# EVIDENCE FOR HISTORICAL SATELLITE FRAGMENTATIONS IN AND NEAR THE GEOSYNCHRONOUS REGIME

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**ABSTRACT**

Satellite fragmentations are well known to be the principal source of debris larger than 1 cm in low Earth orbit (LEO). Since 1963, over 500 missions have placed more than 830 spacecraft and upper stages in or near the geosynchronous (GEO) regime. If the historical non-GEO breakup rate for other than deliberate or aerodynamic causes is applied to GEO, then as many as 15 breakups might be expected near GEO. Some space surveillance specialists have interpreted specific GEO satellite orbital perturbations as evidence for collisions or explosions for up to two dozen GEO satellites. Moreover, recent searches for small (20-100 cm diameter) objects near GEO have been undertaken in the US and Europe, and preliminary results suggest a significant small debris population. However, to date only two GEO regime breakups have been identified with confidence.

This paper summarizes a study of potential indicators of GEO satellite breakups and a review of the two known GEO breakups and of satellites which have been the subject of breakup speculation. Recent GEO debris observations have not revealed obvious breakup clouds which would support these hypotheses. Although some of the detected debris may be of breakup origin, some debris might well have originated from non-fragmentation sources. A LEO non-fragmentation analog might explain some of the observed orbital perturbations in GEO.

## 1. INTRODUCTION

Recent searches for orbital debris at geosynchronous (GEO) altitudes by both NASA and ESA, in support of action items of the Inter-Agency Space Debris Coordination Committee (IADC), have revealed a significant population of uncataloged objects as small as 20 cm in diameter [1], [2]. One potential source of these debris is the breakup of spacecraft and launch vehicle upper stages in or near GEO. Satellite fragmentations are well known to be the principal source of debris larger than 1 cm in low Earth orbit (LEO). More than 50% of all tracked objects in Earth orbit are assessed to have originated in satellite explosions. If the historic non-aerodynamic causes is applied to GEO, than as many as 15 breakups might be expected to have occurred near GEO in the aftermath of over 500 missions which have placed more than 830 spacecraft and upper stages in this unique orbital regime.

## 2. GEO BREAKUPS

To date only two satellite breakups near GEO have been determined with confidence: Ekran 2 (1977-092A, Fig. 1) and a Titan IIIC Transtage (1968-081E, Fig. 2). The former breakup occurred in June 1978 as the result of a nickel-hydrogen battery malfunction but was not acknowledged by Russian specialists until February 1992 [3], [4]. The event caused only a minor perturbation in the orbit of Ekran 2.

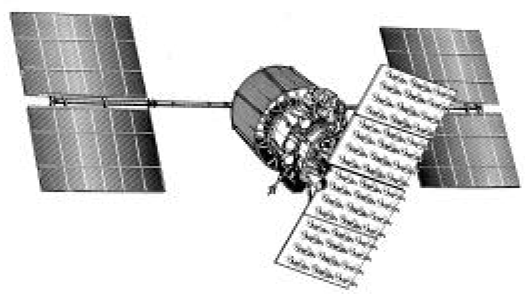

Fig. 1. Ekran 2 spacecraft.

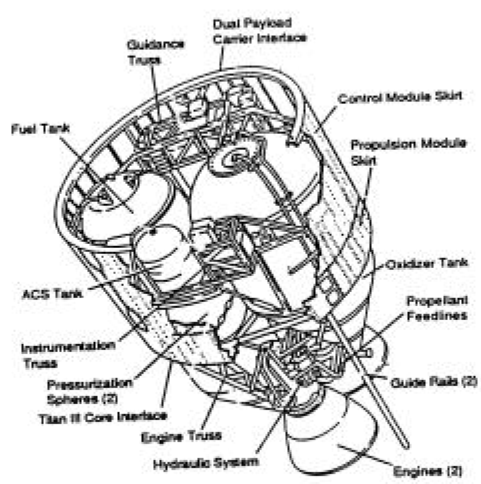


Fig. 2. Titan Transtage.

*Proceedings of the 3rd European Conference on Space Debris, ESOC, Darmstadt, Germany, 19 - 21 March 2001*
*(ESA SP-473, August 2001)*

The second breakup, which affected the OV2-5 Transtage on 21 February 1992, was detected by chance approximately half an hour after the event during normal U.S. space surveillance tracking [5]. A total of 22 new debris were observed, and the orbit of the Transtage was noticeably altered, i.e., an abrupt reduction in orbital period of nearly a minute (Fig. 3). The cause remains unknown but might have been related to residual propellants or a collision with a smaller object.

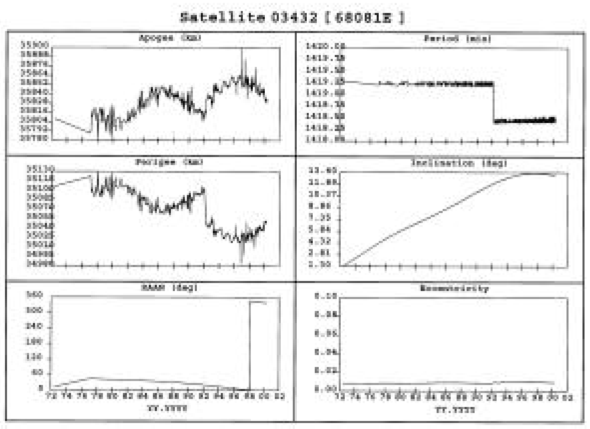


Fig. 3. Orbital history of OV2-5 Transtage

Due to the limitations of space surveillance systems, only one debris fragment from these two incidents has been cataloged, and that came two decades after the breakup. Consequently, other fragmentations of near-GEO objects might have escaped notice.

Breakup candidates may be first identified in four ways:

(1) known catastrophic malfunction of an operational satellite, e.g., Ekran 2;
(2) observation of a debris field in the vicinity of the breakup parent, e.g., OV2-5 Transtage;
(3) observation of large amounts of small objects; and
(4) observation of sharp orbital perturbations in a derelict object.

The first circumstance occurs rarely and is not applicable to the majority of the population of large GEO objects which are inoperable spacecraft and upper stages. Most vehicle malfunctions do not result in debris generation. The second method of detection may be serendipitous or follow a known catastrophic malfunction. The remaining two techniques are the subjects of particular interest today, as shown below.

While the aforementioned GEO debris searches of the IADC have detected significant amounts of debris near GEO, linking these debris to a specific source or sources diverse orbits similar to those of the cataloged population. If breakups are the source, then numerous events over many years are required. Specific searches for debris which might be related to the Ekran 2 and OV2-5 Transtage breakups have not yet found obvious debris cloud remnants. Other sources of small debris should also be considered, including mission-related debris, vehicle degradations, and solid-rocket motor effluents.

Finally, examinations of historical data for signs of distinct perturbations might also not provide unambiguous evidence for satellite breakups, as indicated in the following sections.

## 3. REVIEWING THE TRANSTAGE CASES

At first glance, Titan Transtages would appear to be prime candidates for GEO breakups due to the known breakup of the OV2-5 Transtage and the major breakup of the OV2-1 Transtage in LEO in 1965 [6]. However, the latter accident occurred during powered flight, and the cause is unrelated to the derelict Transtages near GEO.

Between 1966 and 1989 a total of 30 Titan Transtages carried payloads into orbits within a few thousand kilometers of GEO. In addition to the OV2-5 Transtage noted above, four other Titan Transtages are known through publicly available data to have exhibited abrupt, permanent changes in their orbital periods (Fig. 4). Two of these vehicles, 1966-053J and 1967-066G, were in orbits 1,000-2,000 km below GEO at the time of their events in 1987 and 1994, respectively. Debris in these orbits should be especially easy to differentiate, but none have yet been identified. The other two Transtages, 1973-100D and 1978-113D, were in orbits above GEO during their orbit changes in 1992 and 1997, respectively. In all four cases, the observed orbital changes were equivalent to only a few meters per second $\Delta V$, not normally indicative of a major explosion.

A non-breakup explanation for these four Transtage orbital perturbations might be found in the record of the Cosmos 3M second stage, which has been used for over 400 LEO missions. This vehicle is well known in space surveillance circles for exhibiting significant orbital perturbations from a few days to as much as ten years after launch. On the order of 100 such cases have been identified, some with abrupt and discrete orbital perturbations and some with more prolonged orbital perturbations. Importantly, only one of these stages (1991-009J, Fig. 5) has been associated with debris-producing events [7].

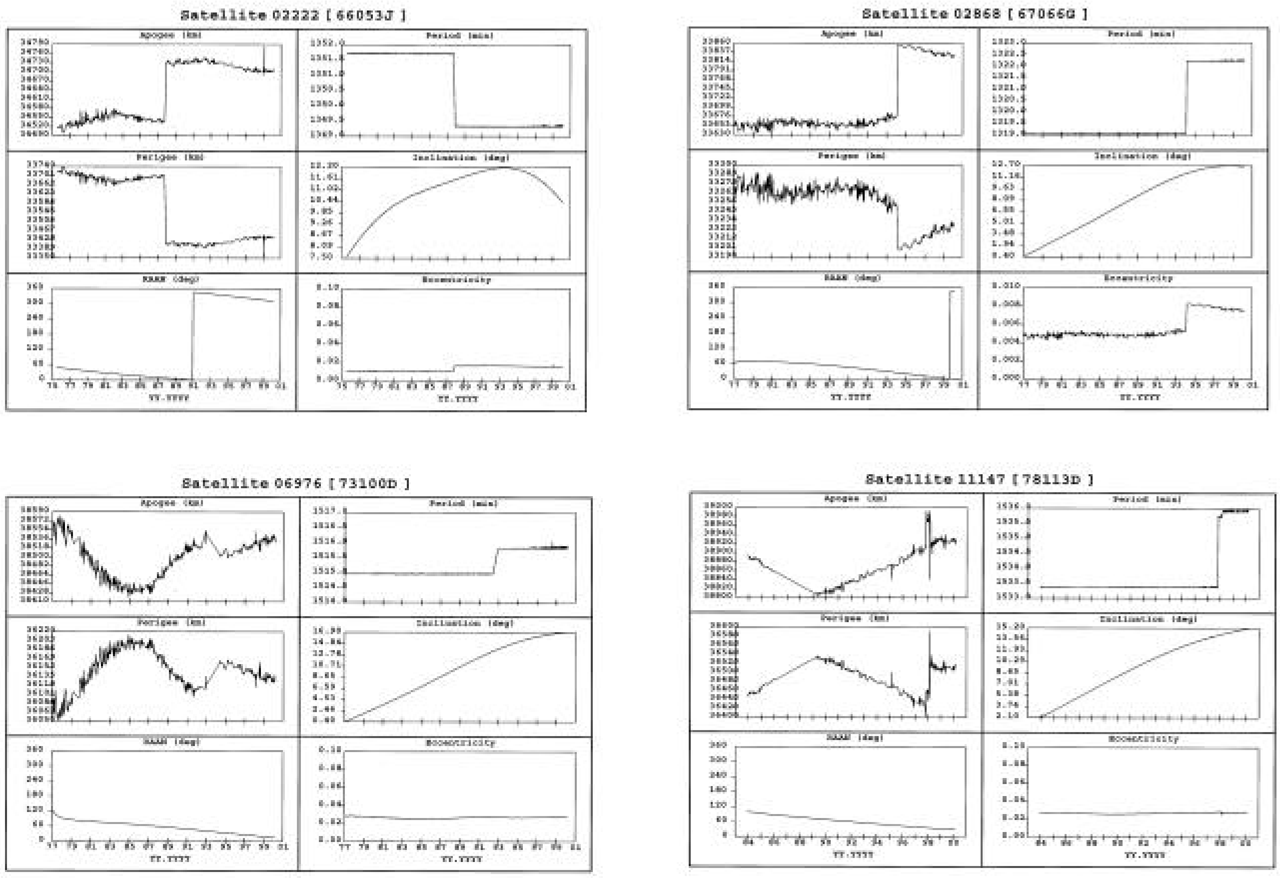


Fig. 4. Orbital histories of four Titan Transtages

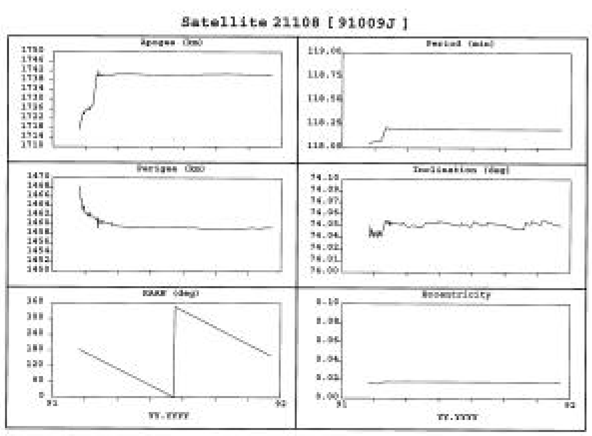


Fig. 5. Early orbital history of Cosmos 2125-2132 rocket body

Fig. 6 depicts the orbit histories of eight example Cosmos 3M second stages launched between 1971 and 1992. In most cases, changes in both apogee and perigee accompany the period alteration. Whereas some changes are clearly abrupt (e.g., 1971-038B and 1986-093B), other stages exhibit prolonged perturbations (e.g., 1983-031B), not unlike those of 1991-009J.

The total $\Delta V$ demonstrated by each of the Cosmos 3M second stages was normally less than 10 m/s, similar to or greater than the Transtage $\Delta V$'s. Another noteworthy similarity is the fact that Transtage and the Cosmos 3M second stage employed the same hypergolic propellants. Thus, the long-accepted explanation of propellant venting for the Cosmos 3M second stages might apply equally to the Transtage.

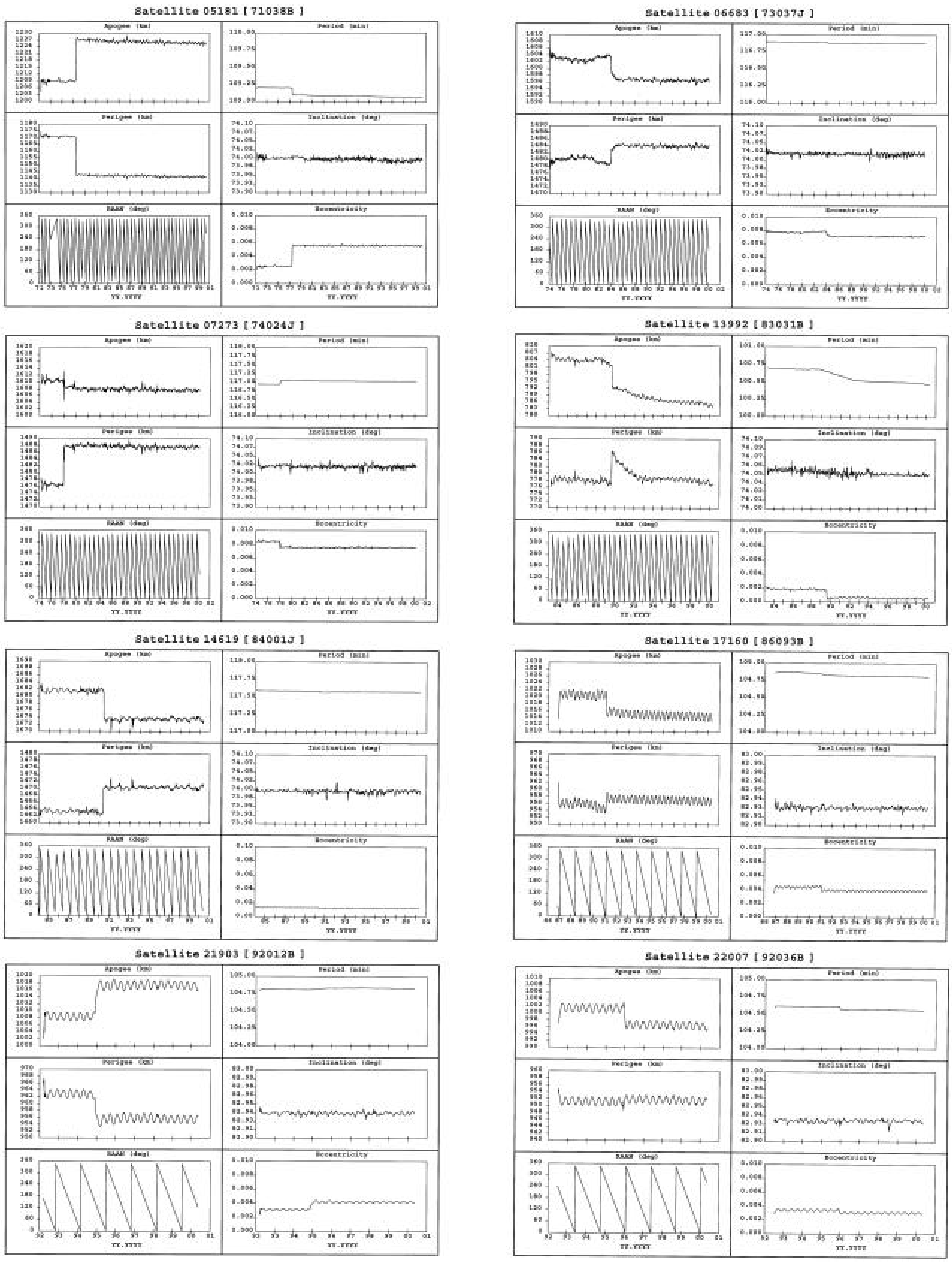


Fig. 6. Other Cosmos 3M second stage orbits.

## 4. OTHER POTENTIAL GEO BREAKUP CANDIDATES

Since 1996 some specialists have examined the orbital history records of other near-GEO satellites in the search for evidence of explosions and collisions. Rykhlova *et al* identified 13 Proton Block DM upper stages which reportedly experienced orbital perturbations between 1987 and 1993 [8]. Kiladze *et al* expanded the list of potential fragmentation candidates with four additional Proton Block DM upper stages, five Russian spacecraft, one Japanese spacecraft, and one Italian spacecraft [9].

An independent review by this author of the orbital histories of the above vehicles revealed that any changes, if real, were of exceptionally small magnitude, i.e., the result of a $\Delta V$ much less than 1 m/s. Some of the minor changes might indeed represent collisions with very small meteoroids or artificial debris, but such collisions would unlikely result in a significant fragmentation.

## 5. CONCLUSIONS

To date only two breakups of satellites near GEO have been identified with high confidence. Although large amounts of debris have been detected in and near GEO by IADC members, the origin of these debris is still unknown. No distinct debris clouds which can be associated with a particular parent object have been found. Several near-GEO satellites have exhibited unexplained perturbations in their orbits, though all are the result of small $\Delta V$s. Such perturbations alone are insufficient evidence of a fragmentation and might instead represent propellant or pressurant venting, as has been seen in LEO on many occasions. Some of the very minor perturbations might have been caused by collisions with small natural or artificial debris, but these are unlikely to have generated significant amounts of debris larger than 20 cm in diameter.

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