# *Self-powered analog sun sensor*

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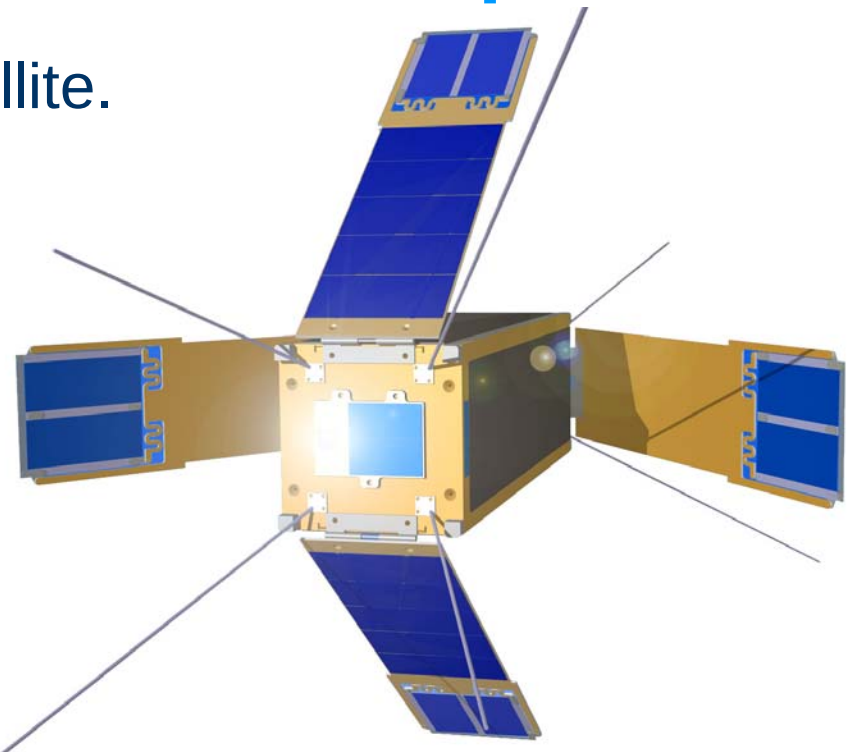
# Sun sensor as an optical sensor system used in space

Sun sensor in a microsatellite.



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MicroNED/MISAT

Function of the sun sensor:
Measuring satellite orientation
with respect to the sun

Purpose:
- Solar panel position control
- Antenna directional control
- Satellite attitude control

# Trend towards: Autonomous Sensor System

An autonomous sensor system is a flexible and fully self-supporting system, which includes:

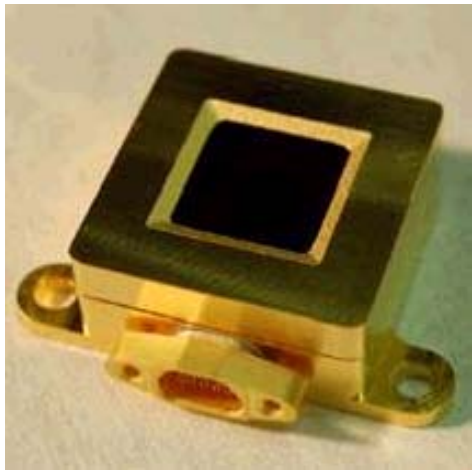
- In system sensing, signal conditioning, data pre-processing and system control
- No el. wiring: o Wireless data communication
  o Local power source – battery
  + self powering

Self-powering = energy scavenging

- Mechanical/vibration: attach a generator
- Thermally: put thermopile between a temperature difference (e.g. human skin and ambient)
- Optical: solar cells on top of a system.

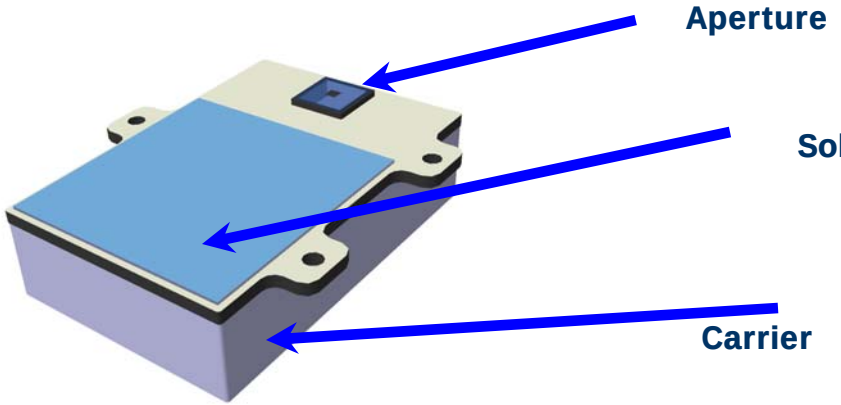
# Autonomous Wireless Sun Sensor (AWSS) developed at TNO

From: Miniaturized conventional sun sensor



includes connector

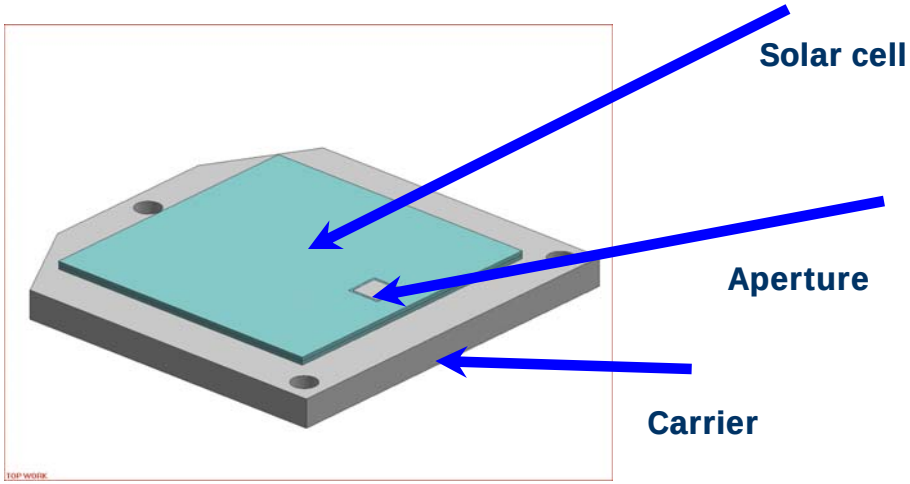
Via: Analog AWSS with RF link and solar cell on top




- Wireless RF-Interface
- Integrated power source
- Dimensions ~ 60x40x20mm
- Mass ~ 150 g

# Future AWSS developments at TNO

To: Immersed AWSS with solar cells on top



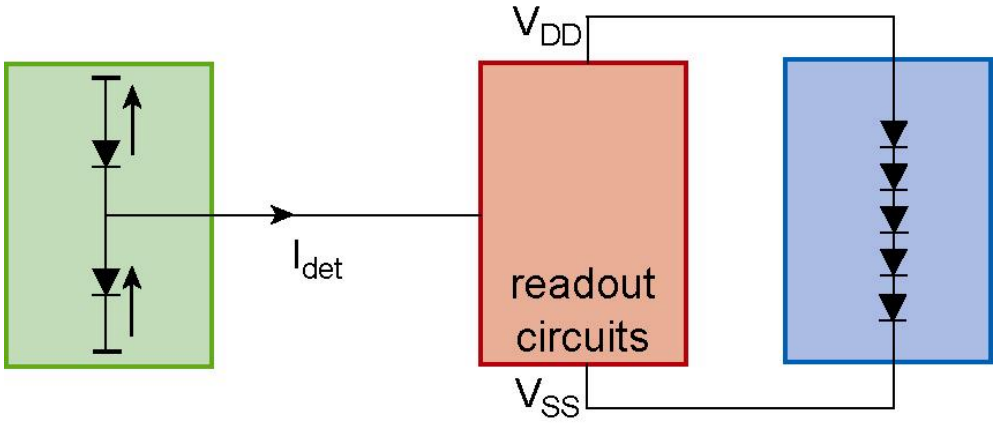

- Digital output
- Wireless RF-Interface
- Thin-film solar cell
- Dimensions ~ 20x20x5mm

The solar cell and the optical detector are separate components

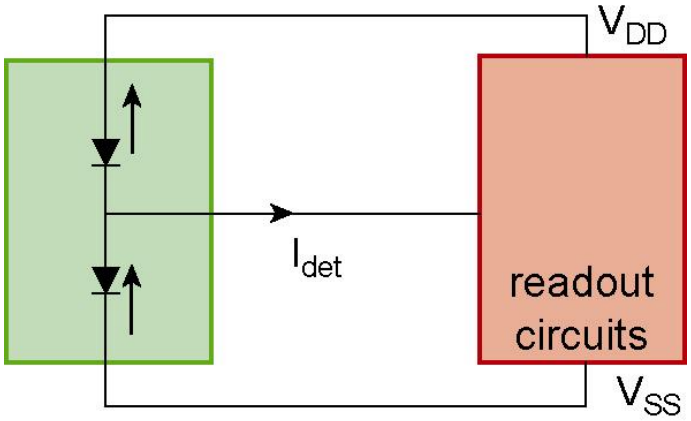
This work is about a self-powered AWSS with one single combined solar cell and sensor component, which is a new concept within an existing product

# Operation of Self-Powered AWSS

From: The conventional system:



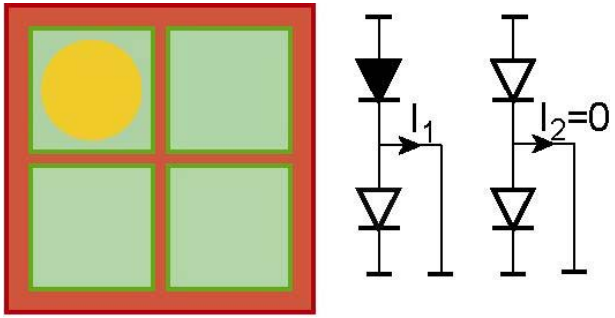

To: The self-powered system:



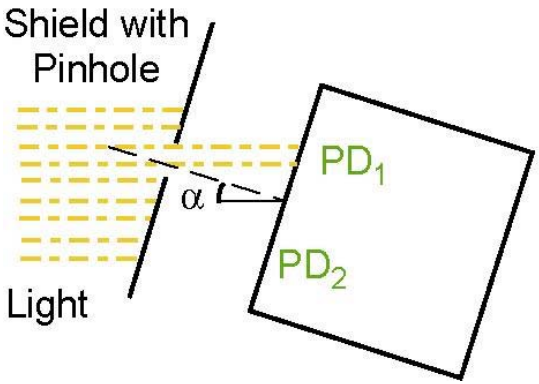

+ Fewer components
+ Reduced dimensions
+ Reduced mass
o Low-voltage operation
o Low-power operation

# Operating principle of the conventional sun sensor

Four photodiodes with readout per pair.
(shown for vertical position)




- Pinhole defines light spot
- Photocurrent generated at illuminated areas only
- Usually, three-out-of four diodes remain idle



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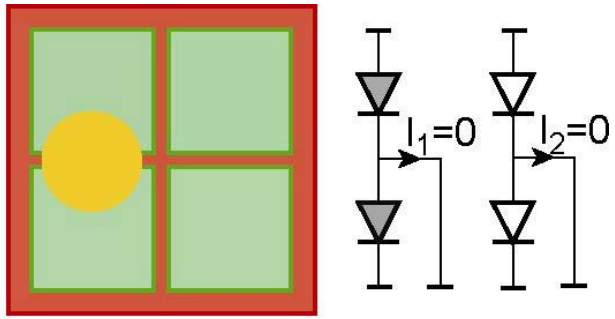


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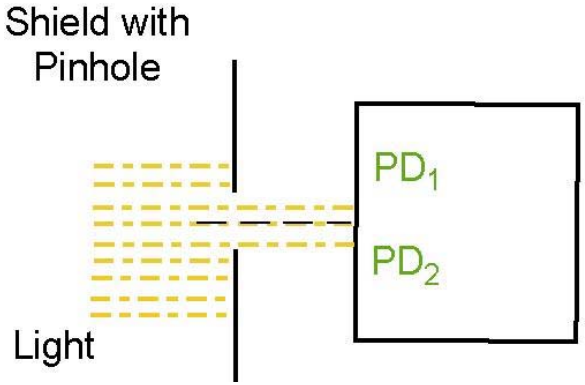

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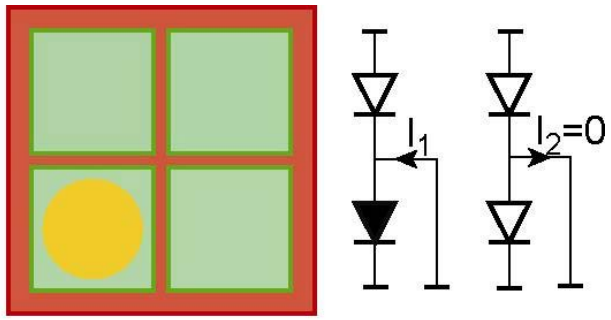


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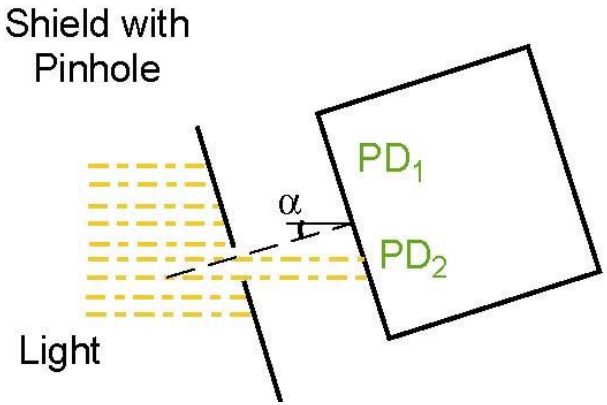

# New concept for sun sensor: The sundail principle

Four photodiodes with readout per pair.
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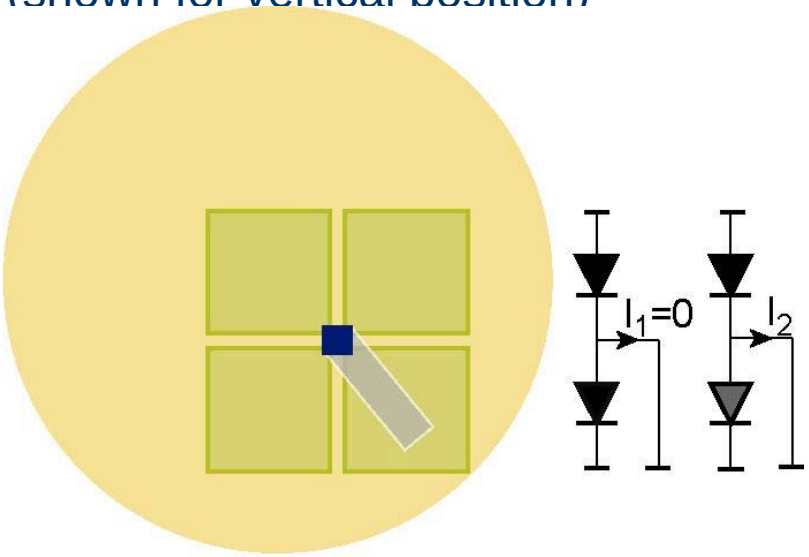
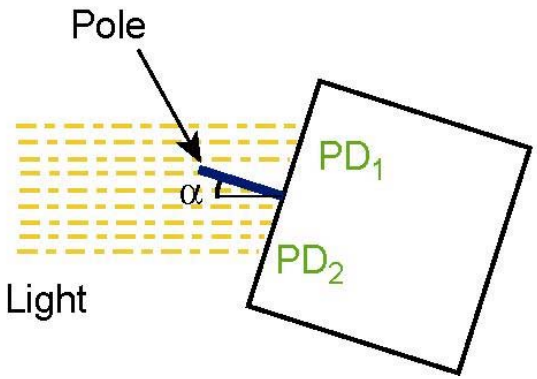



- All diodes illuminated
- Center pole casts a shadow depending position relative to sun



# New concept for sun sensor: The sundial principle

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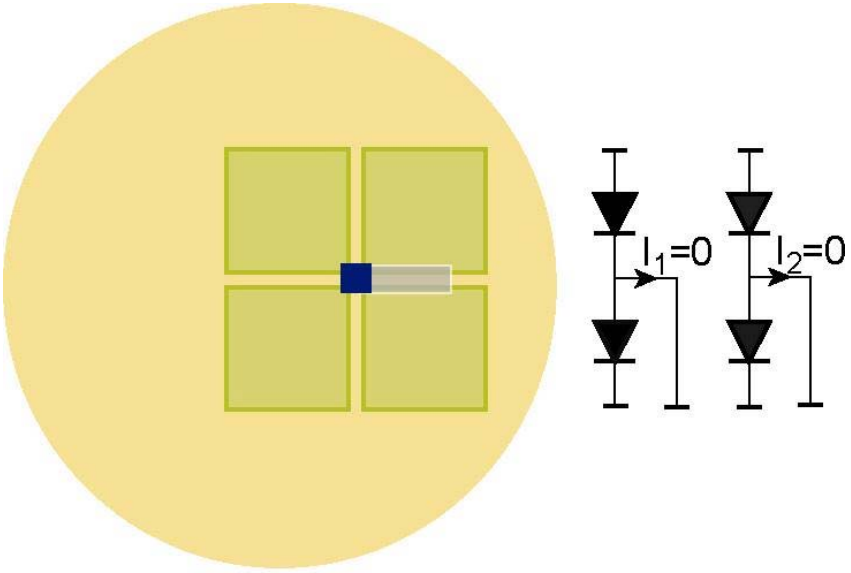


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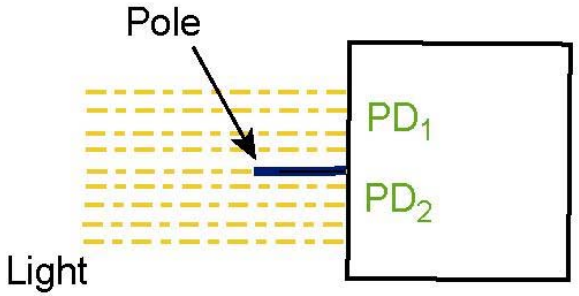

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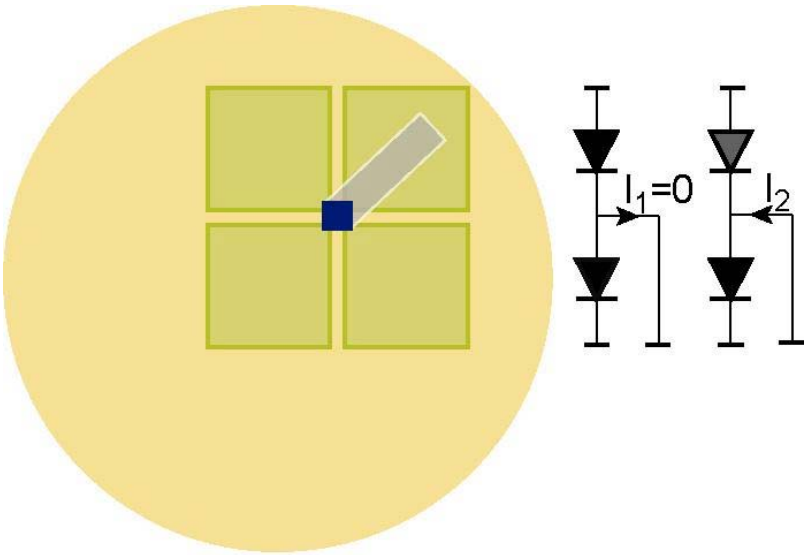


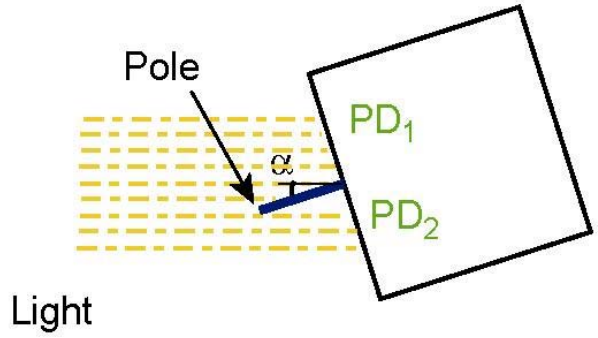


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- Center pole casts a shadow depending position relative to sun

Benefits:
- All diodes available for power generation
- Simplified structure (no aligned pin hole)

Challenge:
- Subtraction of large photocurrents

# Technical Viability

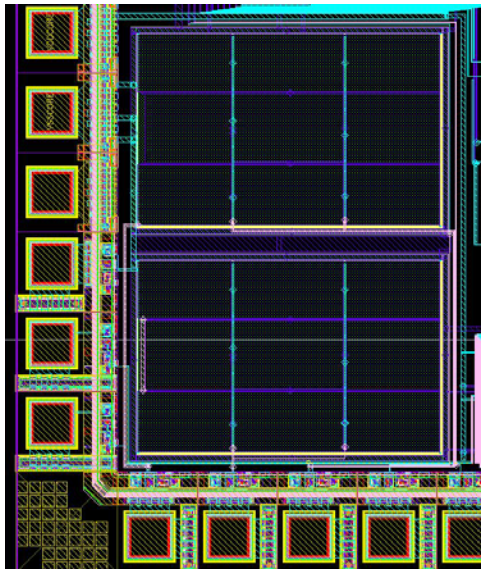
## Low-voltage/low-power circuits required

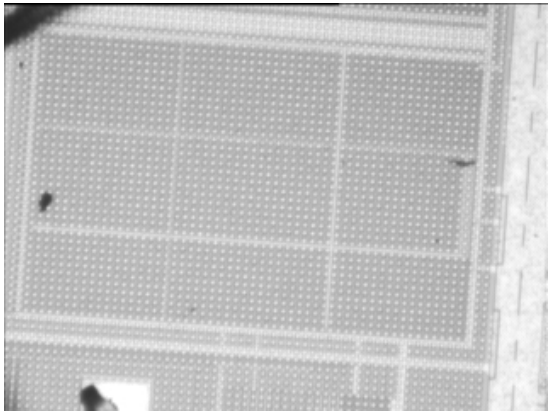
Decisive enabling factor is in the CMOS roadmap:
Power voltage level for 0.35 μm CMOS at 1V

Low-voltage/low power analog circuit design is a challenge (signal dynamic range), but well feasible

# Fabricated Device

Four photodiodes on two different substrates were used to prove the concept with a low-power circuitry used for converting the differential current to a voltage.





# Economic Viability

CMOS chip area is much more expensive than the solar cell

True, but:

Features of the space application:

- Low-volume market with high margins
- Mass all determining (> 20 k€/kg payload)

Moreover:

Rapid price erosion of subsequent CMOS versions

# Conclusions

Microsatelites require microsystems with no wires attached

The sun sensor is very suitable for optical self-powering

The concept is technically and ecomomically viable

First tests confirm basic operation

Design and fabrication of a fully integrated system are scheduled