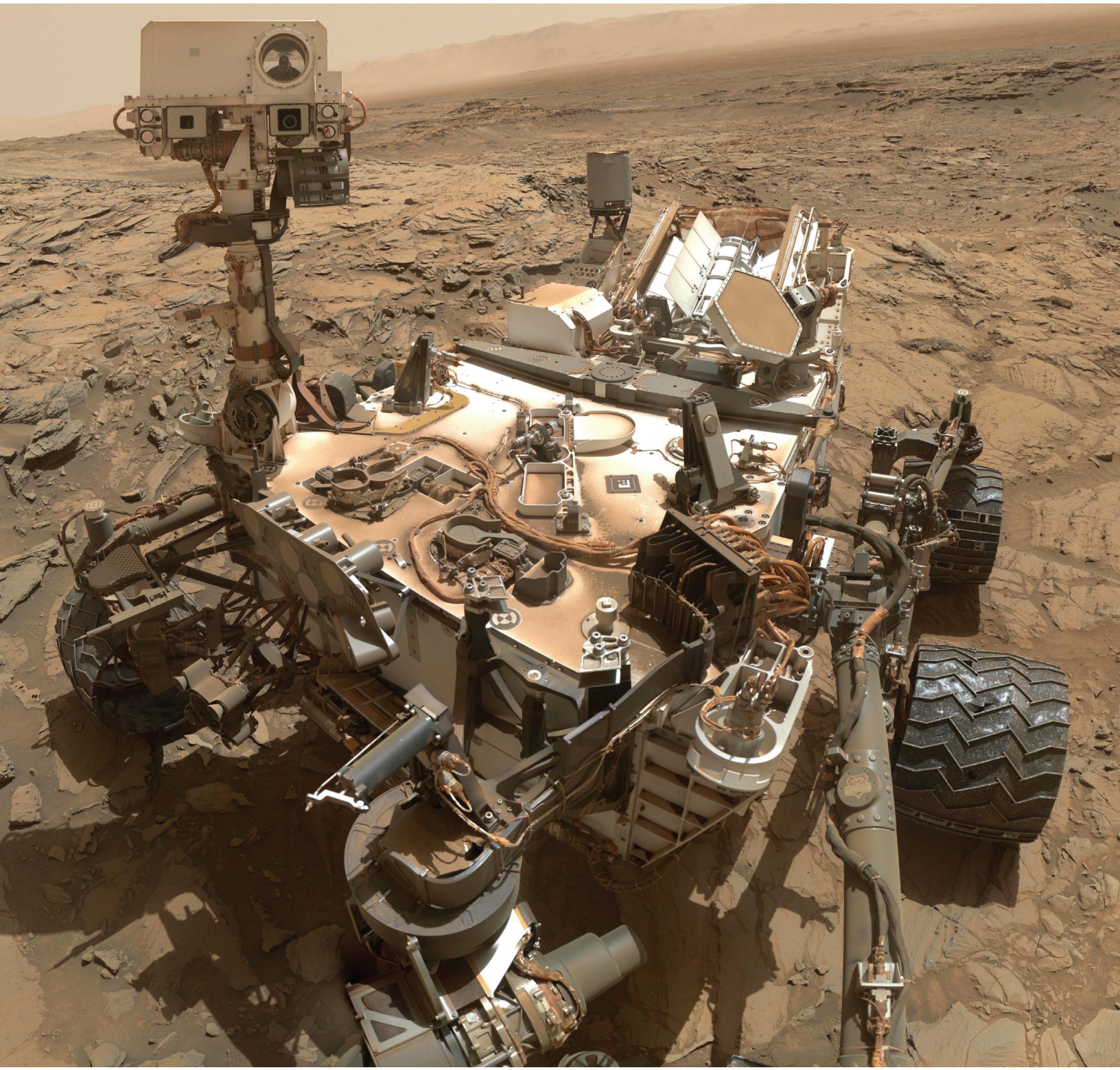
Future Use

The CCD47-20 is in continuous production and is the planned detector in a number of upcoming space agency and scientific/commercial space missions. Some of the main ones are listed below.

LUCY

Lucy is a planned NASA spacecraft that will visit five Jupiter trojans asteroids. A CCD47-20 will be used on the high-resolution visible imager L'LORRI (derived from the LORRI instrument on New Horizons). Launch is expected in late 2021.

CCD42-10 (TRL9)

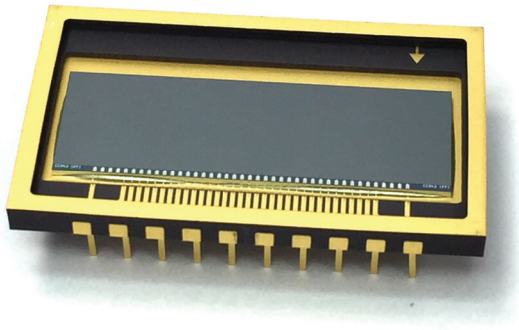


This self-portrait of NASA's Curiosity Mars rover shows the vehicle located at the foothill of Mount Sharp (October 6, 2015). Credit: NASA

DETECTOR OVERVIEW

The CCD42-10 is a small format, full frame, area array, low noise CCD with a simple ceramic package. Its format is suited to spectroscopy applications and small format scientific instruments.

The CCD42-10 is part of the CCD42 family of detectors that are sold in large numbers for commercial applications, as well as also being up-screened or customised for space missions for over 15-years.



CCD42-10 KEY FEATURES	PERFORMANCE PARAMETER	TYPICAL VALUE
• 2048 (H) x 512 (V) image pixels • 27.6 (H) x 6.9 (V) mm image area • Single register with one low noise output • Large register capacity for pixel binning with gated dump drain • Operates in advanced inverted mode (AIMO) for use at Peltier temperatures (-30°C or higher) • Open ceramic package format	Pixel size	13.5 µm
	Output Amplifier Responsivity	4.5 µV/e-
	Read Noise (at 50 kHz)	3 rms e-
	Peak Charge Storage	100 ke- image pixels 400 ke- register
	Pixel Readout Frequency	0.5 MHz Typical, 3 MHz maximum

Space Heritage

CURIOSITY

CCD42-10 detectors are used in the three spectrographs of the NASA Mars Curiosity Rover Chemistry and Camera tool (known as ChemCam) that is used to identify chemical and mineral composition of Martin rocks and soils. Curiosity was launched in 2011 and landed on Mars in 2012 where it continues to explore the Martian surface.

Future Use

The CCD42-10 can be baselined for future missions with spectroscopy instruments or small area imaging needs. Recent examples of this are listed below.

MARS 2020

The same types of CCD42-10 detectors used for Curiosity, supplied to JPL/NASA for the SuperCam and Sherloc instruments on-board the Perseverance Rover launched in August 2020 to Mars along with other imaging and optical components from the Teledyne Imaging group.

CCD42-40/20 (TRL9)

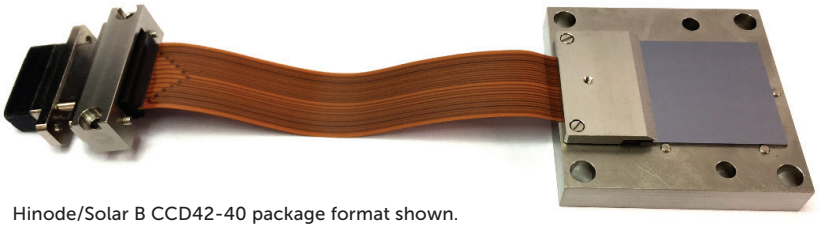
Artist's rendition of a STEREO spacecraft during solar array deployment.

Credit: NASA

DETECTOR OVERVIEW

The CCD42-40 is a large area, full frame array, low noise CCD ideally suited for imaging systems or scientific instruments. The CCD42-20 is a variant with half the number of image pixels.

The CCD42-40/20 is part of the CCD42 family of detectors that are sold in large numbers for commercial applications, as well as also being up-screened or custom-ised for space missions for over 15-years.



Hinode/Solar B CCD42-40 package format shown.

CCD42-40/20 KEY FEATURES	PERFORMANCE PARAMETER	TYPICAL VALUE
• 2048 (H) x 512 (V) image pixels • 27.6 (H) x 6.9 (V) mm image area • Single register with one low noise output • Large register capacity for pixel binning with gated dump drain • Operates in advanced inverted mode (AIMO) for use at Peltier temperatures (-30°C or higher) • Open ceramic package format	Pixel size	13.5 µm
	Output Amplifier Responsivity	4.5 µV/e-
	Read Noise (at 50 kHz)	3 rms e-
	Peak Charge Storage	100 ke- image pixels 400 ke- register
	Pixel Readout Frequency	0.5 MHz Typical, 3 MHz maximum

Space Heritage

ROSETTA

The ESA Rosetta mission launched on 2 March 2004 on a 10-year journey towards comet 67P/Churyumov-Gerasimenko, which it then studied for more than two years before a controlled impact onto the comet in 2016. The OSIRIS (Optical, Spectroscopic, and Infrared Remote Imaging System) was a dual camera that had CCD42-40 detectors in both the narrow angle camera and the wide angle camera imaging systems. The OSIRIS detector had a Rosetta specific package format.

HINODE (SOLAR-B)

Hinode (formerly Solar-B) is a Japanese, US and UK joint solar mission launched in September 2006 to study the magnetic fields of the sun through optical, ultraviolet and x-ray imaging. The CCD42-40 detector is used in the X-ray Telescope (XRT) grazing incidence X-ray imager instrument and the CCD42-20 is used in the Extreme Ultraviolet Imaging Spectrometer (EIS). The CCD42-40 XRT package format for Hinode is shown above. The CCD42-20 EIS package was of similar design. The spacecraft is still operational after more than 12-years of service.

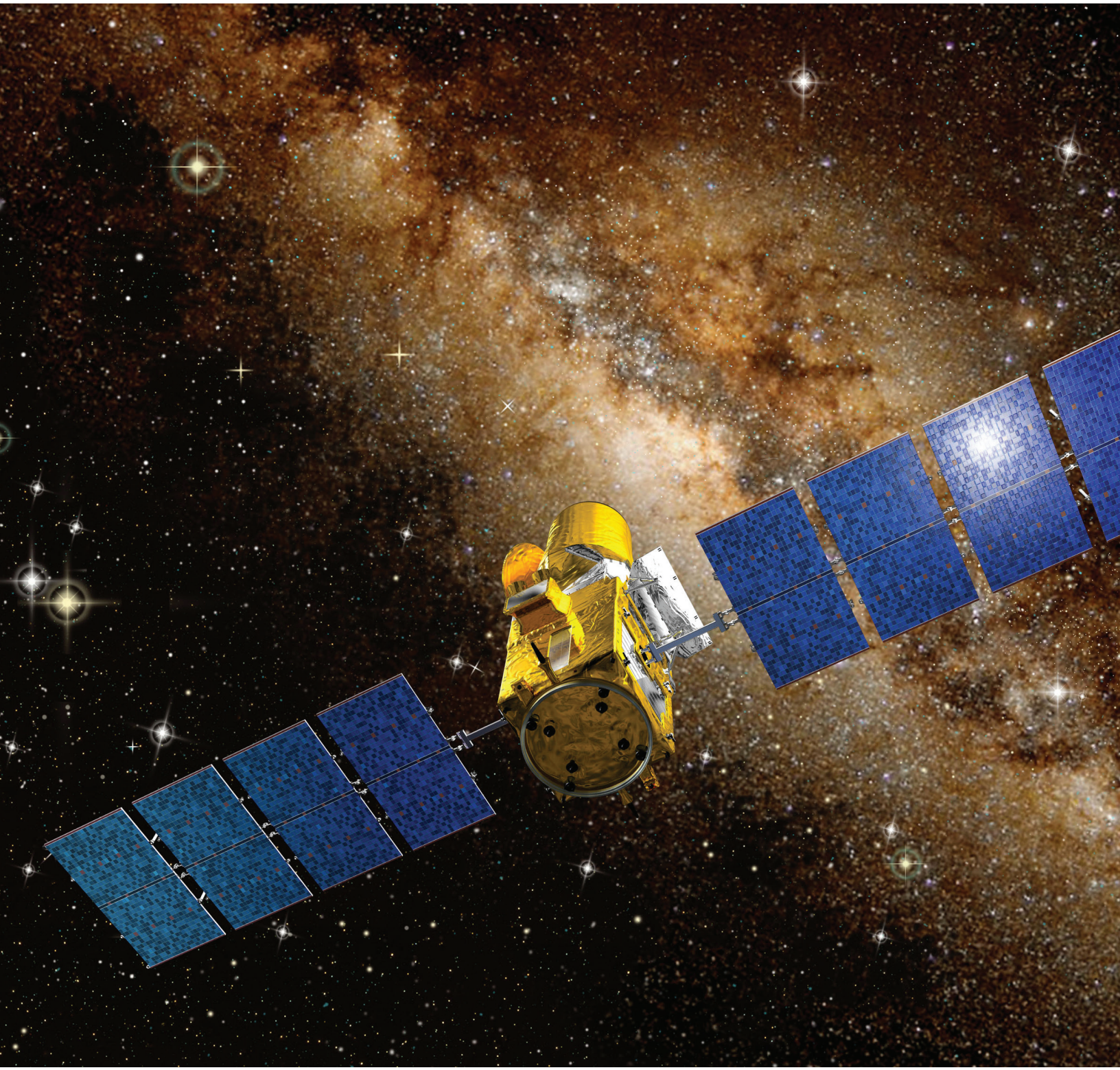
STEREO

NASA's STEREO (Solar TErrestrial RElations Observatory) mission launched in October 2006, with two nearly identical observatories—one ahead of Earth in its orbit, the other trailing behind. They have traced the flow of energy and matter from the Sun to Earth and revealed the 3D structure of coronal mass ejections. The CCD42-40 for STEREO have a similar package format to the Hinode/Solar-B package shown above.

Future Use

The CCD42-40 can be baselined for future imaging or scientific space missions requiring large area full frame detectors. Custom packages can be developed or packages similar to the Hinode or STEREO missions can be re-established for reuse if suitable.

CCD42-80 (TRL9)

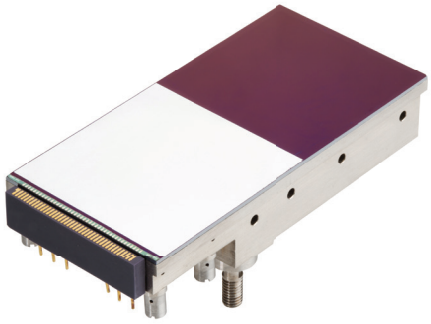


CoRoT will use its telescope to monitor closely the changes in a star's brightness that comes from a planet crossing in front of it. Credit: ESA, CNES/D. Ducros

DETECTOR OVERVIEW

The CCD42-80 is a large area, frame transfer, low noise CCD with close butting package format. Suitable for many applications from large area imaging systems to scientific instruments.

The CCD42-80 is part of the CCD42 family of detectors that are sold in large numbers for commercial applications, as well as also being up-screened or customised for space missions for over 15-years.



CCD42-80 KEY FEATURES	PERFORMANCE PARAMETER	TYPICAL VALUE
• 2048 (H) x 2048 (V) image pixels • 27.6 (H) x 27.6 (V) mm image area • 2048 (H) x 4100 (V) total pixels • Bi-directional register with two low noise outputs • Large register capacity for pixel binning with gated dump drain • Operates in advanced inverted mode (AIMO) for use at Peltier temperatures (-30°C or higher) • Frame transfer operation, full frame option available • Compact metal package with PGA connector, designed for focal plane for close butting	Pixel size	13.5 µm
	Output Amplifier Responsivity	4.5 µV/e-
	Read Noise (at 50 kHz)	3 rms e-
	Peak Charge Storage (AIMO)	100 ke- image pixels 400 ke- register
	Pixel Readout Frequency	0.5 MHz Typical, 3 MHz maximum

Space Heritage

CoRoT

The CCD42-80 was supplied for the wide-field camera on board the CoRoT (Convection, Rotation and planetary Transits) spacecraft. Operated by CNES/ESA CoRoT launched in 2006 and operated for 6 years in a polar Low Earth Orbit (LEO).

PICARD

The CCD42-80 was supplied for the SODISM (SOlar Diameter Imager and Surface Mapper) instrument on board the PICARD satellite. Operated by CNES, PICARD launched in 2010 and operated for 4-years in LEO.

Future Use

The CCD42-80 can be baselined for future missions which require large area frame transfer detectors. These detectors have been supplied/chosen for the upcoming missions outlined below.

ICON

The CCD42-80 was recently supplied in to the Michelson Interferometer for Global High-resolution Thermospheric Imaging (MIGHTI) instrument for NASA's upcoming ICON mission, which was due for launch in 2018 but has been delayed.

SVOM

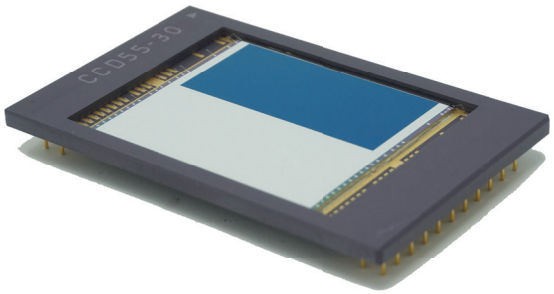
The Space Variable Objects Monitor (SVOM) is a planned small X-ray telescope satellite that will use CCD42-80 detectors. Under development by China National Space Administration (CNSA) and the French Space Agency (CNES) it is due to be launched in 2021.

CCD55-20/30 (TRL9)

SENTINEL-3 is an ocean and land mission composed of three versatile satellites (SENTINEL-3A, SENTINEL-3B and SENTINEL-3C). Credit: ESA

DETECTOR OVERVIEW

The CCD55 comes in two size formats, the CCD55-20 and the larger CCD55-30. It is a large area, large pixel, frame transfer, high speed output CCD. Suitable for many applications it has primarily been used in space based spectrometers and scientific instruments.



CCD42-40/20 KEY FEATURES	PERFORMANCE PARAMETER	TYPICAL VALUE
• CCD55-20: 770 (H) x 576 (V) image pixels 780 (H) x 1152 (V) total pixels • CCD55-30: 1242 (H) x 576 (V) image pixels 1252 (h) x 1152 (V) total pixels • 17.6 / 28.2 (H) x 27.6 (V) mm image area • 576 row store section • Bi-directional register with choice of high-speed output or low noise output • AIMO or NIMO operating mode available • Frame transfer operation • Ceramic PGA type package	Pixel size	2.5 µm
	Output Amplifier Responsivity	1.2 or 3.0 µV/e-
	Read Noise (at 20 kHz)	7 or 4 rms e-
	Peak Charge Storage	450 ke- AIMO 750 ke- NIMO
	Pixel Readout Frequency	0.5 MHz Typical, up to 6 MHz max.

Space Heritage

SENTINEL-3

Sentinel-3 is part of Europe's environmental monitoring Copernicus programme. It consists of a suite of satellites to systematically measure Earth's oceans, land, ice and atmosphere. Sentinel-3A was launched in February 2016 and was joined by Sentinel-3B in April 2018. The Ocean and Land Colour Instrument (OLCI) on Sentinel-3 uses a customised version of the CCD55-20 sensor for hyperspectral imaging.

TANSAT

The Carbon Dioxide Observation Satellite (TanSat) was China's first mini-satellite dedicated to carbon dioxide detection and monitoring. Launched in December 2016, the CCD55-30 was incorporated as part of the CarbonSpec high-resolution spectrometer instrument.

GAOFEN-5

In May 2018, China's first high-resolution satellite for atmospheric observation, Gaofen-5 (GF-5) was launched. Amongst the payloads are the Environment Monitoring Instrument (EMI), a high-resolution imaging spectrometer using the CCD55-20, and the Greenhouse Gases Monitoring Instrument (GMI) hyperspectral instrument using the CCD55-30.

Future Use

The CCD55 can be baselined for future missions which require large pixel, large area frame transfer detectors. These detectors have been supplied/chosen for the upcoming missions outlined below as well as being planned in to other future instruments.

SENTINEL-3

Sentinel-3C and 3D satellites will be copies of the previous satellites with the CCD55-20 on-board. Flight model delivery is ongoing and they are due for launch in the coming few years.

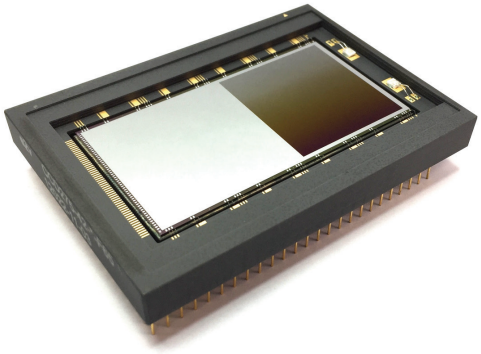
CCD275-42 (TRL9)

Artist's rendition of Sentinel-5 Precursor, the forerunner of Sentinel-5 to provide timely data on a multitude of trace gases and aerosols affecting air quality and climate. Credit: ESA/ATG medialab

DETECTOR OVERVIEW

The CCD275-42 is a large format, large full well capacity CCD designed for fast frame transfer and improved radiation hardness. It is a multi-purpose sensor suitable for space, astronomy or science uses.

The CCD275-42 incorporates many advanced design features to deliver high performance for demanding space and scientific applications.



CCD275-42 KEY FEATURES	PERFORMANCE PARAMETER	TYPICAL VALUE
• 1022 (H) x 954 (V) image pixels • 29.7 (H) x 24.8 (V) mm image area • 1024 (H) x 2050 (V) total pixels • Split register with choice of 2 or 4 outputs • Switchable gain outputs for increased charge handling • 2-phase pixels for fast (1 ms) frame transfer operation • Shielded reference rows/columns • Ceramic PGA open package format	Pixel size	26 µm
	Output Amplifier Responsivity	1.4 µV/e- (low noise amp)
	Read Noise (at 3 kHz)	35 rms e- (low noise amp)
	Peak Charge Storage	700 ke- image pixels 1.4 Me- outputs
	Pixel Readout Frequency	3 MHz Typical, 5 MHz maximum

Space Heritage

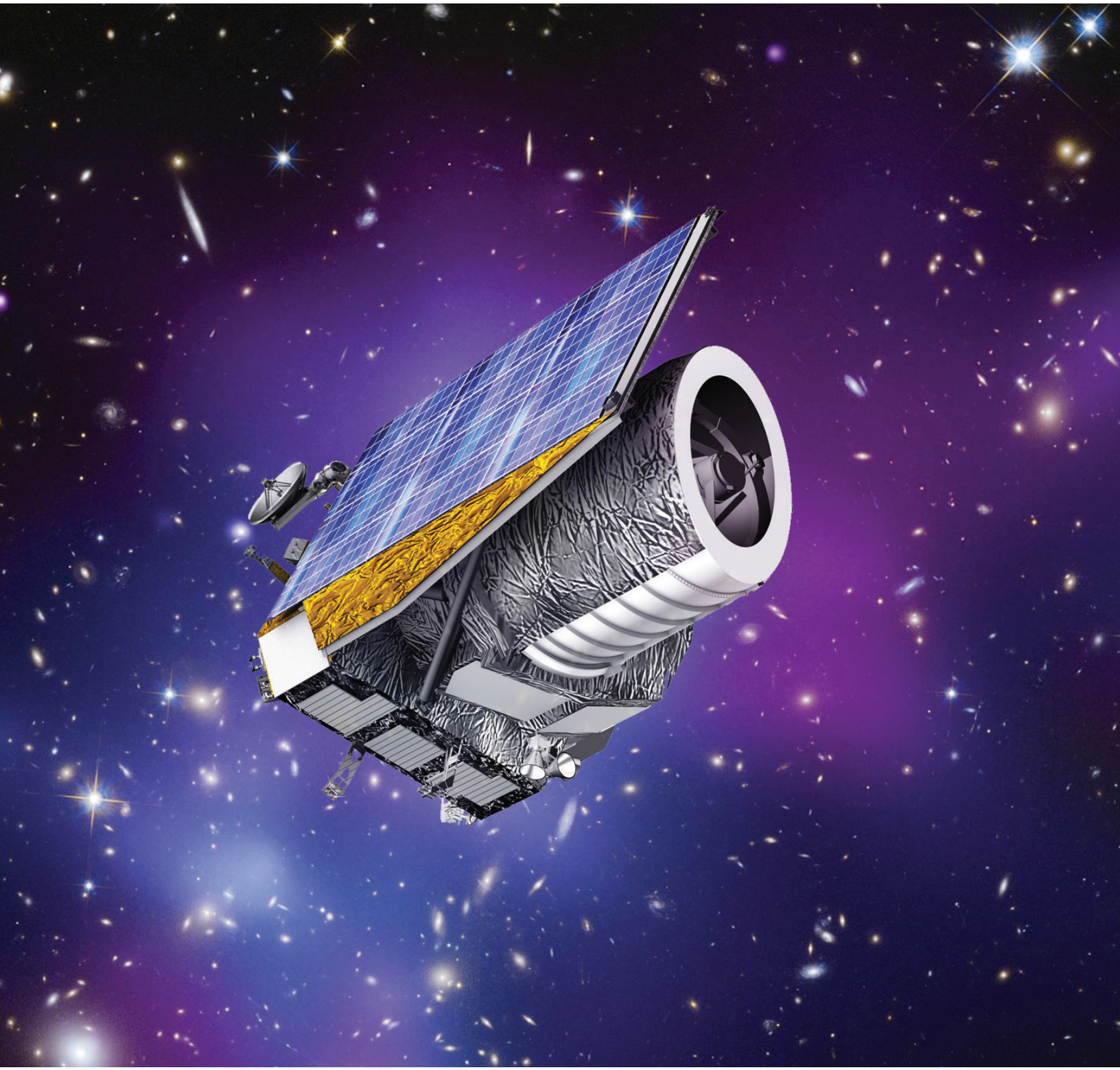
SENTINEL-5P

Launched in to low Earth orbit in October 2017, Sentinel-5P is part of the Copernicus programme, Europe's environmental monitoring programme. Multiple variants of the CCD275-42 optimised for specific wavelength bands were supplied for the Tropomi instrument to perform atmospheric measurements, with high spatial and temporal resolution to monitor air quality, climate forcing, ozone and UV radiation.

Future Use

Teledyne Imaging is in discussions to use the CCD275-42 for a number of upcoming mission proposals.

CCD272-84 (TRL8)

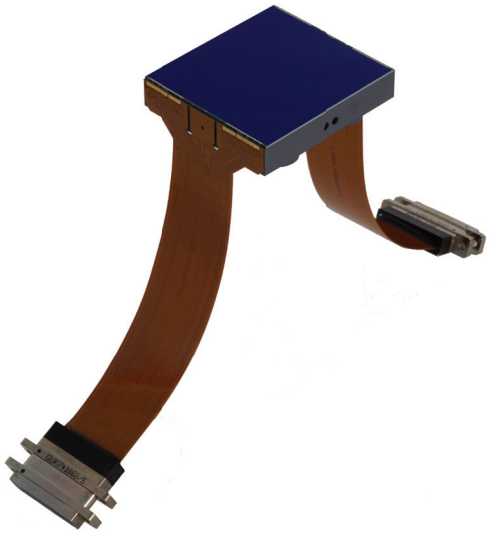


An artist view of the EUCLID Satellite exploring the dark Universe at the L2 Lagrange point. Credit: ESA/C. Carreau

DETECTOR OVERVIEW

The CCD272-84 is a large area, small pixel, and small footprint, low noise CCD ideally suited for science and astronomy application and focal plane mosaics.

The CCD272-84 is designed for low temperature applications, with the flexi PCB connections isolating it from drive electronics. It has a 3-point thermal interface in a silicon carbide precision package with minimised edge space.



CCD272-84 KEY FEATURES	PERFORMANCE PARAMETER	TYPICAL VALUE
• 4096 (H) x 4096 (V) image pixels • 49.15 (H) x 49.15 (V) mm image area • Full frame or split full frame read out • Two registers each with 2 low noise outputs • Operates in NIMO operation for highest signal capacity • Enhanced back-thinning process for high QE • Low voltage design for reduced power consumption and radiation hardness • Silicon carbide package with flexi PCB connector package format	Pixel size	12 µm
	Output Amplifier Responsivity	7.5 µV/e-
	Read Noise (at 70 kHz)	2.5 rms e-
	Peak Charge Storage	220 ke-
	Pixel Readout Frequency	70 MHz Typical, 3 MHz maximum

Space Heritage

The CCD272-84 is a derivative of the CCD273-84 supplied for the ESA Euclid-VIS instrument. The manufacture of the CCD272-84 silicon uses the same lithography masks and processing steps as the CCD273-84 and package components based on the CCD273-84 detector.

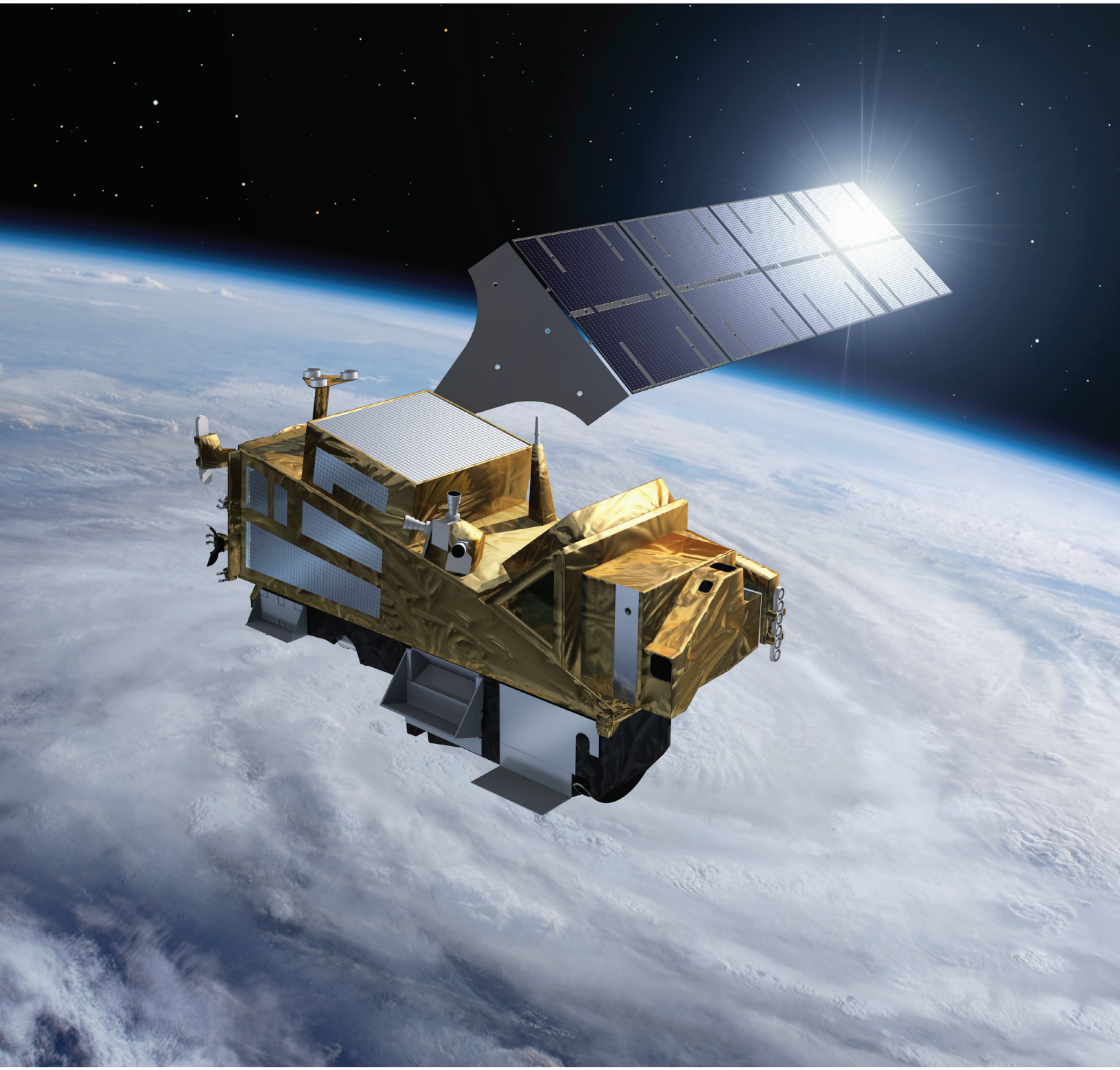
The CCD273-84 is at TRL 8, having successfully completed the qualification, flight build and lot validation phases of the Euclid project. At the Teledyne Imaging detector supply level, the Euclid project has completed with all flight detectors delivered. These detectors are currently being integrated in to the flight instrument for launch in 2020. The TRL level of the CCD273-84 can be read directly across to the CCD272-84 due to the same design blocks used.

Teledyne Imaging has manufactured and tested backthinned CCD272-84 detectors for a space programme, which is expected to complete before 2020. This will then demonstrate the CCD272-84 is at TRL 8 by test as well as similarity to the CCD273-84.

Future Use

The CCD272-84 is being considered for a number of upcoming space missions and is available for consideration for any application requiring a large area precision package CCD.

CCD314-C4 (TRL8)

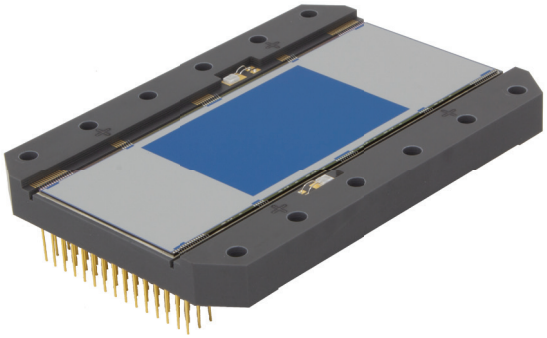


Delivering important data on the composition of the atmosphere, Sentinel-5 is set to make a step change in monitoring and forecasting global air quality. Credit: ESAP. Carril

DETECTOR OVERVIEW

The CCD314-C4 is a large pixel, large format frame transfer CCD primarily designed for Earth observation.

The CCD314-C4 is designed for high full well and employs the low voltage, thin gate process for radiation hardness.



CCD314-C4 KEY FEATURES	PERFORMANCE PARAMETER	TYPICAL VALUE
• 1380 (H) x 1350 (V) image pixels • 27.6 (H) x 40.5 (V) mm image area • 1404 (H) x 2740 (V) image pixels • Two identical image area sections (675 rows) • Two store sections (695 rows) above and below the image region • Split frame transfer or full frame read out • Two registers each with 2 amplifiers which can be clocked independently • Operates in NIMO for highest full well • Low voltage design for reduced power consumption and radiation hardness	Pixel size	20 µm (H) x 30 µm (V)
	Output Amplifier Responsivity	0.85 µV/e-
	Read Noise (at 50 kHz)	40 rms e-
	Peak Charge Storage (image)	2.8 ke-
	Pixel Readout Frequency	3 MHz Typical

Space Heritage

The CCD314-C4 was designed for the Ultra-Violet Near Infra-red Shortwave (UVNS) instrument for the Sentinel-5 programme. Teledyne e2v has manufactured, tested and delivered the CCD314-C4 for Sentinel-5, including a space qualification LAT programme. This demonstrates the CCD314-C4 is at TRL 8.

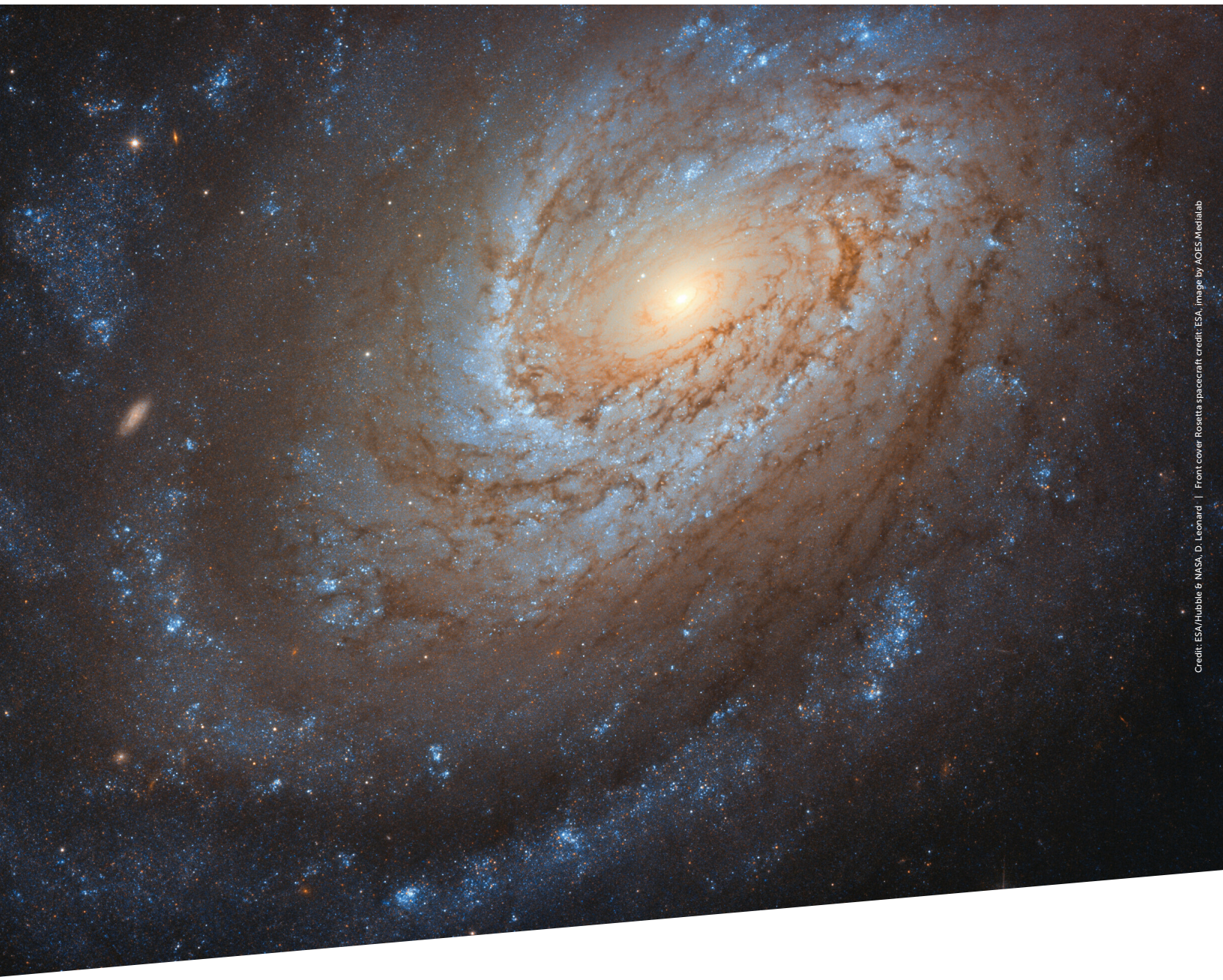
Future Use

SENTINEL-5

The sentinel 5 mission is due to launch in 2020. The prime objective is to monitor air pollution levels in the atmosphere. CCD314-C6 detectors with different back-thinning processing were supplied to detect wavelength ranges from the UV to the NIR in the UVNS instrument.

The detector can be considered for future missions needing large area high pixel capacity area detectors. It could also be well suited to other science or astronomy applications.

Everywhere You Look



Credit: ESA/Hubble & NASA, D. Leonard | Front cover Rosetta spacecraft credit: ESA, image by AOES Medialab

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