Accelerations Associated with the USA-193 Hydrazine Tank

Geoffrey Forden

March 7, 2008

During Liftoff

The USA-193 satellite was lofted into space on a Delta 2/7920. (See the appendix for details on how to model this launch vehicle.) During its takeoff, it experienced a maximum of 6 G's, just before burnout of the central core's first stage. See Figure 1. During liftoff, the hydrazine tank is supported by its surrounding satellite and, presumably, has a safety factor built into it to handle transients during lift off.

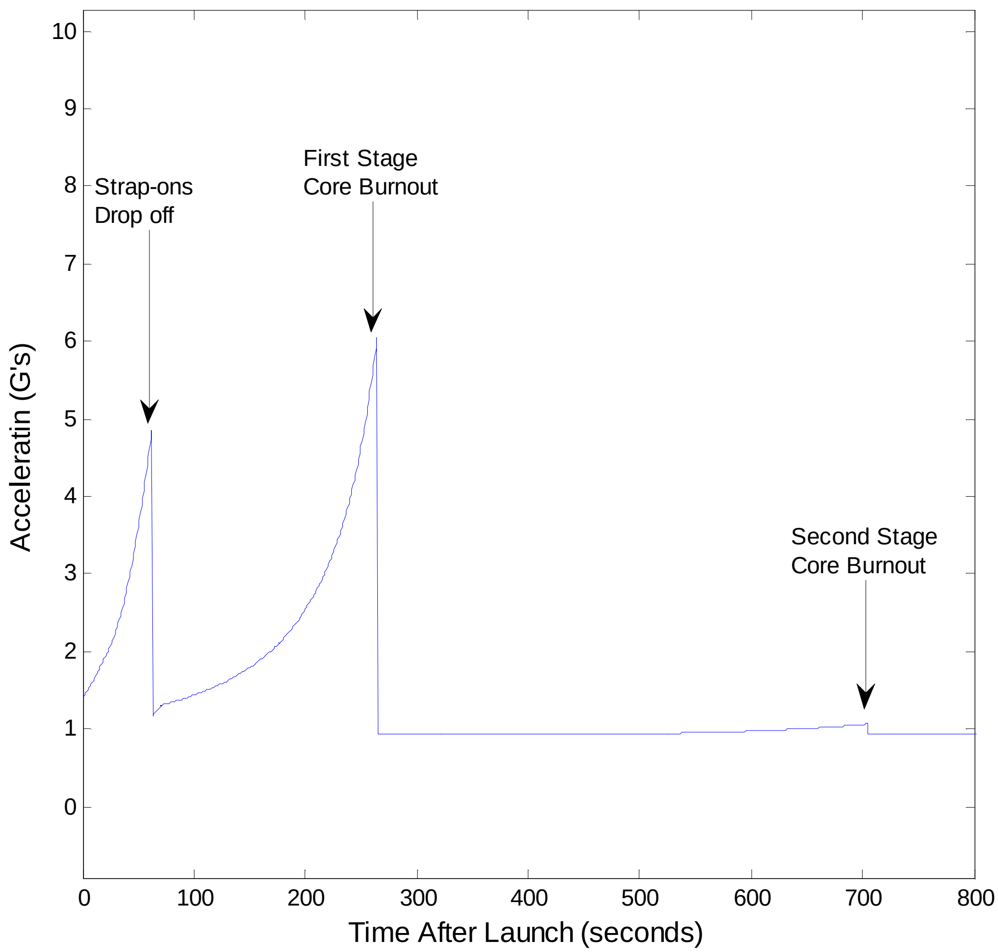

Figure 1. Accelerations experienced by the USA-193 satellite during its launch.

During reentry, the complete satellite would experienced, at any given altitude, greater accelerations than the tank alone because the tank alone has a greater ballistic coefficient than the complete satellite. If we assume that tank breaks out of the satellite early, than we can easily calculate the acceleration of it as it reenters. The only difficulty is determining the incident angle with which the tank reenters the upper atmosphere. The most likely incident angle is zero degrees, which is about 10 G's, which it experiences for several tens of seconds. However, the maximum acceleration the tank experiences is very sensitive to this angle. See Figure 2 for the accelerations experienced at different incident angles and Figure 3 for the tank acceleration as a function of time. (There is significant atmospheric breaking at high altitudes—even above 60 km—because of the long time the tank would spend at those altitudes with shallow incident angles.)

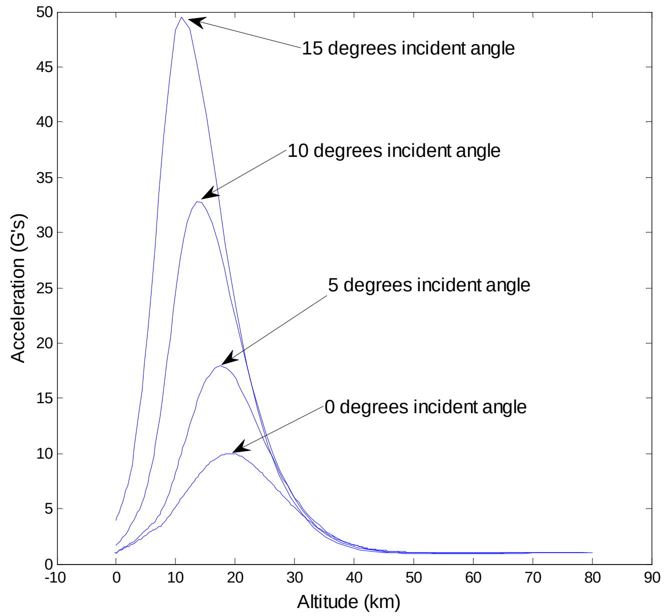

Figure 2. Acceleration vs. Altitude of ½ ton hydrazine tanks reentering the atmosphere at different incident angles.

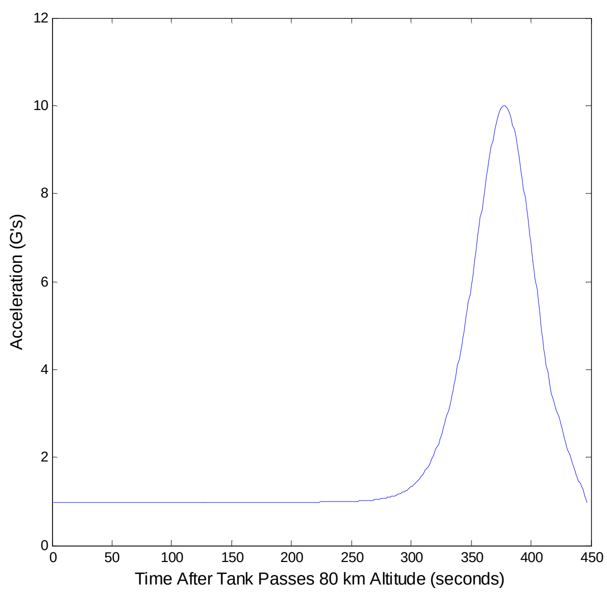

Figure 3. Tank acceleration vs. time after the tank passes 80 km with a zero incident angle.

At a minimum, the tank experiences four G's more during its reentry than it did during liftoff. It seems likely that what ever safety margin the engineers built into the tank would be exceeded by this, if the tank was not frozen. However, it is possible that the frozen hydrazine inside the tank would increase the structural strength of the tank. It is not clear if that would be enough to preserve the tank during reentry (this could presumably be calculated by using a finite element model) but it is also not clear that it would not.

Appendix
Simulating the Delta 2 Launch Vehicle

In order to use GUI_missileFlyout to simulate the Delta 2, it is necessary to use pseudo-stages for the first and second stages since strap-ons cannot be directly simulated. This file is the file used for that simulation. The m-file for the Delta 2 Simulation can be found at: http://mit.edu/stgs/spaceprograms.html

```
Missile Name: Delta_2_9920

Number of Stages: 3
Payload: 3896 (kg)
Missiles Mass Ratio: 0.901002

Missile References:
Article the model is based on: '     '
Arthors: '   Geoff Forden'
Journal: '   '
Description of Method for Determining Model:
 ['   The information for the various stages was determined from the
web page
';'http://www.spaceandtech.com/spacedata/elvs/delta2_specs.shtml
';'
';'Kludged 1st and 2nd stages were calculated so that they had the
total thrust and the average Isp for the strap-ons and core.']

Stage 1 Parameters:
Stage Diameter (m): 4.4 (m)
Isp: 269.77 (s)
Propellant Mass: 128669 (kg)
Stage mass (with fuel): 140495 (kg)
Burn time 63 (s)
Mass fraction for this stage: 0.915826
Thurst 550.596 (tons)

Stage 2 Parameters:
Stage Diameter (m): 3.5 (m)
Isp: 301.7 (s)
Propellant Mass: 73024.9 (kg)
Stage mass (with fuel): 79124.9 (kg)
Burn time 202 (s)
Mass fraction for this stage: 0.922907
Thurst 108.993 (tons)

Stage 3 Parameters:
Stage Diameter (m): 3.5 (m)
Isp: 319.2 (s)
Propellant Mass: 6004 (kg)
Stage mass (with fuel): 6953 (kg)
Burn time 440 (s)
Mass fraction for this stage: 0.863512
Thurst 115.316 (tons)

Launch site Latitude 0 Longitude 0

Loft Angle: 0 Loft Angle Rate: 0
```