

SLS Block II with optimised Second Stage and six RS–25E engines. Payload to 200 km LEO = 137.0 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	1C6J2	1C4J1.1	1C5J2.1	1C6J2.1
Aft Skirt Diameter (m)	5.156	5.288	5.288	5.288
Additional Area (m <sup>2</sup> )	0.000	–0.038	–0.038	–0.038
Nozzle Diameter (m)	3.875	3.875	3.875	3.875
Sea Level Thrust at 0.2 s (N)	15,599,386	15,471,544	15,471,544	15,471,544
Vacuum Isp (m/s)	2,622.3	2,605.4	2,605.4	2,605.4
Total Mass (kg)	733,776	729,240	729,240	729,240
Usable Propellant (kg)	632,791	631,185	631,185	631,185
Residual Propellant (kg)	442	1,304	1,304	1,304
Burnout Mass (kg)	100,543	96,751	96,751	96,751
Action Time (s)	131.9	128.4	128.4	128.4

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

Core Stage	1C6J2	1C4J1.1	1C5J2.1	1C6J2.1
Stage Diameter (m)	8.407	8.407	8.407	8.407
Additional Area (m <sup>2</sup> )	0.235	2.073	2.377	3.087
Engines	RS–25D	RS–25E	RS–25E	RS–25E
Number of Engines	6	4	5	6
Nozzle Diameter (m)	2.304	2.304	2.304	2.304
Vacuum Isp (m/s)	4,436.5	4,420.8	4,420.8	4,420.8
Engine Thrust (N)	2,278,824	2,320,637	2,320,637	2,320,637
Engine Thrust Rating (%)	109	111	111	111
Total Mass at Liftoff (kg)	1,106,061	1,074,908	1,084,256	1,093,602
Dry Mass (kg)	122,673	100,682	112,139	123,595
Usable Propellant (kg)	961,556	964,564	962,035	959,506
Reserve Propellant (kg)	8,156	7,984	7,984	7,984
Fuel Bias Propellant (kg)	2,517	1,678	2,098	2,517
Startup Propellant (kg)	11,159	8,437	10,546	12,656

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	1C6J2	1C4J1.1	1C5J2.1	1C6J2.1
Stage Diameter (m)	8.407	8.407	8.407	8.407
Engines	J-2X	J-2X	J-2X	J-2X
Number of Engines	2	1	2	2
Nozzle Diameter (m)	3.048	3.048	3.048	3.048
Vacuum Isp (m/s)	4,275.7	4,393.4	4,393.4	4,393.4
Single Engine Thrust (N)	1,281,088	1,307,777	1,307,777	1,307,777
Total Mass (kg)	217,933	113,802	203,602	227,756
Usable Propellant (kg)	188,621	97,651	175,703	197,478
Reserve/Residual Propellant (kg)	3,177	1,644	2,960	3,325
Startup Propellant (kg)	771	386	771	771
RCS Propellant (kg)	143	92	136	148
Dry Mass (kg)	24,802	13,833	23,647	25,586
Ullage Motors Propellant (kg)	218	96	199	234
Ullage Motors Dry Mass (kg)	201	100	186	214
Ullage Motors Action Time (s)	3.87	3.87	3.87	3.87
Ullage Motors Thrust (N)	122,736	54,319	111,961	131,925
Ullage Motors Offset Angle (°)	30	30	30	30
Interstage Mass (kg)	9,257	5,811	8,011	9,507

The LAS/SAJ jettison time was obtained from [3]. Simulation results for 1C6J2.1 are shown in Figures 1–4. The increase in core thrust and increase of upper stage Isp and thrust allows for an increase of payload of 3,927 kg or 3.0% from 133.0 t to 137.0 t. Compared to a core with five engines, payload increases by 6,350 kg or 4.9% from 130.6 to 137.0 t.

	1C6J2	1C4J1.1	1C5J2.1	1C6J2.1
Orbit (km)	200 ± 0.2	200 ± 0.1	200 ± 0.2	200 ± 0.1
Liftoff Thrust at 0.2 s (N)	43,336,228	38,536,173	40,434,444	42,332,715
Liftoff Mass (kg)	2,930,991	2,774,924	2,893,272	2,934,618
Liftoff Acceleration (m/s <sup>2</sup> )	14.45	13.90	13.98	14.43
MaxQ (Pa)	27,765	23,524	24,655	27,752
Maximum Acceleration (m/s <sup>2</sup> )	27.14	26.92	24.90	26.85
LAS/SAJ Jettison Time (s)	330	330	330	330
Launch Abort System (kg)	7,394	7,394	7,394	7,394
Orion Jettisoned Adaptors (kg)	920	920	920	920
Total Payload (kg)	133,032	113,609	130,609	136,959
Total Delta-V (m/s)	9,234	9,708	9,460	9,247

- [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

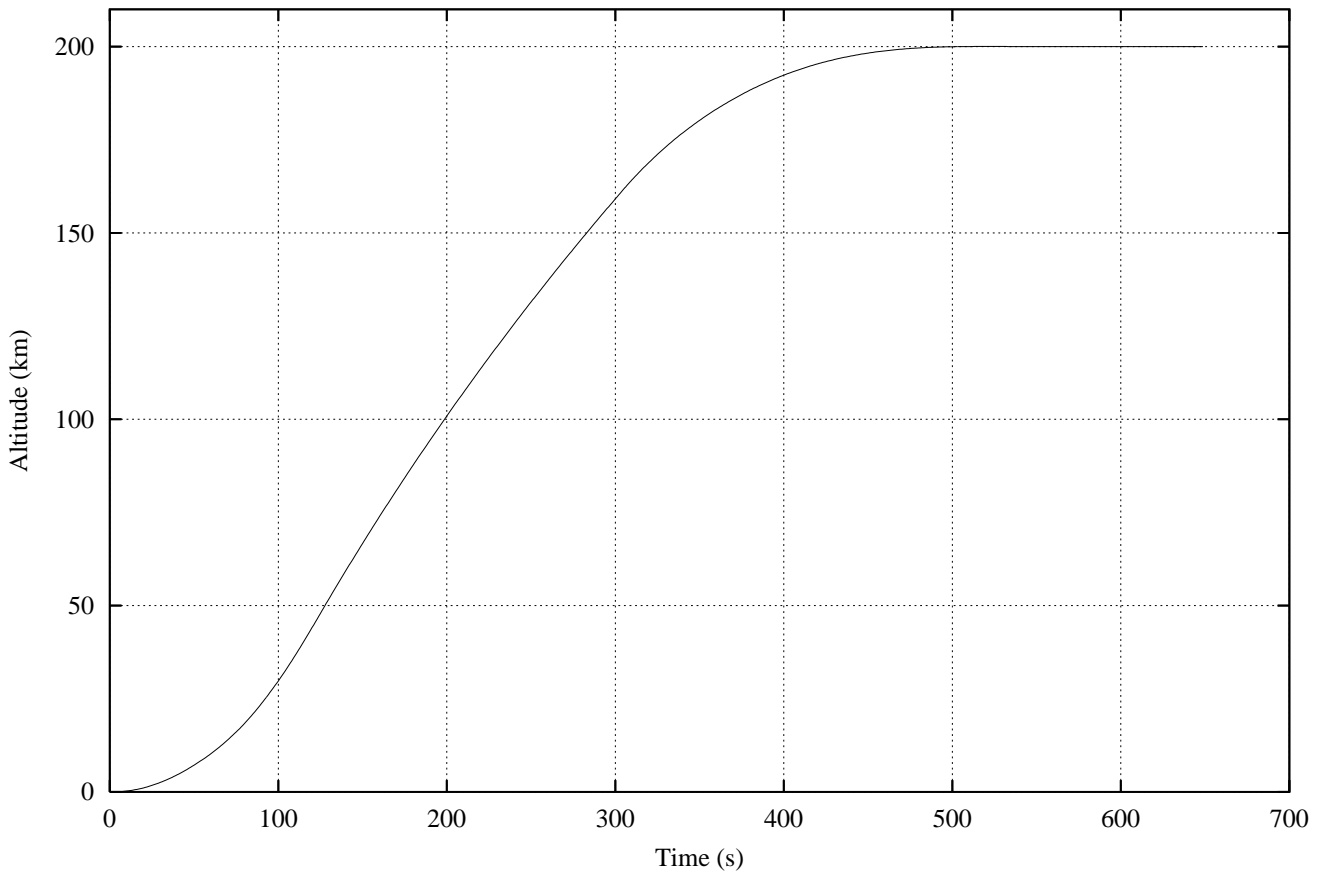


Figure 2: Speed versus time for SLS Block II

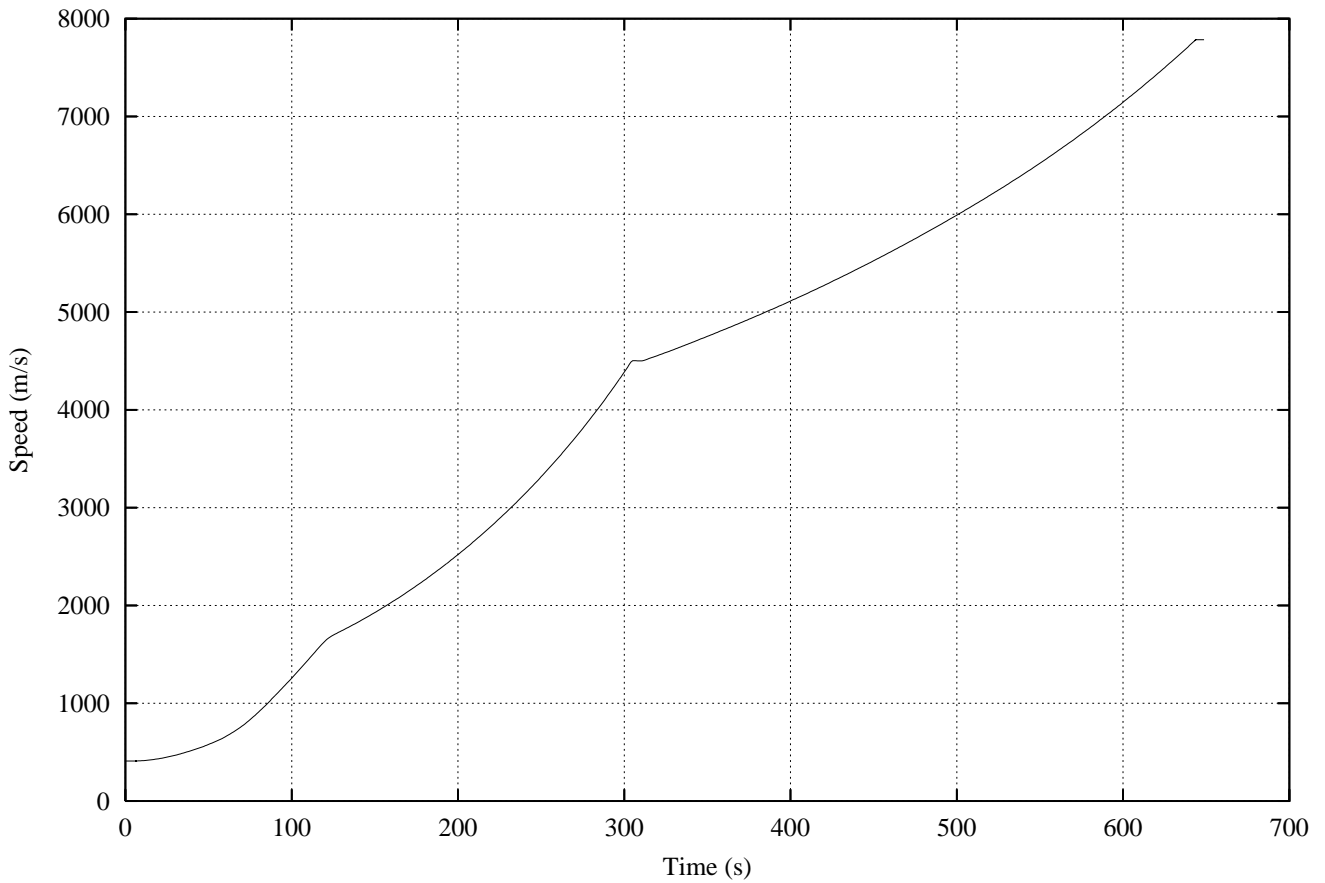


Figure 3: Acceleration versus time for SLS Block II

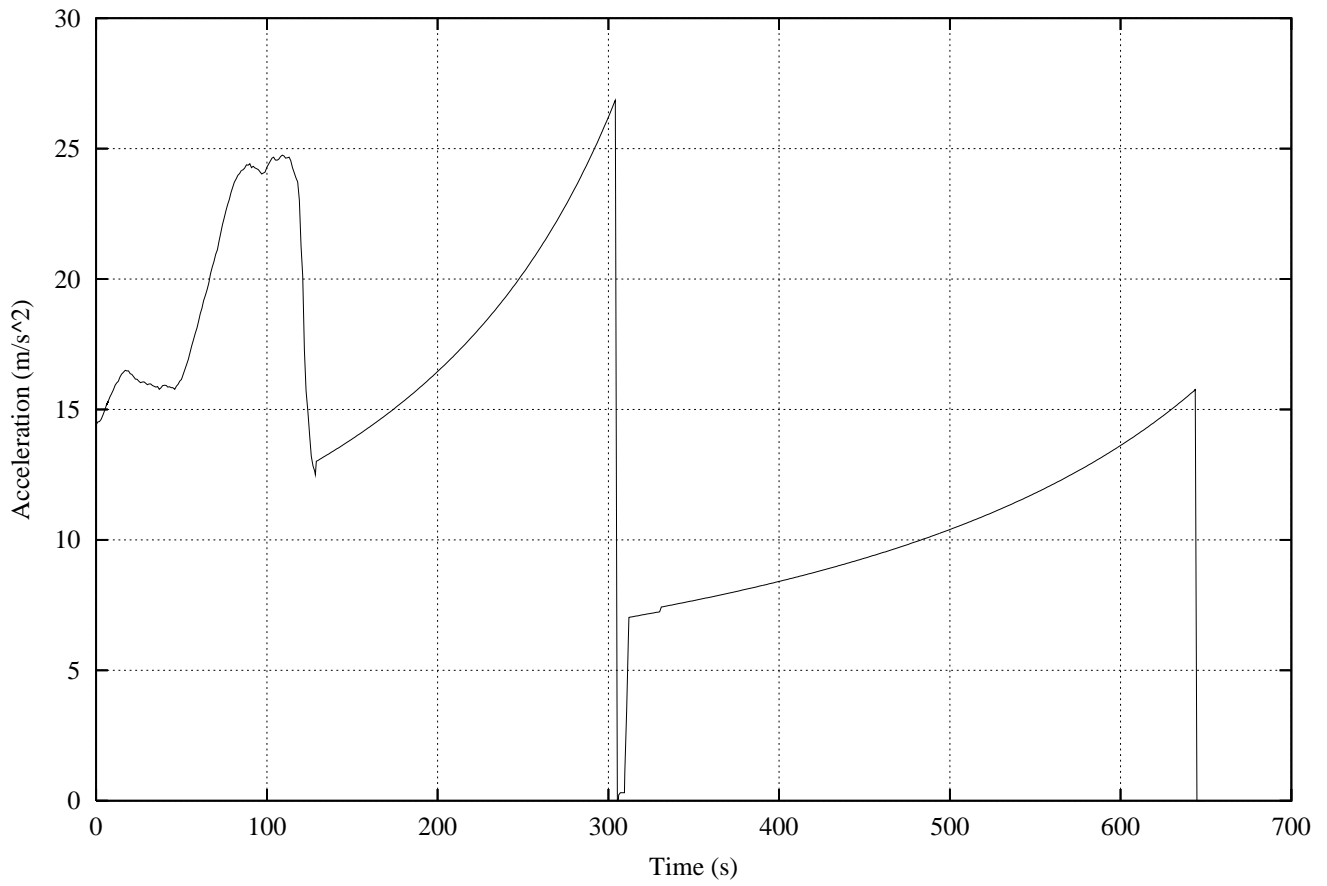


Figure 4: Dynamic pressure versus time for SLS Block II

