Sensory robotics

Lecture 09.

i) Visual sensing

ii) Sensors of mobile robots, sensors of humanoid robots

Sensors of UAV, UUV and UGV

György Cserey

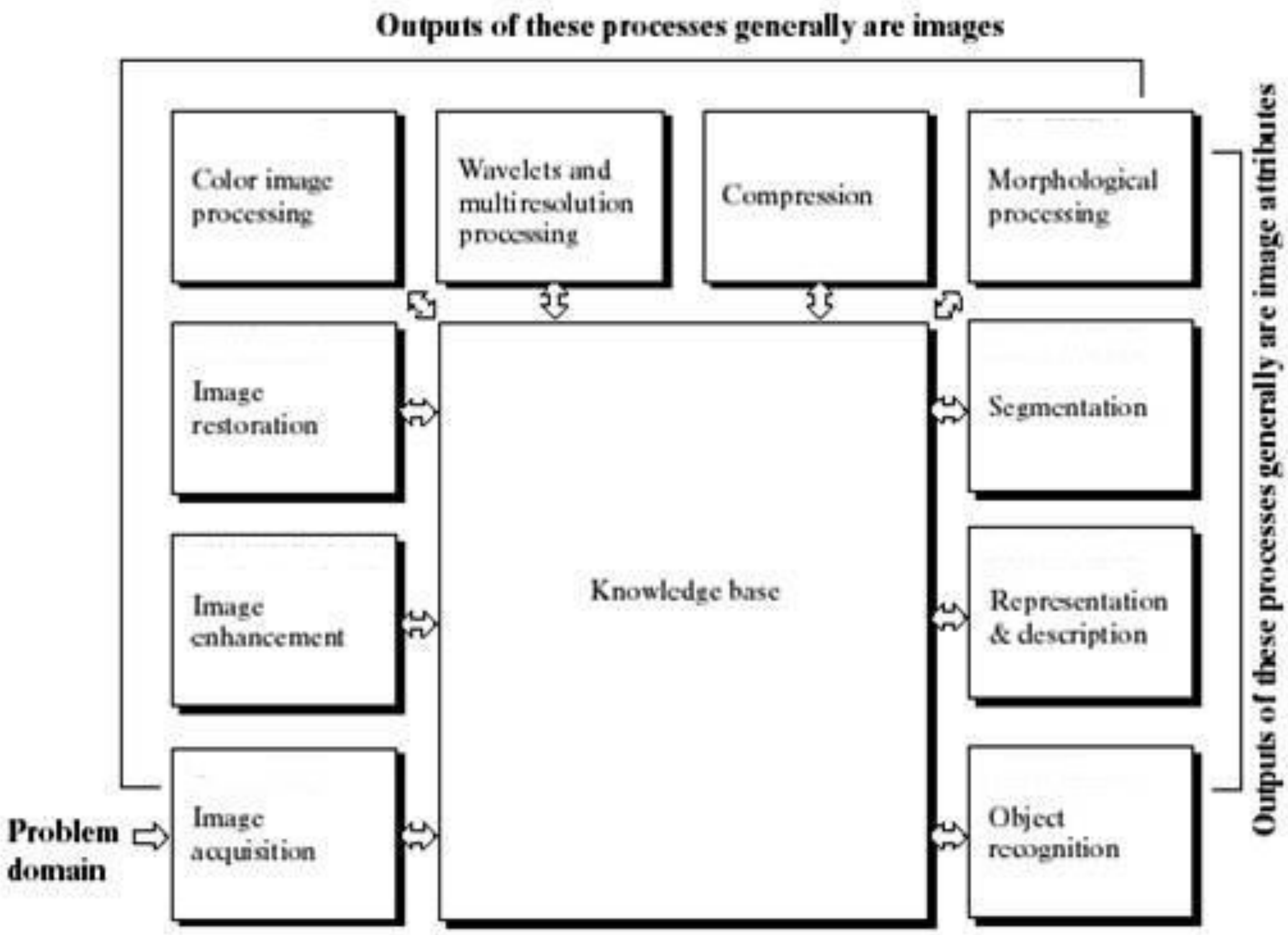
04. 26. 2021.

Image processing

- One of the most important sensor in biology provides visual input.
- Importance is obvious in mobile robotics. We have seen that Curiousity rover has a lot of cameras as well.
- 2D input data – huge amount of information, hard to replace this modality
- Classical image processing vs. Deep Neural Networks

Steps in classical image processing

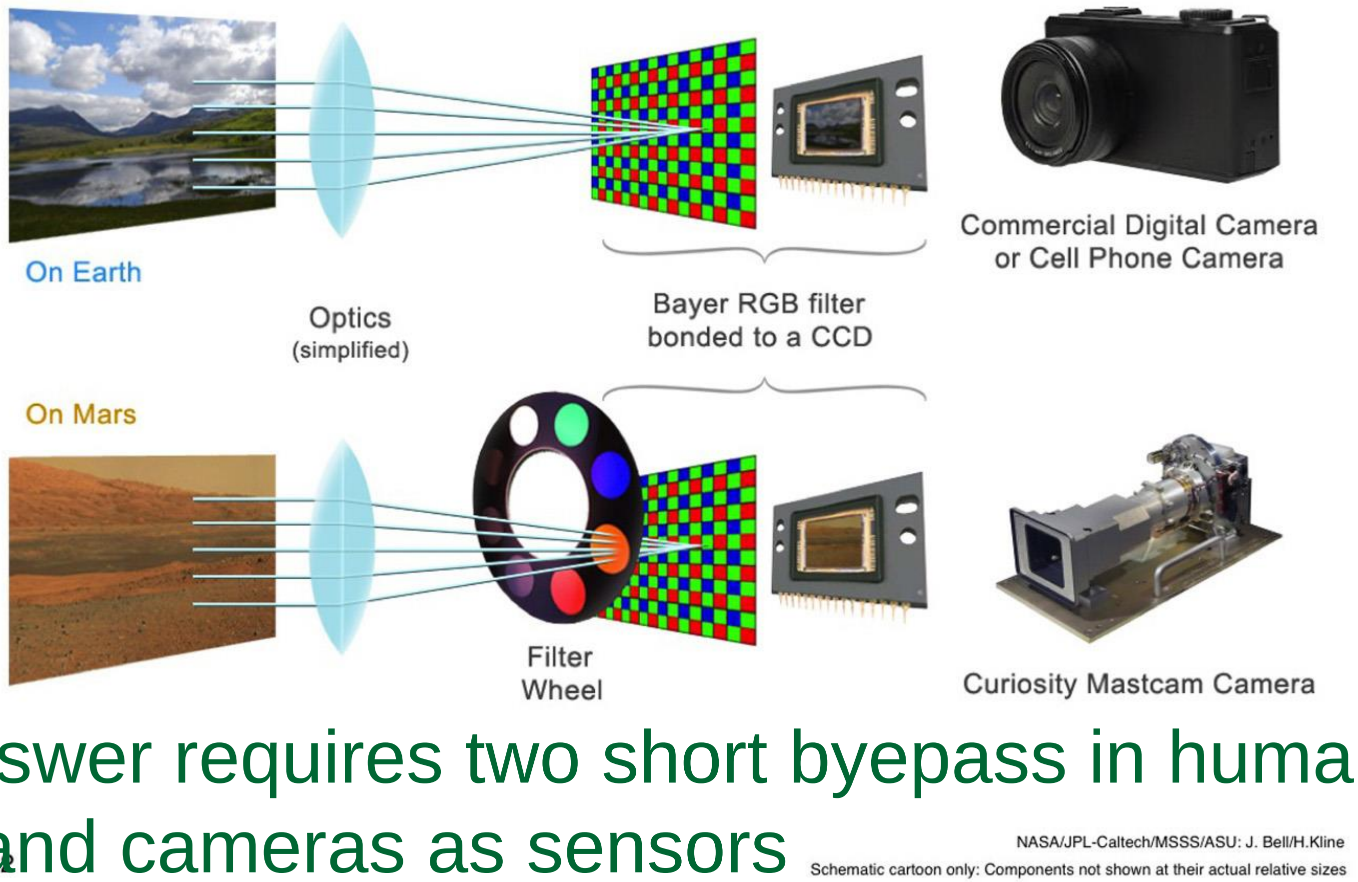
Fundamental steps in digital image processing.



Source: https://en.wikipedia.org/wiki/File:DIP-Steps.jpg

Digital images

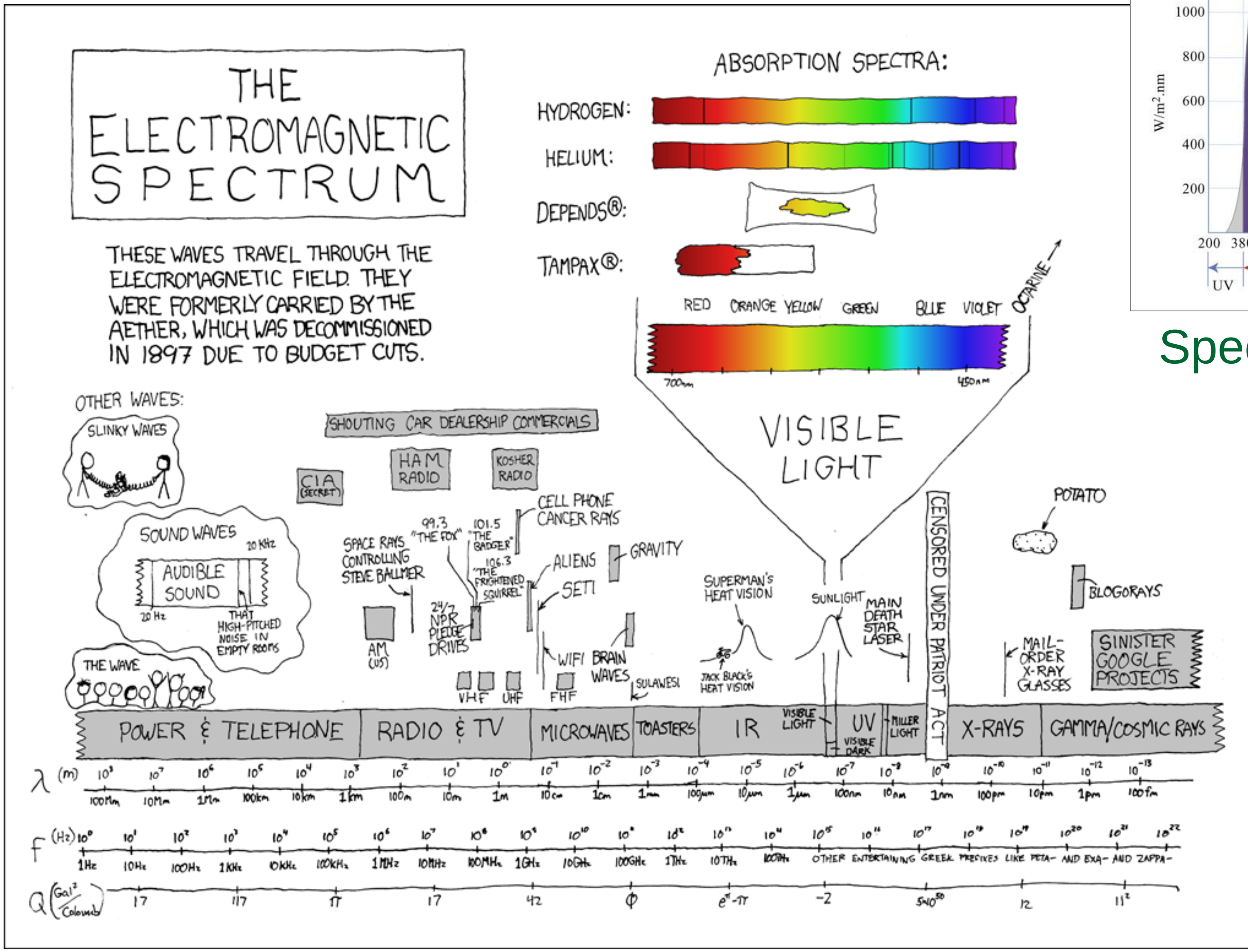
- Pixels represented in an RGB system?

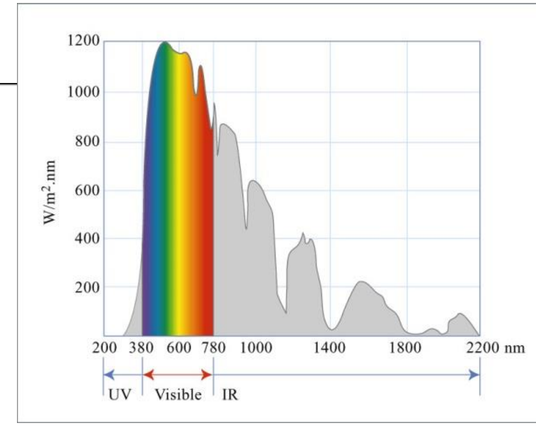


- The answer requires two short byepass in human vision and cameras as sensors

Source: https://www.jpl.nasa.gov/spaceimages/images/largesize/PIA16799_hires.jpg

Spectrum of visible light

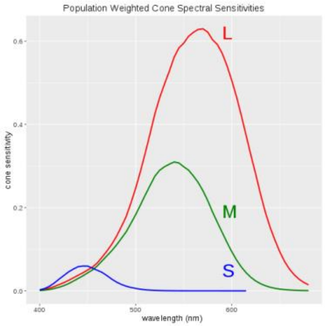


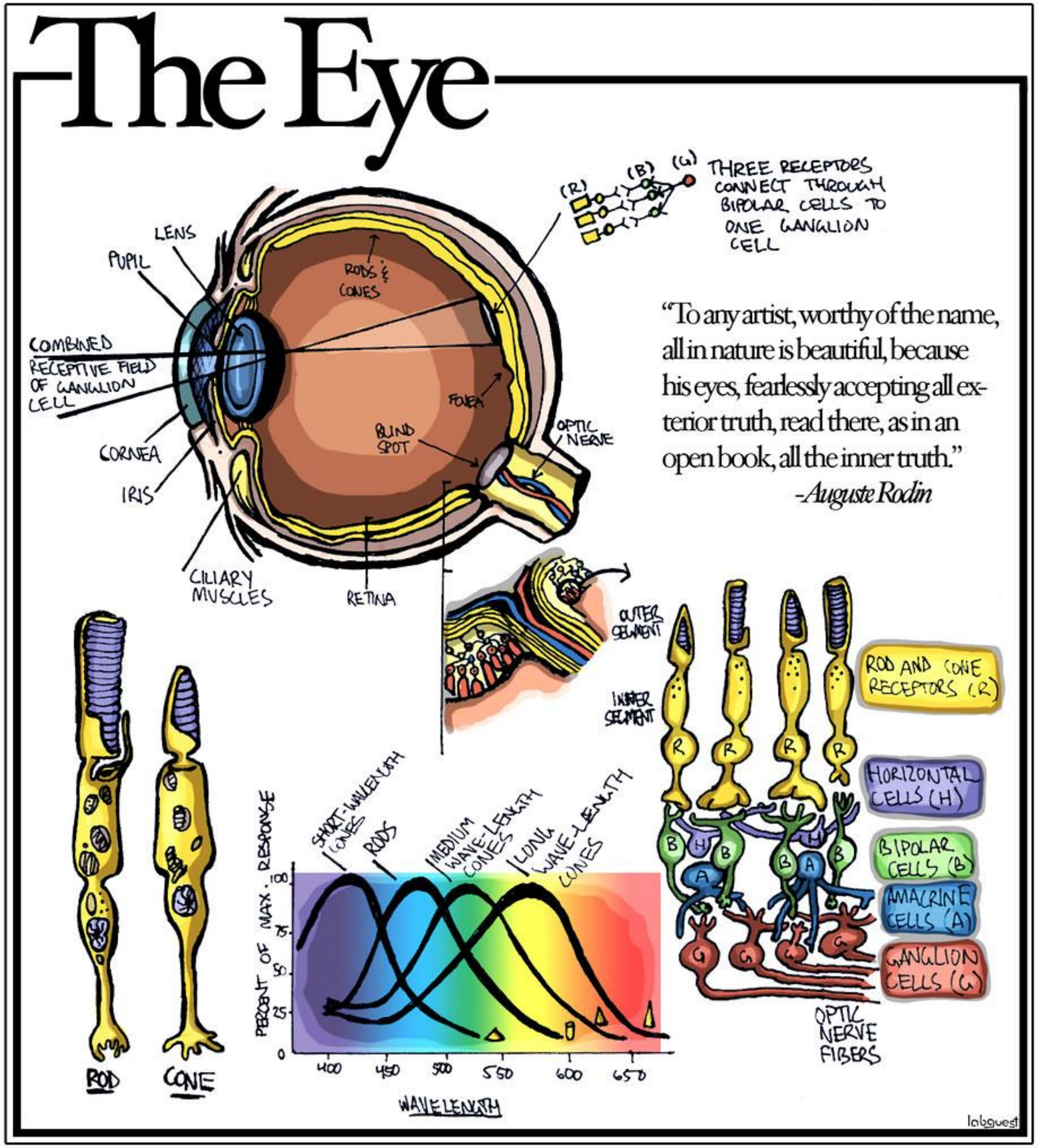


Spectrum of the Sun

Source: http://imgs.xkcd.com/comics/electromagnetic_spectrum.png

- The input: The product of lighting and reflection spectra
- Rods and cones
- R-G-B

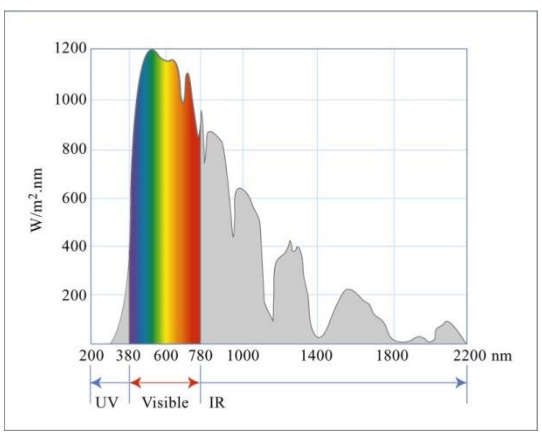




[Source: https://www.flickr.com/photos/labguest/3320241976](https://www.flickr.com/photos/labguest/3320241976)

Color vision

- The input: the product of lighting and reflection spectra
- Population weighted cone spectral sensitivities in the visible light range. The product of input and its spectra leads to color vision.



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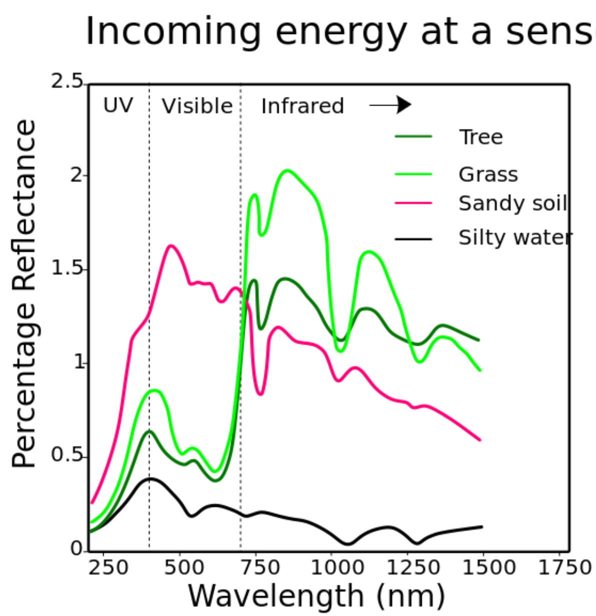

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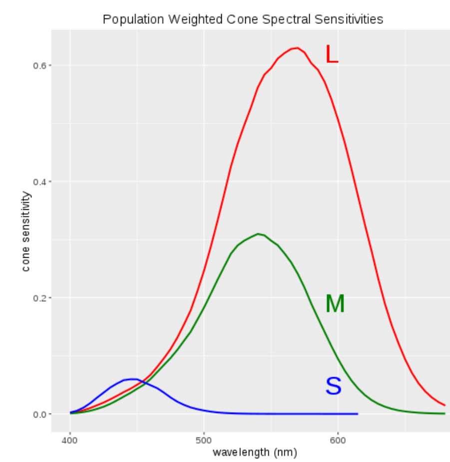
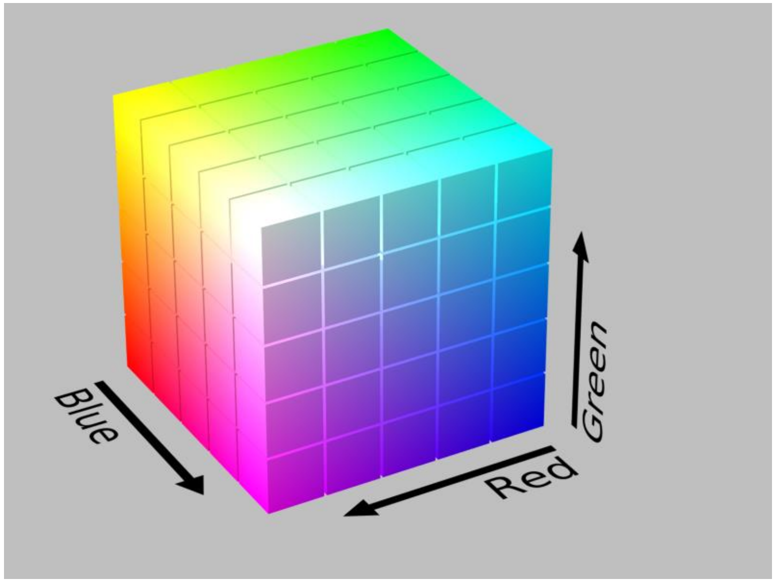


Source: https://commons.wikimedia.org/wiki

RGB color model

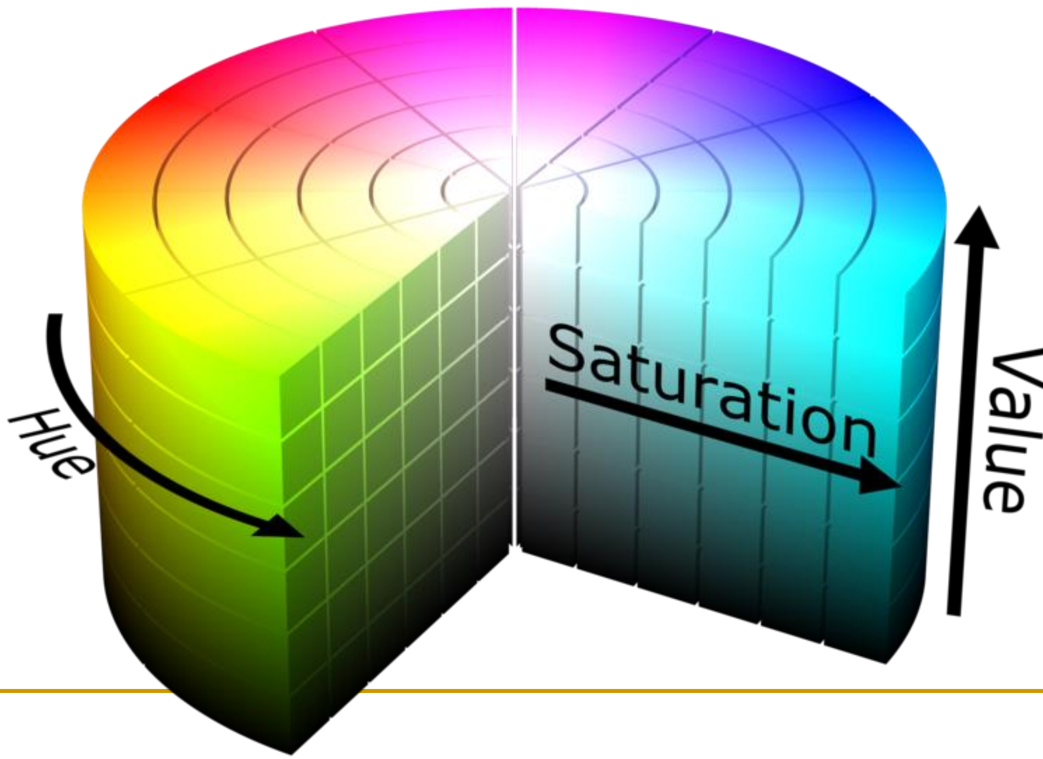
- Image sensor chips (CCD) are desinged as RGB sensors in order to emulate the human visual system
- R,G,B are elements of an „color” orthobasis



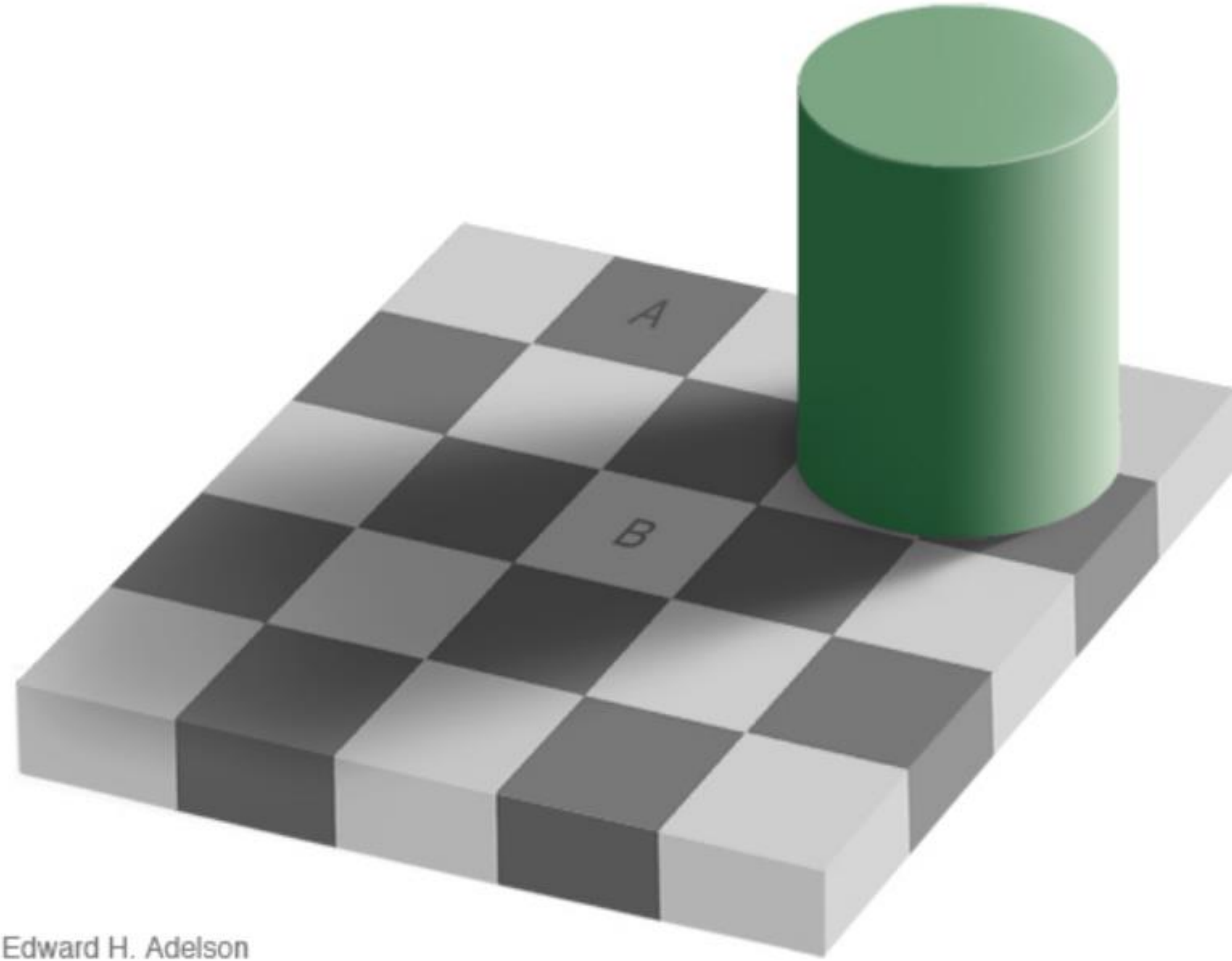
Source: https://commons.wikimedia.org/wiki/File:RGB_Cube_Show_lowgamma_cutout_a.png

Alternative: HSV Color Model

- Hue – árnyalat, Saturation – telítettség, Value – színérték
- More robust under illumination changes (why?) (better fit to the psychological perception of color than RGB)
- Still must confront noise, specularity etc.



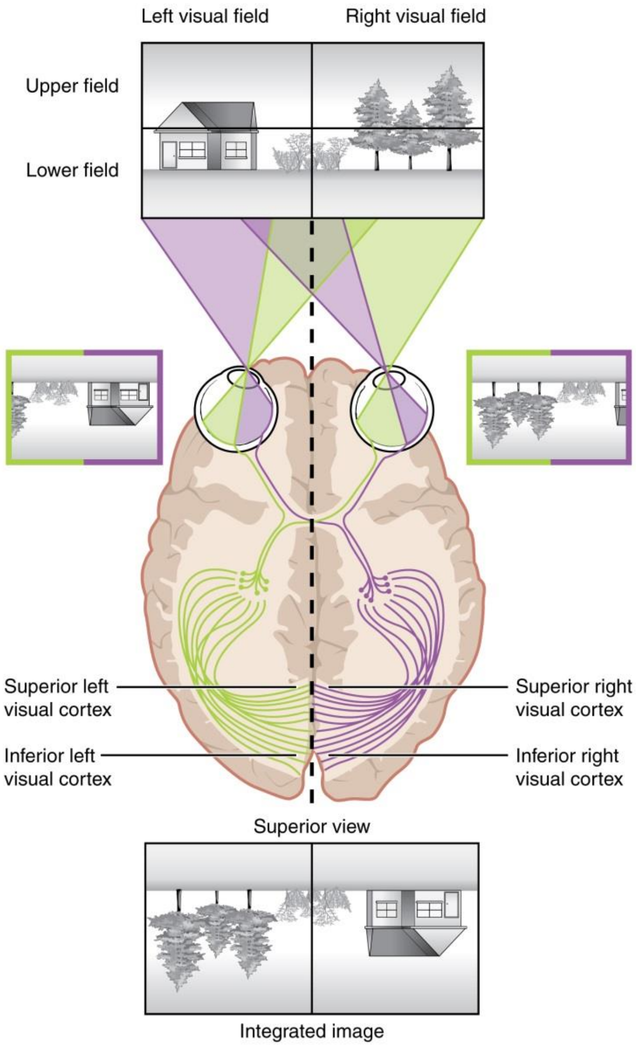
Source: https://commons.wikimedia.org/wiki/File:HSV_color_solid_cylinder.png



Edward H. Adelson

Processing of the visual system

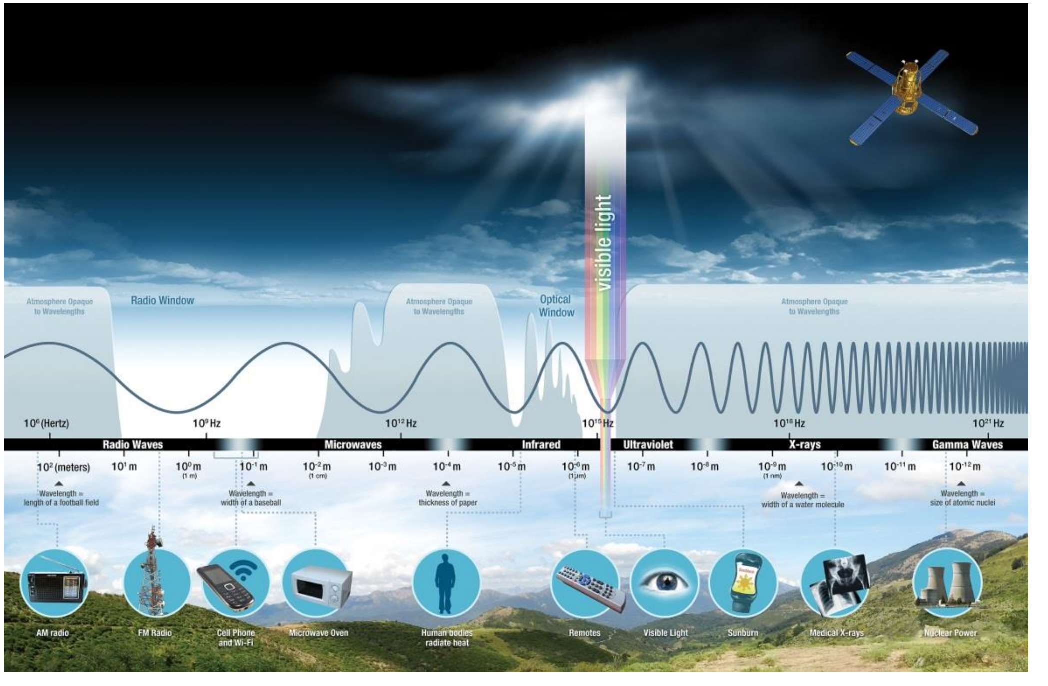
- Temporal adaptation
  - Pupil adjustment (~4 sec)
  - Change focus (~220 msec)
- Spatial adaptation
  - Color
  - Surround
- Resolution
  - Fovea
  - Periphery
- Activity
  - Processing channels
  - Saccadic effects
  - Approaching objects



Source: https://commons.wikimedia.org/wiki/File:1422_Topographical_Image_on_Retina.jpg

Infrared

- Electromagnetic radiation of all matters
- “Infrared” refers to biological life-forms
- Eye can not detect infrared
- Can be sense as heat



Source: https://www.jpl.nasa.gov/edu/news/2020/

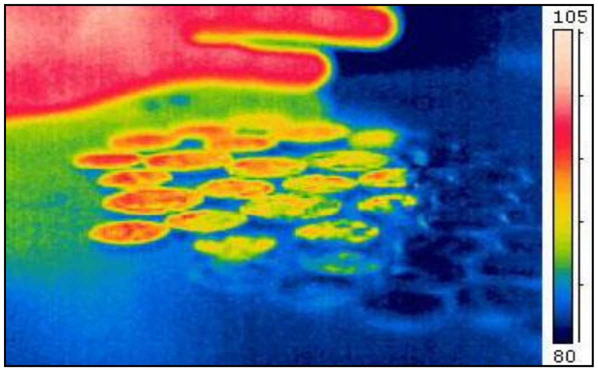
FLIR TG165 Spot Thermal Imaging Camera

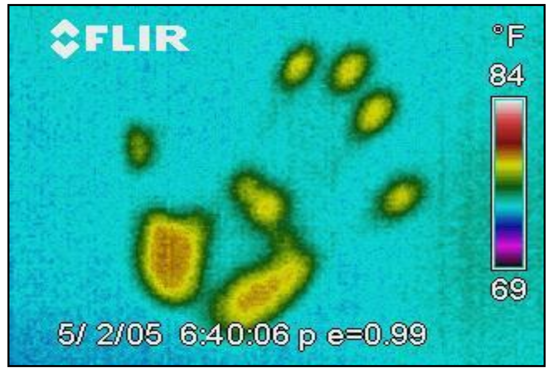
- Accuracy ±1.5% or 1.5°C (2.7°F)
- Field of view (FOV) 50° x 38,6°
- IR Resolution 80 × 60 pixels
- Object Temperature Range -25°C to 380°C (-13°F to 716°F)
- Thermal Sensitivity/NETD <150 mK
- Humidity (Operating and Storage) 0-90% RH (0-37°C (32-98.6°F)), 0-65% RH (37-45°C (98.6-113°F)), 0-45% RH (45-55°C (113-131°F))
- Operating Temperature Range -10°C to 45°C (14°F to 113°F)
- Storage Temperature Range -30°C to 55°C (-22°F to 131°F)
- Image Frequency 9 Hz
- Minimum Focus Distance 0.1 m (4 in.)
- Minimum Measurement Distance 26 cm (10 in.)
- Spectral Range 8–14 µm
- Camera weight incl battery 0.312 kg (11 oz)

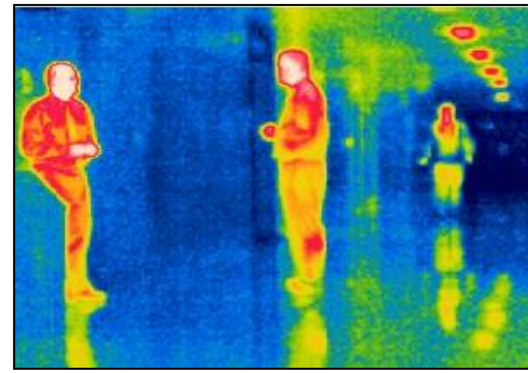
Source: https://www.flir.com/products/tg165/

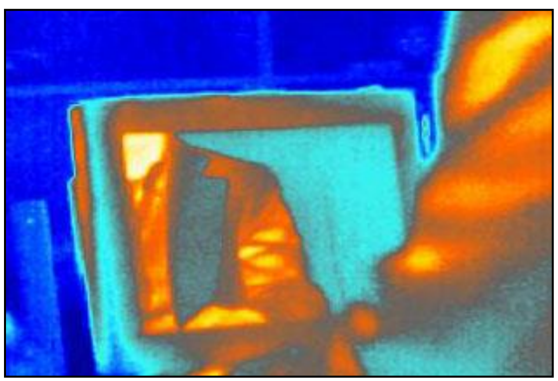
Examples

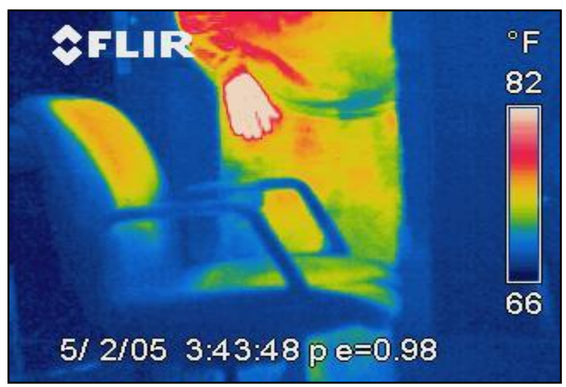
- Hands over buttons (keyboard), hand print on window, people outside, reflection off computer monitor, body print on chair, lighter.

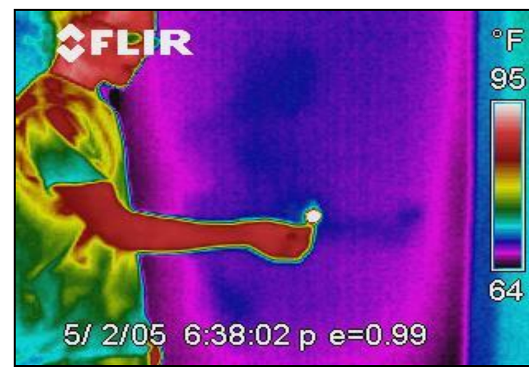




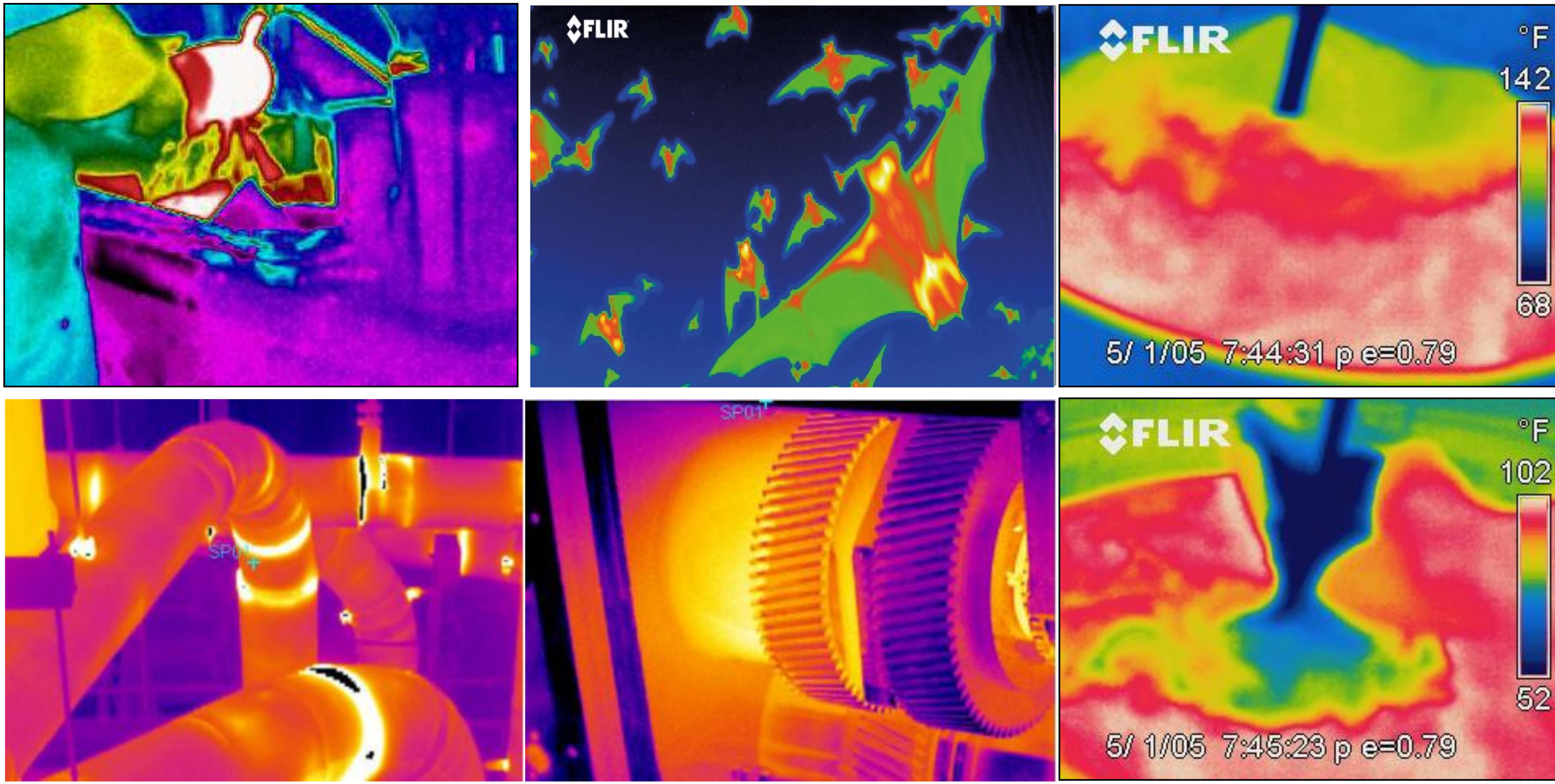






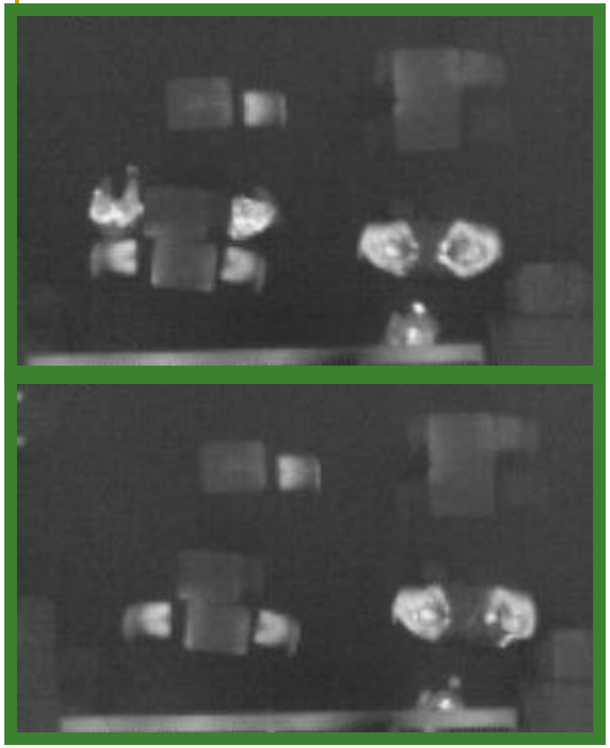


Hot & Cold Water, bats, industrial apps

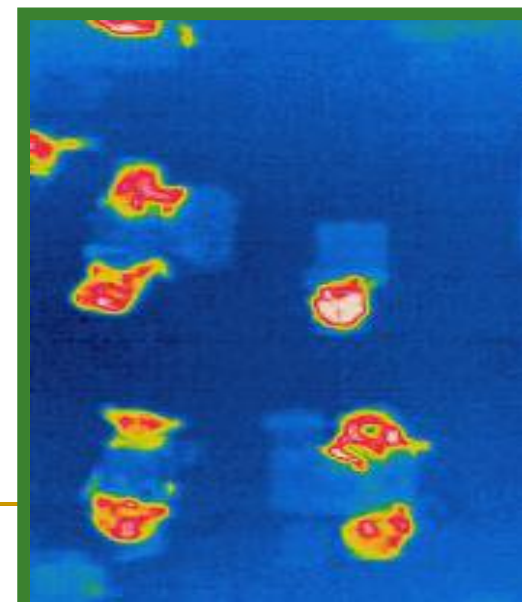


Source: http://www.jacksonelectronics.co.uk/thermal.htm

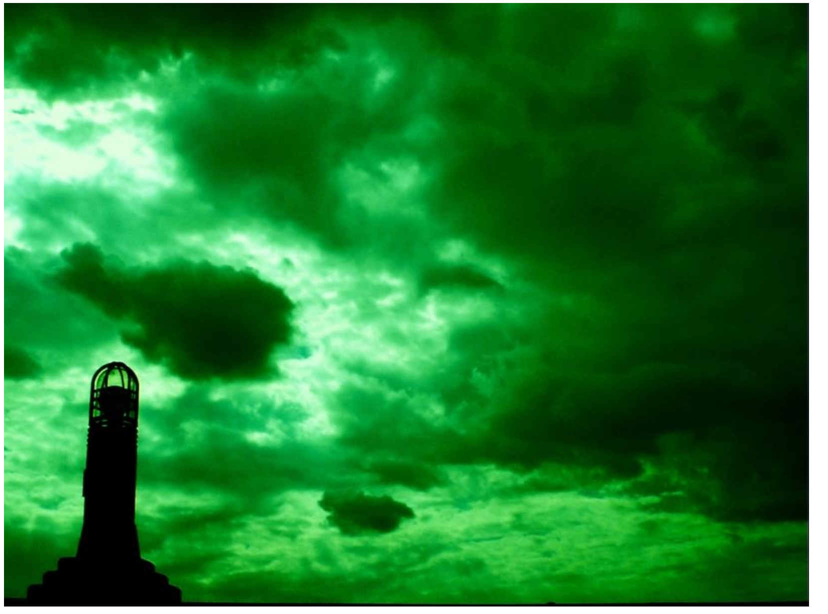
What will the camera see?

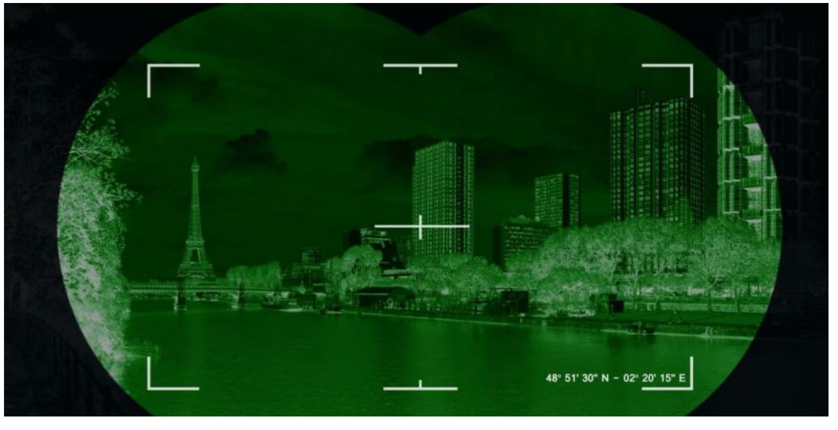


- Infrared camera captiured images
- Body prints are on the furniture
- Heat signatures remain lit until the heat dissipates



Nighvision camera





Source: https://opticsandlab.com/why-is-night-vision-green/

Need of night vision cameras

- Human eyes see reflected light
- Daylight and night vision cameras, as well as human eye detect reflected visible light energy
- This is how we have an image
- These detectors need enough light to make an image
- Starlight, moonlight and artificial lights are limited

Thermal imaging vs. Night vision

- Thermal imaging is not based on classical cameras
- Thermal imaging **makes pictures from heat, not visible light.**
- Thermal cameras **detect tiny *differences* in heat** – as small as 0.01°C
- **Everything gives off thermal energy**
- **Thermal energy comes from a combination of sources**
- **Different materials absorb and radiate thermal energy at different rates**

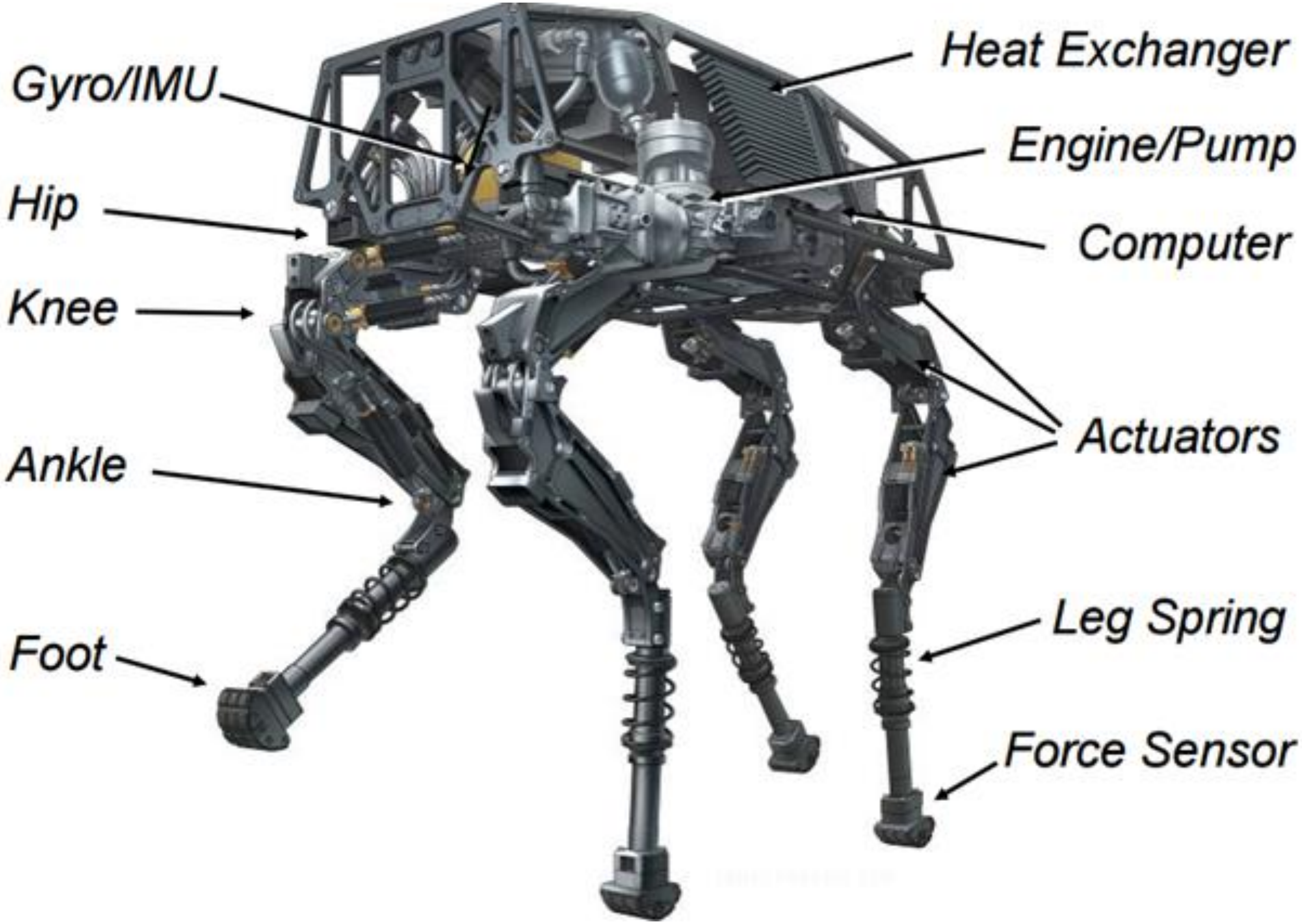
Thermal imaging vs. **Night vision**

- Night vision goggles take in **small amounts of visible light, magnify it greatly**.
- **If there isn't enough visible light available, they can't see well**.
- They are **not very useful** during twilight hours, **when there is too much light.**
- Infrared illuminated I^2 cameras **projects a beam** which **bounces off an object**. I^2 cameras still rely on reflected light to make an image, they have the **same limitations as any other night vision camera – short range, and poor contrast**.

ASIMO senses

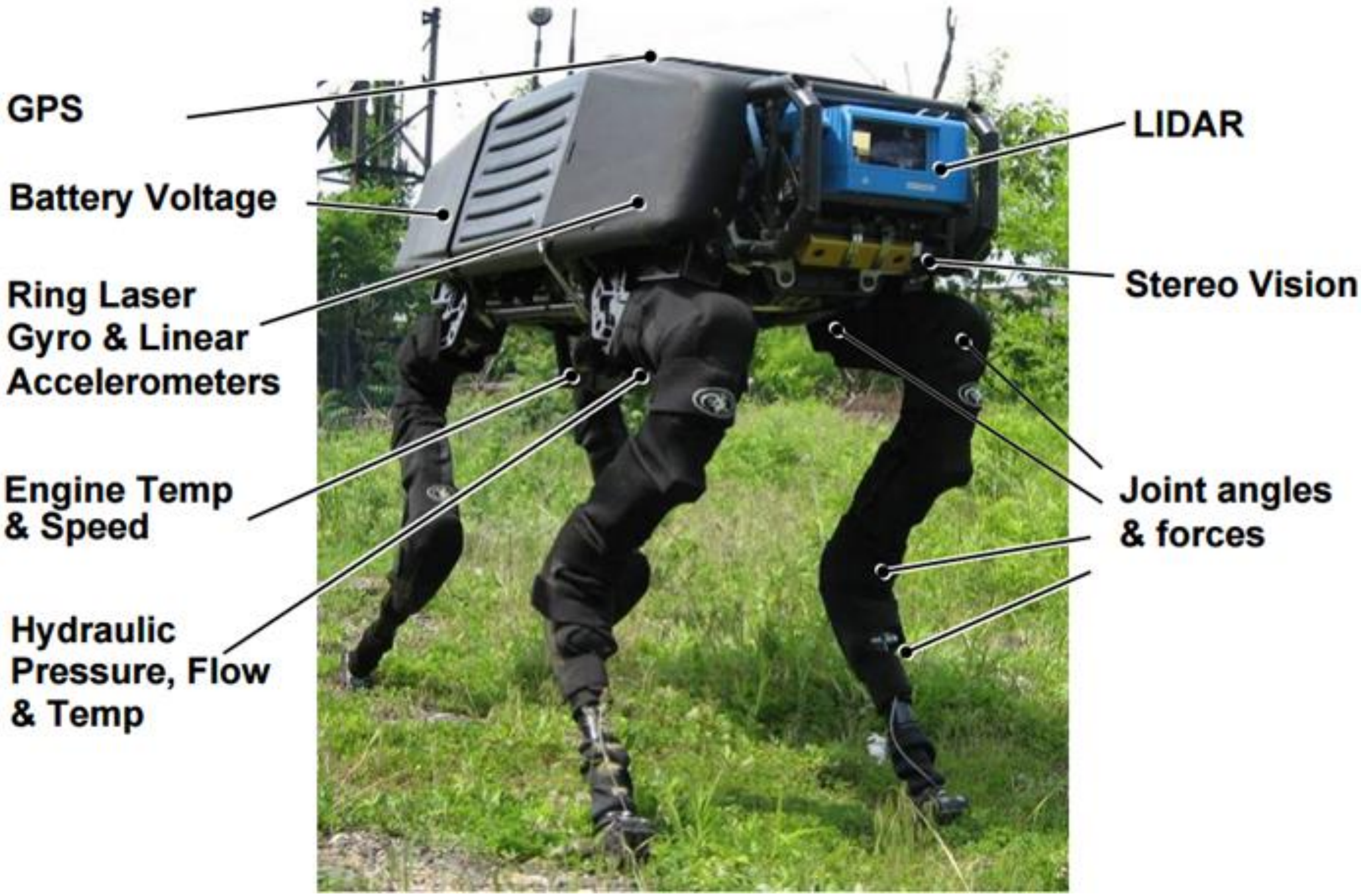
- Two basic **video cameras** for eyes, **Stereoscopic vision**
- Able to recognize, and avoid objects
  - detect multiple objects,
  - determine distance,
  - perceive motion,
  - recognize programmed faces
  - interpret hand motions
  - follow a person
  - allow a moving object to cross its path
  - greet you
- **Several sensors for maneuver through environments and interact with objects and people**
- **Sense of touch: force sensors**

Bigdog - structure



Source: Jawaad, Plummer. "Hydraulic running robots: the prospects for fluid power in agile locomotion." In Proceedings of the twelfth Scandinavian international conference on fluid power, pp. 9-25. 2011.

Bigdog - sensors



Source: HongChao, Zhuang, Gao HaiBo, Deng ZongQuan, Ding Liang, and Liu Zhen. "A review of heavy-duty legged robots." SCIENCE CHINA-TECHNOLOGICAL SCIENCES 57, no. 2 (2014): 298-314.

Bigdog - sensors

Type	Measurement Quantity	Location	#	
Linear Pot	Joint displacements	Knee, Hip(2), Ankle	16	
Load Cell	Actuator, ankle force	Legs eBox	16	
Current sensor	Servo valve current	eBox	16	Proprioception
Stereo Vision	Obstacles, Optic Flos, Ground Slope	Body	3	
LIDAR	Human Tracking	Body	1	
Gyro	3 angular rates 3 linear accelerations	Body	6	Exteroception
Temperature	Engine, Oil temperature	Body	3	
Flow	Oil flow	Body	4	
Pressure	Oil pressure	Body	2	Homeostasis
Governor	Engine RPM Battery voltage	Body	2	
Total			69	

Source: https://www.edn.com/bigdog-robot-a-sensor-based-enhancement-of-human-capabilities/

UAV platforms

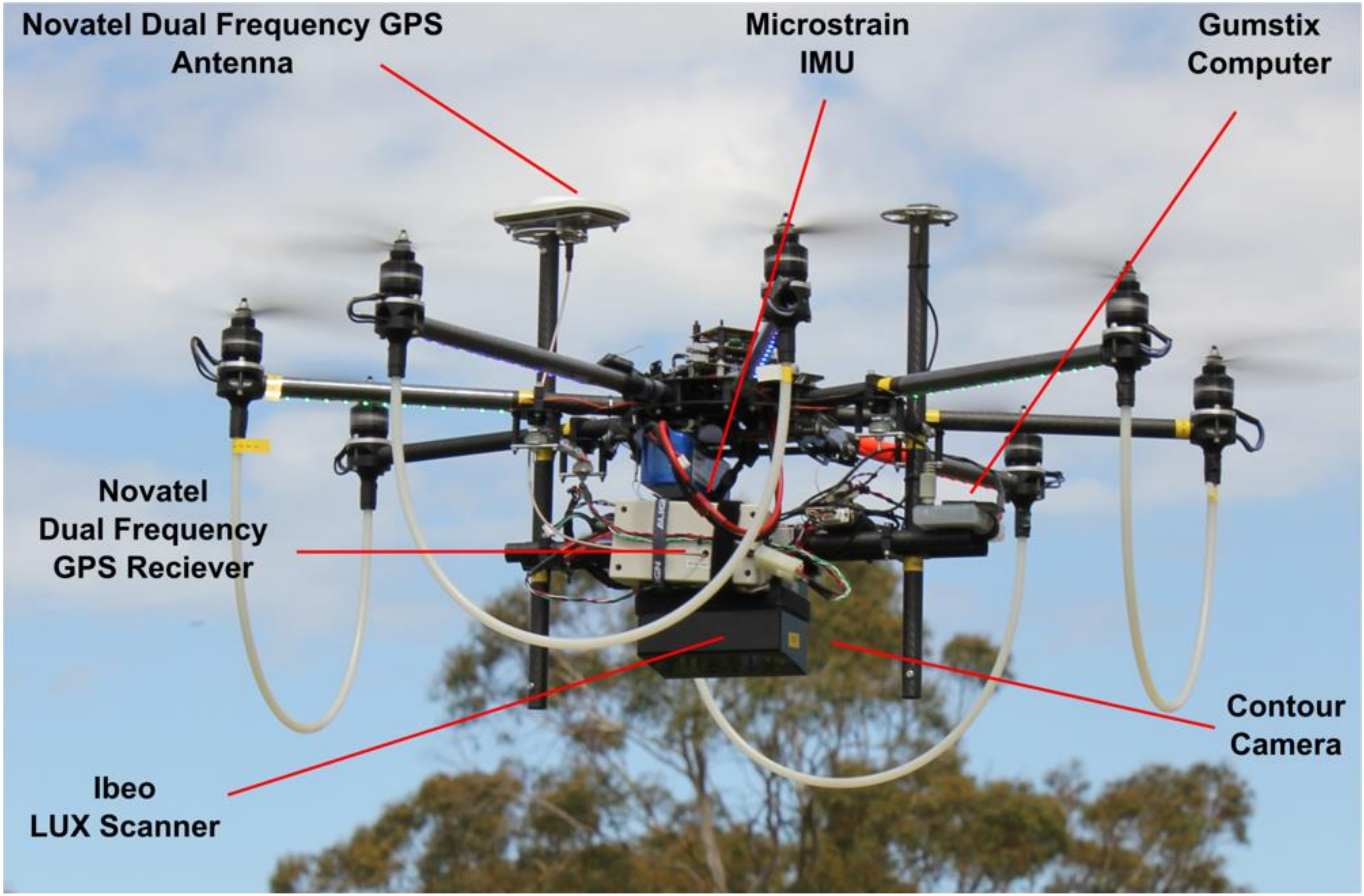
- Fixed wing airplanes
  - Simple, durable, cheaper, longer flight time / distance for larger areas

- Multi-rotor airplanes
  - Simple, VTOL, durable, lightweight, cheaper, many applications,

- Helicopters
  - VTOL, durable, stable, loadable, different sizes, longer flight time / distance

- Lighter than air – ballon
  - VTOL, durable, different sizes, sensitive

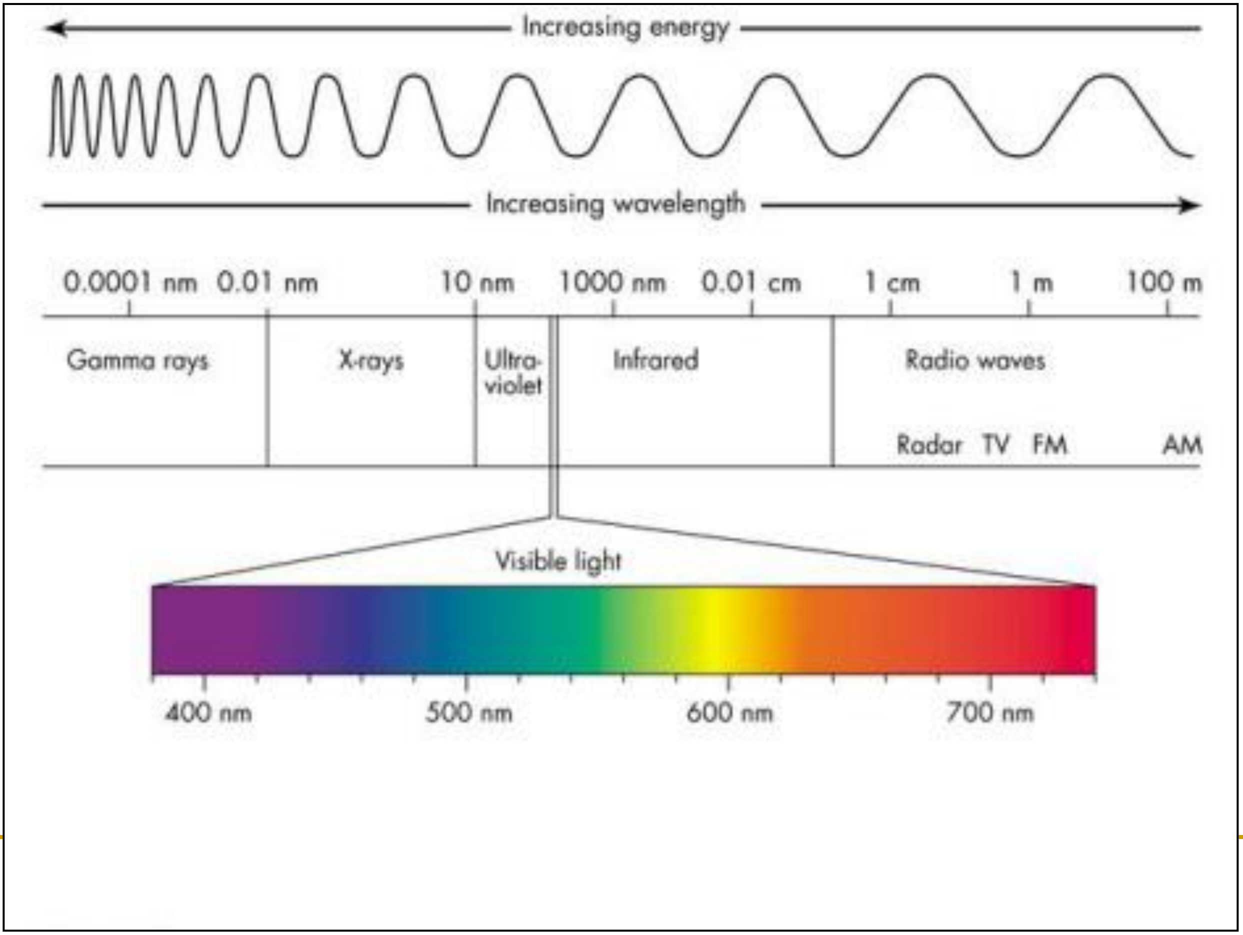
UAV - sensors



Source: Wallace, Luke, Arko Lucieer, Christopher Watson, and Darren Turner. "Development of a UAV-LiDAR system with application to forest inventory." Remote Sensing 4, no. 6 (2012): 1519-1543.

UAV – remote sensing

- The phenomenon of collecting and analyzing information without direct contact is science, art and technology as well.



LandSat Bands			
Band	**Wavelength (µm)**	**Name**	**Applications**
1	0.45 – 0.52	Blue	Useful for soil/vegetation discrimination, forest type mapping and cultural feature identification.
2	0.52 – 0.60	Green	Used for discrimination and vigor assessment of vegetation.
3	0.63 – 0.69	Red	Designed to sense in a chlorophyll absorption region, aiding in plant species differentiation.
4	0.76 – 0.90	Near IR	Useful for determining vegetation types, vigor and biomass content and soil moisture discrimination.
5	1.55 – 1.75	Mid IR	Indicative of vegetation moisture content and soil moisture. Also useful in differentiation of snow from clouds
6	10.4 – 12.5	Thermal IR	Useful in vegetation stress analysis, soil moisture discrimination and thermal mapping applications.
7	2.09 – 2.35	Mid IR	Useful for discrimination of mineral and rock types.

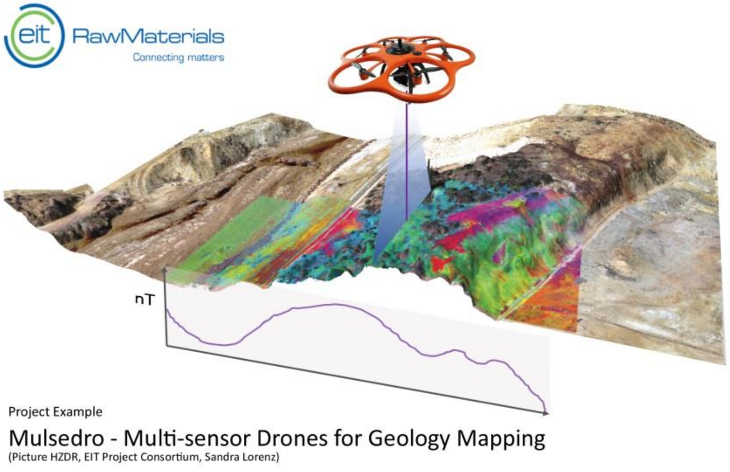
UAV – remote sensing

- UAV remote sensing with electromagnetic spectrum sensors, biological sensors, and chemical sensors
- A UAV sensors include visual spectrum, IR, or near IR cameras as well as radar systems.
- Biological sensors are capable of detecting the airborne presence of various microorganisms and other biological factors.
- Chemical sensors use laser spectroscopy to analyze the concentrations of elements in the air.

Source:Xiang, Tian-Zhu, Gui-Song Xia, and Liangpei Zhang. "Mini-Unmanned Aerial Vehicle-Based Remote Sensing: Techniques, applications, and prospects." IEEE Geoscience and Remote Sensing Magazine 7, no. 3 (2019): 29-63.

UAV - Oil, gas and mineral exploration

- UAVs can be used to perform geomagnetic surveys where based on the measurement of the differential Earths magnetic field strength **magnetic rock structure can be calculated**.
- Helps to predict **the location of mineral** deposits.
- The **oil and gas exploration** and monitoring of the integrity of oil and gas pipelines and installations.



Source: https://eitrawmaterials.eu/project/mulsedro/

UAV - Transport

- UAVs can **transport payloads**
  - rare population
  - COVID

Source: https://medium.com/@ahmetkonak55/the-importance-and-future-of-drone-in-cargo-transportation-3ad20ff022d7

UAV – scientific research

- Penetrating areas which may be **too dangerous for piloted craft**. (Hurricane, fire, colcano eruption)
- **Measurements far closer** to the water's surface
- For scientific research in severe **climates** such as the Antarctic.
- **Search and rescue**.
- **Photographic-like images** through clouds, rain or fog, even in daytime or nighttime conditions.
- **Archeology**
- **Geology**

Source: https://frontierscientists.com/2016/01/research-opportunities-videos-unmanned-aerial-vehicles/

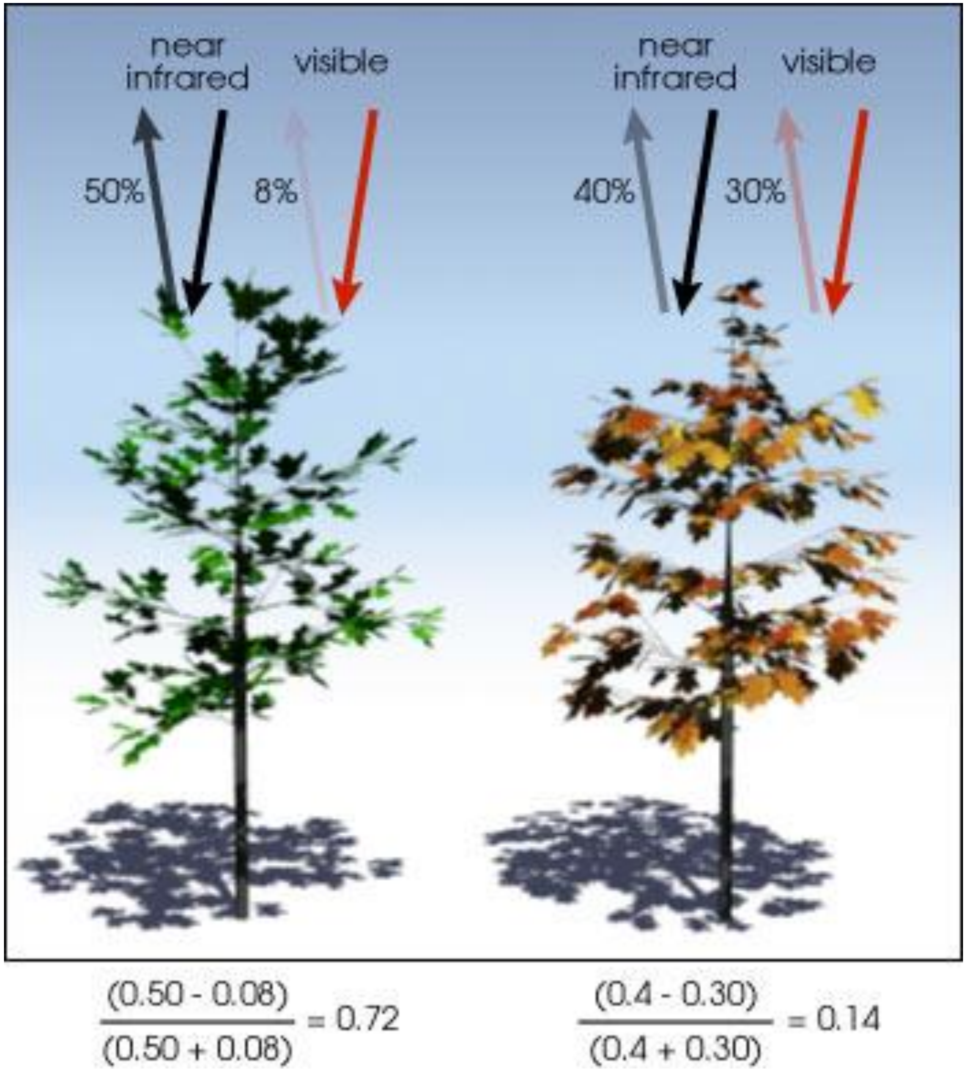
UAV – military aims

- **With high-precision zoom lens cameras, and video cameras with both electric optic and infrared capability that can see at night,**
- **„Painting the target"** Sensors to calculate wind speed, direction, and other battlefield variables to gather all of this data into a firing solution.
- Military intelligence

Source: https://www.mydronelab.com/blog/types-of-military-drones.html

UAV – NDVI

- Proportion of visible and infrared
- NDVI - normailzed differential vegetative index
- It allows comparison of the vegetation of different areas

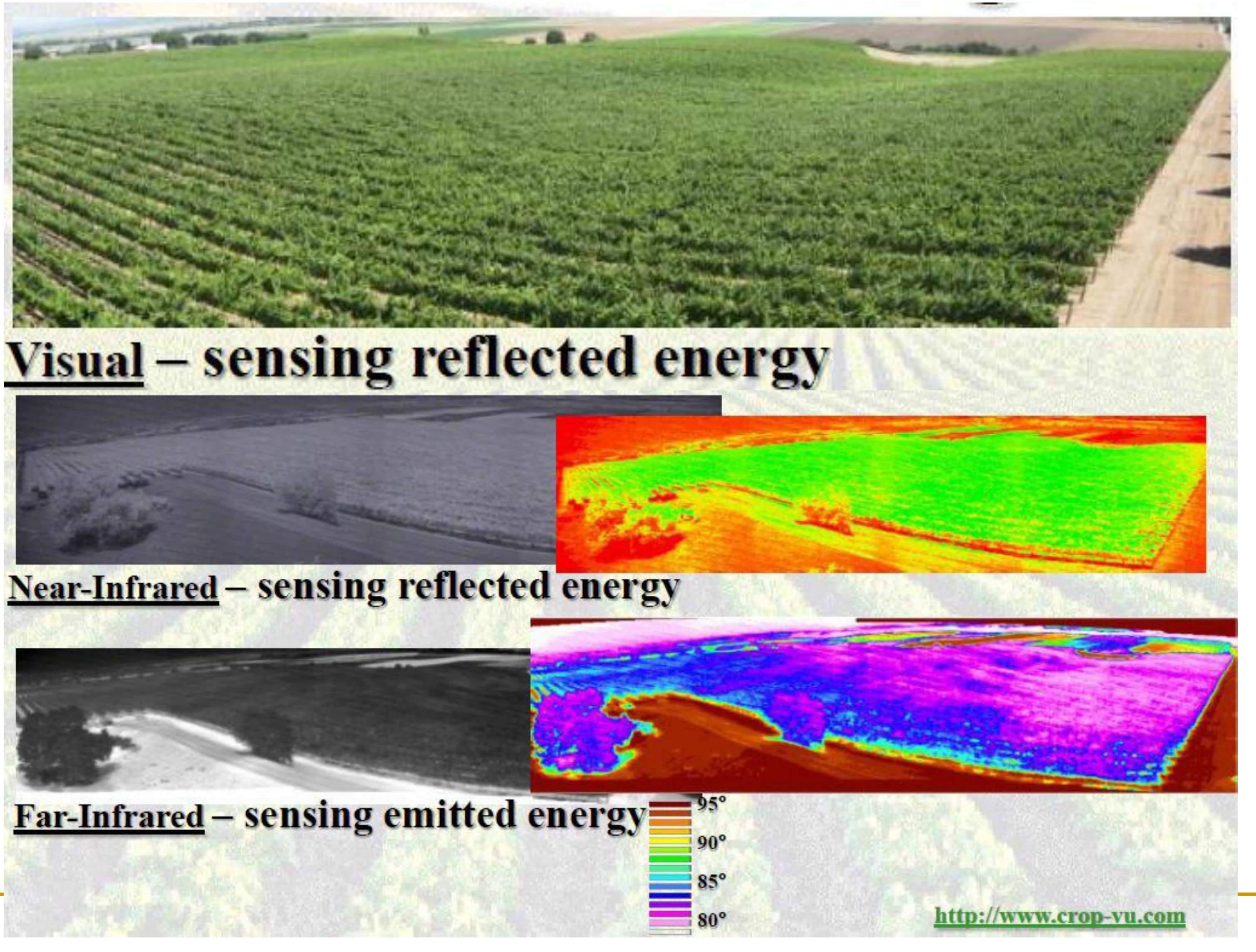


Source: https://www.wikiagro.com/en/NDVI_-_Vegetation_Index

UAV – remote sensing

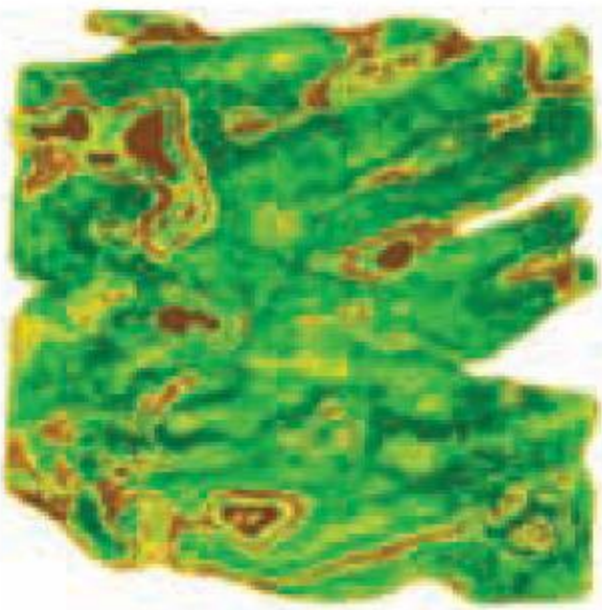
Satellite vs. UAV image

Applications of thermal cameras



Source: http://crop-vu.com/

Fungicide application

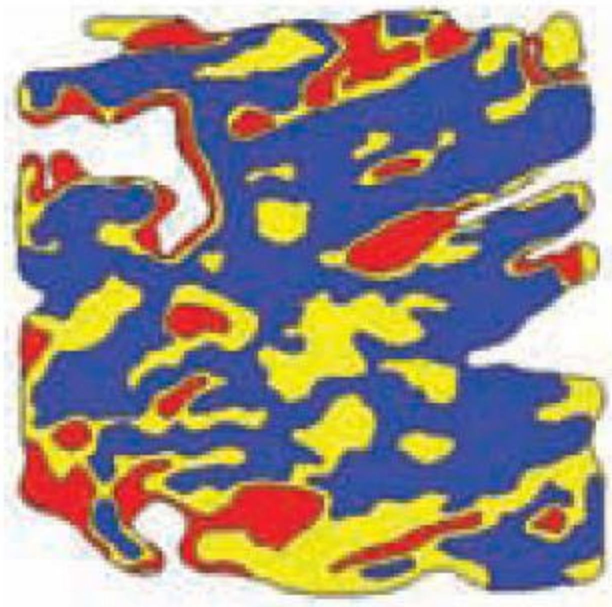


NDVI readings from Real Shot imagery

Green - high NDVI reading

Yellow - medium NDVI reading

Brown - low NDVI reading



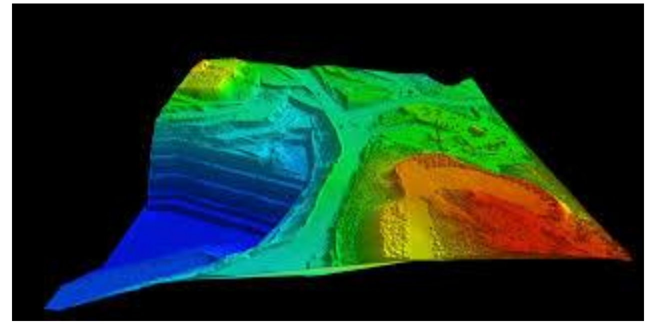
Fungicide application zones

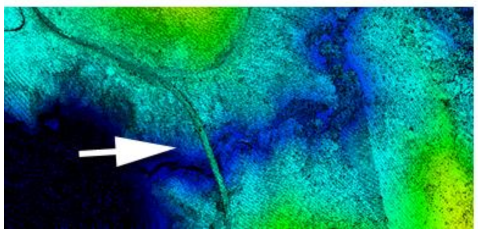
Blue - high label rate

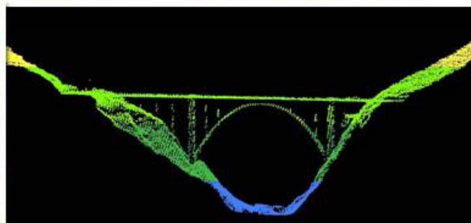
Yellow - reduced label rate

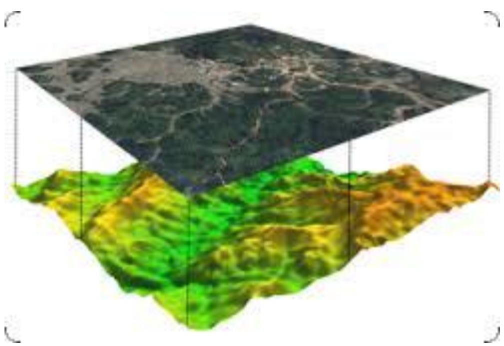
Red - no product applied

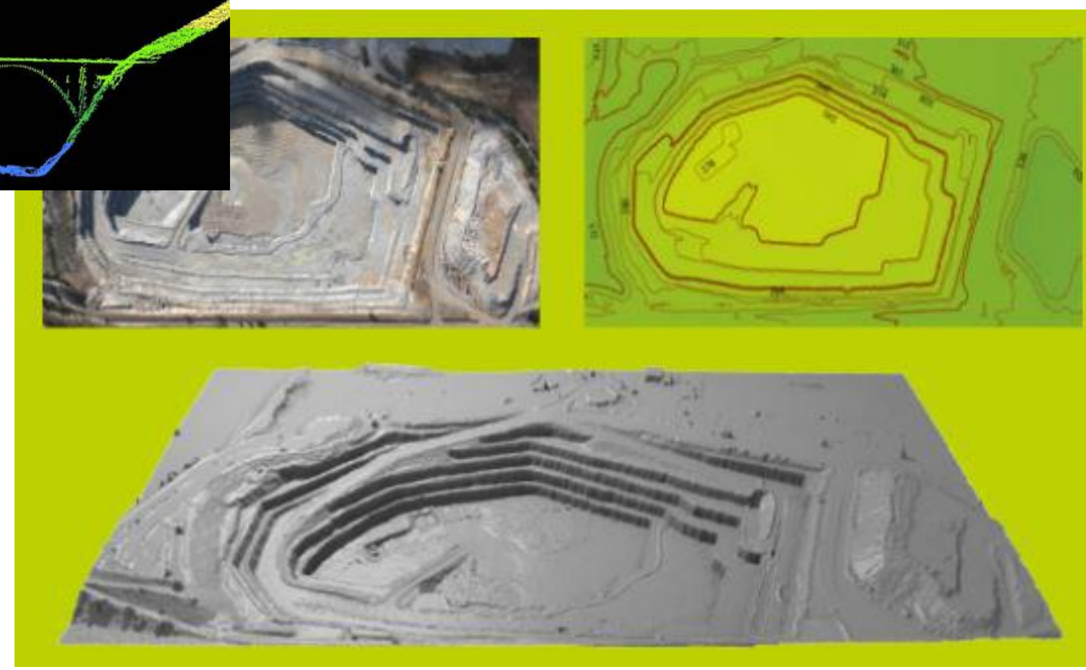
Applications - lidar

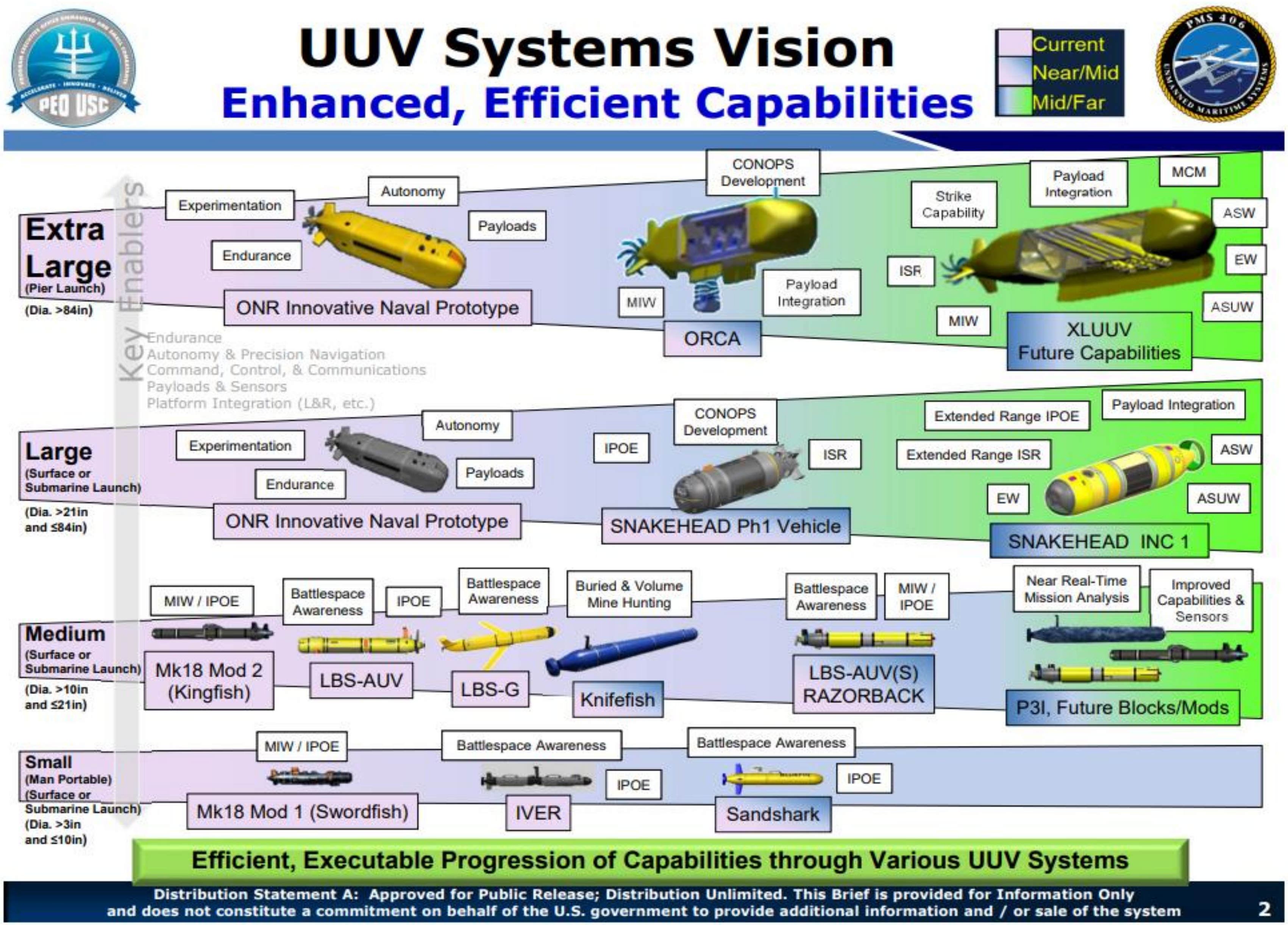




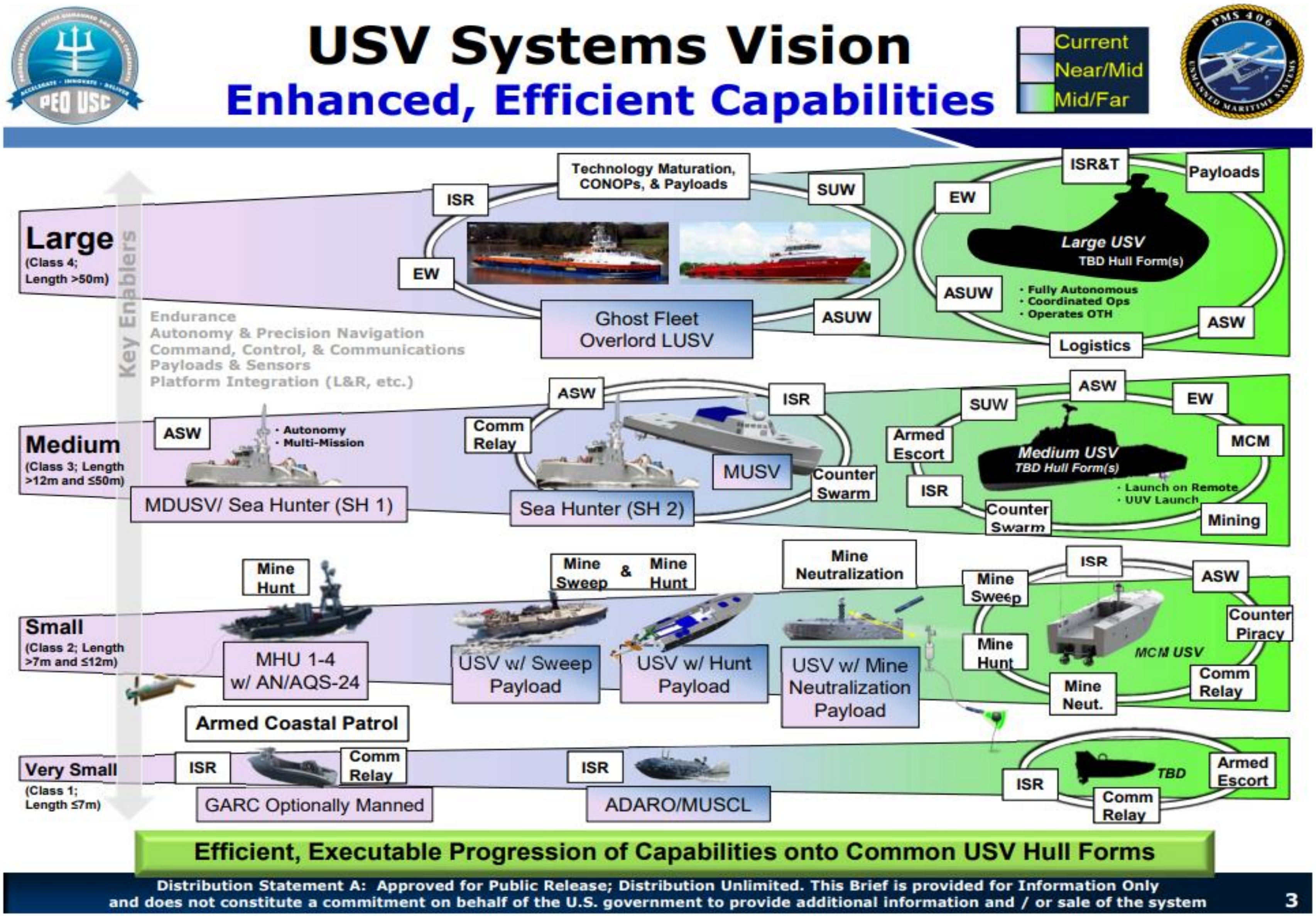








Source: Slide 2 of briefing by Captain Pete Small, Program Manager, Unmanned Maritime Systems (PMS 406), entitled "Unmanned Maritime Systems Update," January 15, 2019, accessed May 22, 2019,



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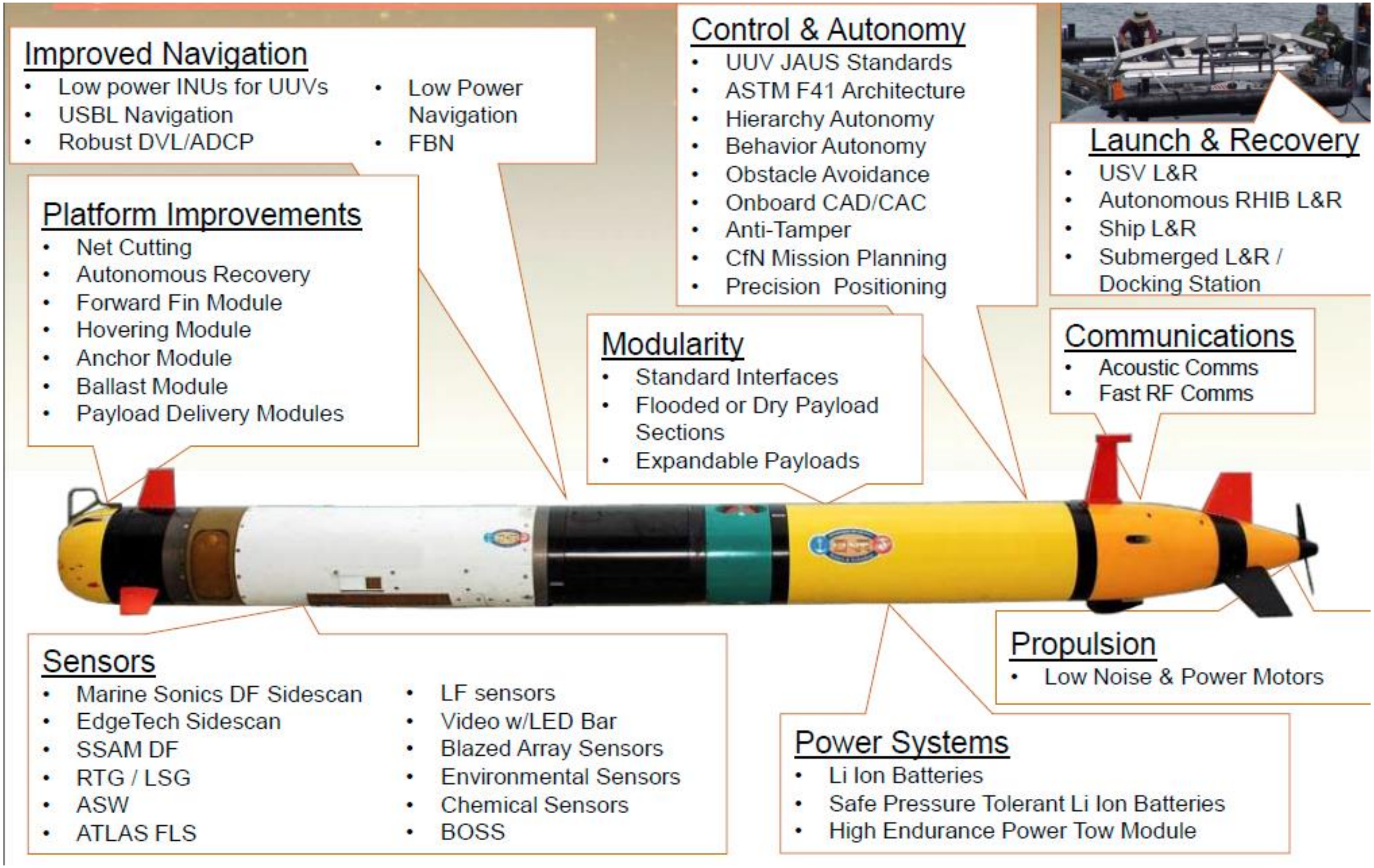
UUV - sensors



Improved Navigation
Low power INUs for UUVs
USBL Navigation
Robust DVL/ADCP
Low Power Navigation
FBN
Platform Improvements
Net Cutting
Autonomous Recovery
Forward Fin Module
Hovering Module
Anchor Module
Ballast Module
Payload Delivery Modules
Control & Autonomy
UUV JAUS Standards
ASTM F41 Architecture
Hierarchy Autonomy
Behavior Autonomy
Obstacle Avoidance
Onboard CAD/CAC
Anti-Tamper
CfN Mission Planning
Precision Positioning
Launch & Recovery
USV L&R
Autonomous RHIB L&R
Ship L&R
Submerged L&R / Docking Station
Modularity
Standard Interfaces
Flooded or Dry Payload Sections
Expandable Payloads
Communications
Acoustic Comms
Fast RF Comms
Sensors
Marine Sonics DF Sidescan
EdgeTech Sidescan
SSAM DF
RTG / LSG
ASW
ATLAS FLS
LF sensors
Video w/LED Bar
Blazed Array Sensors
Environmental Sensors
Chemical Sensors
BOSS
Propulsion
Low Noise & Power Motors
Power Systems
Li Ion Batteries
Safe Pressure Tolerant Li Ion Batteries
High Endurance Power Tow Module

UUV sensors

- Marine Sonics DF sidescan – ultrasound scanner
- EdgeTech sidescan – ultrasound scanner
- SSAM DF (Simultaneous **dual frequency** band operation)
- ASW (anti submarine war)
- LF sensors – low frequency sensors
- Video w/LED Bar
- Environmental Sensors
- Chemical Sensors
- BOSS – bio-optical sensor system

UGV sensors

- Visual sensor – tilt camera
- Passive/active thermal camera
- Chemical sensors – nitrates, toxic materials
- Night vision sensors / cameras
- Acoustic sensors
- Radiation detectors
- Sensing biological materials
- Licence plate recognition

References

- *Roland Siegwart, Illah R. Nourbakhsh, Davide Scaramuzza: Autonomous Mobile Robots*
- *H. R. Everett, A. K. Peters: Sensors for mobile robots: theory and applications, 1995, ISBN: 1-56881-048-2*

End of lecture 09.

i) Visual sensing
ii) Sensors of mobile robots, sensors of humanoid robots
Sensors of UAV, UUV and UGV

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