Parker Zenith & Crown
Aerospace and deep-tech engineering · Lafayette, Louisiana · October 2026

Illustrative example PRELIMINARY

Screening of frequency combinations prone to internal resonance in a CubeSat deployable boom

What this document is. An **illustrative scenario** built on a textbook beam model. **It is not a client or a real project**, it does not come from any satellite and it has no experimental validation. It only shows what data goes into the service and what report comes out.

1. Scenario

A small team (university or start-up) is designing a **cantilevered deployable boom** for a CubeSat, for example to move a magnetometer away from the spacecraft body. It has a linear modal analysis but no budget for a full nonlinear dynamic analysis. At design review it wants to know whether some modes have frequencies that form combinations able to **exchange energy** through nonlinear effects (internal resonance). A linear analysis does not show such transfers. The rule of avoiding these combinations is classical (A. H. Nayfeh and D. T. Mook, *Nonlinear Oscillations*, Wiley, 1979).

2. Input: design natural frequencies

Uniform boom modelled as a cantilever beam in planar bending. The first frequency, $f_1 = 0.8$ Hz, is an **assumed value** for the example. Assumed modal damping: 1 % (the NASA-STD-5002 default when no measurements are available).

Mode	1	2	3	4	5	6	7
f (Hz)	0.80	5.01	14.04	27.51	45.47	67.93	94.88

The detunings in the next table do not depend on f_1 or on the boom length: they recur in any uniform cantilever with these conditions. Only changes such as a tip mass, a change of cross-section or of stiffness modify them.

3. Output: candidate combinations and review priority

Detected combination	Type	Detuning	Review priority	Suggested test or analysis focus
$\omega_4 + \omega_1 \approx 2\omega_3$	cubic	+0.82 %	1 (high)	Forced sweep around mode 3, measuring the response of modes 1 and 4.
$\omega_6 + \omega_2 \approx \omega_5 + \omega_4$	cubic	−0.053 %	2 (medium)	Mainly relevant under broadband random vibration (launch) exciting several modes at once; monitor modes 2, 4, 5 and 6.
$\omega_7 + \omega_1 \approx \omega_6 + \omega_4$	cubic	+0.25 %	3 (low)	No specific test; keep on the watch list.
$\omega_7 \approx \omega_4 + \omega_6$	quadratic (triad)	+0.59 %	— (conditional)	In an ideal straight cantilever this triad does not couple, by symmetry. Review it only if there is initial curvature, preload, gravity sag, asymmetry or joints.

Detuning: relative difference between the two sides of the combination. The **priority** is a suggested review order, not a risk measure. If the expected excitation band included higher modes (8–10), further near-exact combinations would appear and should be added to the review.

Report recommendation (illustrative). No combination is flagged as a failure. The test or nonlinear analysis effort should focus on the priority-1 combination. If needed, the design could be detuned (for example with a tip mass) and the new frequencies screened again.

4. Limits

- **Preliminary.** Computational results on an idealised model (uniform beam, planar bending); **no experimental validation** and no time-domain simulation of these combinations.
- **Frequency coincidence does not imply risk.** With realistic damping (≈ 1 %), a combination that is close in frequency may never transfer energy. Whether it does depends on the amplitude, coupling and damping of each design. Screening guides the review; it does not predict failures.
- **Damping matters.** In our preliminary simulations, the energy transfer seen without damping almost vanishes at 1 % damping.
- **Flutter is out of scope.** The service does not analyse flutter or other aeroelastic phenomena (coupling with the airflow); it only addresses internal resonances between structural modes.
- **It does not replace** finite-element analysis, nonlinear analysis or qualification testing: it only helps decide where to focus them.
- The tool’s internal method is not disclosed.

Contact: www.parkerzenithcrown.com · Parker Zenith & Crown, Lafayette, Louisiana (USA)