RELATIVE MERITS OF LOW-EARTH, ECCENTRIC, GEOSYNCHRONOUS, AND INTERPLANETARY ORBITS AND SITES IN SPACE

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1. Introduction

One criterium for the best orbit (or site) for an observatory has to be "that which is both scientifically and cost-effective". Perhaps the worst orbits are those offered by "infrastructures", which were not designed with astronomy as their primary driver, yet have to be used "because they are there". The ESA astronomy programme currently tends to favour highly eccentric or geostationary orbits (e.g. COS-B, IUE, EXOSAT, HIPPARCOS, ISO), as these appear to satisfy the above criterium. However, depending on the scientific mission to be accomplished and the availability of funds, other orbits are not ruled out priori.

2. Low Earth Orbits (LEO)

The obvious disadvantage is the proximity of the Earth:

- for typical pointed, narrow field-of-view telescopes, the Earth obscures (occults) celestial objects for up to 50% of a typical 90 minute orbital period, hence resulting in poor, on-target, observing efficiencies.
- the high heat input can reduce the longevity of expendable cryogenic systems.
- passage through the South Atlantic anomaly and the horns of the radiation belts can be detrimental to observations due to the particle background.

On the other hand, all-sky surveys can be conducted from low earth orbit, e.g. IRAS, COBE, ROSAT, while a O inclination orbit, below the belts, can give a very low cosmic-ray background as exploited by SAS II, in providing the first measurement of the cosmic gamma-ray diffuse background at about 100 MeV, and intended for SAX.

3. Highly Eccentric Orbits (HEO)

The obvious advantages of these orbits which may range from 24 hour (about 70,000 km apogee, ISO) to 96 hour (about 200,000 km, EXOSAT) or beyond, are that they:

- permit long, uninterrupted observations of celestial objects (as exemplified by EXOSAT, observations of eclipsing, dipping and bursting X-ray binaries);

Y. Kondo (ed.), Observatories in Earth Orbit and Beyond, 377–379.

– provide for the possibility of practically continuous contact through two ground stations (one if the orbital inclination is chosen correctly) allowing real-time, "observatory-like" operations;
– maximise observing time.

On the other hand, the satellite approaches the Earth once per orbit, traversing the radiation belts. At worst the belts are a major source of radiation damage to components or detectors, may require detectors to be switched-off temporarily or at least may raise background levels, reducing instrument sensitivity. When beyond the Earth's geomagnetic cavity, the satellite is, of course, exposed to solar flare radiation, which can, as in the case of EXOSAT, require that observations be interrupted. While the radiation belts and the magnetosphere are relatively well mapped to allow proper design of spacecraft and instruments, nonetheless, it may prove necessary to raise the perigee above the altitudes of peak intensity. For instance in the case of XMM, the perigee will be raised initially to $>$ 1000 km. Nevertheless the yearly dose rate in silicon with 4 mm equivalent of aluminium shielding is of the order of 15 krad.

4. Geostationary/geosynchronous orbits (GSO)

These are a special case of the HEO; the "classical" observatory in this orbit being IUE. It was also the orbit of choice for Hipparcos. The radiation belts by and large are avoided and a single ground station offers full 24 hour, real-time coverage. However, the particle background at 36,000 km is still too high for X-ray astronomy missions and not ideal for IR detectors (the reason ISO's HEO apogee was raised from about 36,000 to about 70,000 km).

5. Interplanetary orbits

With the exception of the occasional solar flare such orbits probably provide the most stable, unchanging environments for an observatory. ESA's SOHO solar observatory will be placed at the L1 Sun-Earth Lagrangian point.

6. Sites

The moon as a location for astronomical instruments has been discussed at this colloquium and indeed will be studied within ESA over the next year. The advantages for radio astronomy (on the far side) and interferometric arrays requiring large, stable structures at UV/optical/IR wavelengths are self-evident. However, a sizeable "infrastructure" is first required for some of the schemes put forward.

7. Launcher size/"delta V"

Generally speaking, the farther from the Earth the observatory has to be placed, the greater the increment in velocity (delta V) from low earth orbit required. Thus a bigger booster or additional motors are required with associated higher costs.

(Perhaps it should be noted here that the costs quoted for ESA's stand-alone scientific missions include launcher costs, which have to be paid from the Agency's Scientific Programme Budget.)

8. Spacecraft complexity and costs

Probably, observatories designed for low earth orbit are more complex, hence costly, than those for the other orbits considered here. For instance:

- on-board data storage is required for later play back via ground stations or data relay satellites.
- the power and thermal subsystems have to be designed (other than for sun-synchronous orbits) to cope with the sunlit and eclipse operations of comparable duration.
- the attitude control system may have to be designed to ensure that the instruments do not view the Earth, or cope with gravity gradient or magnetic torques.
- greater autonomy has to be built-in to maximise fail-safe protection for protracted periods outside real-time control possibilities.

As one moves progressively through the other orbits, the spacecraft complexity and hence cost ought to decrease.

9. Serviceability, man intervention and robotics

Observatories in low-earth orbit can, in principle, be serviced by man from space planes or space stations (or be returned to Earth and re-launched). However, the observatories would have to be designed for that (of course SMM was certainly one notable exception), and man has to be brought into orbit, kept alive and returned at the end of servicing as well as being trained for the servicing mission in the first place. Servicing, of course, perhaps in higher orbits, could also be done robotically.

However, returning to the introductory criterium of "scientific- and cost-effectiveness", taking all cost elements into account (as done in ESA and perhaps we owe that to the tax-payer), the real differences in scientific returns and costs for an observatory launched once and serviced/modified/upgraded n times and the launch of $n + 1$ observatories in an upgradable series should, for once, be determined.