

SLS Block II with optimised Second Stage and five RS–25E engines. Payload to 200 km LEO = 130.6 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	1C5J2	1C4J1.1	1C5J2.1
Aft Skirt Diameter (m)	5.156	5.288	5.288
Additional Area (m ²)	0.000	–0.038	–0.038
Nozzle Diameter (m)	3.875	3.875	3.875
Sea Level Thrust at 0.2 s (N)	15,599,386	15,471,544	15,471,544
Vacuum Isp (m/s)	2,622.3	2,605.4	2,605.4
Total Mass (kg)	733,776	729,240	729,240
Usable Propellant (kg)	632,791	631,185	631,185
Residual Propellant (kg)	442	1,304	1,304
Burnout Mass (kg)	100,543	96,751	96,751
Action Time (s)	131.9	128.4	128.4

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

Core Stage	1C5J2	1C4J1.1	1C5J2.1
Stage Diameter (m)	8.407	8.407	8.407
Additional Area (m ²)	0.235	2.073	2.377
Engines	RS–25D	RS–25E	RS–25E
Number of Engines	5	4	5
Nozzle Diameter (m)	2.304	2.304	2.304
Vacuum Isp (m/s)	4,436.5	4,420.8	4,420.8
Engine Thrust (N)	2,278,824	2,320,637	2,320,637
Engine Thrust Rating (%)	109	111	111
Total Mass at Liftoff (kg)	1,102,512	1,074,908	1,084,256
Dry Mass (kg)	119,124	100,682	112,139
Usable Propellant (kg)	963,800	964,564	962,035
Reserve Propellant (kg)	8,191	7,984	7,984
Fuel Bias Propellant (kg)	2,098	1,678	2,098
Startup Propellant (kg)	9,299	8,437	10,546

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	1C5J2	1C4J1.1	1C5J2.1
Stage Diameter (m)	8.407	8.407	8.407
Engines	J-2X	J-2X	J-2X
Number of Engines	2	1	2
Nozzle Diameter (m)	3.048	3.048	3.048
Vacuum Isp (m/s)	4,275.7	4,393.4	4,393.4
Single Engine Thrust (N)	1,281,088	1,307,777	1,307,777
Total Mass (kg)	204,711	113,802	203,602
Usable Propellant (kg)	176,718	97,651	175,703
Reserve/Residual Propellant (kg)	2,977	1,644	2,960
Startup Propellant (kg)	771	386	771
RCS Propellant (kg)	134	92	136
Dry Mass (kg)	23,738	13,833	23,647
Ullage Motors Propellant (kg)	192	96	199
Ullage Motors Dry Mass (kg)	181	100	186
Ullage Motors Action Time (s)	3.87	3.87	3.87
Ullage Motors Thrust (N)	108,332	54,319	111,961
Ullage Motors Offset Angle (°)	30	30	30
Interstage Mass (kg)	7,822	5,811	8,011

The LAS/SAJ jettison time was obtained from [3]. Simulation results for 1C5J2.1 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 6,920 kg or 5.6% from 123.7 t to 130.6 t. Compared to a core with four engines, payload increases by 17,000 kg or 15.0% from 113.6 to 130.7 t.

	1C5J2	1C4J1.1	1C5J2.1
Orbit (km)	200 ± 0.2	200 ± 0.1	200 ± 0.2
Liftoff Thrust at 0.2 s (N)	40,479,985	38,536,173	40,434,444
Liftoff Mass (kg)	2,905,302	2,774,924	2,893,272
Liftoff Acceleration (m/s ²)	13.94	13.90	13.98
MaxQ (Pa)	24,291	23,524	24,655
Maximum Acceleration (m/s ²)	24.39	26.92	24.90
LAS/SAJ Jettison Time (s)	330	330	330
Launch Abort System (kg)	7,394	7,394	7,394
Orion Jettisoned Adaptors (kg)	920	920	920
Total Payload (kg)	123,689	113,609	130,609
Total Delta-V (m/s)	9,508	9,708	9,460

- [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

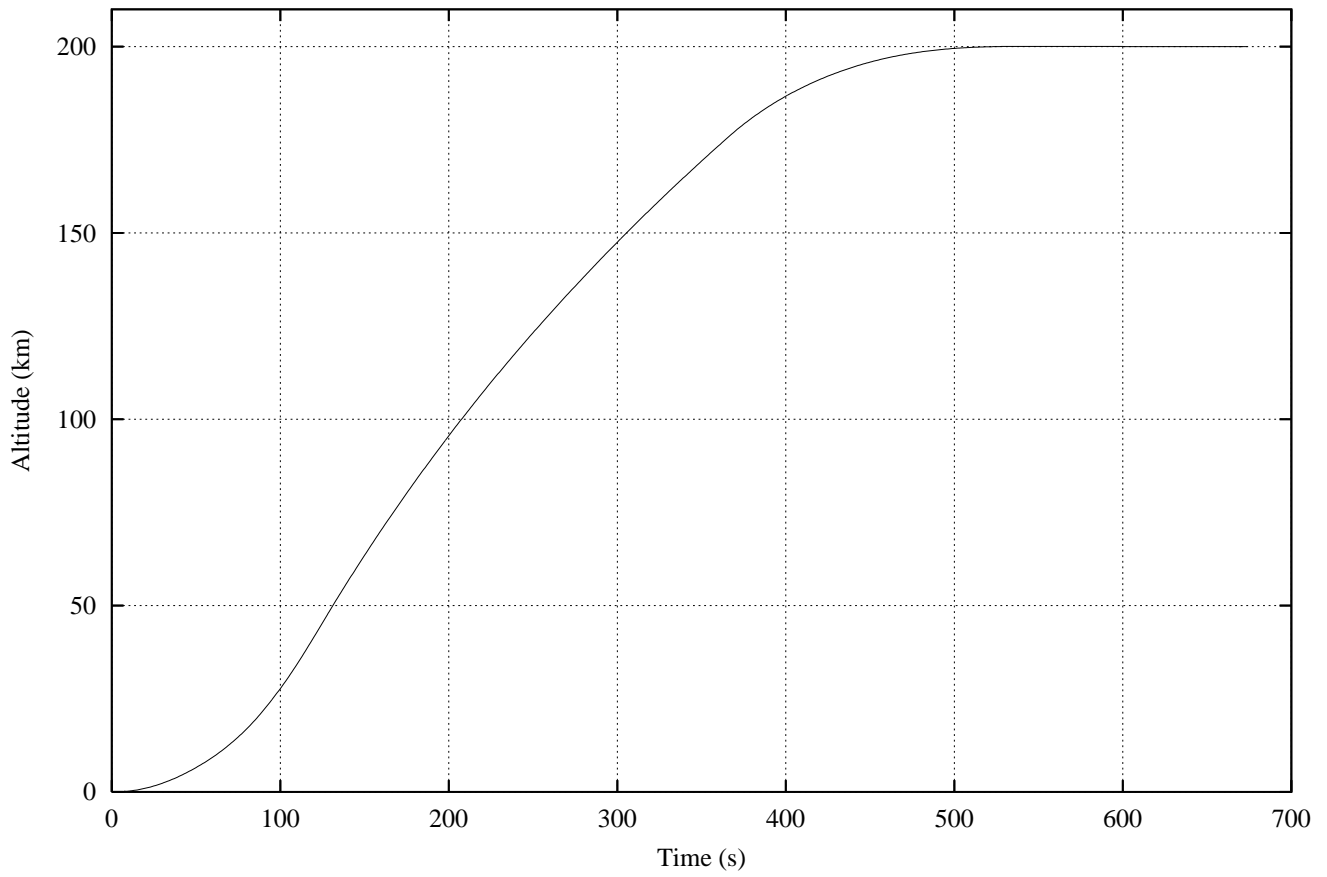


Figure 2: Speed versus time for SLS Block II

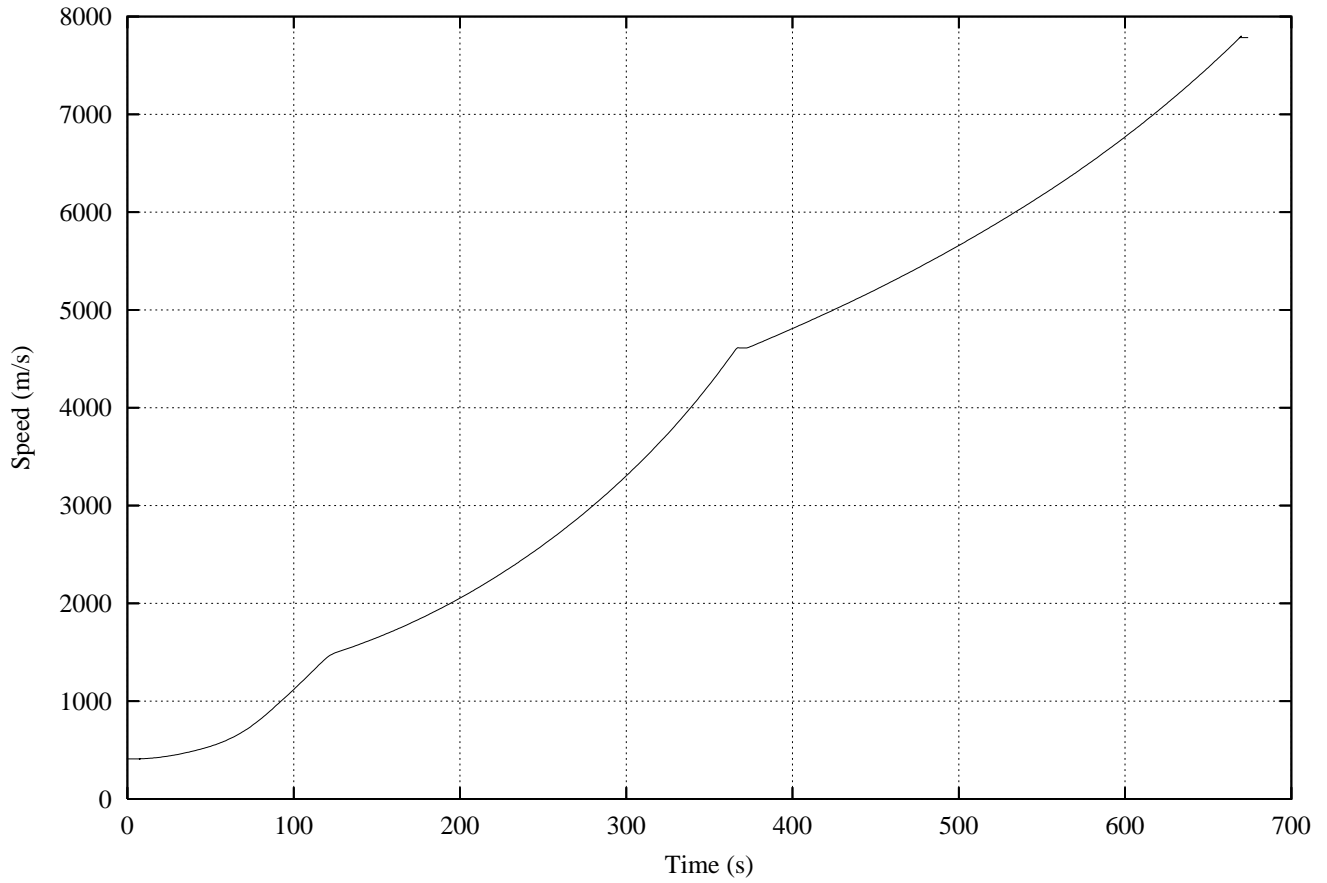


Figure 3: Acceleration versus time for SLS Block II

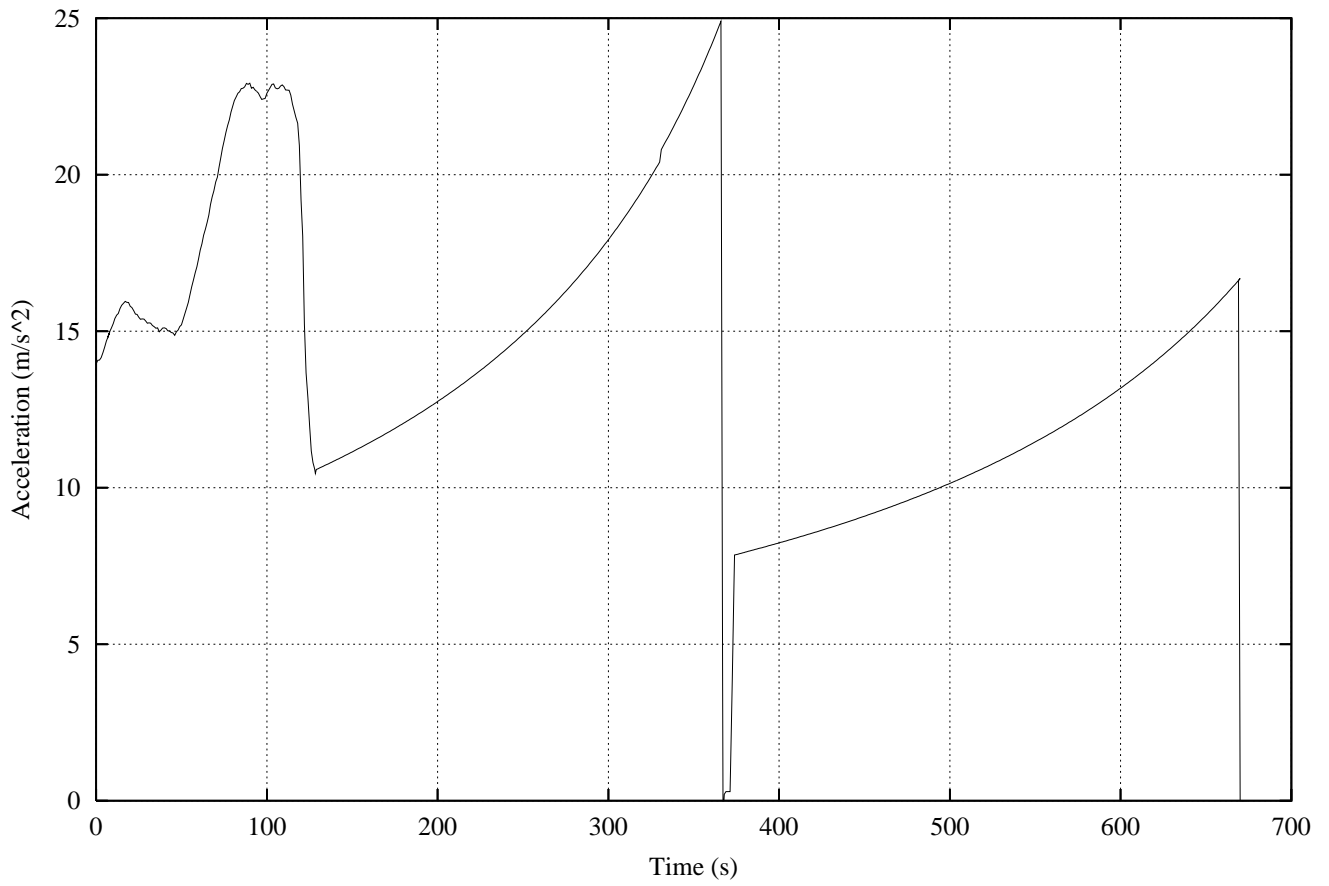


Figure 4: Dynamic pressure versus time for SLS Block II

