A WAVELET SERIES SYNTHESIS OF THE PEGASUS DROP TRANSIENT FOR SHAKER SHOCK TESTING OF PAYLOADS

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February 15, 2006

Introduction

The most significant event for the payload on the Pegasus launch vehicle is the drop transient from the carrier aircraft. In fact, this is event is the sole focus of the coupled-loads analysis.

The Pegasus vehicle is mounted to the L-1011 aircraft by four load bearing hooks. The aircraft hooks attach to fittings on the topside of the Pegasus wing.

In this configuration, the Pegasus vehicle bows downward due to the effects of gravity. In addition, the Pegasus vehicle is subjected to aerodynamic drag forces during captive carry. These loads thus induce initial strain energy in the Pegasus vehicle.

In some sense, the Pegasus vehicle is like a free-free beam subjected to an initial displacement that varies along its length.

During the five-second free-fall interval, the initial strain energy is released, causing the Pegasus vehicle to experience a damped, transient oscillation. The oscillation frequency is typically 9 Hz to 10 Hz, depending on the payload mass. The oscillation occurs in the vertical axis. It is the fundamental body-bending frequency of the vehicle with its payload. A sample drop transient time history is shown in Figure 1. The time history is measured data from a typical Pegasus XL mission. The amplitude is normalized for proprietary reasons.

Reference 1 states that the payload's individual fundamental lateral frequency should be above 20 Hz in order to minimize coupling with the vehicle's first bending mode. This recommendation satisfies the "octave rule."

Shaker Table Test

The spacecraft or payload should be subjected to a shaker table test to verify that it can withstand the drop transient. The shaker must be controlled so that it has zero net velocity and zero net displacement. A method to accomplish this is given in this paper.

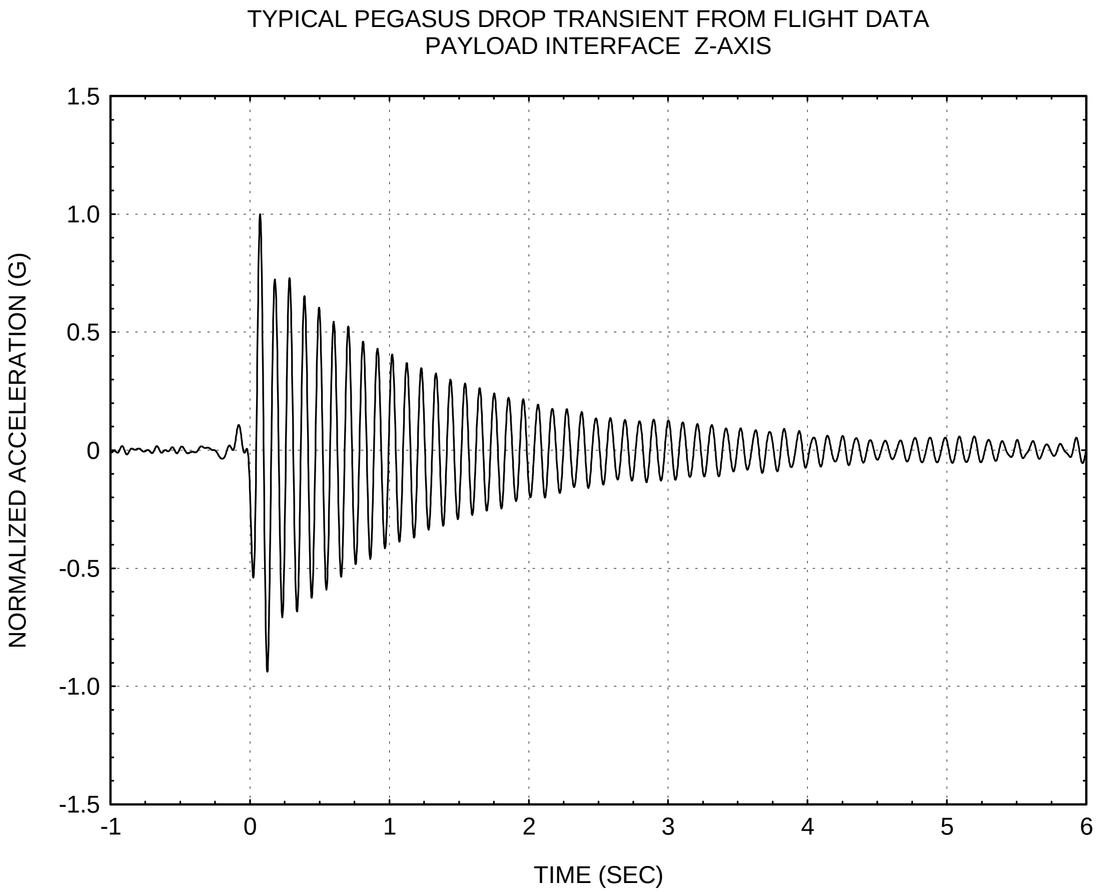

Figure 1.

The waveform is normalized so that its peak acceleration is 1 G.

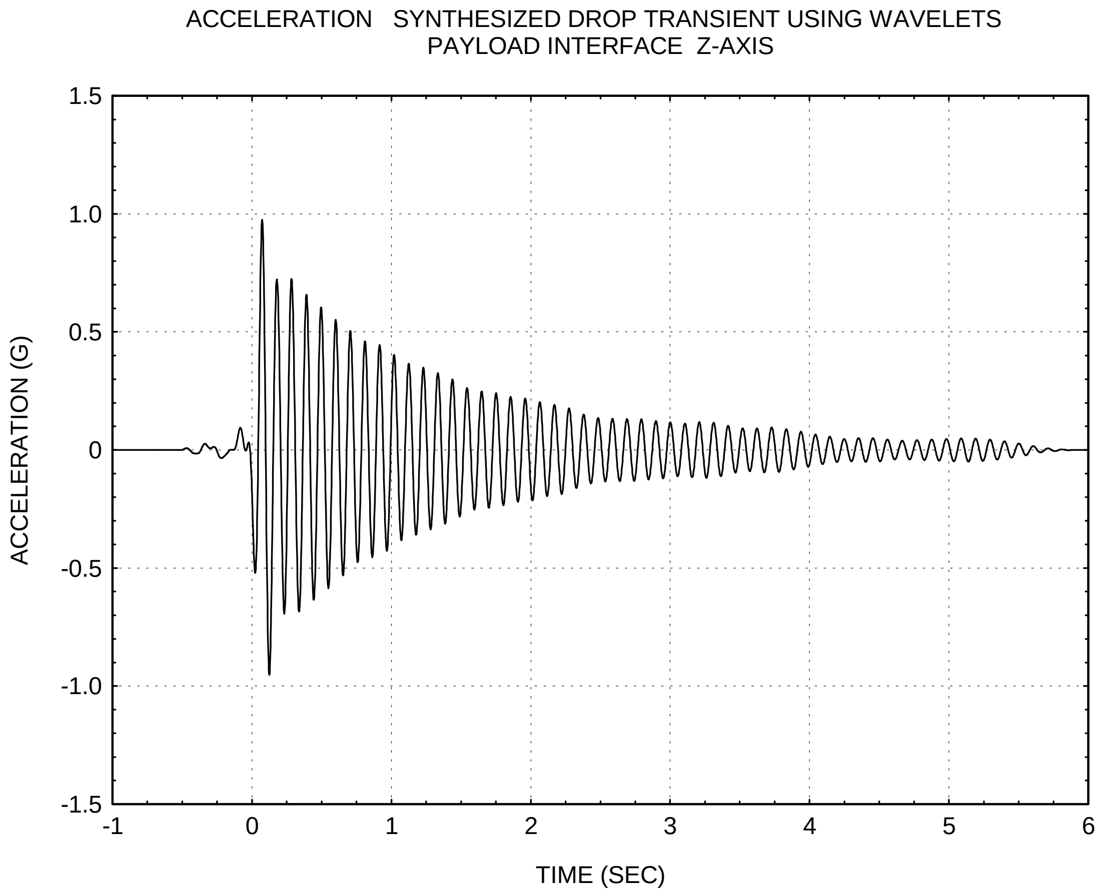

Figure 2.

The synthesized waveform in Figure 2 consists of 40 individual wavelets. The parameters are given in Appendix A.

The synthesized waveform in Figure 2 has excellent agreement with the flight data in Figure 1. The direct comparison is omitted for brevity.

The ASCII text file for the synthesized waveform can be input to the shaker via a suitable control computer.

The wavelet series has zero net velocity and zero net displacement. These are both requirements for shaker shock testing.

The synthesized waveform can be readily performed on a suitable shaker system. The system may include a slip table. Consideration must be given to velocity and displacement, as shown in Figures 3 and 4.

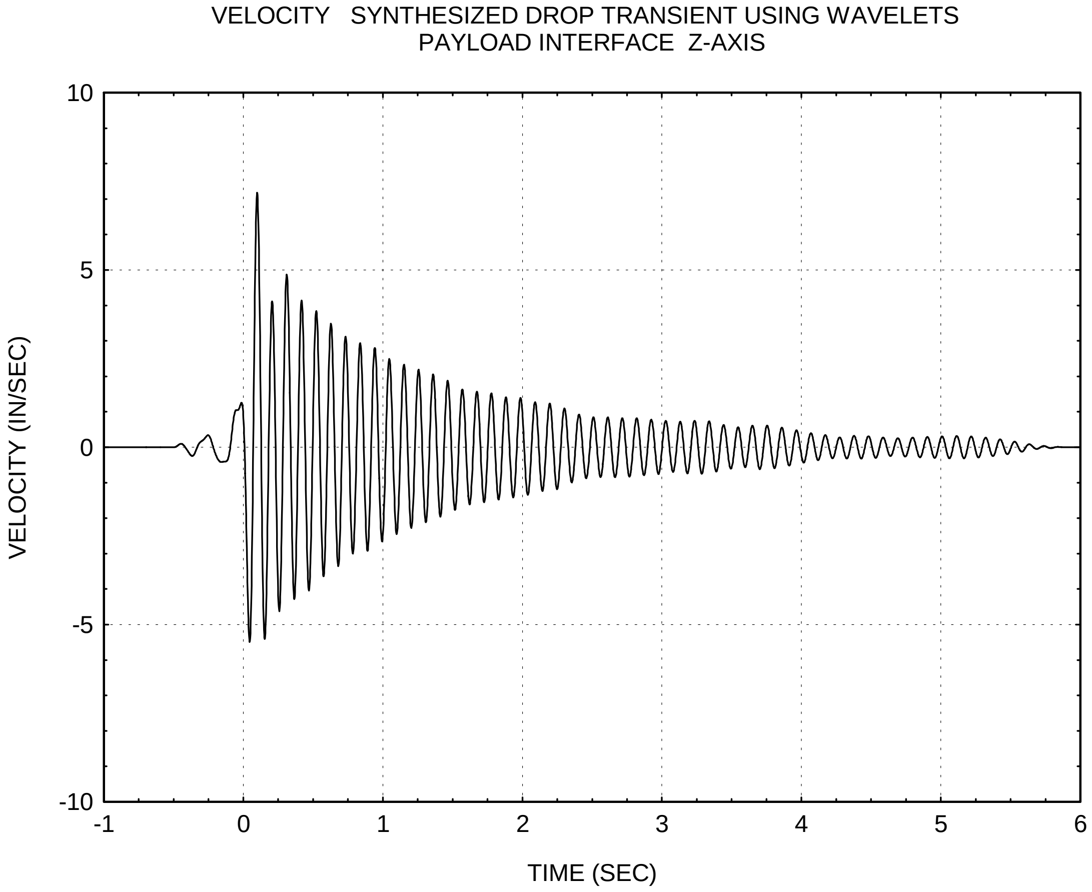
VELOCITY   SYNTHESIZED DROP TRANSIENT USING WAVELETS
PAYLOAD INTERFACE Z-AXIS
VELOCITY (IN/SEC)
TIME (SEC)
10
5
0
-5
-10
-1
0
1
2
3
4
5
6

Figure 3.

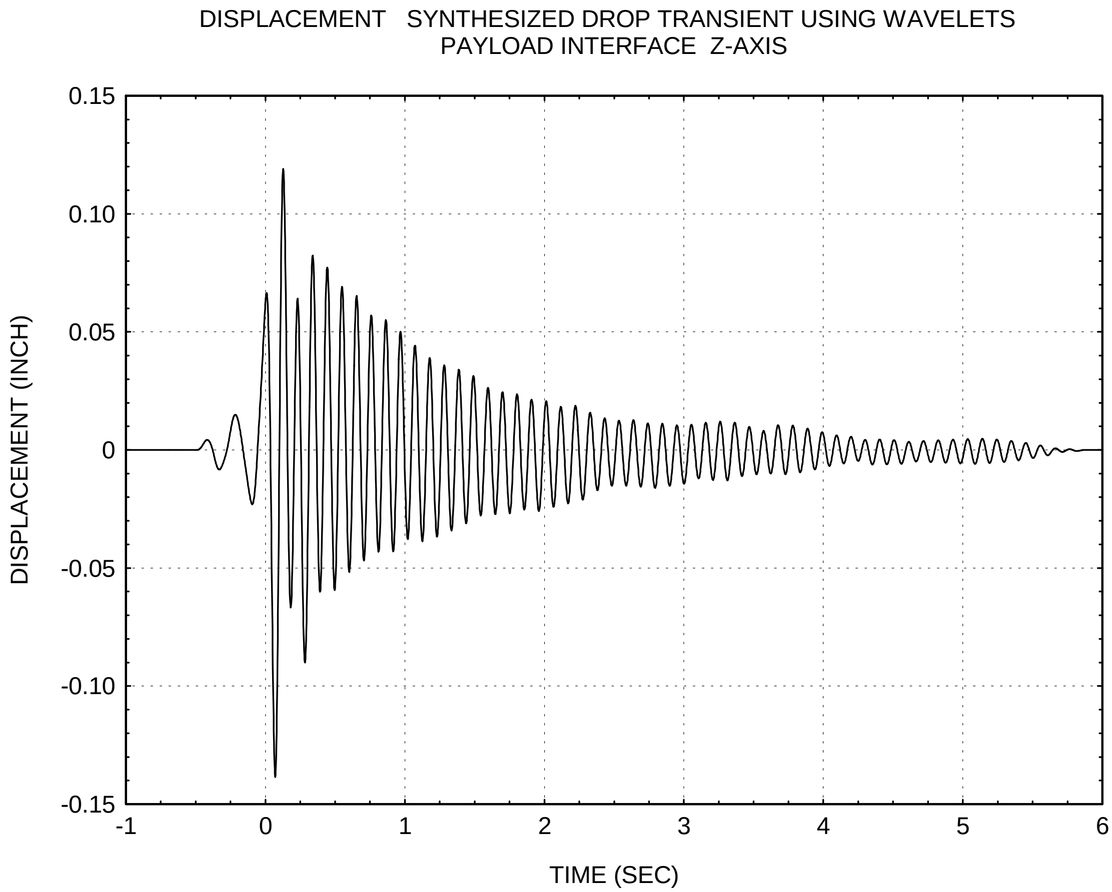

Figure 4.

The peak displacement is 0.14 inches based on 1 G peak acceleration.

The displacement may be scaled in direct proportion to the acceleration level.

Peak Accel (G)	Peak Disp (inch)
1	0.14
2	0.28
3	0.42
4	0.56
5	0.70
6	0.84

References

1. Pegasus® User's Guide Release 5.0, Orbital Sciences Corporation, August 2000.

2. T. Irvine, Shock Time History Reconstruction using Wavelets Revision A, Vibrationdata, 2005.

APPENDIX A

Wavelet Table for Synthesized Time History

NHS = number of half-sine pulses.

N	Accel (G)	Freq(Hz)	NHS	Delay (sec)
1	0.336	9.72	25	0.846
2	0.199	9.36	27	0.623
3	-0.140	9.60	27	1.736
4	0.181	9.79	25	1.286
5	0.146	8.72	21	0.563
6	-0.108	9.69	23	2.885
7	0.119	9.59	23	0.836
8	0.108	9.62	23	1.887
9	0.130	7.54	21	0.493
10	-0.107	10.26	13	0.905
11	0.062	9.71	27	3.869
12	-0.100	6.32	9	0.626
13	0.083	12.83	15	0.821
14	-0.086	9.35	25	2.663
15	-0.070	9.18	17	3.693
16	0.072	11.13	19	0.610
17	-0.043	9.66	27	5.279

This table is continued on the next page.

N	Accel (G)	Freq(Hz)	NHS	Delay (sec)
18	-0.043	9.70	23	4.449
19	-0.052	9.91	19	2.379
20	-0.053	5.00	9	0.508
21	-0.047	9.12	17	1.475
22	-0.041	8.21	13	1.328
23	0.036	13.32	15	0.753
24	-0.042	7.06	13	0.863
25	0.037	8.49	25	3.051
26	0.028	11.16	25	1.366
27	-0.034	15.14	21	0.886
28	0.026	10.19	21	0.543
29	-0.017	9.84	27	5.517
30	-0.024	9.03	23	3.898
31	0.028	6.78	5	0.540
32	-0.017	9.89	25	4.865
33	-0.022	9.48	19	1.312
34	0.018	10.69	25	2.669
35	0.017	5.19	9	0.636
36	0.015	8.54	17	0.711
37	-0.015	10.53	23	3.560
38	-0.013	6.74	19	0.966
39	0.022	8.80	17	4.356
40	-0.019	12.36	7	1.421

APPENDIX B

Wavelet Equation

The equation for an individual wavelet acceleration is

$$
W_m(t) = \begin{cases} 0, \quad \text{for } t < t_{dm} \\ A_m \sin\left[\dfrac{2\pi f_m}{N_m}(t - t_{dm})\right]\sin[2\pi f_m (t - t_{dm})], \ \text{for } t_{dm} \le t \le \left[t_{dm} + \dfrac{N_m}{2f_m}\right] \\ 0, \quad \text{for } t > \left[t_{dm} + \dfrac{N_m}{2f_m}\right] \end{cases}
$$

(B-1)

where

$W_m(t)$	=	acceleration of wavelet m at time t
A_m	=	wavelet acceleration amplitude
f_m	=	wavelet frequency
N_m	=	number of half-sines
t_{dm}	=	wavelet time delay

Note that N_m must be an odd integer greater than or equal to 3.