

SLS Block II with four RS–25E core and optimised single J–2X optimised upper stage. Payload to 200 km LEO = 113.6 t. 10 Aug. 2014. Author: Steven S. Pietrobon, PhD.

RSRMV thrust curve obtained from page 56 of [1]. A number of corrections have been made so as to match the parameters in [2] and other sources.

Boosters: RSRMV 2x5–Segment	1C4J1	1C4J1.1
Aft Skirt Diameter (m)	5.156	5.288
Additional Area (m <sup>2</sup> )	0.000	–0.038
Nozzle Diameter (m)	3.875	3.875
Sea Level Thrust at 0.2 s (N)	15,599,386	15,471,544
Vacuum Isp (m/s)	2,622.3	2,605.4
Total Mass (kg)	733,776	729,240
Usable Propellant (kg)	632,791	631,185
Residual Propellant (kg)	442	1,304
Burnout Mass (kg)	100,543	96,751
Action Time (s)	131.9	128.4

The core values have been updated according to [2] and other sources with RS–25E engines.

Core Stage	1C4J1	1C4J1.1
Stage Diameter (m)	8.407	8.407
Additional Area (m <sup>2</sup> )	0.235	2.073
Engines	RS–25D	RS–25E
Number of Engines	4	4
Nozzle Diameter (m)	2.304	2.304
Vacuum Isp (m/s)	4,436.5	4,420.8
Engine Thrust (N)	2,278,824	2,320,637
Engine Thrust Rating (%)	109	111
Total Mass at Liftoff (kg)	1,091,525	1,074,908
Dry Mass (kg)	115,575	100,682
Usable Propellant (kg)	966,061	964,564
Reserve Propellant (kg)	8,210	7,984
Fuel Bias Propellant (kg)	1,678	1,678
Startup Propellant (kg)	7,439	8,437

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.

Upper Stage:	1C4J1	1C4J1.1
Stage Diameter (m)	8.407	8.407
Engines	J-2X	J-2X
Number of Engines	1	1
Nozzle Diameter (m)	3.048	3.048
Vacuum Isp (m/s)	4,275.7	4,393.4
Single Engine Thrust (N)	1,281,088	1,307,777
Total Mass (kg)	110,547	113,802
Usable Propellant (kg)	94,752	97,651
Reserve/Residual Propellant (kg)	1,596	1,644
Startup Propellant (kg)	386	386
RCS Propellant (kg)	87	92
Dry Mass (kg)	13,548	13,833
Ullage Motors Propellant (kg)	86	96
Ullage Motors Dry Mass (kg)	92	100
Ullage Motors Action Time (s)	3.87	3.87
Ullage Motors Thrust (N)	48,405	54,319
Ullage Motors Offset Angle (°)	30	30
Interstage Mass (kg)	5,346	5,811

The LAS/SAJ jettison time was obtained from [3]. Simulation results for 1C4J1.1 are shown in Figures 1–4. The reduction in core mass, increase in core thrust and increase of upper stage Isp and thrust allows for an increase of payload of 10,280 kg or 9.9% from 103.3 t to 113.6 t.

	1C4J1	1C4J1.1
Orbit (km)	200 ± 0.4	200 ± 0.1
Liftoff Thrust at 0.2 s (N)	38,623,742	38,536,173
Liftoff Mass (kg)	2,786,613	2,774,924
Liftoff Acceleration (m/s <sup>2</sup> )	13.87	13.90
MaxQ (Pa)	23,180	23,524
Maximum Acceleration (m/s <sup>2</sup> )	26.35	26.92
LAS/SAJ Jettison Time (s)	330	330
Launch Abort System (kg)	7,394	7,394
Orion Jettisoned Adaptors (kg)	920	920
Total Payload (kg)	103,329	113,609
Total Delta-V (m/s)	9,767	9,708

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

- [2] B. Donahue and S. Sigmon, "The Space Launch System capabilities with a new large upper stage," *AIAA Space Conf. and Exhib.*, San Diego, CA, USA, Sep. 2013.
- [3] 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 II

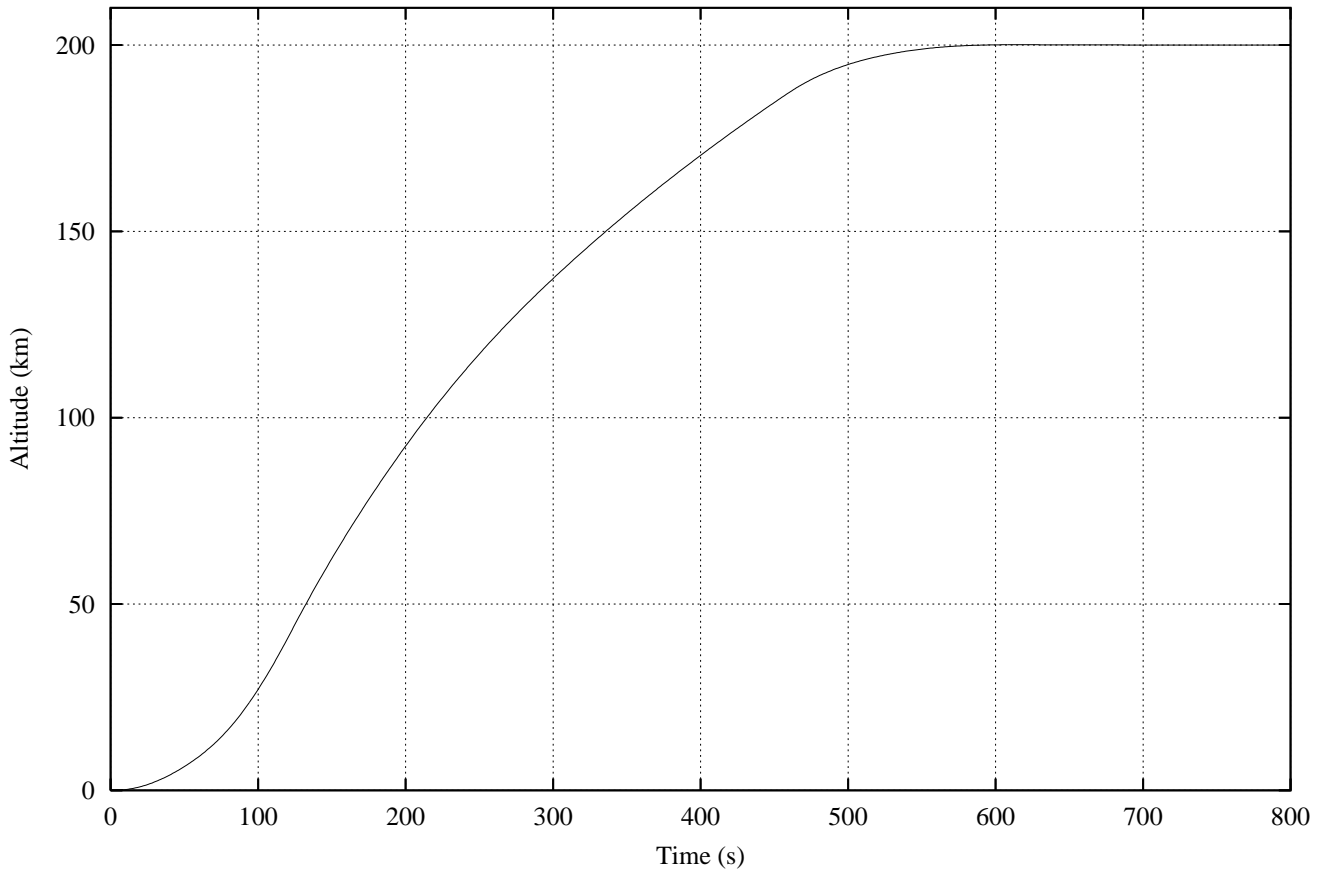


Figure 2: Speed versus time for SLS Block II

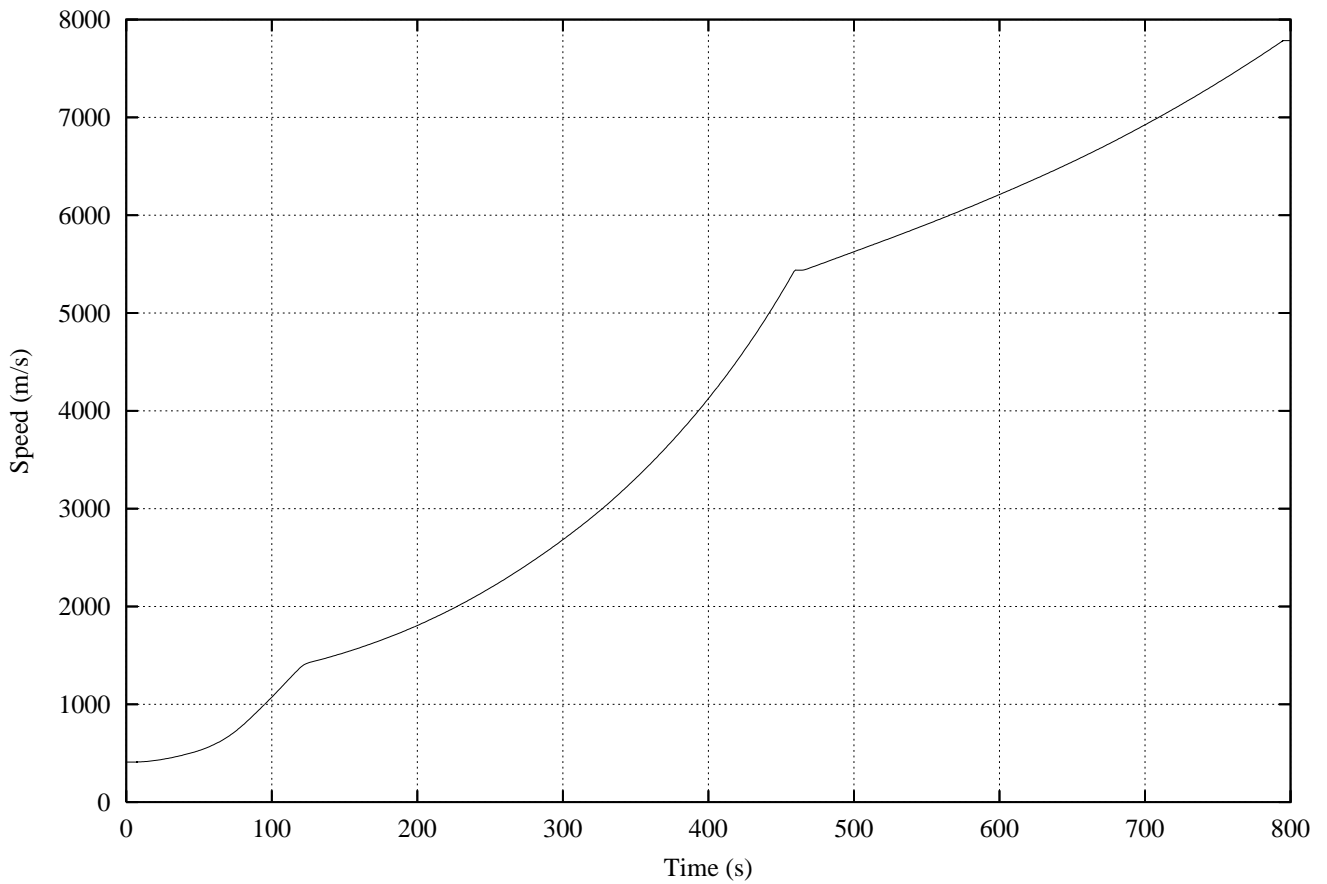


Figure 3: Acceleration versus time for SLS Block II

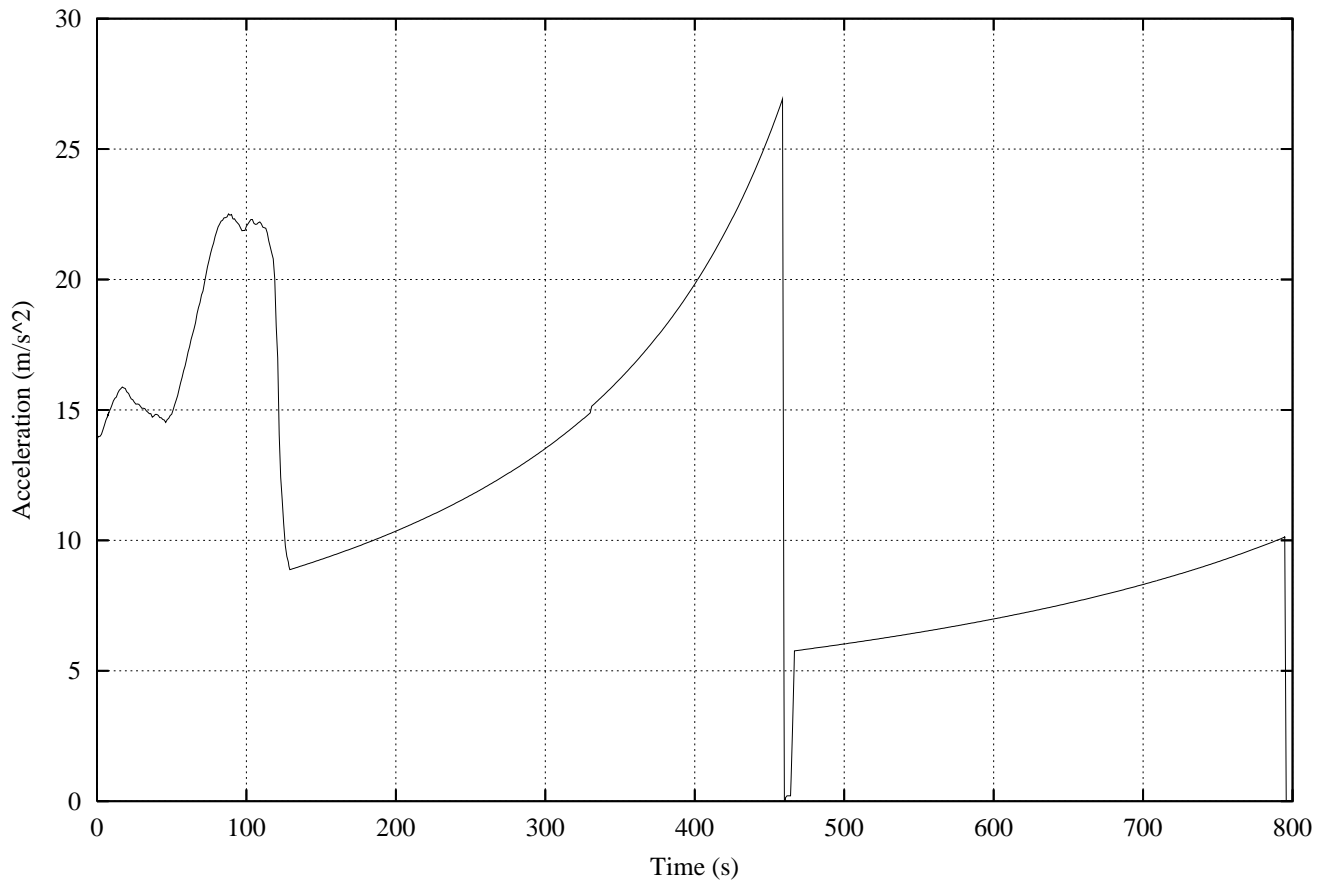


Figure 4: Dynamic pressure versus time for SLS Block II

