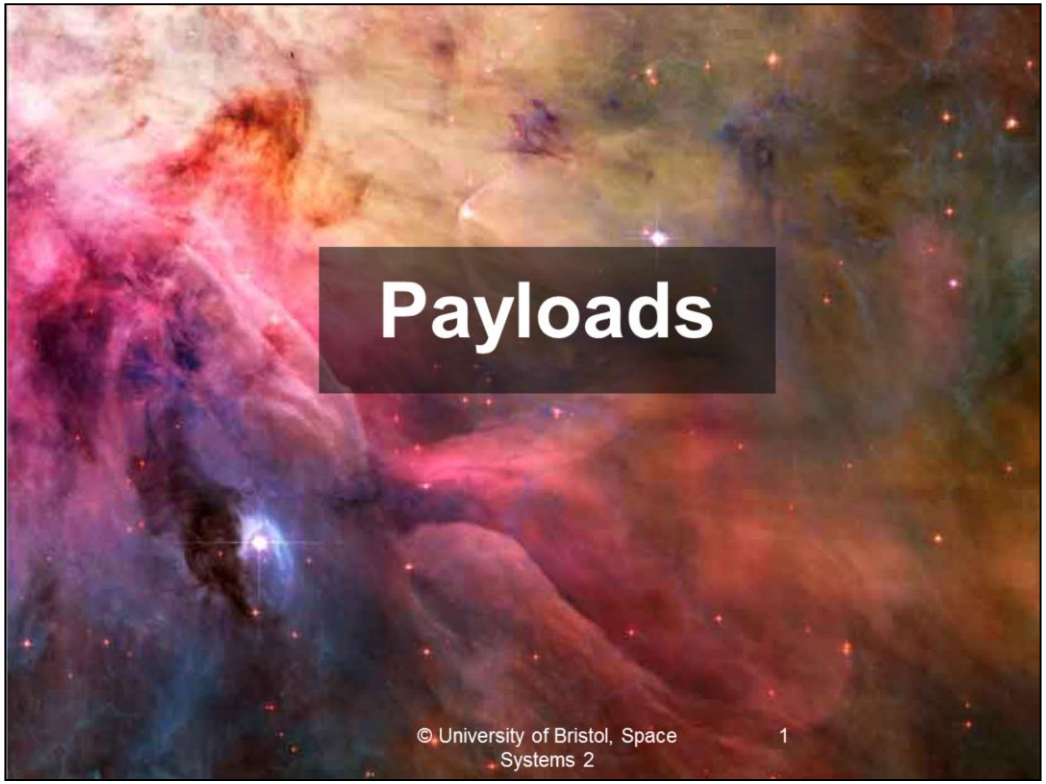
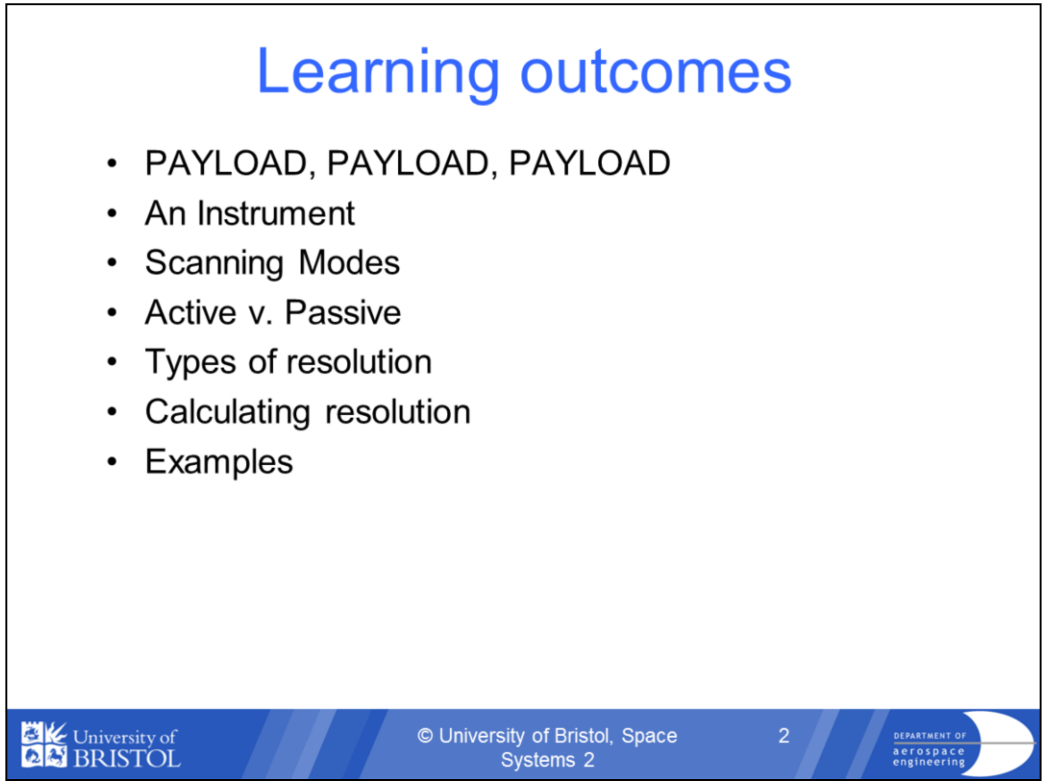


The notes below the slides are to give you an idea of what has been said in the lecture.

Background reading: Chapter 9 in ‘Space Mission Analysis and Design’ (or SMAD), 3rd Edition, J.R. Wertz and W.J. Larson, 1999. Pub. Kluwer. covers payloads well.



Learning Objectives

Know that the payload drives mission

Describe building blocks of a generic instrument

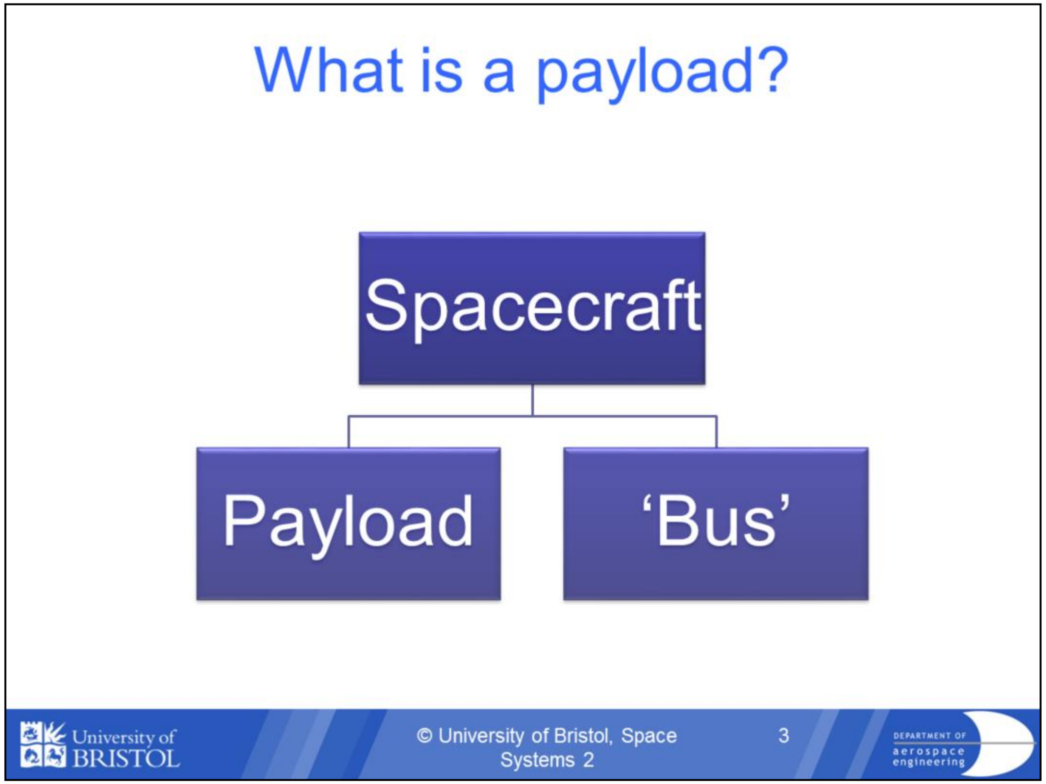
Describe difference between scanning modes

Explain active and passive sensors

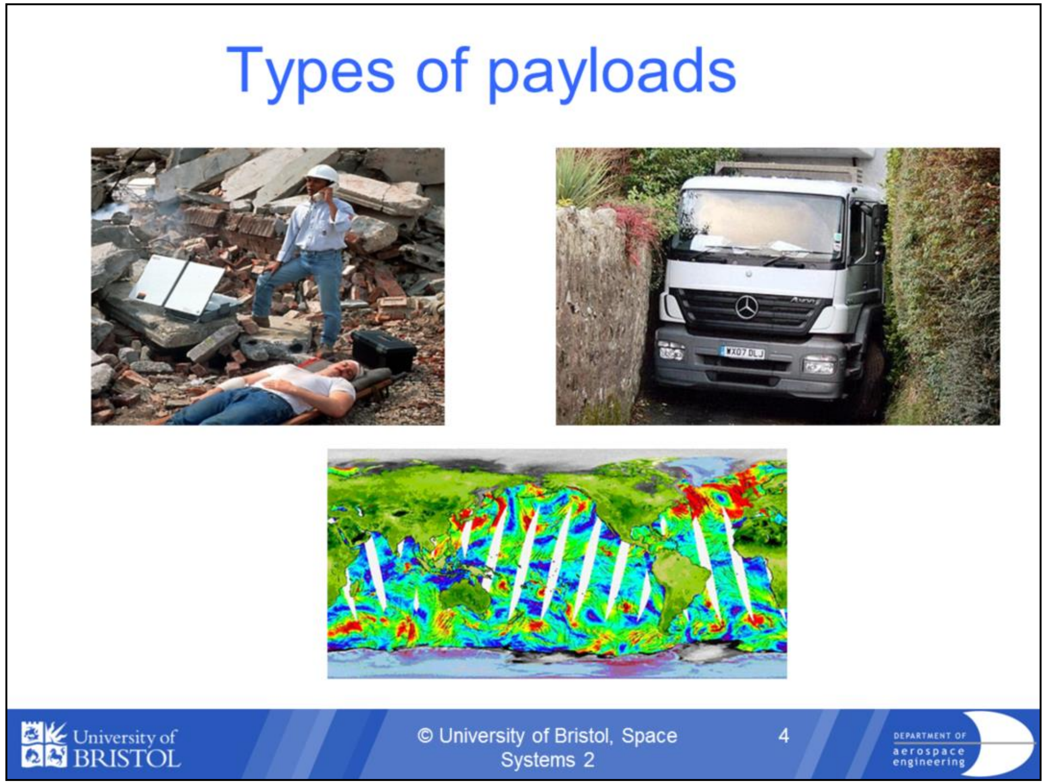
Explain different types of resolution

Be able to calculate spatial and angular resolution

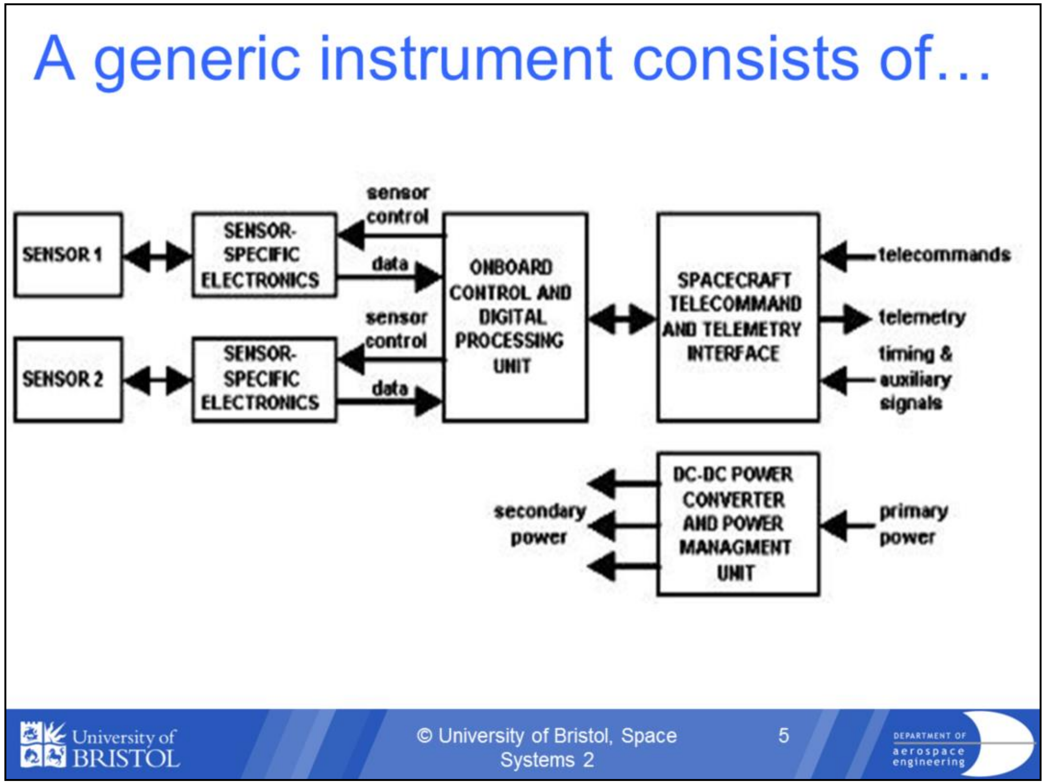
Have a basic understanding of some example payloads (but not detailed)



The payload is the part that fulfils the space mission. In some cases it is called an instrument. Often payload is built and operated separately from the spacecraft bus. Eg: Space telescope time is controlled by astronomers but the spacecraft is usually operated elsewhere from a mission control station. Sometimes several payloads will meet the demands of one mission eg: a mission to detect forest fires could use several types of sensor. If this is the case, the payload will be selected on by performance, cost, risk, mass and size, power, operability, past history. Payload is THE most significant driver of satellite design.



The list of types of payload includes: navigation, earth observation, science, telecommunications, outreach, military, crewed missions and commercial tourism.



A generic instrument consists of the following elements:

One or more sensors or detectors.

An electronics unit/s associated with the sensors which transform the basic physical parameters to be measured (e.g. magnetic fields, particle fluxes/energies etc.) into electrical signals.

An onboard control and data processing unit.

Spacecraft interface

[If nec: power converter unit to convert spacecraft voltage]

Instrument performance

1. *Storage/transmission of data*
2. *Sensitivity or signal/noise*
3. Spectral band
4. Swath width
5. Field of view
6. Coverage
7. Scanning modes
8. Resolution

Storage/transmission of data (memory and link budget for orbit)

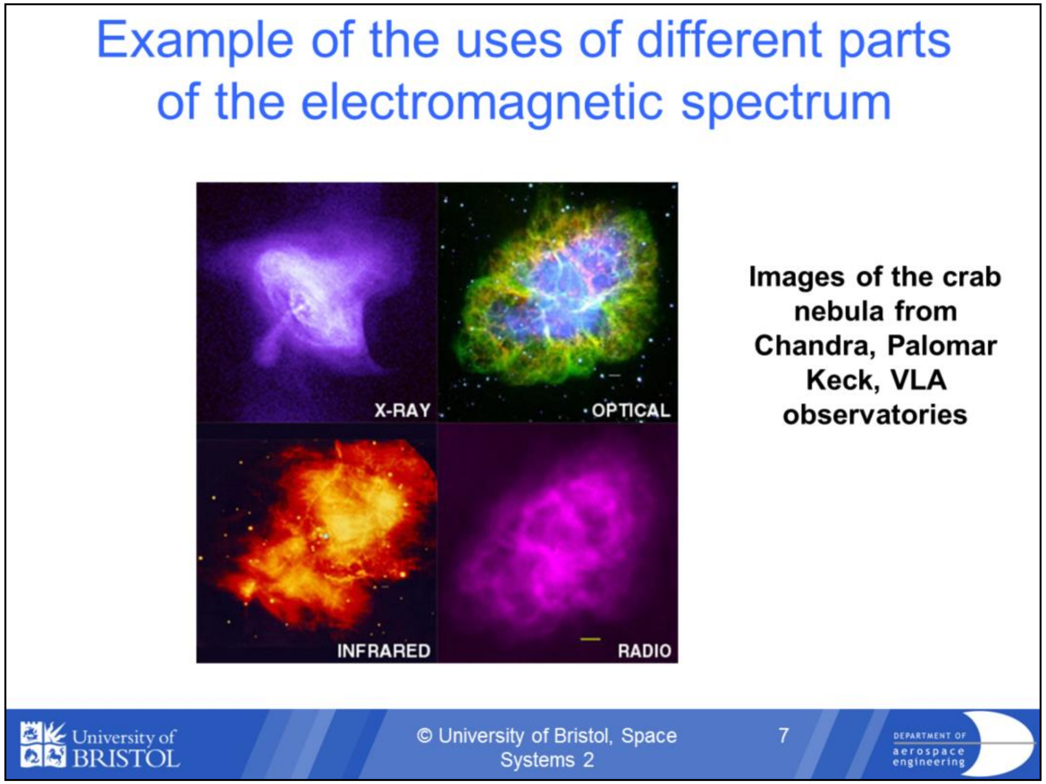
Sensitivity or signal/noise (detector, temp, aperture, link, dwell time, focal length) 5dB

You are probably familiar with the first 2 and the last.

Spectral band (aperture, detector, cooling)

Swath is the path that the sensor looks at on the ground. It is determined by the height of the orbit and the sensor field of view.

Coverage (orbit, pointing and scanning modes)



Spectral band just means the part of the electromagnetic spectrum that the instrument is using (if it is using em spectrum at all). For example here are 4 pics using different part of the spectrum:

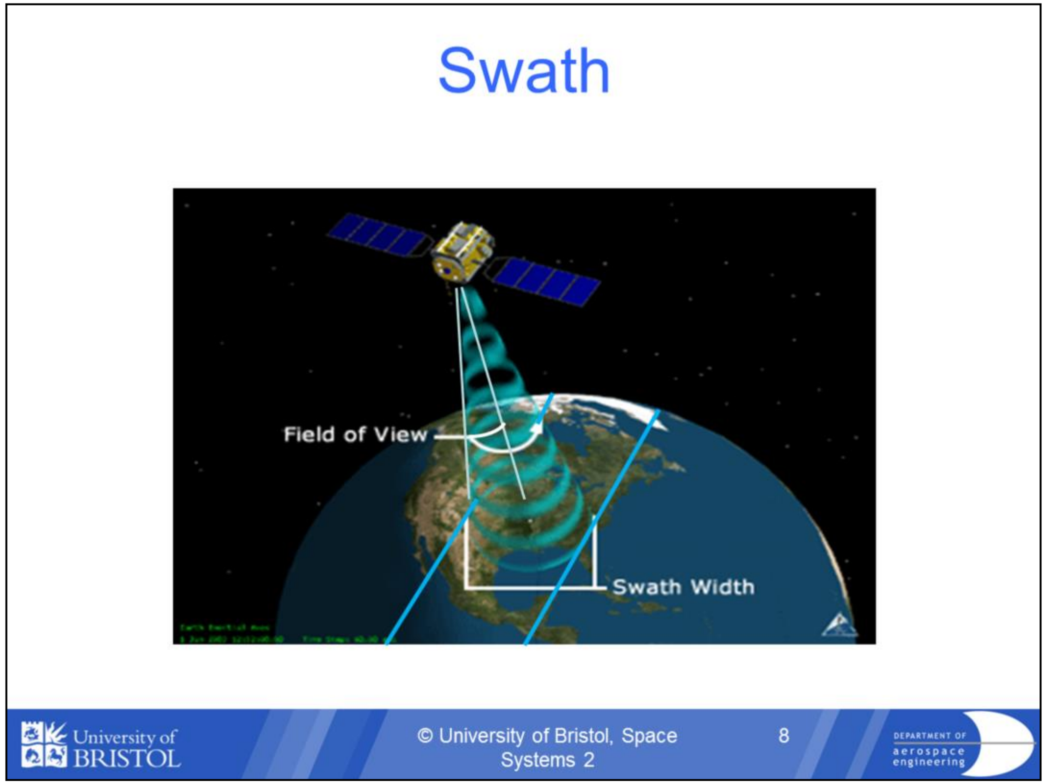
Xrays show Pulsar (rapidly rotating neutron star) in middle of nebula spewing out perpendicular jet of matter and anti-matter particles

Infra Red shows ‘wisps’

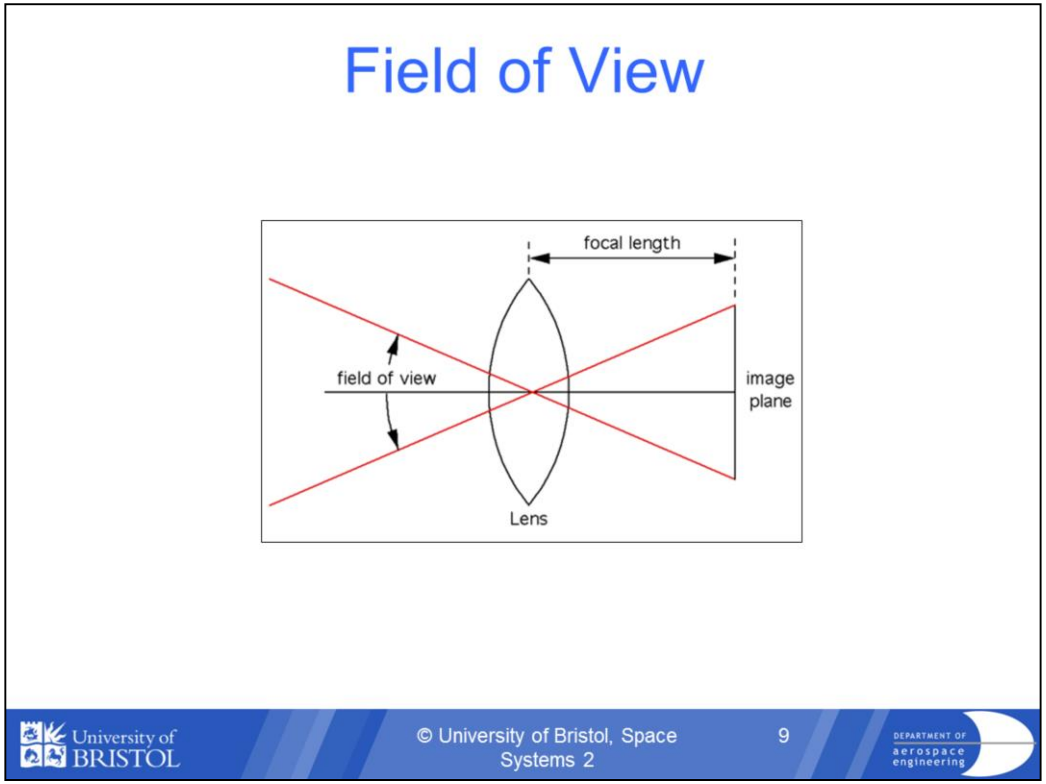
Visible shows remnants of star at outer edges (orange bits), blue bits are high energy particles

Radio shows high energy particles expanding out away from point

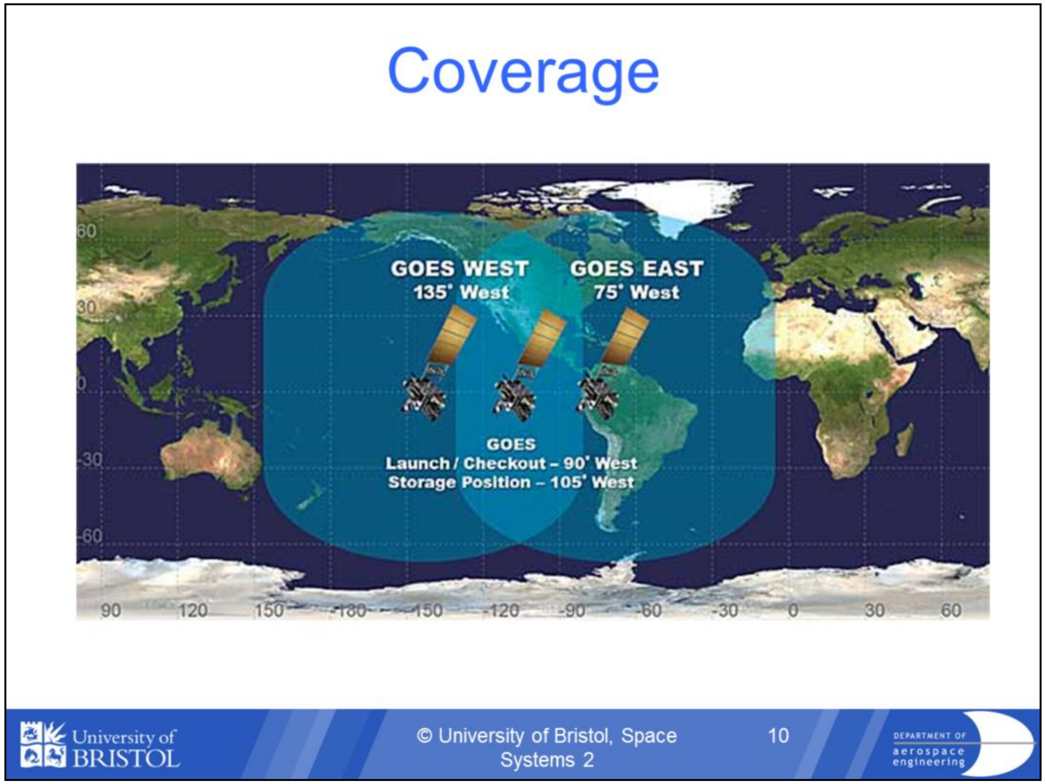
All together tell us: a superdense neutron star is energizing the expanding Nebula by spewing out magnetic fields and a blizzard of extremely high-energy particles



Swath is the path that the sensor looks at on the ground. It’s width is determined by the height of the orbit and the sensor field of view.

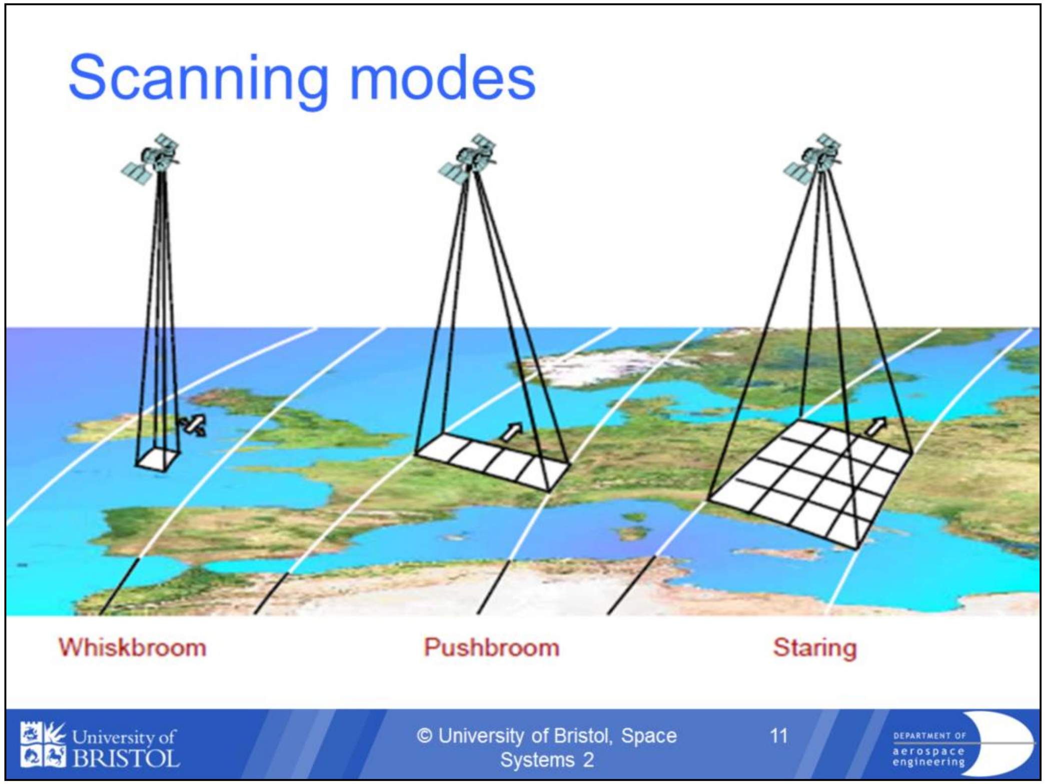


The field of view (also field of vision, abbreviated FOV) is the extent of the observable world that is seen at any given moment. Usually measured in degrees (eg: 25x12 deg), radians, arcminutes or arcsec. FoV is defined by focal length and detector size (large detector means large FoV, long focal length means small FoV)



Coverage means what parts of the Earth can the satellite communicate with or observe.

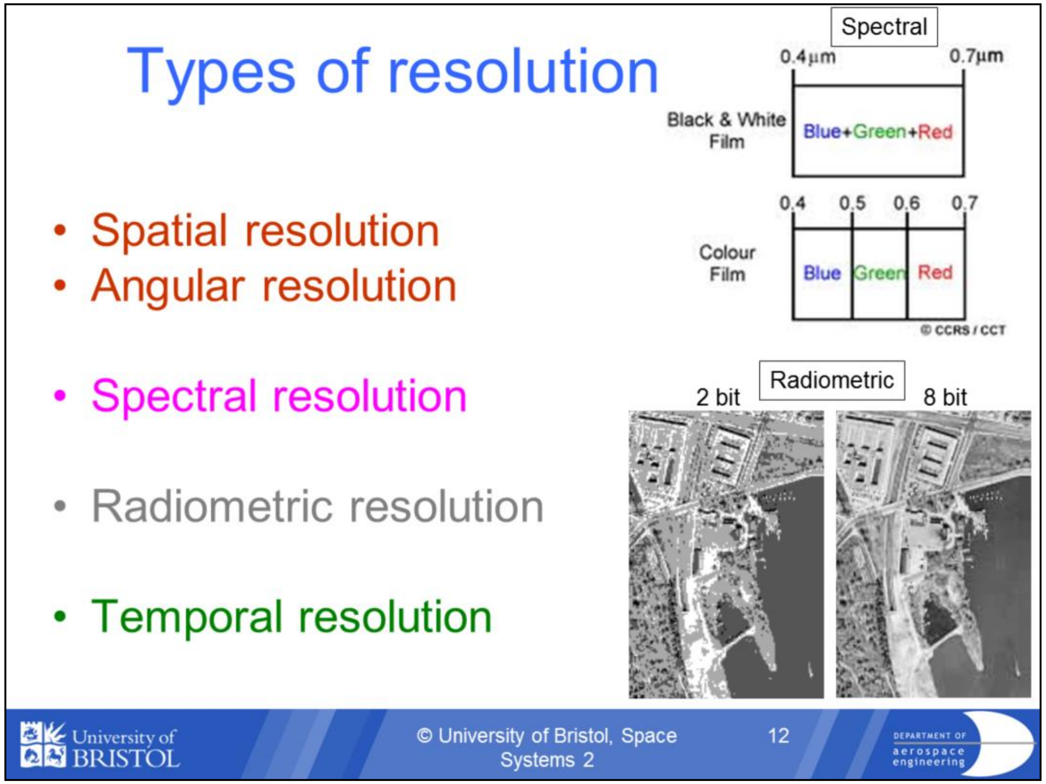
Example: Geostationary Operational Environmental Satellites (GOES) provide continuous imagery and data on atmospheric conditions and solar activity (space weather) from Geostationary orbit. This allows them to remain in a fixed position in the sky, stationary with respect to a point on the ground. GOES East is located at 75° W and provides most of the U.S. weather information. GOES West is located at 135°W over the Pacific Ocean.



Whiskbroom – uses rotating mirrors to sweep from side to side across the track and reflect image on to one detector. They are simple but have mechanical (moving) parts which is not a good idea in a vacuum. Dwell time is limited.

Pushbroom – uses a line of CCD detectors. These offer more dwell time, but have narrow field of view.

Staring – uses a 2D array and offers even more dwell time for fast frame rates. However, they are computationally intensive.

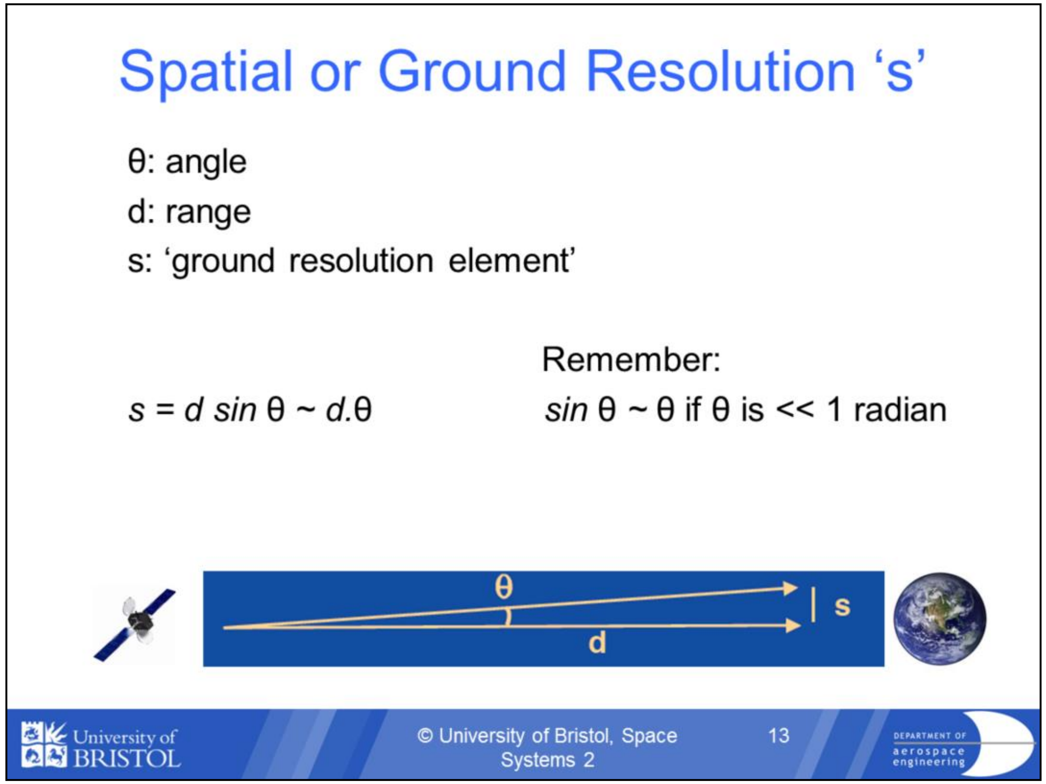


Spatial resolution of the sensor refers to the size of the smallest possible feature that can be detected, it depends on the Instantaneous Field of View (IFOV). Angular resolution we will cover next.

Spectral resolution describes the ability of a sensor to define fine wavelength intervals. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band.

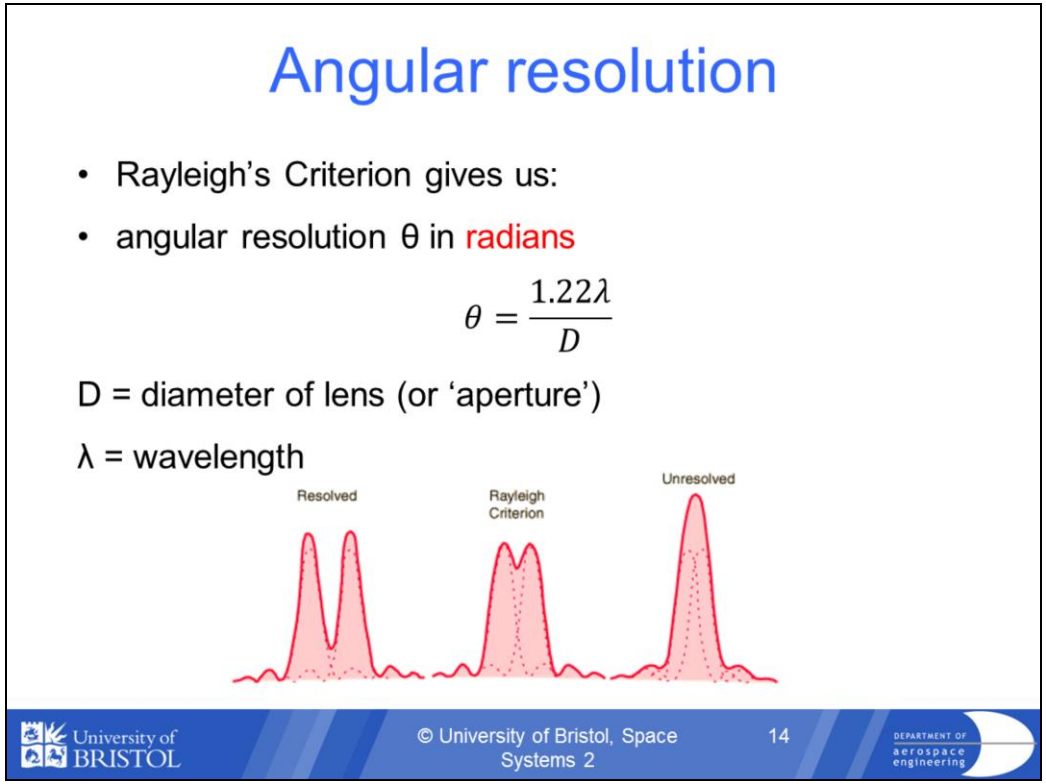
Radiometric resolution of an imaging system describes its ability to discriminate very slight differences in energy. The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in reflected or emitted energy.

Temporal resolution of a sensor is the revisit frequency (time it takes to return to the same view of the Earth).



The spatial resolution is the size of the pixel on the ground 's' or ground resolution. θ is required angle, d is range and s is size of object or 'ground resolution element'.

In remote sensing, one can use small angle approximations.



Do not confuse angular and spatial resolution. Spatial is measured at the target, whereas angular is measured at the lens.

Rayleigh's Criterion gives us angular resolution θ in radians.

D is diameter of lens, sometimes called 'aperture' and λ is wavelength.

Example

Using Rayleigh's Criterion, we can calculate the angular resolution of the human eye. Let's say in daytime the pupil size is 3 mm and its optimal sensitivity is 0.55 μm:

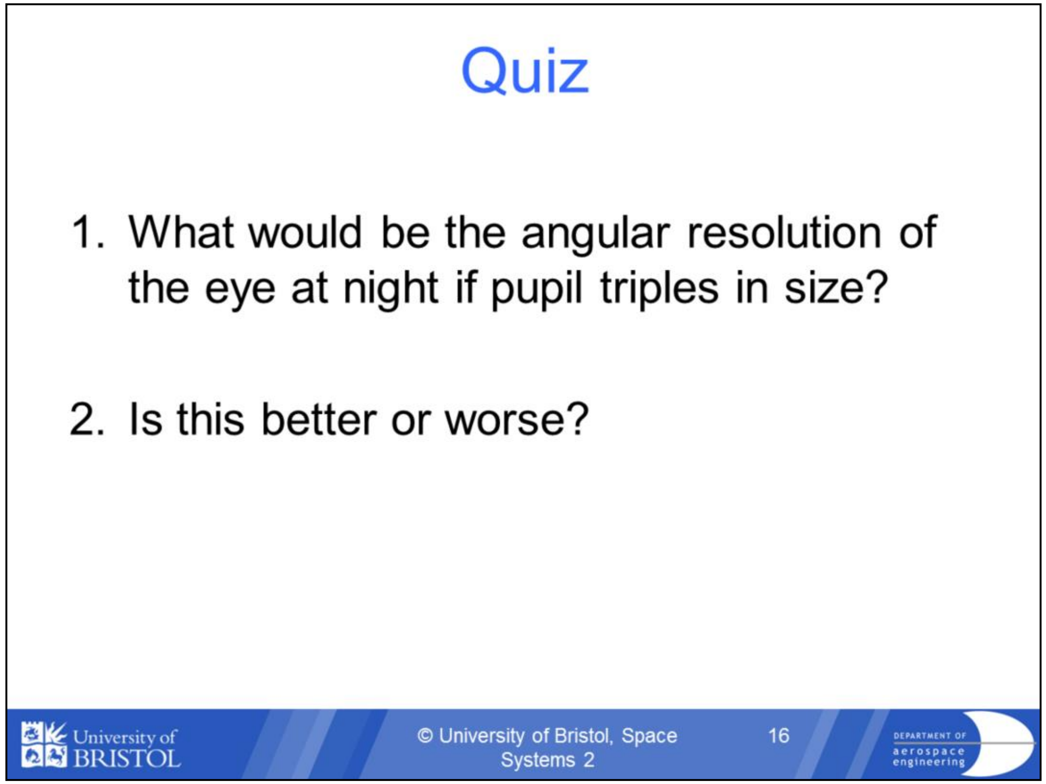
$$Angular\ resolution\ \theta = \frac{1.22\lambda}{D}$$

$= 1.22(0.55 \times 10^{-6}/3 \times 10^{-3})$

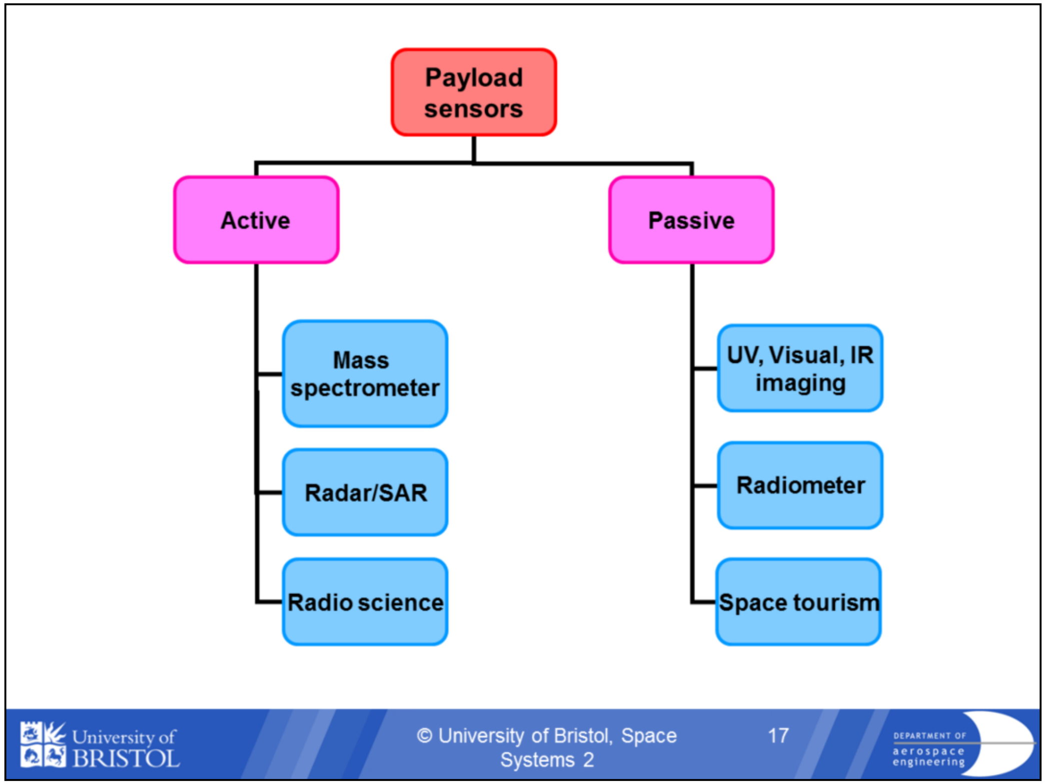
$= 2.24 \times 10^{-4}$ rad

= *46arcseconds*

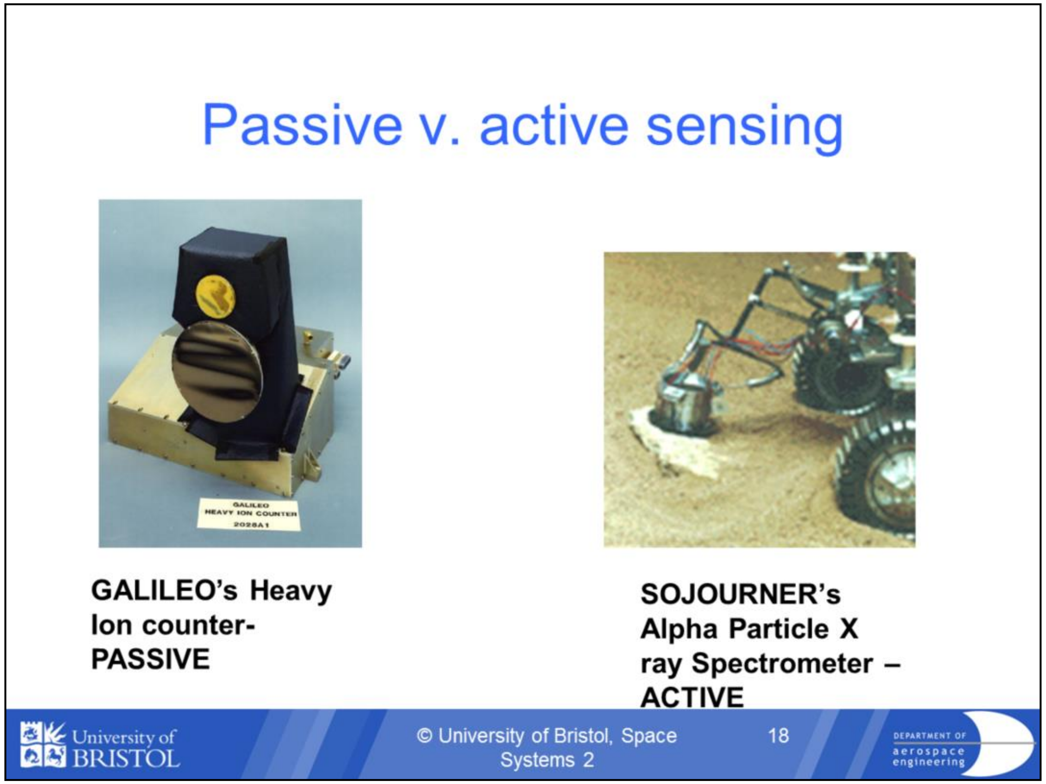
(convert to deg then x3600)



At night the angular resolution would be 2.24/3, this is better!



Passive sensors receive and process data only. Active sensors provide their own means of sensing the subject eg: radar generates radio waves which are sent to subject, sensors then receive reflections to create image or data to analyse.

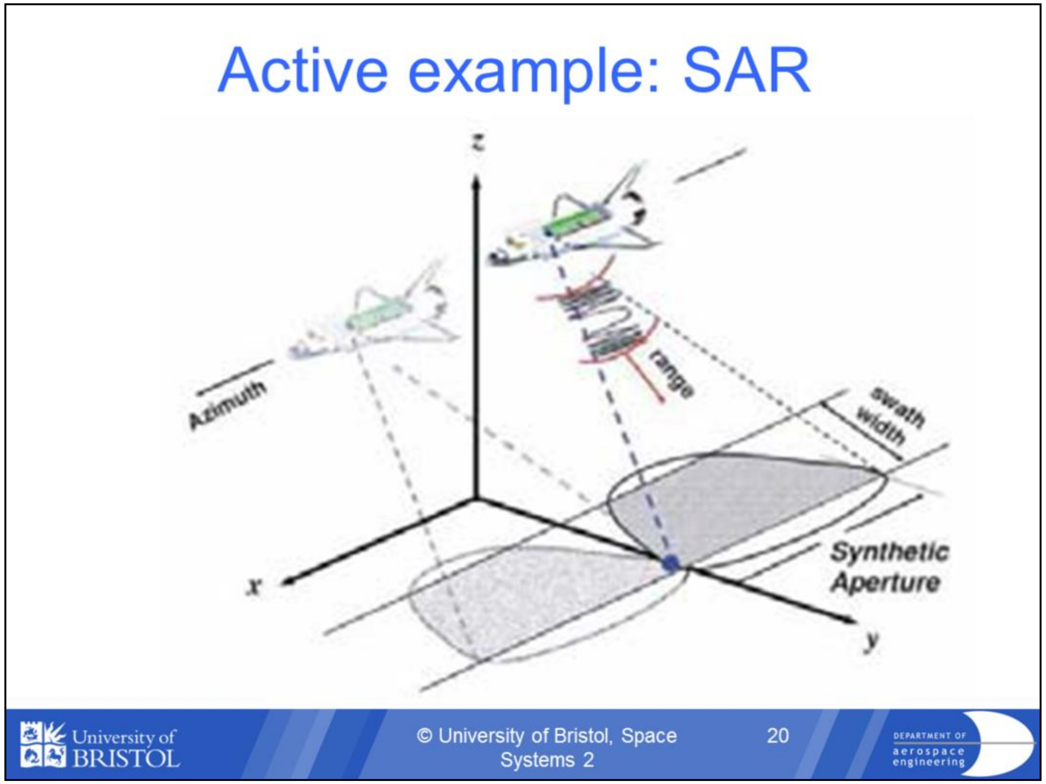


Sometimes we have a choice, we could detect aircraft passively with an IR sensor or actively with radar or by interrogating a transponder on the aircraft.

APXS – active sensor which sends out X ray and analyses reflected spectrometry to detect chemical element presence in rocks

Heavy Ion counter – passive sensor which monitors envt for energetic ions which could cause event upsets in the electronics.

Military requirements: availability (night and rapid reaction), safe operation, protection from enemy, minimum dependence on ground, power and data rates, cooling for IR imager.



A Synthetic Aperture Radar is a type of radar. Synthetic Aperture Radar imaging improves azimuth resolution by using the forward motion of the platform and special recording and processing of the backscattered echoes to simulate an antenna (aperture) kilometres in size. The satellite provides own radar signal to ‘illuminate’ scene. Radar is useful for night/all-weather imaging as it is not dependent on sunlight. SAR due to its greater aperture gives a high resolution image at night and in all weathers. BUT it is power hungry, large and heavy, data intensive and needs precision steering and knowledge.

Short revisit time (hrs), rapid response (10's hrs), up to 1m resolution, high geo-location accuracy <15m, interferometric (using multiple craft) and polarimetric (using polarisation) imaging -> 4 x 1900kg X-band SAR satellites in 620km orbits. BUT SAR is …

is large and heavy, is power hungry, is data intensive, needs precision knowledge of spacecraft's position and velocity and precision steering.

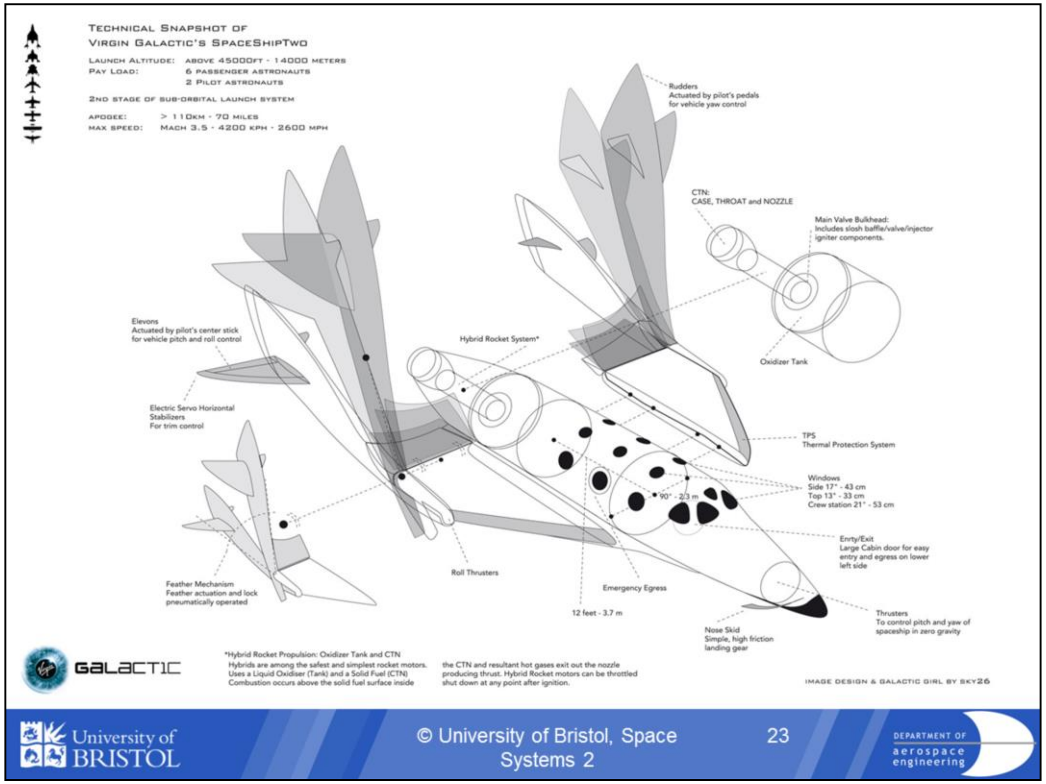
VG's WhiteKnight and SpaceShipTwo.

Requirements: to fly to 110km, 5mins zero-g, flight time 2.5hrs, shirtsleeve environment, 2 pilots and 6 passengers. Cost $200000.

Design features: Single hybrid rocket using solid fuel and liquid oxidiser,

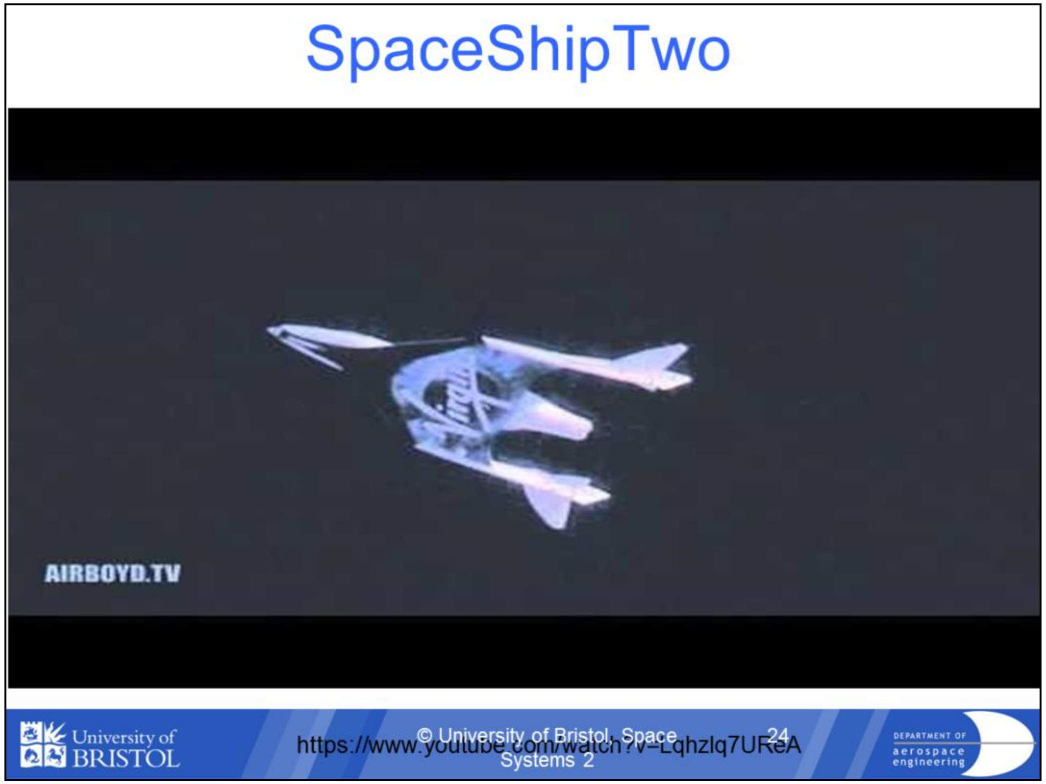
air-launched from carrier aircraft for safety

lightweight composite material construction with feathering wings to enable drag at higher altitudes so reduced thermal protection system is required.

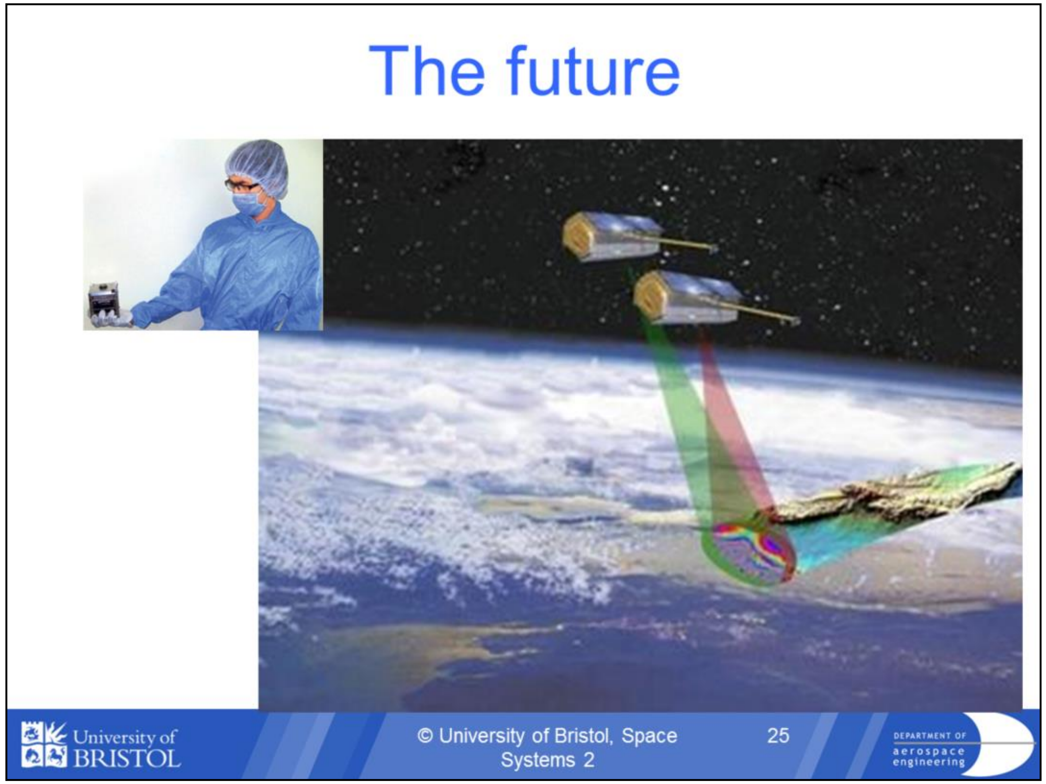


Space qualified Environment and Control Life Support System: oxygen, water, (food), CO_2, waste, pressure

Seat design for 7g on descent through chest (and not through head as for fighter pilots).



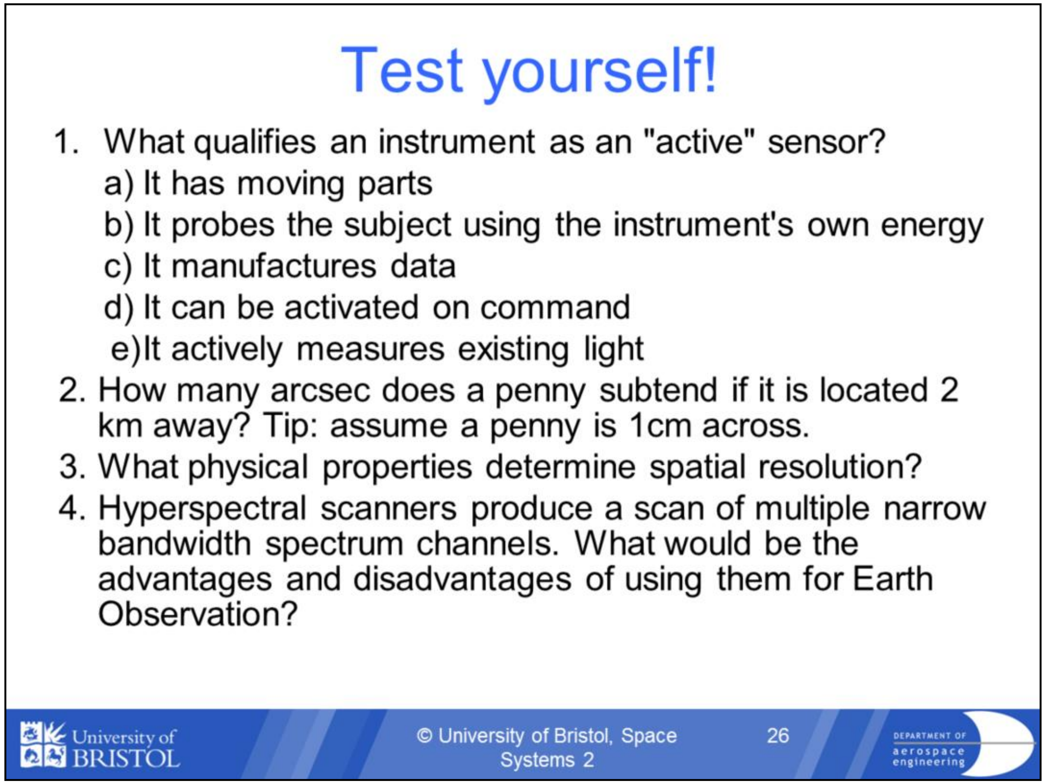
First feathered flight of Virgin Galactic’s SpaceShipTwo.



TerraSAR and TandemX doing interferometric SAR for Digital Elevation model

Studsat an indian picosatellite

Interferometry refers to a family of techniques in which electromagnetic waves are superimposed in order to extract information about the waves.



1. b)

2. theta=s/d=1cm/2km=0.5x(1e-5)rad=5microradian or 1arcsec

3. Orbit altitude, aperture and wavelength

4. By measuring radiation over several small wavelength ranges, we are able to effectively build up a continuous spectrum of the radiation detected for each pixel in an image. This allows for fine differentiation between targets based on detailed reflectance and absorption responses which are not detectable using the broad wavelength ranges of conventional multispectral scanners. However, with this increased sensitivity comes significant increases in the volume of data collected. This makes both storage and manipulation of the data, even in a computer environment, much more difficult. Analyzing

multiple images at one time or combining them, becomes cumbersome, and trying to identify and explain what each unique response represents in the "real world" is often difficult.

Summary

1. The payload drives mission
2. Payload Performance parameters include: Storage/transmission of data, Sensitivity or signal/noise, Spectral band, Swath width, Field of view, Coverage, Scanning modes, Resolution.
3. Scanning modes include Whiskbroom, Pushbroom and Staring
4. Passive sensors receive and process data only. Active sensors provide their own means of sensing the subject
5. Use Rayleigh’s criterion to calculate angular resolution.
6. Spatial resolution can be calculated from geometry

