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cosine workshop

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Case study

➢The *Nederlandse krijgsmacht* is concerned that North Korea will soon launch a nuclear warhead towards Amsterdam.

➢ You do not know the exact launch location, but intelligence has confirmed that it would be within North Korea's borders.

➢The warhead will likely be carried by a Hwasong-15 missile.

Case study description

➢Bids are being accepted to create a remote sensing system that can detect a launch within 5 minutes anywhere in North Korea's borders

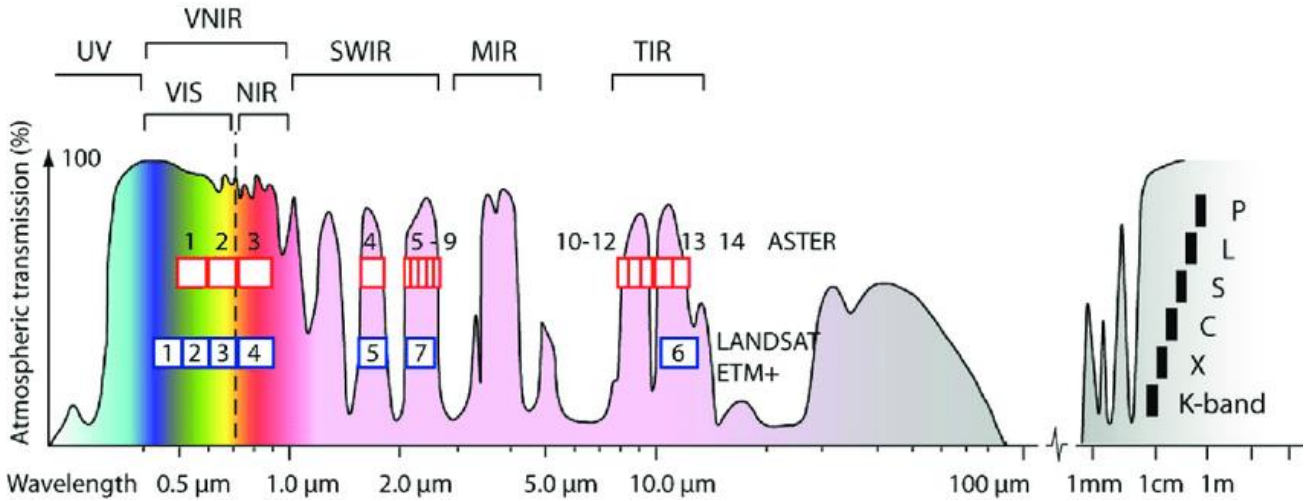
➢The systems can operate in LEO and/or GEO in any wavelength range.

➢The bids will be judged on their effectiveness, feasibility and estimated cost.

Atmospheric windows

➢The transmission windows of the atmosphere must be taken into consideration.

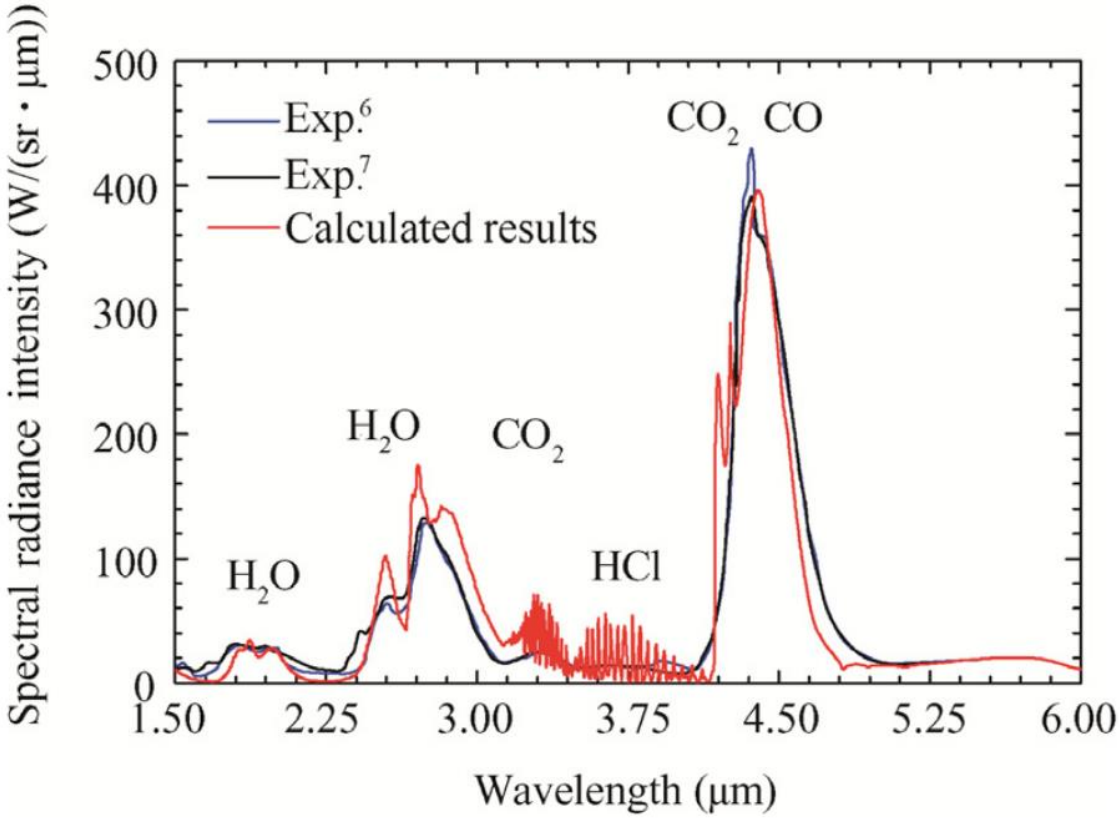
➢The VNIR, MIR and TIR windows are popular choices for Earth observation systems.



Spectrum of rocket exhaust

➢The IR signature from rocket motor exhaust plumes is closely related to motor type, propellant composition, burn time, rocket geometry, chamber parameters and flight conditions. [NIU, et. al. 2016]

➢Spectral information can potentially be used to distinguish motor exhaust from other IR sources.



LEO versus GEO

➢Low Earth Orbit (LEO) - an orbit less than 2,000 km

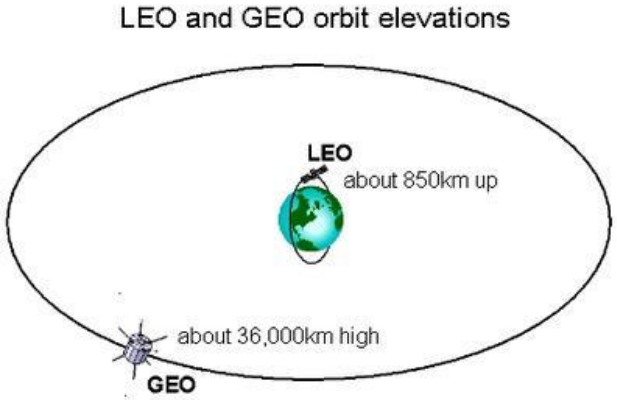
➢The satellite will orbit at 800 kilometers above the Earth's surface making 15 orbits per day and will have the ability to steer +/- 40°

•Assuming this, a single satellite could image the same location every 1.5 days at a latitude of 40°.

➢Launch cost around 2700 $/kg

➢Geosynchronous Equatorial Orbit (GEO) - a 35,786 km orbit above a constant ground location.

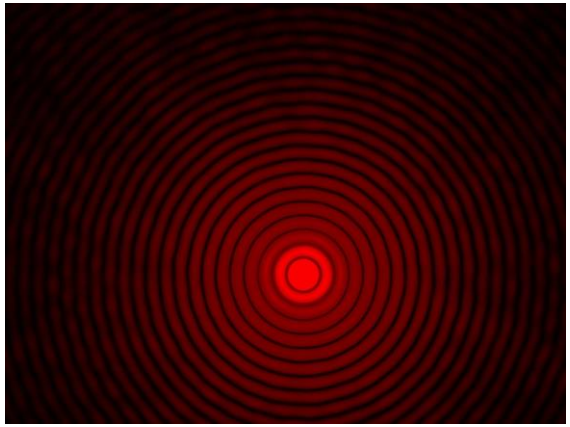
➢Launch cost around 7500 $/kg



Some useful equations

➢Your maximum angular resolution is limited by the size of your aperture. Because of the atmosphere, it is not possible to get below 1-2 arc second resolution.

$$\theta \approx 1.22 \frac{\lambda}{d}$$



➢Wien's displacement law can be used to estimate the peak emission wavelength, while Planck's law can be used to estimate the intensity.

$$\lambda_{\text{peak}} = \frac{b}{T}$$

$$B(\nu, T) = \frac{2h\nu^3}{c^2} \frac{1}{e^{\frac{h\nu}{k_B T}} - 1}$$

Brain storm

➢Some things to consider

- Specify the orbit(s) of your detection system and how many satellites it is composed of
- Consider the aperture size and estimated size of your satellites
- What is the revisit time of your observation system considering that North Korea is about 500km across?
- What wavelength range will you be sensing in?
- Will your satellite(s) have multi / hyperspectral imaging capabilities?
- What image processing techniques will you use?
- How affordable is your solutions?

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measurement systems

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