SLS Block 1C with optimised RS–25D Second Stage. Payload to 200 km LEO = 107.5 t. 7 Dec. 2013. Author: Steven S. Pietrobon, PhD.

RSRMV thrust curve obtained from page 56 of [2]. There is a discrepancy in that Loaded Mass minus Burnout Mass in [2] is 650,743 kg compared to 633,233 kg in [1] and 628,701 kg in [3]. Therefore, we have adjusted the propellant mass and impulse in [2] to match the values in [1].

Boosters: RSRMV 2x5–Segment	1C4J2.2	1C4A1
Aft Skirt Diameter (m)	5.156	5.156
Nozzle Diameter (m)	3.875	3.875
Sea Level Thrust at 0.2 s (N)	15,599,386	15,599,386
Vacuum Isp (m/s)	2,622.3	2,622.3
Total Mass (kg)	733,776	733,776
Usable Propellant (kg)	632,791	632,791
Residual Propellant (kg)	442	442
Burnout Mass (kg)	100,543	100,543
Action Time (s)	131.9	131.9

The simulations have no thrust bucket and reduced the thrust rating to 109%, as reported in [4].

Core Stage: 4xRS–25 Engines	1C4J2.2	1C4A1
Stage Diameter (m)	8.407	8.407
Nozzle Diameter (m)	2.304	2.304
Vacuum Isp (m/s)	4,436.5	4,436.5
Engine Thrust (N)	2,278,824	2,278,824
Engine Thrust Rating (%)	109	109
Thrust Bucket (%)	109	109
Total Mass (kg)	1,091,525	1,091,525
Usable Propellant (kg)	966,061	966,061
Reserve Propellant (kg)	8,210	8,210
Fuel Bias Propellant (kg)	1,678	1,678
Startup Propellant (kg)	7,439	7,439
Dry Mass (kg)	115,575	115,575

The size of the upper stage was optimised to maximise payload delivered into a 200 km orbit. The interstage mass was adjusted according to total maximum weight carried by the core. Ullage motors were added to ensure propellant settling, similar to that used by the Saturn V. The two J–2X engines were replaced with a single RS–25D engine (engine mass obtained from [5]).

Upper Stage:	1C4J2.2	1C4A1
Engines	J–2X	RS–25D
Number of Engines	2	1
Stage Diameter (m)	8.407	8.407
Nozzle Diameter (m)	3.048	2.304
Vacuum Isp (m/s)	4,275.7	4,436.5
Single Engine Thrust (N)	1,281,088	2,278,824
Single Engine Mass (kg)	2,472	3,549
Total Mass (kg)	147,516	142,816
Usable Propellant (kg)	125,292	122,015
Reserve Propellant (kg)	2,114	2,058
Startup Propellant (kg)	771	661
Residual Propellant (kg)	0	420
RCS Propellant (kg)	102	102
Dry Mass (kg)	19,005	17,328
Ullage Motors Propellant (kg)	115	115
Ullage Motors Dry Mass (kg)	117	117
Ullage Motors Action Time (s)	3.87	3.87
Ullage Motors Thrust (N)	65,032	65,028
Ullage Motors Offset Angle (°)	30	30
Interstage Mass (kg)	5,944	5,951

The LAS/SAJ jettison time was obtained from [6]. Simulation results for 1C4A1 are shown in Figures 1–4. The higher efficiency of the RS–25D engine compared to the J–2X allows for an increase of payload of 4.7 t or 4.6% from 102.8 t to 107.5 t.

	1C4J2.2	1C4A1
Orbit (km)	200 ± 0.4	200 ± 0.4
Liftoff Thrust at 0.2 s (N)	38,623,742	38,623,742
Liftoff Mass (kg)	2,823,613	2,823,613
Liftoff Acceleration (m/s^2)	13.69	13.69
MaxQ (Pa)	21,877	21,986
Maximum Acceleration (m/s^2)	23.80	23.80
LAS/SAJ Jettison Time (s)	330	330
Launch Abort System (kg)	7,394	7,394
Orion Jettisoned Adaptors (kg)	920	920
Other Spacecraft (kg)	102,762	107,455
Remaining Propellant (kg)	0	0
Total Payload (kg)	102,762	107,455
Total Delta–V (m/s)	9,905	9,898

[1] B. Donahue and J. Bridges, “The Space Launch System capabilities for enabling crewed Lunar and Mars exploration,” *63rd Int. Astronautical Congress*, Naples, Italy, IAC–12–D2.8.7, Oct. 2012.

[2] Alliant Techsystems Inc., “ATK space propulsion products catalog,” Aug. 2012.

[3] P. Phillips, “Ground systems development and operations,” NASA, July 2012.

[4] M. Davidson, “RS–25: The Clark Kent of engines for the Space Launch System,” 13 Sep. 2013. http://www.nasa.gov/exploration/systems/sls/rs25–engine–powers–sls.html

[5] R. Ryan, “Lesson in system engineering – The SSME weight growth history,” NASA, Aug. 2008.

[6] S. Creech, J. Holladay and D. Jones, “SLS dual use upper stage (DUUS) opportunities,” NASA, Apr. 2013.

Figure 1: Altitude versus time for SLS Block 1C

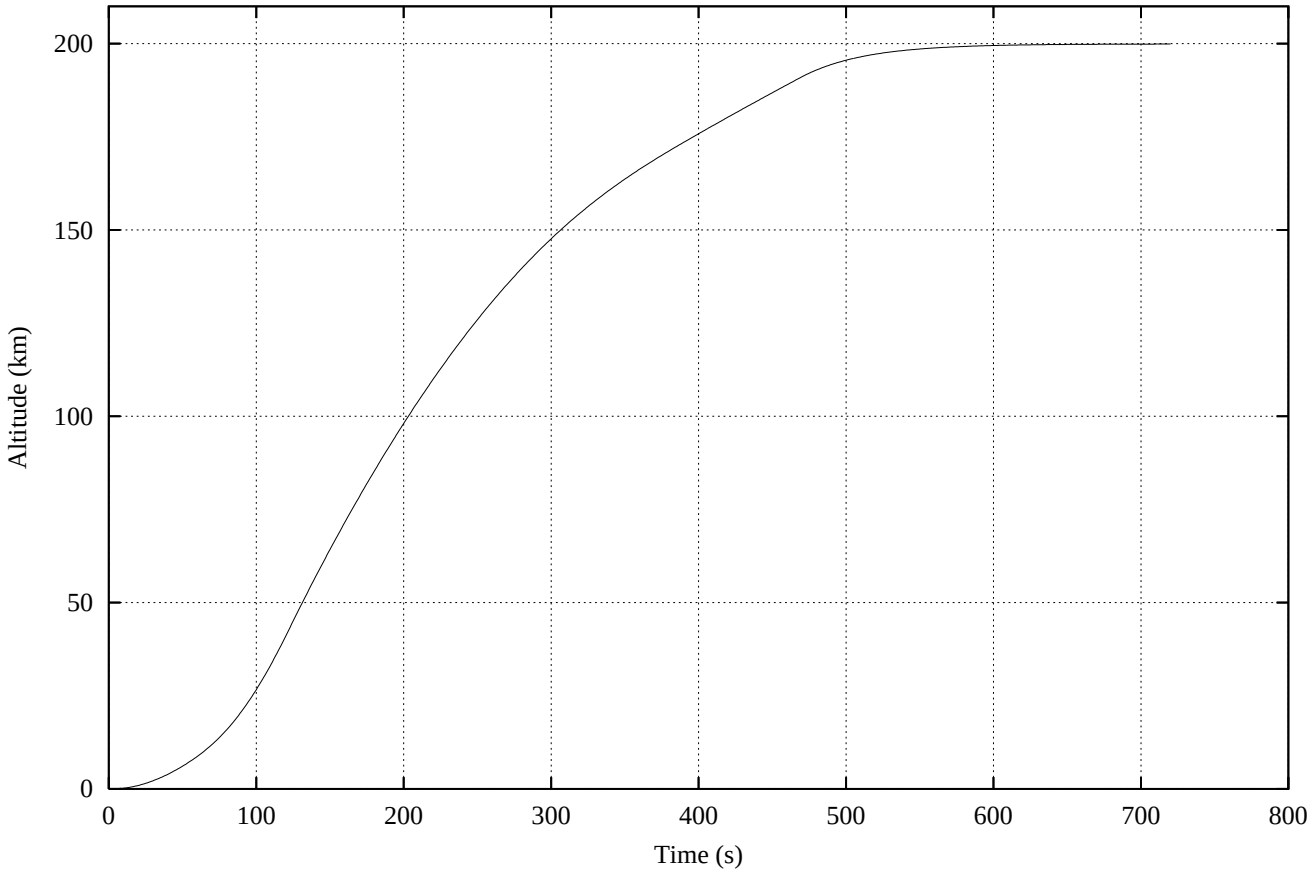

Figure 2: Speed versus time for SLS Block 1C

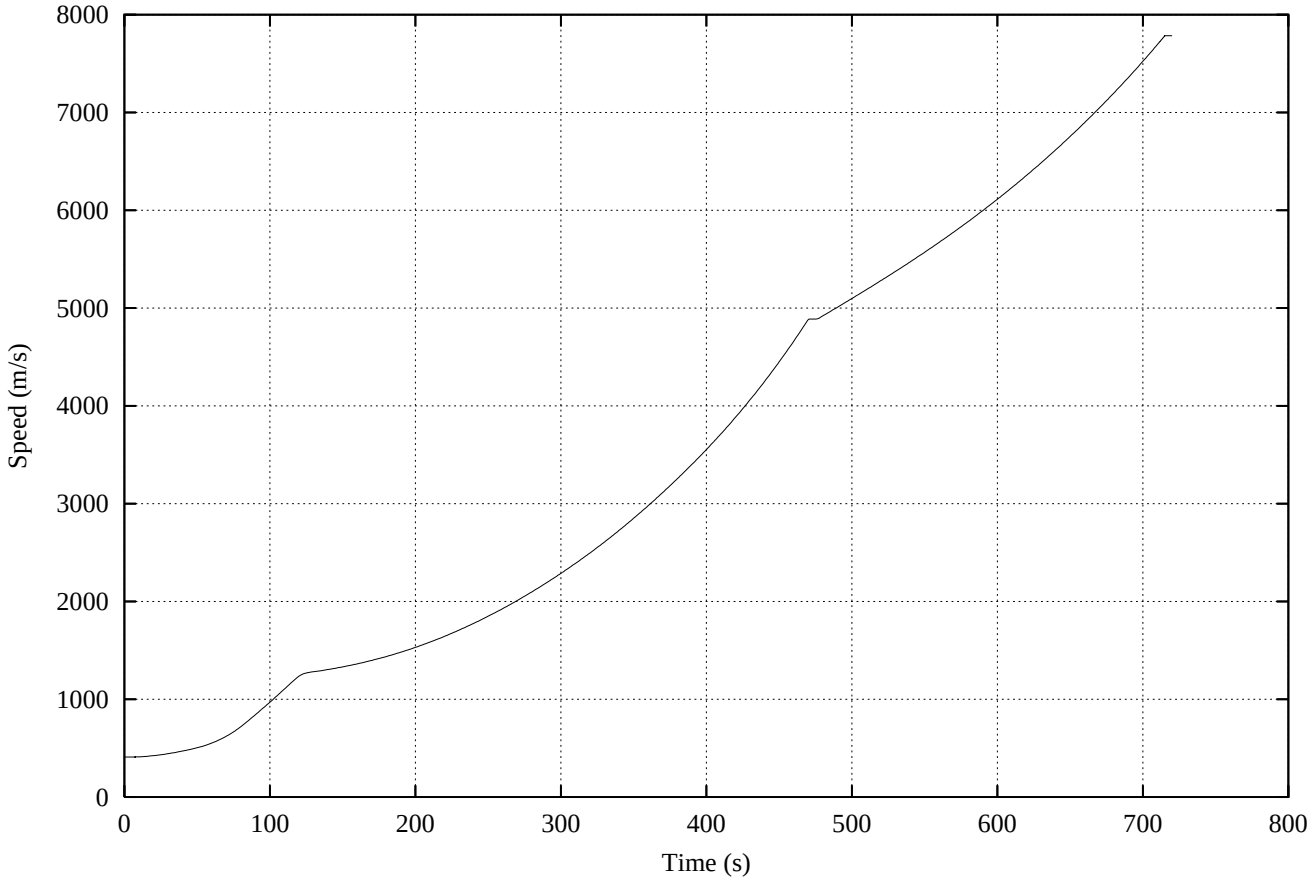

Figure 3: Acceleration versus time for SLS Block 1C

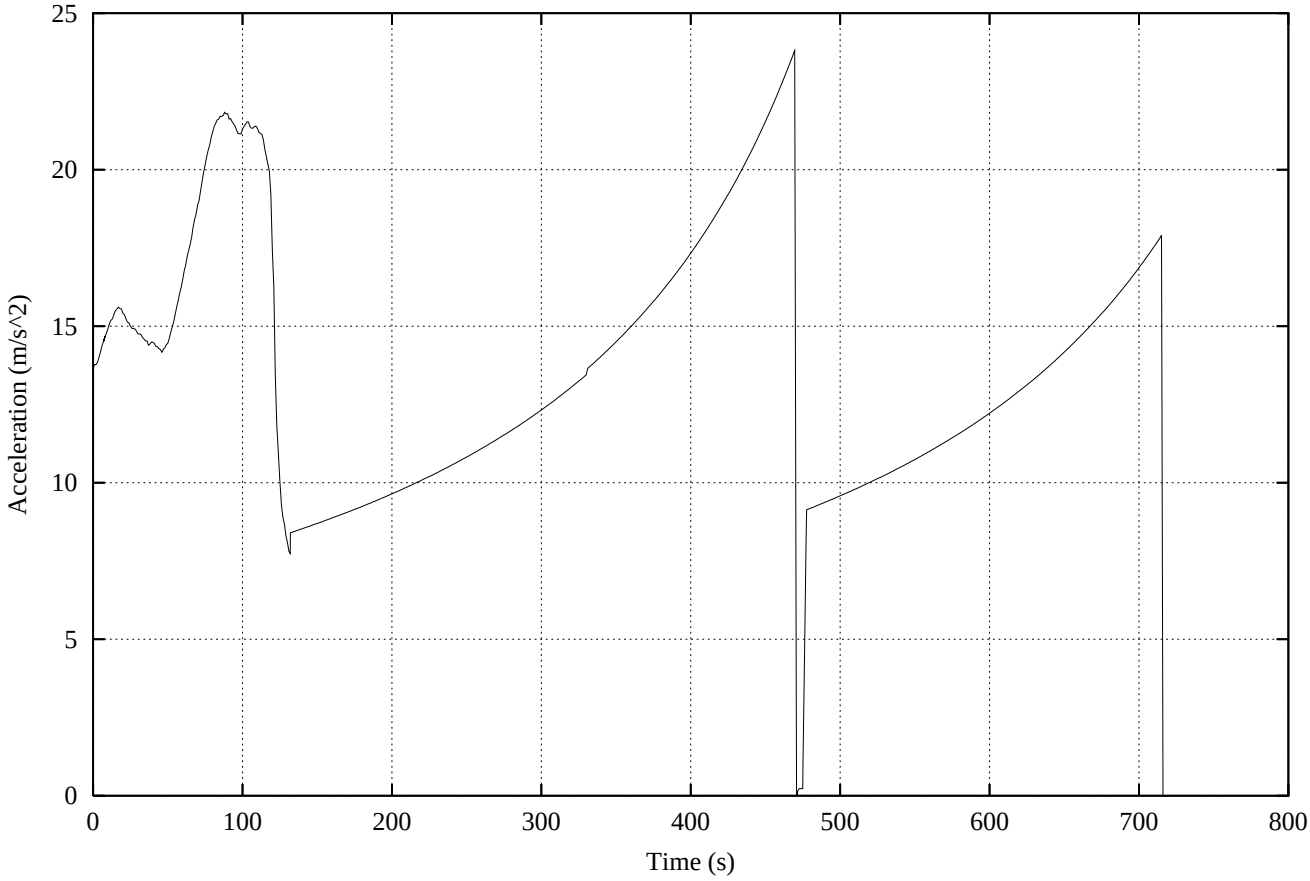

Figure 4: Dynamic pressure versus time for SLS Block 1C