COMMENT ON DISPOSAL OF RETIRED GEO COMMUNICATIONS SATELLITES for IB Docket No. 02-54

The FCC seeks comment (in sec. 35, p.16) on the relationship between economic incentives and the likelihood that FCC-licensed satellite systems will carry out debris-mitigation measures voluntarily.

For space stations in geostationary orbit, the FCC should consider economic incentives to insure proper end-of-life removal above the geostationary altitude. For example, operators might be required to make a "disposal altitude monetary deposit" (of at least $1,000,000 per spacecraft) to some agency [or into an interest-bearing escrow account??] before launch, to be refunded after space-station removal to the required orbit separation from the geostationary altitude. A pro-rated refund might be made if the orbit perigee were raised only part way to the minimum required separation.

Instead of using propellant for the end-of-life orbit raising, an operator might use that propellant for maneuver stationkeeping near end of life to extend the station's operational lifetime, and thereby produce extra revenue. To encourage proper orbit raising, the monetary deposit should be larger than the expected extra revenue.

To estimate this extra revenue, one first determines the amount of propellant required for the specified orbit raising. One then computes the additional number of months of operation obtained by using this propellant for attitude control and longitude stationkeeping. (North-south stationkeeping is not included in this estimate since the operator can always extend the lifetime by abandoning north-south stationkeeping and operating the spacecraft in an inclined GEO orbit [see FCC sec. 48, p.21].) Multiplying (this number of months) by (the expected revenue per month) gives the expected extra revenue; this gives a lower bound on the monetary deposit.

Another reason that an incentive is suggested is that removal from geostationary orbit is not a simple process; one does not simply send the command to the spacecraft to "raise the orbit by 300 km above the present orbit". One generally needs a series of commands whose execution must be properly spaced in time and occur near specified points in the orbit; the command sequence depends on spacecraft design idiosyncrasies and on the onboard equipment still operating at end-of-life. The maneuver planning and execution requires engineering expertise to overcome the practical obstacles that can arise, as listed below.

Reports concerning propellant reserves and end-of-life plans (as suggested in sec. 40, p.18 and sec. 55, p.24) are not sufficient to insure that the required orbit altitude separation will be achieved, either because proper maneuver procedures are not actually followed or because of unforeseen emergencies (explained below).

1) The good intentions of the satellite system proposers and initial operators are not being questioned here. Problems may arise from the operational longevity (10-15 years or more) of space stations. During that time the original managers and knowledgeable spacecraft engineers may die or retire, so the required expertise is not at hand at end-of-life. Or the original operator may suffer bankruptcy, or the space assets may have been sold to another organization for other reasons, so the spacecraft operator at end-of-life may not be aware of the original orbit-raising commitment or plans or expertise required. A financial incentive could serve as a reminder to the new owners about end-of-life obligations.

2) Expert spacecraft engineers familiar with the idiosyncrasies of the space station need to be involved at the end-of-life orbit raising because this is a more complex maneuver process than employed for routine stationkeeping. The planning may be further complicated

a) by the long series of thruster pulses that must be used, which may required that thruster overheating be monitored,

b) by previous failure of one or more attitude sensors so that proper thrust direction is more difficult to plan and achieve, and

c) by previous failure of the thruster originally envisioned to be used for the maneuver.

3) The just listed equipment failures may leave the spacecraft in a stable state which allows leisurely planning of an alternate orbit-raising procedure. But oftentimes alternate orbit-raising operations must be undertaken in emergency conditions because of a sudden space-station equipment failure (such as a failure of the automatic attitude-control system) which makes routine station operation impossible or requires a high rate of propellant use for attitude control. Orbit-raising planning and execution must then occur in a short time frame, before the required orbit-raising propellant is exhausted by attitude control. A financial incentive could insure that an operator facing financial difficulty (such as bankruptcy) retains knowledgeable experts capable of planning and directing such unscheduled disposal operations.

4) Voluntary removal from geostationary orbit may not occur if an operator has an overworked engineering staff. The engineers may avoid the required orbit-removal planning in favor of solving other pressing problems. Interrupting their work in order to produce a proper orbit-removal plan (based on end-of-life exigencies) may not be viewed as advancing an engineer's career with the company. If there is sufficient economic incentive for removal, management will more likely assign proper priority to the removal operation.

5) An economic incentive to remove the station to a specified minimum distance above geostationary altitude guards against the human tendency of the personnel who actually operate and monitor the station to cut short a long, tedious operation. When one is tired or handling an unscheduled operation, one is more likely to treat the collision hazard as an unlikely event and wonder "what real difference does achieving the required minimum distance make"?

For example, if a small thruster must be used for the orbit raising, or if ordinary propellant has been depleted so that pressurant gas from the propellant tanks must be used for thrusting (so the thruster is used as a "cold gas jet"), thruster firing must occur over a long time. In addition, orbit raising requires thrusting on diametrically opposite sides of the spacecraft orbit; since the geostationary orbit period is 24 hours (in inertial space), the two (or more) sets of thruster firings occur at times of day approximately 12 hours different. Thus at least one set of such thruster firings will occur at an inconvenient time of day, outside of normal business hours. The operations personnel may be tempted to make an early termination of the required long series of thruster firings, especially for the series at the inconvenient time, in order to shorten a special operation so they can go home.

The following ground-based problem should also be considered:

6) The FCC should require that the satellite operator procure and maintain spacecraft system documentation that explains the spacecraft idiosyncrasies and end-of-life maneuver procedures. This documentation needs to be

- a) readily available and readable through end-of-life,
- b) up-to-date (including reports of all operational anomalies), and
- c) comprehensive.

A paper copy of this documentation should be required. If the operator maintains a "paperless office", the required documentation would exist only in computer-machine-readable form; but because of changing technology during the ~15 year lifetime, there may be no operating devices capable of reading the electronic storage medium, or document formats may have changed so that currently maintained software is unable to read the documents. Paper copies are not subject to these problems.