SESA3041 and 6079

Problem sheet 1: Mission Selection, Payload Selection and Remote Sensing SOLUTIONS

1. Choose a current spacecraft in the NASA New Frontiers Program and explain how it meets the key Program objective.
   [5 marks]

The New Frontiers Program is focused on <u>targeted solar system exploration with the aim of improving our understanding of the origins of the solar system</u>. There have been three missions : New Horizons (visiting Pluto and other objects in the Kuiper Belt), Juno (visiting Jupiter) and OSIRIS-Rex (visiting asteroid Bennu). The National Academy of Sciences ranked the exploration of the Kuiper Belt of the highest priority for solar system exploration (see web page for New Horizons mission) because of the knowledge gained about the origins of the solar system. Jupiter has a profound influence on the solar system but its origin remains a mystery, so the goal of the Juno mission is to understand the origin and evolution of Jupiter, to look for solid planetary core, map the magnetic field, measure water and ammonia in the deep atmosphere and to observe the auroras (see web page for Juno mission). OSIRIS-Rex will travel to near-Earth Asteroid Bennu and return a sample for study.

2. Explain the function of a Mission Assessment Group in the selection of a mission for ESA's Earth Explorer Programme.
   [4 marks]

The Mission Assessment Group comprises independent experts from fields that are relevant to the programme. The experts are selected from a set of nominations. Their role is to assess the quality of mission proposals, in terms of the scientific objectives, requirements, and scientific support activities from industrial studies of the proposed missions (at phase 0), and to propose a short-list of candidate missions.

3. What are the differences between ESA's Earth Explorer Programme and ESA's Earth Watch Programme? Comment on how these differences might affect the types of mission and design of the spacecraft that are funded.
   [6 marks]

Earth Explorer is focused on science and research related to the Earth System and processes, especially in the context of climate change. Missions can collect robust, long-term climate relevant datasets and also demonstrate innovative remote sensing technologies. Earth Explore missions are categorised as "Core" or "Opportunity". Missions will likely be focused on a limited set of science challenges (e.g. GOCE = gravity field) and may utilise new technologies for sensing to achieve the mission (e.g. GOCE = low thrust propulsion, low altitude, to achieve "drag-free" flight). Earth Watch is focused on operational services for weather, natural hazards, etc. As such, missions will make use of instruments that provide continuity of data (i.e. deliver data that is compatible with older datasets) and will likely not demonstrate any innovative technology to ensure robustness of the service.

4. Identify four microwave remote sensing techniques that can be used by instruments on an Earth-orbiting satellite and explain the possible impacts of each instrument on the power and attitude control sub-systems.
   [8 marks]

Radar, Radiometer, Altimeter, Scatterometer and Synthetic Aperture Radar. All of these (except Radiometers) are active systems and have a high power requirement. Radiometers are passive instruments (detecting emitted microwave radiation – e.g. SMOS mission) and so have a relatively low power requirement. The instruments are high spatial resolution (except perhaps the Radiometer, which can be low spatial resolution) and need fine pointing control (e.g. reaction wheels)

5. Describe the operation of the main SIRAL instrument on the Cryosat-2 spacecraft and explain how the choice of this instrument led to the selection of the spacecraft's attitude sensors.
[9 marks]

- Radar pulses at 50 μs (satellite moves 250 m in this time)
- Image swath is 250 m
- Successive image strips can be superimposed and averaged (SAR mode)
- Star trackers are used to measure the orientation of the baseline (the line joining the two antennas)
- Two antennas receive radar echo simultaneously
- Difference in path length of radar wave is measured and used to provide the echo direction

The spacecraft requires accurate knowledge of the spacecraft position: it uses DORIS to measure the Doppler shift of signals broadcast from ground-based radio beacons, and short laser pulses fired from the ground at the satellite are reflected from its retro-reflector to measure the time interval – and hence position of the satellite. The DORIS and retro-reflector systems are mounted on the Earth-facing side of the spacecraft. Star trackers, looking in the cross-track direction, provide information that is used to determine the orientation of the baseline (the line joining the microwave transmitter and receiver). Both position and baseline-orientation are needed to determine the altitude of the satellite above the Earth's surface.

6. A satellite in a dawn dusk Sun-synchronous 720 km circular orbit is to be used to measure the extent and characteristics of ice extent over the poles. Propose a suitable payload for this orbit and application and give reasons for your choice.
[8 marks]

A dawn dusk orbit would be suitable for a payload that was not concerned about the sun illumination angle i.e. a microwave payload. A microwave payload would be ideal because it can observe the earth at all times and is unaffected by cloud. Possible microwave payloads can be active or passive
The synthetic aperture radar would be able to provide high resolution imagery that would be able to map the extent of the ice
An altimeter would be able to map the extent of ice if it was similar to Cryosat. This instrument would require additional instrumentation in order to track the orbit accurately. The sun-synchronous orbit is not ideal for this instrument.
A passive microwave radiometer would be able to measure the characteristics of the ice.

7. A satellite in a circular orbit at an altitude of 616 km uses a single waveband (panchromatic) instrument with a focal length f = 4 m to provide imagery of the Earth' surface. Images are built-up line-by-line using a push-broom scanning method, the instrument has a linear CCD sensor with N = 8000 pixels and an inter-detector spacing w = 13 μm. Each pixel is encoded using Q = 8 bits. Use the information above and formulae below:

   a. How many discrete Digital Numbers can be used to represent the reflectance of each pixel?
   b. What is the spatial resolution of the instrument in the cross track direction (defined by the Ground-projected Sample Interval)?
   c. What speed does the sub-satellite point travel over the Earth's surface?
   d. What is the approximate swath width of the instrument?

e. If the spatial resolution of the instrument in the in-track direction is the same as the spatial resolution in the cross-track direction, at what rate does the CCD array need to be sampled?
f. What is the uncompressed data rate of the instrument in bits per second?

[16 marks]

H	616000	m		
f	4	m		
w	1.30E-05	m		
Q	8	bits		
DN	**256**	**levels**	(a)	2 marks
GSI	**2.002**	**m**	(b)	2 marks
Vorb	7549.28521	m/s		
Vgd	**6884.378191**	**m/s**	(c)	4 marks
IFOV	0.000186211	deg.		
Npix	8000			
FOV	1.489690267	deg.		
Swath	**16016.9023**	**m**		
	16.0169023	km	(d)	4 marks
ts	**0.000290803**	**s**	(e)	2 marks
	0.290803315	ms		
Q	8			
data rate Q	**220080022.1**	**bits/sec**		
	220.0800221	Mbits/sec	(f)	2 marks