THE RADAR MONITORING OF THE RORSAT ATTITUDE

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ABSTRACT

The necessity of determination of the RORSAT satellite current attitude arose in connection with foreign publications concerning the Goldstone and Haystack observations of small space debris (0.6...2 cm) at the 600...1000 km circular orbits with 65 deg. inclination, alleged to be due to the outflow of Na-K coolant caused by heating, centrifugal force, or the satellite cover damage (Ref.1). This allegation seems to be controversal. The results of analysis of radar signatures for several RORSAT satellites are presented, which has allowed to determine their real spatial attitude evolution. The rotation and precession velocities as well as kinetic moment vector evolution were estimated. The velocities appear to be low and the kinetic moment vector seeks to take a stable position the same for all RORSAT satellites now in orbits. These results show that neither the temperature regime nor the centrifugal forces could account for the alleged outflow of Na-K droplets.

The RORSAT has no on-board attitude or rotation velocity sensors. So, after launch to the 900...1000 km circular graveyard orbit, determination of its spatial attitude is possible only by means of analysis of the radar signatures.

The typical RORSAT signature is shown at Fig.1. One can see periodically repeated reflections from cylindrical and conic surfaces. Similar signatures were given in Refs.2,3. The arrangement of these reflections in time depends on the rotation axis orientation and the direction of the radar irradiation. Over the time interval [0 s, 20 s], the reflection from a cylindrical surface can be observed, which witnesses the practical collinearity of the irradiation vector at time t=10 s and the satellite precession angular velocity vector. It is this phenomenon that the direct method of determination of the kinetic moment vector is based on.

The more fine analysis of radar signatures enables to accurately determine the angular velocity (errors are less than 1% of its value) and the direction of the angular velocity vector (errors are less than 1 deg.).

During the sample radar monitoring of several RORSATs the next general findings were obtained:

1. The initial rotation mode (fast rotation around the long axis) is unstable and can be saved only for several days after deorbiting the RORSAT. In one or two days the satellite practically utterly transits into the stable rotation mode around the maximum inertia moment axis, that is, the cross-axis (transversal). So, the spacecraft begins to precess with the nutation angle nearly 90 deg. ("tumbling"). The value and direction of the initial kinetic moment $\bar{L}$ being practically the same:

$$\bar{L} = A \cdot \bar{\dot{\varphi}} \approx C \cdot \bar{\dot{\psi}}.$$

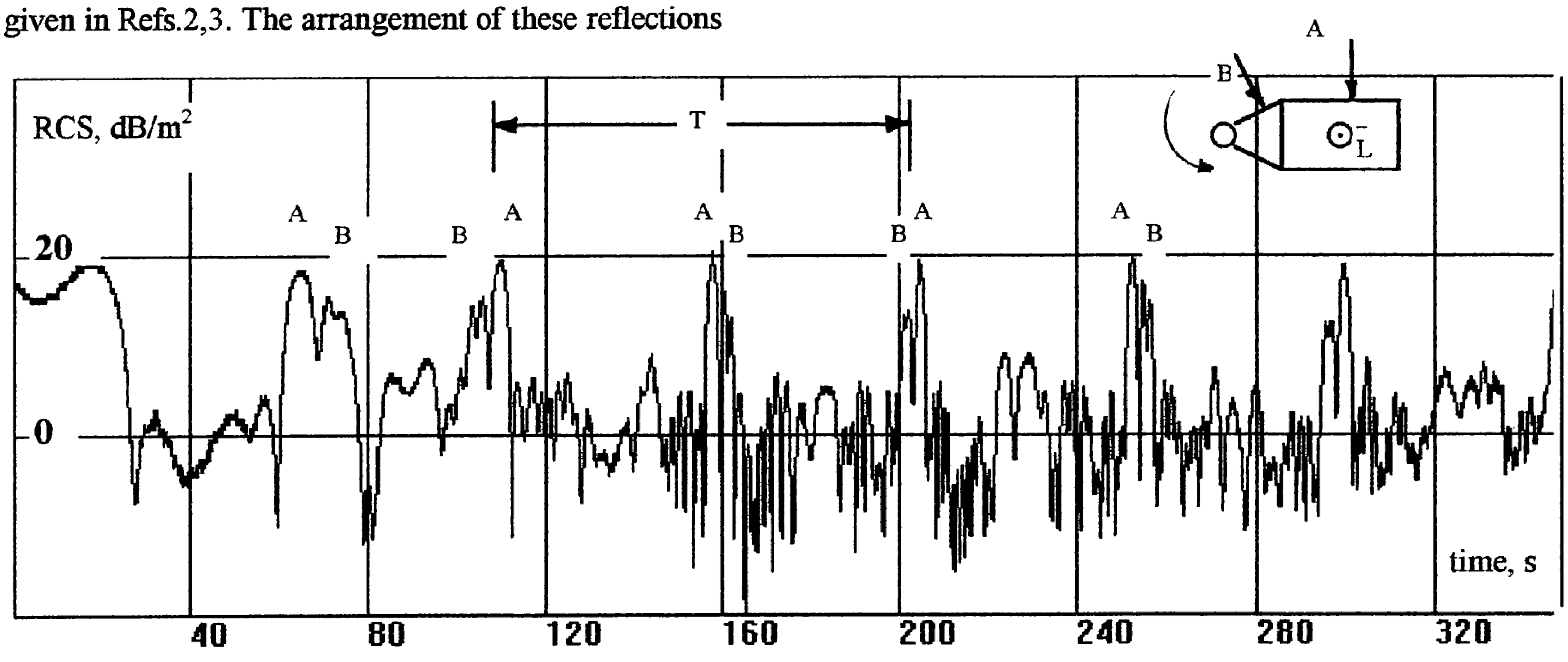

Figure 1. RORSAT typical radar signature (Cosmos 1900, Nov.19, 1996).

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Here, A and C are the long and cross inertia moments respectively, φ and ψ are rotation and precession angular velocities. The initial precession velocity measured was about 3 revolutions per minute (precession period was equal to about 20 s).

2. The remaining angular velocity of the RORSAT rotation about its long axis is low. So, it cannot be measured by radar. But judging by rather small deflection of the nutation angle θ from 90 deg. (usually less than 1 to 3 deg.), it is less and commensurable with the precession angular velocity due to

$$\dot{\varphi} \approx \dot{\psi} \cdot \frac{C}{A} \cdot \cos\theta = \dot{\psi} \cdot \frac{C}{A} \cdot \sin\Delta\theta,$$

the ratio $\frac{C}{A}$ being equal to about 20.

3. Further, due to influence of the magnetic dissipative moment, the precession velocity is exponentially decreasing. It diminishes as much as twice in every 3 years. Fig. 2 illustrates the typical character of growth of the RORSAT precession period for "Cosmos 469", "Cosmos 861", and "Cosmos 1932" as an examples. The character of "Cosmos 1900" rotation deceleration somewhat differs from those above, which may be related with difference of initial rotation velocity and with more notable influence of aerodynamic dissipative moment for a satellite in the 700 km circular orbit.

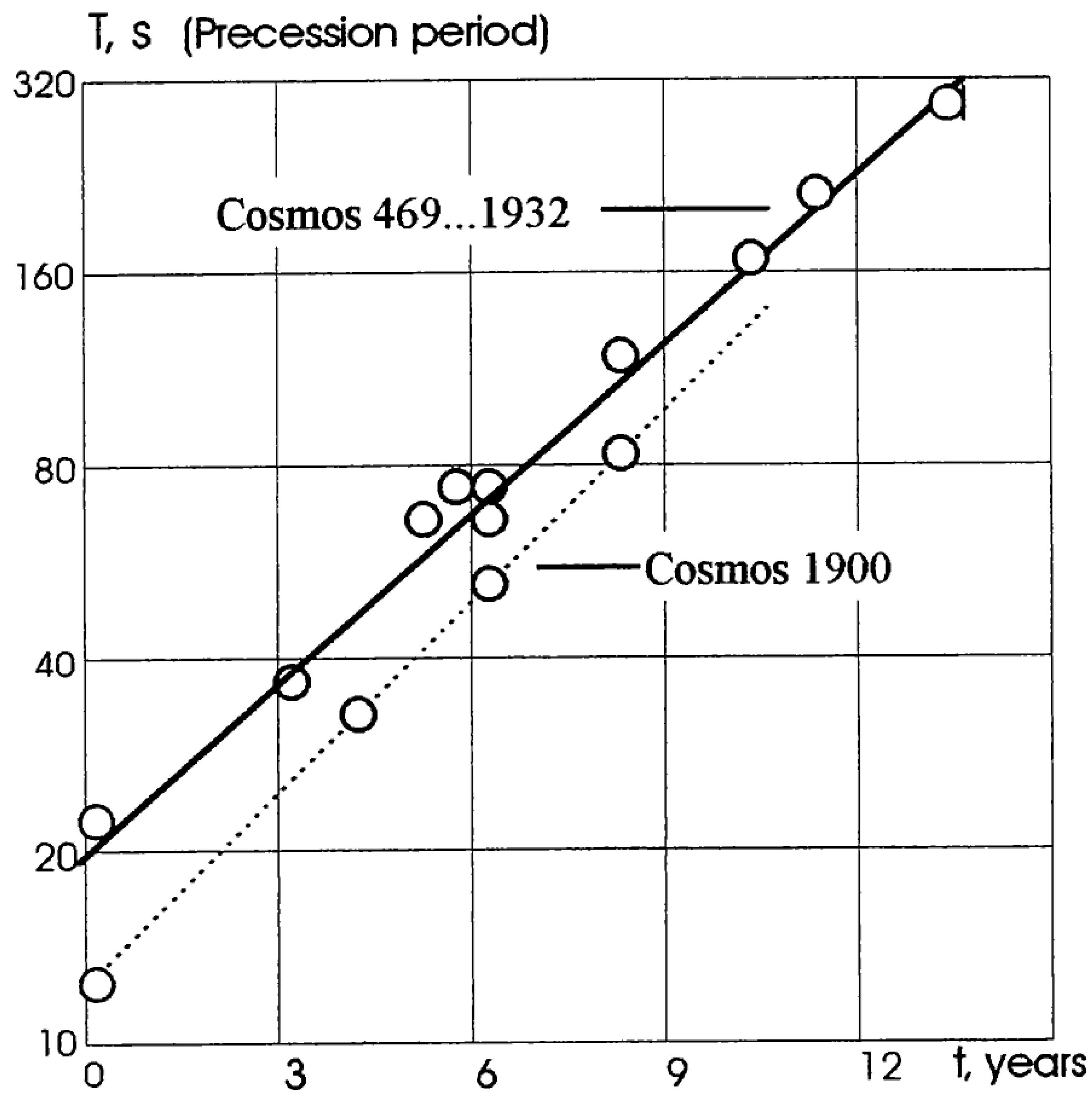

Figure 2. RORSAT precession velocity drift.

4. The modeling calculation and sample observational data on kinetic moment vector evolution of "Cosmos 723", "Cosmos 861", "Cosmos 1176", "Cosmos 1900", and "Cosmos 1932" have shown that due to the action of magnetic and gravitational perturbing moments, vector $\bar{L}$ seeks to take a stable position relative to the orbit, namely, tangent to orbit at the ascending node, and nutates about this position with declination up to 10 deg. from the orbit plane and up to 20 deg. in the plane. The vector $\bar{L}$ nutation period is about 40 days. Fig. 3 shows the calculated and the real trajectories of the vector $\bar{L}$ for "Cosmos 861" and "Cosmos 1900" as an examples. In spite of different altitudes of the satellites the appropriate trajectories practically coinside.

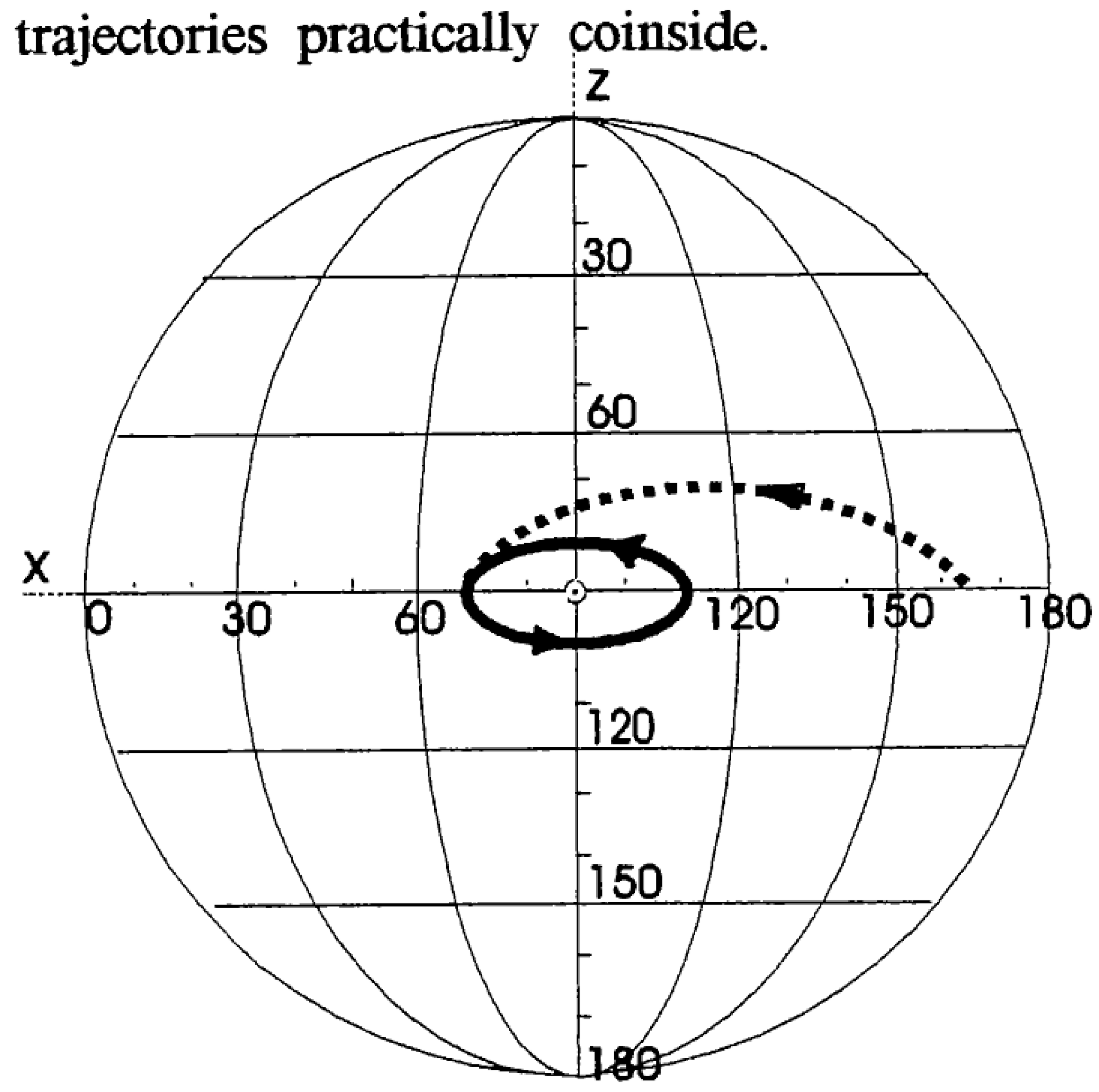

Figure 3. RORSAT kinetic moment vector evolution , xy- orbit plane, z- normal to orbit plane.

CONCLUSION

It is evident that provided such a motion character the uniform heating of the RORSAT surface takes place and the small angular velocities do not cause notable centrifugal forces. So, the thermal mode and the centrifugal forces could not account for the alleged outflow of Na-K droplets.

REFERENCES

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2. Brindley, Ch., Target Recognition, *Space Aeronautics*, June 1965.
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