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LAUNCH WINDOW FOR ARIANE THIRD STAGES ON GEOSTATIONARY TRANSFER ORBIT

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ABSTRACT

Spent launcher's upper stages, used to inject a geostationary satellite and its apogee boost motor into transfer orbit, can stay quite a long time (up to several thousands of years) in transfer orbit. They create a collision hazard with geostationary or low Earth orbiting satellites.

Lifetime in transfer orbit depends on the initial perigee height and on the Sun and Moon configuration at launch. In order not to have excessive orbital lifetime, a low initial perigee height is recommended. Furthermore, it is proposed to launch under conditions where the orbit is unstable, namely when the perigee height decreases due to luni-solar perturbations.

1. ARIANE THIRD STAGES ON GTO

The Geostationary Transfer Orbit is used as an intermediate orbit for carrying a satellite from the near-Earth environment to the geostationary ring. Most of the launchers are not able to provide the GTO apogee boost for circularization on the geostationary orbit and a dedicated motor, attached to the payload, is used for that purpose. This means that the launcher's upper stage stays on GTO. This is the case for all ARIANE launches of geostationary payloads.

ARIANE third stages are rather large objects (more than 11 m long and 2.6 m diameter, see Ref. 1), which are constantly moving along their GTO from low altitude regions up to the geostationary ring, creating a collision hazard in those regions. At the present time (March 1993), 35 ARIANE third stages are orbiting on GTO.

The question now is: how can the crowding of GTO by spent upper stages be controlled ?

2. PERTURBATIONS ON GTO

The critical parameter for lifetime estimation on highly eccentric orbits is the perigee height. Should it raise and long lifetimes are expected, should it decrease and the Earth atmosphere will burn the satellite. A discussion on the effect of perturbations on the perigee height for GTO can be found in Ref. 1. The main results are recalled here:

1. Third-body perturbation by the Sun induces a perigee height oscillation of at most ± 75 km amplitude and a period of less than a year.
2. Third-body perturbation by the Moon induces a small perigee height oscillation of a few km and a period of about a month.
3. Drag perturbation acts at perigee, therefore does not change perigee height but reduces apogee height. As a consequence, third-body effects become less pronounced and orbital lifetime may possibly be extended !

3. LIFETIME OF GTO OBJECTS

As discussed in the preceding section, the combined effect of third-body and drag perturbations lead to rather unpredictable orbital behaviour. There is no analytical theory, which can handle simultaneously all main perturbations acting on a highly eccentric orbit. One has therefore to resort to semi-analytical computation, numerical simulation, or to observation of real objects.

Such simulation or observation shows that, indeed, lifetime of GTO objects can extend from one day to several thousands of years, depending mainly on the luni-solar configuration at launch. As an example, Table 1 shows a list of ARIANE third stages launched on GTO in 1989 with the corresponding actual or predicted lifetime.

4. LAUNCH WINDOW FOR ARIANE GTO

Power and thermal satellite design result in constraints on the maximum eclipse duration and on the orienta-

COSPAR	AR-Type	Flight No.	Payloads	Launch Date	Apogee	Perigee	Incl.	Lifetime
1989-006B	AR-2	V28	Intelsat V F15	89-01-27	35776	501	7.99	5000
1989-020C	AR-44LP	V29	MET-4 + JC-Sat-1	89-03-06	36251	200	7.28	3
1989-027B	AR-2	V30	Tele-X	89-04-02	35993	174	3.63	15
1989-041C	AR-4	V31	Kopernicus-1 + Superbird-A	89-06-05	35857	215	6.74	7
1989-053B	AR-3	V32	Olympus	89-07-12	36208	235	6.14	5
1989-062C	AR-44LP	V33	Hipparcos	89-08-08	35961	355	7.18	500
1989-087B	AR-44L	V34	Intelsat-VI-F2	89-10-27	35799	304	7.07	300

Table 1. List of 1989 ARIANE GTO launches. Apogee and perigee heights are in km, inclination in degrees and lifetimes in years.

tion of the satellite relative to the Sun direction during manoeuvres.

Such constraints impose seasonal and daily launch windows, as it is well known for geostationary missions. For ARIANE dual launches, in order to prevent conflicts between the constraints on both passengers, a standard launch window is imposed (see Ref. 2, page 5.26).

For satellites, which operational orbit is highly eccentric (this is the case for some scientific satellites such as EXOSAT or ISO), orbital stability is an essential constraint: during the satellite's operational lifetime, the perigee height should not decrease below a certain value, otherwise the satellite would burn into the atmosphere.

A possible way to prevent ARIANE third stages of having too long lifetime on GTO is to inject them on *unstable* orbits, whose perigee height decreases in a relatively short time.

To illustrate the application of such a constraint, a GTO launch window for the year 1989 was calculated. The initial state was borrowed from injection parameters of object 1989-20C, third stage of ARIANE launch V29 of Meteosat-4 and JC-Sat-1 on 1989 March 6 at 23h31:

Perigee height:	200 km
Apogee height:	36251 km
Inclination:	7.28°
Argument of perigee:	180°

These initial elements are very close to the standard ARIANE GTO elements as given in Ref. 2. For a grid of launch dates covering year 1989 and a grid of launch hours between 22h00 and 3h00 (for having a continuous scale in hours on the graphical representation (Fig. 1), morning hours are labelled 26h00, 27h00, ...), the orbit was propagated along 10 years with a semi-analytic method (the *stroboscopic method,* see Ref. 1) including third-body perturbations by Sun and Moon, atmospheric drag and Earth oblateness. The ballistic coefficient of the ARIANE third stage was scaled in such a way as to result in the observed orbital lifetime for the propagation under the launch condition of 1989-20C.

Level-lines on Fig. 1 delimit regions where orbital lifetime is shorter than 3500, 2500 or 1500 days. Regions where orbital lifetime is longer than about 10 years (3500 days limit) are shaded with + symbols.

The standard ARIANE 4 dual launch window as defined in Ref. 2 is also indicated on Fig. 1.

Other 1989 launches mentioned in Table 1, whose initial perigee height are not too different from the standard one (200 km) are also indicated (dual launch of 1989-41C just at the opening of the standard ARIANE 4 launch window, and single launches of 1989-27B and 1989-53B). Due to discrepancies with the standard ARIANE 4 GTO initial elements, the corresponding computed lifetimes are not exactly matching the actual lifetimes listed on Table 1.

Other 1989 ARIANE GTO launches have their initial perigee height at 300 km or higher. The corresponding launch window would show nothing else than a region covered with + symbols: whatever is the launch date and time, orbital lifetime is longer than 10 years for such high initial perigee height.

5. CONCLUSION

Due to the combined effect of third-body and drag perturbation on GTO, orbital lifetimes can extend from one day to several thousands of years, depending on the initial perigee height and the configuration of Sun and Moon at launch.

In order to prevent ARIANE 4 third stages to stay excessively long time on GTO, creating a possible collision hazard with geostationary and low Earth orbiting satellites, the initial perigee height should be chosen as low as possible, preferably in the 200 km range. Furthermore, a constraint on orbital instability, preventing injection into stable orbits which lifetime is higher than a few years, should be added to the usual launch window constraints.

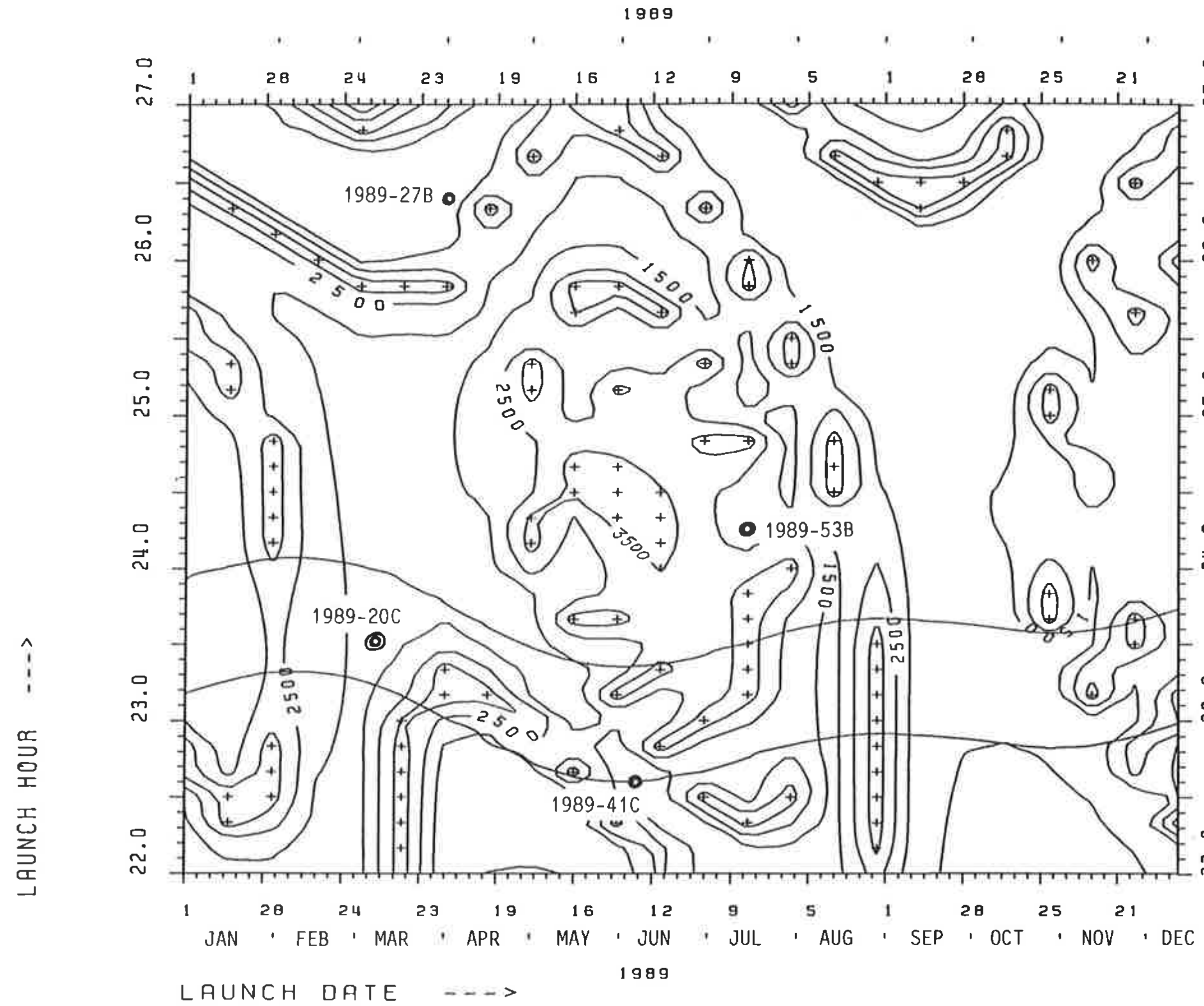

Fig. 1. 1989 launch window for standard ARIANE GTO elements. Level-lines enclose area where the orbital lifetime is longer than the level label. Regions with lifetime longer than about 10 years (3500 days level) are shaded with + symbols. The standard ARIANE GTO dual launch window is also shown. Along the date axis, tick mark intervals span 4.5 days.

6. REFERENCES

1. Janin G., Lifetime of Objects in Geostationary Transfer Orbit, *Internat. Workshop on Salyut-7/Kosmos-1686 Re-entry*, ESOC, Darmstadt, 1991 April 9, *ESA SP-345*, Aug. 1991.

2. ARIANE 4 User's Manual, *Arianespace*, Evry, April 1983.