Fusee a eau. (Compressed air over water rockets) msc

Performance parameters

Comparison Table showing how parametrs change when you vary one parameter at a time> In this case Launch pressure in Bar

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Badoit 0,33L

Launcher Physical characteristics

Exp.

Nozzle Diameter mm d		22	22	22	22		22	22	22	22	22	22	22	22	22	22	22	22
Nozzle Area m² Na (π)r²	A	0,000380133	0,000380133	0,000380133	0,000380133		0,000380133	0,000380133	0,000380133	0,000380133	0,000380133	0,000380133	0,000380133	0,000380133	0,000380133	0,000380133	0,000380133	0,000380133
Length of rocket body from lip to nozzle(L) mm		520	520	520	287		520	520	520	520	520	520	520	520	520	520	520	520
Diameter of rocket body (D) mm		80	80	80	58		80	80	80	80	80	80	80	80	80	80	80	80
Aerodynamic ratio L/D		6,5	6,5	6,5	4,95		6,5	6,5	6,5	6,5	6,5	6,5	6,5	6,5	6,5	6,5	6,5	6,5
Type of bottle used for main reservoir		Badoit 1L	Badoit 1L	Badoit 1L	Badoit 0,33L		Badoit 1L	Badoit 1L	Badoit 1L	Badoit 1L	Badoit 1L	Badoit 1L	Badoit 1L	Badoit 1L	Badoit 1L	Badoit 1L	Badoit 1L	Badoit 1L
Volume of bottle ml		1000	1000	1000	350		1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Type of bottle used for payload capsule/ Coiffe		Aix les Bains	Aix les Bains	Aix les Bains			Aix	Aix	Aix	Aix	Aix	Aix	Aix	Aix	Aix	Aix	Aix	Aix
Height of liquid level Hydraulic head (h) mm		230	230	230	125		230	230	230	230	230	230	230	230	230	230	230	230
Rocket launch pressure Bar. Pe bar		7	7	9	9		2	3	4	5	6	7	8	9	10	15		
Launch pressure in Pa or N/m²		709275	709275	911925	911925		202650	303975	405300	506625	607950	709275	810600	911925	1013250	1519875		
Density of liquid Kgs/m³ Dn (ρ)	ρ	1000	1000	1000	1000		1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Density of air/gas Kgs/m³ⁿ		1,1614	1,1614	1,1614	1,1614													
Acceleration due to gravity (g) 9,81 m/s²		9,81	9,81	9,81	9,81		9,81	9,81	9,81	9,81	9,81	9,81	9,81	9,81	9,81	9,81		
Discharge coefficient 0,97 > 0,998 W	ψ	0,97	0,97	0,97	0,97		0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97		
Coefficient of contraction 0,52 > 0,99 X	χ	0,8	0,8	0,8	0,8		0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8		
2*g*h		4,5126	4,5126	4,5126	2,4525		4,5126	4,5126	4,5126	4,5126	4,5126	4,5126	4,5126	4,5126	4,5126	4,5126		
2*Pa/Dn		1418,55	1418,55	1823,85	1823,85		405,3	607,95	810,6	1013,25	1215,9	1418,55	1621,2	1823,85	2026,5	3039,75		
1 Jet velocity V1 from a pressurised reservoir		37,72350196	37,72350196	42,75935687	42,73526062		20,24382869	24,74798174	28,55017688	31,90239176	34,93440425	37,72350196	40,32012649	42,75935687	45,06675715	55,17483666		
V1=W *(2gh+ 2Pa/Dn)^0,5 Note to power 0.5																		
Velocity of water jet discharged V1 m/s		36,5917969	36,5917969	41,47657616	41,4532028		19,63651383	24,00554228	27,69367158	30,94532001	33,88637212	36,5917969	39,11052269	41,47657616	43,71475444	53,51959156		
Air jet 2*Pa/2 Da		305353,4527	305353,4527	392597,2964	392597,2964													
		552,5879593	552,5879593	626,5758504	626,5758504													
Air jet V1=W *(Pa/Dn)^0,5 Note to power 0.5		536,0103205	536,0103205	607,7785749	607,7785749													
3.Tsiolkovski Parameter V2=V1*LN(M1/M2) m/s																		
Mass initial gms M1		600	750	750	245		600	600	600	600	600	600	600	600	600	600		
Mass final gms M2		100	118	118	70		100	100	100	100	100	100	100	100	100	100		
Ratio M1/M2		6	6,355932203	6,355932203	3,5		6	6	6	6	6	6	6	6	6	6		
Ln M1/M2		1,791759469	1,849388582	1,849388582	1,252762968		1,791759469	1,791759469	1,791759469	1,791759469	1,791759469	1,79175469	1,791759469	1,791759469	1,791759469	1,791759469		
Volume of liquid ml cm³		500	632	632	175		500	500	500	500	500	500	500	500	500	500		
Volume of air ml cm³		500	368	368	175		500	500	500	500	500	500	500	500	500	500		
Final velocity of fusee/rocket V2																		
Tsiolkovski formula V2=V1*LN(M1/M2) m/s		65,56369859	67,67245138	76,70630638	51,93103739		35,18390959	43,0121577	49,62039828	55,44657015	60,71622812	65,56369859	70,07664938	74,31604809	78,3263252	95,89423496		
F= Pa*At*Cf Cf divergent expansion nozzle coef.1.6>2.0		1	1	1	1		1	1	1	1	1	1	1	1	1	1		
4.DischargeFlow Rate Qs m³/s																		
Qs= X*A*V1 m³/s		0,011127791	0,011127791	0,012613283	0,012606175		0,005971585	0,007300233	0,008421816	0,009410663	0,010305055	0,011127791	0,011893751	0,012613283	0,013293926	0,016275638		
Qs Equivalent ml/s		11127,79117	11127,79117	12613,28268	12606,17469		5971,58499	7300,233496	8421,816365	9410,662712	10305,0548	11127,79117	11893,75122	12613,28268	13293,92649	16275,63795		
Mass flow rate ṁ Kgs/s		11,12779117	11,12779117	12,61328268	12,60617469		5,97158499	7,300233496	8,421816365	9,410662712	10,3050548	11,12779117	11,89375122	12,61328268	13,29392649	16,27563795		
Tjet Duration of jet stream Qs/B23 Seconds		0,044932547	0,056794739	0,050105909	0,013882086		0,083729864	0,06849096	0,059369616	0,053131221	0,048519878	0,044932547	0,042038882	0,039640751	0,03761116	0,030720762		
Air Qs= X*A*V1 m³/s		0,163004045	0,163004045	0,184829214	0,184829214													
Air Qs Equivalent ml/s		163004,045	163004,045	184829,2139	184829,2139													
Air Mass flow rate ṁ Kgs/s		0,195930862	0,195930862	0,222164715	0,222164715													
		0,006134817	0,004515225	0,003982054	0,00189364													
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Kinematic viscosity of air at 200m Vis 14* 10⁻⁶ m²/s	γ																	
L/Vis		37142,85714	37142,85714	37142,85714	20500		37142,85714	37142,85714	37142,85714	37142,85714	37142,85714	37142,85714	37142,85714	37142,85714	37142,85714	37142,85714		
Density of air (de) at 200m Kg/m3	ρ	1,202	1,202	1,202	1,202		1,202	1,202	1,202	1,202	1,202	1,202	1,202	1,202	1,202	1,202		
Coeficient of drag Cd 0,05 Equiv L/D=6		0,05	0,05	0,05	0,07		0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05		
Cd varies from 0,4 > 0,05																		
Cd depends on aerodynamic pure form shape																		
Cross section area A m2		0,005026548	0,005026548	0,005026548	0,002642079		0,005026548	0,005026548	0,005026548	0,005026548	0,005026548	0,005026548	0,005026548	0,005026548	0,005026548	0,005026548		
V2 Velocity of fusee/rocket. m/s		65,56369859	67,67245138	76,70630638	51,93103739		35,18390959	43,0121577	49,62039828	55,44657015	60,71622812	65,56369859	70,07664938	74,31604809	78,3263252	95,89423496		
Vair Head on wind velocity m/s		0	0	0	0		0	0	0	0	0	0	0	0	0	0		
Reynolds NumberRe =(V2+Vair) L/Vis m/s		2435223,091	2513548,194	2849091,38	1064586,267		1306830,928	1597594,429	1843043,365	2059444,034	2255174,187	2435223,091	2602846,977	2760310,358	2909263,508	3561785,87		
Reynolds NumberRe ~72000(V2+Vair) L m/s		2454704,875	2533656,58	2871884,111	1073102,957		1317285,575	1610375,184	1857787,712	2075919,586	2273215,581	2454704,875	2623669,753	2782392,841	2932537,616	3590280,157		
(V2+Vair)²		4298,598573	4579,560678	5883,857439	2696,832645		1237,907494	1850,04571	2462,183926	3074,322142	3686,460357	4298,598573	4910,736789	5522,875004	6135,01322	9195,704299		
5.Aerodynamic drag Force (Fd)																		
Fd = 0,5(de)(Cd)A(V2+Vair)² N		0,649293749	0,69173245	0,888743573	0,299759101		0,186983172	0,279445288	0,371907403	0,464369518	0,556831634	0,649293749	0,741755864	0,83421798	0,926680095	1,388990672		
6.Thrust Force F= q* V1 + (Pe-Pa)*Se N																		
Mass flow from nozzle/ Debit d'gas q Kgs/s		11,12779117	11,12779117	12,61328268	12,60617469		5,97158499	7,300233496	8,421816365	9,410662712	10,3050548	11,12779117	11,89375122	12,61328268	13,29392649	16,27563795		
q*V1 N		407,1858743	407,1858743	523,1557796	522,566316		117,2611112	175,2460639	233,2310165	291,2159691	349,2009217	407,1858743	465,1708269	523,1557796	581,1407322	871,0654953		
q*V2 N		729,5791461	753,0449068	967,52	654,6517292		210,1037064	313,9987944	417,8938823	521,7889702	625,6840581	729,5791461	833,4742234	937,3693219	1041,26441	1560,739849		
Velocity of fluid /gas V1																		
F= q* V1 + (Pl-Pa)*Se N		407,1858743	407,1858743	523,1557796	522,566316		117,2611112	175,2460639	233,2310165	291,2159691	349,2009217	407,1858743	465,1708269	523,1557796	581,1407322	871,0654953		
Note: For ideal nozzle Pl=Pa																		
F= q* V2 + (Pl-Pa)*Se N				523,1557796	522,566316													
1/g		0,101936799	0,101936799	0,101936799	0,101936799		0,101936799	0,101936799	0,101936799	0,101936799	0,101936799	0,101936799	0,101936799	0,101936799	0,101936799	0,101936799		
7. Specific Impulse																		
Specific Impulse Isp= F/g.ṁ Sec		3,730050652	3,730050652	4,227989415	4,225606809		2,001683367	2,447048143	2,823004238	3,154466871	3,45426831	3,730050652	3,986801498	4,227989415	4,456142144	5,455615857		
Specific impulse 2 for water jet period t F(t) /(g*ṁ)	tω	7,460101305	7,460101305	8,455978831	8,451213618		0,167600676	0,167600676	0,167600676	0,167600676	0,167600676	0,167600676	0,167600676	0,167600676	0,167600676	0,167600676		
Specific impulse due to comp.air	tα																	
Ariane5		431																
F=Thrust force N, ṁ* =mass flowrate Kgs/s																		
Acceleration a																		
F=ṁ*a Acceleration a1 =F/ M1 m/s²		1214,883087	1003,137566	1288,839442	2670,824368		350,1728441	523,3313239	696,4898038	869,6482837	1042,806764	1215,965243	1389,123723	1562,282203	1735,440683	2601,233082		
F=ṁ*a a3 =F/ M1 m/s²		4071,858743	3450,727749	4433,523556	7465,233085		1172,611112	1752,460639	2332,310165	2912,159691	3492,009217	4071,858743	4651,708269	5231,557796	5811,407322	8710,654953		
F=ṁ*a a2 =F/ M2 m/s²		7289,298523	6375,874359	8191,776117	9347,885287		2101,037094	3139,987944	4178,938823	5217,889702	6256,840581	7295,791461	8334,74234	9373,693219	10412,6441	15607,39849		
Multiple of g 9.81 m/s²		123,8412933	102,2566326	131,3801674	272,2552872		35,69549889	53,34672008	70,99794127	88,64916246	106,3003836	123,9516048	141,602826	159,2540472	176,9052684	265,1613744		
		743,0477597	649,9362241	835,043437	952,8935053		214,1729933	320,0803205	425,9876476	531,8949747	637,8023019	743,709629	849,6169562	955,5242833	1061,43161	1590,968246		
Refer to specific duct formula developed for modelling output																		
before adding expansion nozzle.																		
8.Potential Increase in jet efficiency by using expansion nozzle																		
Launch Force (F) N without Tuyau/ divergent nozzle Cf>1		407,1858743	407,1858743	523,1557796	522,566316		117,2611112	175,2460639	233,2310165	291,2159691	349,2009217	407,1858743	465,1708269	523,1557796	581,1407322	871,0654953		
Cf divergent expansion nozzle coef.1.6>2.0	1,0	407,1858743	407,1858743	523,1557796	522,566316		1	1	1	1	1	1	1	1	1	1		
F= Pe*At*Cf Assume Cf=1,8 N	1,8	485,3135316	485,3135316	623,9745406	623,9745406		138,661009	207,9915135	277,322018	346,6525226	415,9830271	485,3135316	554,6440361	623,9745406	693,3050451	1039,957668		
	1,6	431,3898658	431,3898658	554,644	554,644		123,2542302	184,8813454	246,5084605	308,1355756	369,7626907	431,3898658	493,016921	554,644361	616,2711512	924,4067268		
	2,0	539,2372573	539,2372573	693,3050451	693,3050451		154,0677878	231,1016817	308,1355756	385,1694695	462,2033634	539,2372573	616,2711512	693,3050451	770,338939	1155,508409		
Potential acceleration at launch with divergent nozzle/tuyau m/s²	2,0	5392,372573	4569,807265	5875,466484	9904,357787		1540,677878	2311,016817	3081,355756	3851,694695	4622,033634	5392,372573	6162,711512	6933,050451	7703,38939	11555,08409		
Modified V1 for expansion nozzle V1=F/q	1,8			96,469639	49,4973243													
				91,4885853	62,0867566													
Measured Velocity at decollage																		
Launch pressure Pe=7 bar																		
No divergent tuyau /nozzle Cf>1																		
Test Data				27,10.02														
Phase2 Velocity 3,18m at 0,04s > m/s		79,500	79,500	83,75														
Phase1 Velocity m/s		44,370	42,987	56,15														
Ln M1/M2		1,791759469	1,849388582	1,849388582														
Calculated V2 using Tsiolkovski formula >		79,5		103,8431689														
Measured acceleration (h1)2,24m >(h2)5,59 t0.04s m/s²				693,75														
Measured acceleration (h0)0m >(h2)5,59 t0.08s m/s²				1046,875														
Rateof change of acceleration per second.				13085,9375														
Flight time to apogee tap sec		3,280	3,280	4,52														
Impulse time ι		0,040	0,040	0,05010509			0,040	0,040	0,040	0,040	0,040	0,040	0,040	0,040	0,040	0,040		
Altitude 250>270m																		
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World Record.323,092m (1060 ft.)																		
Approximations>Research																		
Launch pressure Pe bar		7	7	9	9		2	3	4	5	6	7	8	9	10	15		
Tsiolkovski formula V2=V1*LN(M1/M2)																		
V2 m/s				91,489			35,184	43,012	49,620	55,447	60,716	65,564	70,077	74,316	78,326	95,8942		
Fd Drag force N							0,187	0,279	0,372	0,464	0,557	0,649	0,742	0,834	0,927	1,3890		
Thrust Force F N							117,261	175,246	233,231	291,216	349,201	407,186	465,171	523,156	581,141	871,065		
Tjet s		0,045	0,057	0,050	0,014		0,084	0,068	0,059	0,053	0,049	0,045	0,042	0,040	0,038	0,0307		
Height of jet Hjet m (Constant Kh)	κ	1,644	2,078	2,078	0,575		1,644	1,644	1,644	1,644	1,644	1,644	1,644	1,644	1,644	1,644		
Acceleration in (g) Multiple of g (9.81m/s²)							35,695	53,347	70,998	88,649	106,300	123,952	141,603	159,254	176,905	265,1614		
Height of flight approximation (Apogee)																		
Assume body thrown vertically upwards after 3m No aero drag																		
1. Basic approximation h2 = (V2)²/2g m.		322,1330275	322,1330275	426,6137249	195,9773628													
2. Observations Gwynn 2 Specific impluse factor a2'ι > h3 m		291,5719409	255,0349743	410,4563928	0		84,04148258	125,5995177	167,1575529	208,7155881	250,2736233	291,8316584	333,3896936	374,9477288	416,5057639	624,2959398		
Measured acceln./jet Impulse time. > V1				34,7609747	0													
3. Gwynn parameter a2 /g² > v2		75,74391027	66,25241836	85,12165515	97,1349139		21,83210941	32,62796335	43,42381729	54,21967123	65,01552517	75,8113791	86,60723304	97,40308698	108,1989409	162,1782106		
Modified Aerodynamic drag Force for higher V2 (Fd)																		
(V2+Vair)²		5737,139943	4389,382939	7245,696175	9435,191498		1237,907494	1850,04571	2462,183926	3074,322142	3686,460357	4298,598573	4910,736789	5522,875004	6135,01322	9195,704299		
Fd= 0,5(de)(Cd)A(V2+Vair)²		0,866582222	0,663006526	1,094446284	1,048743059		0,186983172	0,279445288	0,371907403	0,464369518	0,556831634	0,649293749	0,741755864	0,83421798	0,926680095	1,388990672		
h = V2.t + 0.5.a.t²																		
4.Neglecting air resistance h = vt1 - 0.5(9.81)t²																		
Normally t=V2/g		8,103975535	8,103975535	8,537206932	0													
Try tapogee		3,280	3,280	4,250	4,250		3,280	3,280	3,280	3,280	3,280	3,280	3,280	3,280	3,280	3,280		
V2'i		260,76	260,76	355,9375	0		115,4032235	141,0798773	162,7549064	181,8647501	199,1492282	215,0489314	229,85141	243,7566377	256,9103467	314,5330907		
JG Exp.value>1 h = t* a2 /g² > Approx. V2 (Value130) * I	m	248,4400257	217,3079322	361,7670344	412,8233841		71,60931886	107,0197198	142,4301207	177,8405216	213,2509225	248,6613235	284,0717244	319,4821253	354,8925262	531,9445308		
0.5(9.81)t2		52,769952	52,769952	88,5965625	88,5965625		52,769952	52,769952	52,769952	52,769952	52,769952	52,769952	52,769952	52,769952	52,769952	52,769952		
4.Neglecting air resistance h=vt1 - 0.5(9.81)t²		207,990048	207,990048	267,3409375	-88,5965625		62,63327147	88,30992526	109,9849544	129,0947981	146,3792762	162,2789794	177,081458	190,9866857	204,1403947	261,7631387		
5.FLs = 0.5(M2)(V)²t + M2.g.h + FD.Vm.tv																		
Vinitial		79,5	67,67245138	83,75	83,75		35,18390959	43,0121577	49,62039828	55,44657015	60,71622812	65,56369859	70,07664938	74,31604809	78,3263252	95,89423496		
Horizontal Deviation in flight Max> 20m		20	20	10	10		20	20	20	20	20	20	20	20	20	20		
Flight time secs		6,56	6,56	10,56	10,56		6,56	6,56	6,56	6,56	6,56	6,56	6,56	6,56	6,56	6,56		
VH Note: at apogee Vv > 0		3,048780488	3,048780488	0,946969697	0,946969697		3,048780488	3,048780488	3,048780488	3,048780488	3,048780488	3,048780488	3,048780488	3,048780488	3,048780488	3,048780488		
Horz velocity comp (VH)²		9,290562463	9,290562463	8,896751607	8,896751607		9,290562463	9,290562463	9,290562463	9,290562463	9,290562463	9,290562463	9,290562463	9,290562463	9,290562463	9,290562463		
0.5(M2)(VH)²		0,464753123	0,549408685	0,052908345	0,031386306		0,464753123	0,464753123	0,464753123	0,464753123	0,464753123	0,464753123	0,464753123	0,464753123	0,464753123	0,464753123		
Aerodynamic drag force FD		0,866582222	0,663006526	1,094446284	1,048743059		0,186983172	0,279445288	0,371907403	0,464369518	0,556831634	0,649293749	0,741755864	0,83421798	0,926680095	1,388990672		
e		2,718282					0,186983172	0,279445288	0,371907403	0,464369518	0,556831634	0,649293749	0,741755864	0,83421798	0,926680095	1,388990672		
Vm		39,75	33,83622569	41,875	41,875		17,5919548	21,50607885	24,81019914	27,72328506	30,3581406	32,7818493	35,03832469	37,15802405	39,1631626	47,94711748		
t		3,28	3,28	3,28	3,28		3,28	3,28	3,28	3,28	3,28	3,28	3,28	3,28	3,28	3,28		
Vm*t		130,38	110,9826203	137,35	137,35		57,70161174	70,53993863	81,37745318	90,93237505	99,57461412	107,5244657	114,9257705	121,8783189	128,4557733	157,2665453		
Fd*Vm*t		112,9849901	73,58233406	150,3221971	144,0448592		10,78923042	19,71205345	30,26487729	42,22622321	55,44629506	69,81496345	85,24681565	101,673085	119,0368523	218,4417645		
e^jets		1,045957305	1,058438532	1,051382442	1,013978889		1,087335126	1,070890944	1,061167392	1,054568017	1,049716238	1,045957305	1,042935029	1,040436931	1,038327411	1,031197514		
LN(Hjet)		0,497231218	0,731512514	0,731512514	-0,552590906		0,497231218	0,497231218	0,497231218	0,497231218	0,497231218	0,497231218	0,497231218	0,497231218	0,497231218	0,497231218		
FLs		389,2949287	384,7043185	497,588469	515,3621257		107,842659	163,6451077	219,7872062	276,1471657	332,6622063	389,2949287	446,0209064	502,8231542	559,6892905	844,7125631		
Substituting and resolving for height (h) m	h	281,1877528	268,2955612	299,9476179	540,681346		98,45940417	146,246994	192,7182414	237,977767	282,1112743	325,1938962	367,2878059	408,4457861	448,7132366	637,9266519		
Jet Efficiency expansion 100% when Pe=Pa Possibly> 0,82 ?Constant. K	0,82	230,5739573	220,0023602	245,9570467	443,3587037		80,73671142	119,9225351	158,0297779	195,1417689	231,3312449	266,6589949	301,1760039	334,9255446	367,944854	523,0998546		

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