# Considerations for the S1B Altitude Event

**Prepared by**

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**November, 2009**

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*Note: This document contains opinions of Chris Flanigan. Others may have different views.*

# S1B REQUIREMENTS

# Requirements for S1B Vehicle

- **Smallest body diameter must be not less than 18 mm for at least 75% of the overall length of each stage**
  - **Rule 2.4.3**
- **Minimum diameter = 40 mm for at least of 50% of the overall length**
  - **Rule 2.4.4**
- **Minimum overall length = 500 mm (19.69 in)**
  - **Rule 2.4.4**
- **Maximum weight = 60 gr (2.116 oz)**
  - **Rule 5.3**


***Reference: FAI Code, 2009 Edition***

# 2009 EUROPEAN CHAMPIONSHIPS

# S1A and S1B Results from the 2009 European Championships

*12th European Spacemodelling Championship*
Irig, Serbia
22. - 29.08.2009.

Air conditions:
Temperature: 21-30°C
Wind: 4-5 m/s from W
Humidity: 40-24%
Pressure: 1010 hPa
Time: 25.08.2009. 08:00-12:30h

**S1 – A Juniors**
**Final classifications – Individual:**

| No | SN | Name and Surname | NAC | FAI licence | TURNUS | | | res. | place |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | INDIVIDUAL | |
| 1 | 117 | MIHAILO PETROVIĆ | SRB | S867 | 0,0 | 323 | DQ | 323 | 1 |
| 2 | 7 | JAN CHMELIK | CZE | CZE 1049 | DQ | NC, 306 | 271 | 306 | 2 |
| 3 | 85 | ANDREI PATRAUTEANU | ROU | ROU 19 | 0,0 | NC,298 | DQ | 298 | 3 |
| 4 | 87 | ALEXANDRU NICA | ROU | ROU 2421 | 246 | 218 | 279 | 279 | 4 |
| 5 | 5 | MARTIN PAVKA | CZE | CZE 1047 | NC,NC | 239 | 278 | 278 | 5 |
| 6 | 16 | JAKUB FIAŁKOWSKI | POL | POL 6263 | 0,0 | NC,269 | DQ | 269 | 6 |
| 7 | 111 | MILAN PETKOVIĆ | SRB | S571 | NC | NC,262 | DQ | 262 | 7 |
| 8 | 133 | MICHAL POTFAJ | SVK | SVK 42-60 | TL | TL,DQ | TL,259 | 259 | 8 |
| 9 | 55 | DENIS GAGANOV | RUS | RUS 145 | 0,0 | TL,DQ | 0 | 243 | 9 |
| 10 | 59 | MAXIM DEMIDOV | RUS | RUS 01277 | 238,0 | NC | DQ | 238 | 10 |
| 11 | 18 | MATEUSZ DYBA | POL | POL 6694 | DQ | 167,0 | TL, 221 | 221 | 11 |
| 12 | 28 | VLADISLAV GURBA | BLR | BLR 179 | 199,01 | NC, 171 | 170 | 199 | 12 |
| 13 | 75 | MYKOAS TREIKAUSKAS | LTU | LTU 559 | TL | NC,193 | 137,0 | 193 | 13 |
| 14 | 74 | AURIMAS PETKEVIČIUS | LTU | LTU 664 | 182,0 | NC,189 | NC,123 | 189 | 14 |
| 15 | 17 | SZYMON BYRTEK | POL | POL 6225 | DQ | DQ | 182 | 182 | 15 |
| 16 | 131 | ANNA MARIA ŠILAROVA | SVK | SVK 42-78 | 0,0 | DQ | 178 | 178 | 16 |
| 17 | 29 | ARTSIOM RYBKO | BLR | BLR 180 | NC,NC | 164,0 | 145 | 164 | 17 |
| 18 | 43 | ALEJANDRO FILLAT | ESP | 2900 | 0,0 | NC, 162 | NC,TL | 162 | 18 |
| 19 | 73 | AUGUSTINAS VASILIAUSKAS | LTU | LTU 517 | DQ | NC,137 | 158,0 | 158 | 19 |
| 20 | 30 | DZIMITRY MAKSIMCHYK | BLR | BLR 184 | NC | NC,NC | 137 | 137 | 20 |
| 21 | 42 | FRANCISCO PALOMAR | ESP | 2674 | 0,0 | TL,123 | NC | 123 | 21 |
| 22 | 130 | MAREK DURAJ | SVK | SVK 42-48 | 0,0 | DQ | TL,100 | 100 | 22 |
| 23 | 86 | MIHAI CONSTANTINESCU | ROU | ROU 78 | DQ | DQ | TL,NC,98 | 98 | 23 |
| 24 | 112 | VESNA KATANIĆ | SRB | S472 | 0,0 | DQ | DQ | 0 | 24 |
| 25 | 58 | VADIM KRASOVSKIY | RUS | RUS 0119 | 0,0 | TL | NC,TL,DQ | 0 | 28 |
| 26 | 41 | JESUS MORAN | ESP | 2626 | NC,TL | TL,DQ | DQ | 0 | 29 |
| 27 | 6 | JAN SRŠEN | CZE | CZE 1048 | TL | TL,DQ | DQ | 0 | 30 |

TL - track lost NC - No Close DQ - Disqualification CE - Crash of engine

*12th European Spacemodelling Championship*
Irig, Serbia
22. - 29.08.2009.

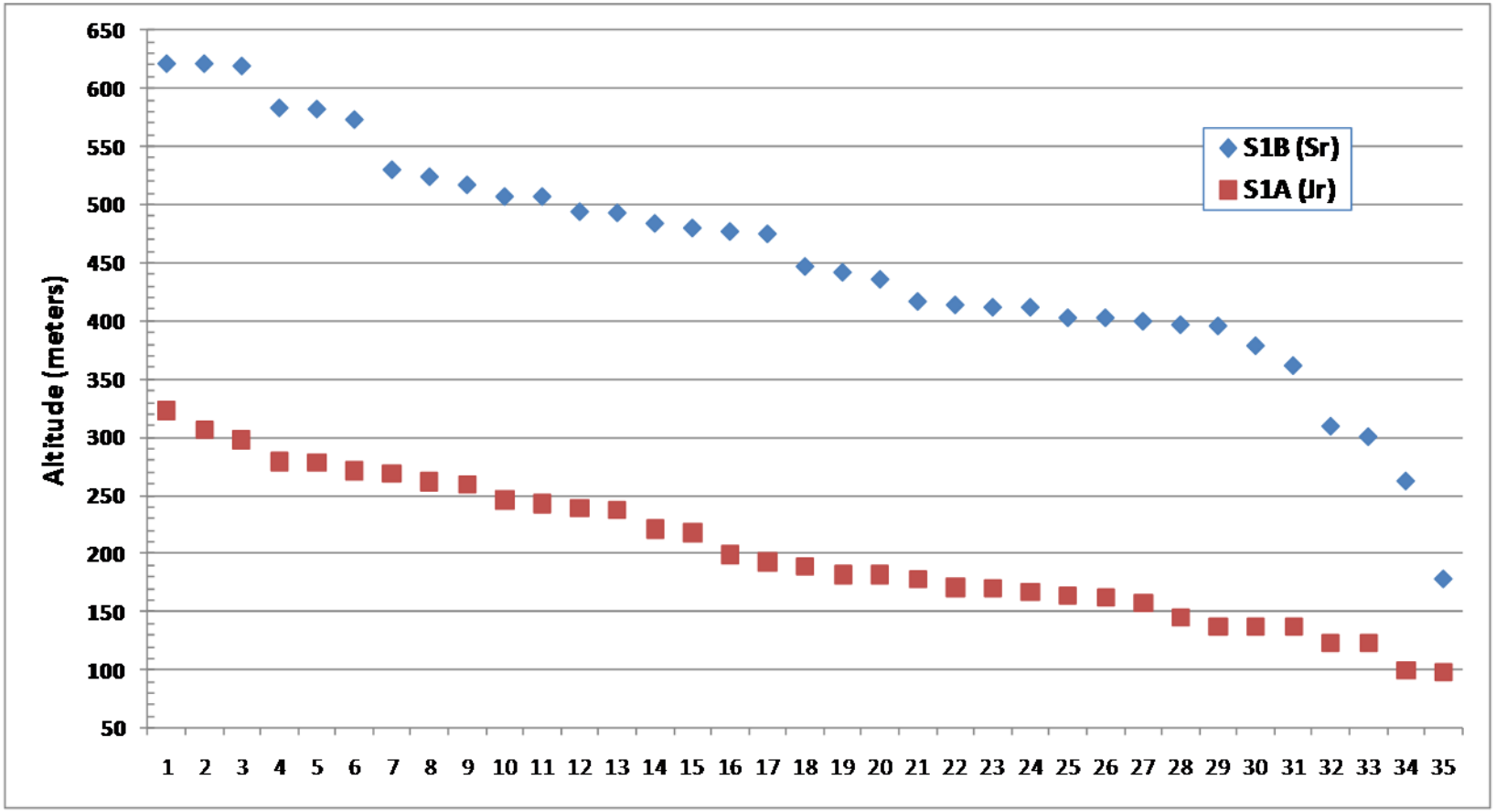
Air conditions:
Temperature: 28°C
Wind: 3 km/h from SW
Humidity: 46%
Pressure: 995 hPa
Time: 25.08.2009. 13:00-18:00h

**S1 – B Seniors**
**Final classifications – Individual**

| start num | Competitor | Team | FAI license | TURNUS | | | res. | place |
|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | INDIVIDUAL | |
| 4 | JAROSLAV CHMELIK | CZE | CZE 1046 | DQ | 621 | NC | 621 | 1 |
| 95 | JOŽA ČUDEN | SLO | S552000I | 0 | 621 | TL | 621 | 1 |
| 123 | MILAN JAVORIK II | SVK | SVK 71-23 | 400 | 619 | 583 | 619 | 3 |
| 64 | TOSHKO STOYANOV | BUL | BUL 00360 | NC | 582 | 403 | 582 | 4 |
| 8 | ANTONIO MAZZARACCHIO | ITA | ITA-S1 | DQ | 517 | 573 | 573 | 5 |
| 45 | SERGEY ROMANYUK | RUS | RUS 0251 | 530 | DQ | TL | 530 | 6 |
| 81 | MARIAN KRAUSE | ROU | ROU 213 | DQ | 524 | 0 | 524 | 7 |
| 9 | LESZEK MAŁMYGA | POL | POL 4578 | DQ | 507 | TL, TL | 507 | 8 |
| 91 | STANIŠA PETROVIĆ | MKD | S 151 | NC | DQ | 507 | 507 | 8 |
| 125 | MICHAL ŽITNAN | SVK | SVK 42-12 | 494 | DQ | 480 | 494 | 10 |
| 44 | VLADIMIR MENSHIKOV | RUS | RUS 0248 | 484 | NC | 493 | 493 | 11 |
| 11 | KRZYSZTOF PRZYBYTEK | POL | POL 3754 | TL,DQ | 477 | 447 | 477 | 12 |
| 79 | FLORICA SERCAIANU | ROU | ROU 2396 | 475 | NC | NC | 475 | 13 |
| 66 | SASHA STOYANOVA | BUL | BUL 00361 | 442 | 0 | 412 | 442 | 14 |
| 2 | PAVEL BROŇY | CZE | CZE 1044 | 436 | 417 | 403 | 436 | 15 |
| 1 | BEDRICH PAVKA | CZE | CZE 1043 | 414 | DQ | DQ | 414 | 16 |
| 126 | VASIL PAVLIUK | SVK | SVK 26-14 | NC,TL | 397 | 412 | 412 | 17 |
| 78 | LUCIAN SERCAIANU | ROU | ROU 228 | 396 | NC | NC | 396 | 18 |
| 105 | BRANISLAV KRČEDINAC | SRB | S 209 | NC | 379 | 0 | 379 | 19 |
| 27 | VALERY HRABOUSKI | BLR | BLR 128 | NC,NC | 362 | 0 | 362 | 20 |
| 25 | ULADZIMIR MINKEVICH | BLR | BLR 042 | 263 | 310 | 0 | 310 | 21 |
| 31 | TREVOR SEABROOK | GBR | GBR 113101 | NC,TL | 301 | DQ | 301 | 22 |
| 26 | ALIAKSANDR LIPAI | BLR | BLR 071 | 179 | 0 | DQ | 179 | 23 |
| 10 | SŁAWOMIR ŁASOCHA | POL | POL 3896 | DQ | DQ | TL | 0 | |
| 32 | NIGEL BATHE | GBR | GBR 063592 | DQ | NC | 0 | 0 | |
| 33 | MIKE FRANCIES | GBR | GBR 039222 | DQ | 0 | 0 | 0 | |
| 34 | JORDI ROURA FONT | ESP | ESP 708 | 0 | TL | DQ | 0 | |
| 39 | ENRIQUE MORAN | ESP | ESP 2808 | DQ | 0 | DQ | 0 | |
| 38 | ROSA SANZ | ESP | ESP 2899 | NC | 0 | TL | 0 | |
| 49 | ALEXEY RESHETNIKOV | RUS | RUS 0340 | DQ | TL,TL | NC | 0 | |
| 65 | BORIS LEKOV | BUL | BUL 00429 | TL | DQ | DQ | 0 | |
| 70 | MAKSIM TIMOFEJEV | LTU | LTU 284 | NC,DQ | NC,DQ | DQ | 0 | |
| 71 | JURGIS STRAZDAS | LTU | LTU 066 | DQ | 0 | 0 | 0 | |
| 72 | EUGENIJUS GUOBYS | LTU | LTU 385 | 0 | DQ | DQ | 0 | |
| 89 | GOCE JOSIFOVSKI | MKD | S 133 | DQ | DQ | DQ | 0 | |
| 90 | GLIGORČO ČEJKOV | MKD | S 127 | DQ | DQ | DQ | 0 | |
| 96 | MIHA ČUDEN | SLO | S552018 | TL | 0 | DQ | 0 | |
| 99 | TONE ŠUANEC | SLO | S552003 | TL | 0 | NC,DQ | 0 | |
| 104 | MIRKO KATANIĆ | SRB | S 471 | DQ | NC,TL | 0 | 0 | |
| 106 | VLADIMIR ČIPČIĆ | SRB | S 040 | DQ | TL | 0 | 0 | |

TL - track lost NC - No Close DQ - Disqualification CE - Crash of engine

# S1A and S1B Results from the 2009 European Championships




# 2009 Results – S1B

- **Visual impression of S1B results graph…**
  - **One group of S1B flights went to ~400 meters**
  - **Another group of S1B flights went to ~500 meters**
  - **Only three few flights exceeded 600 meters**
- **Questions**
  - **Is >600 m flight feasible?**
  - **Were >600 m altitudes due to tracking anomalies?**
  - **Is piston launcher or staging "enhancement" required to achieve super altitudes?**
    - **Black powder or pyrodex added to assure ignition of piston launcher and/or staging may add performance**

# EUROPEAN AND U.S. ENGINES

# U.S. Small Engine Selection Is Limited

| Type | Designation | Manufacturer | Dimensions (mm) | Impulse (N-sec) | Propellant Mass (g) | Tested By | Contest Approved | Sport Use Ends |
|---|---|---|---|---|---|---|---|---|
| S | 1/8A.2 (MicroMaxx)-1 | Quest | 6 x 26 | 0.2 | 0.4 | NAR | No | |
| S | 1/8A.5 (MicroMaxxII)-1,NE | Quest | 6 x 26 | 0.31 | 0.5 | NAR | Yes | |

| Type | Designation | Manufacturer | Dimensions (mm) | Impulse (N-sec) | Propellant Mass (g) | Tested By | Contest Approved | Sport Use Ends |
|---|---|---|---|---|---|---|---|---|
| S | 1/4A3T-3 | Estes | 13 x 45 | 0.62 | 0.8 | NAR | Yes | |

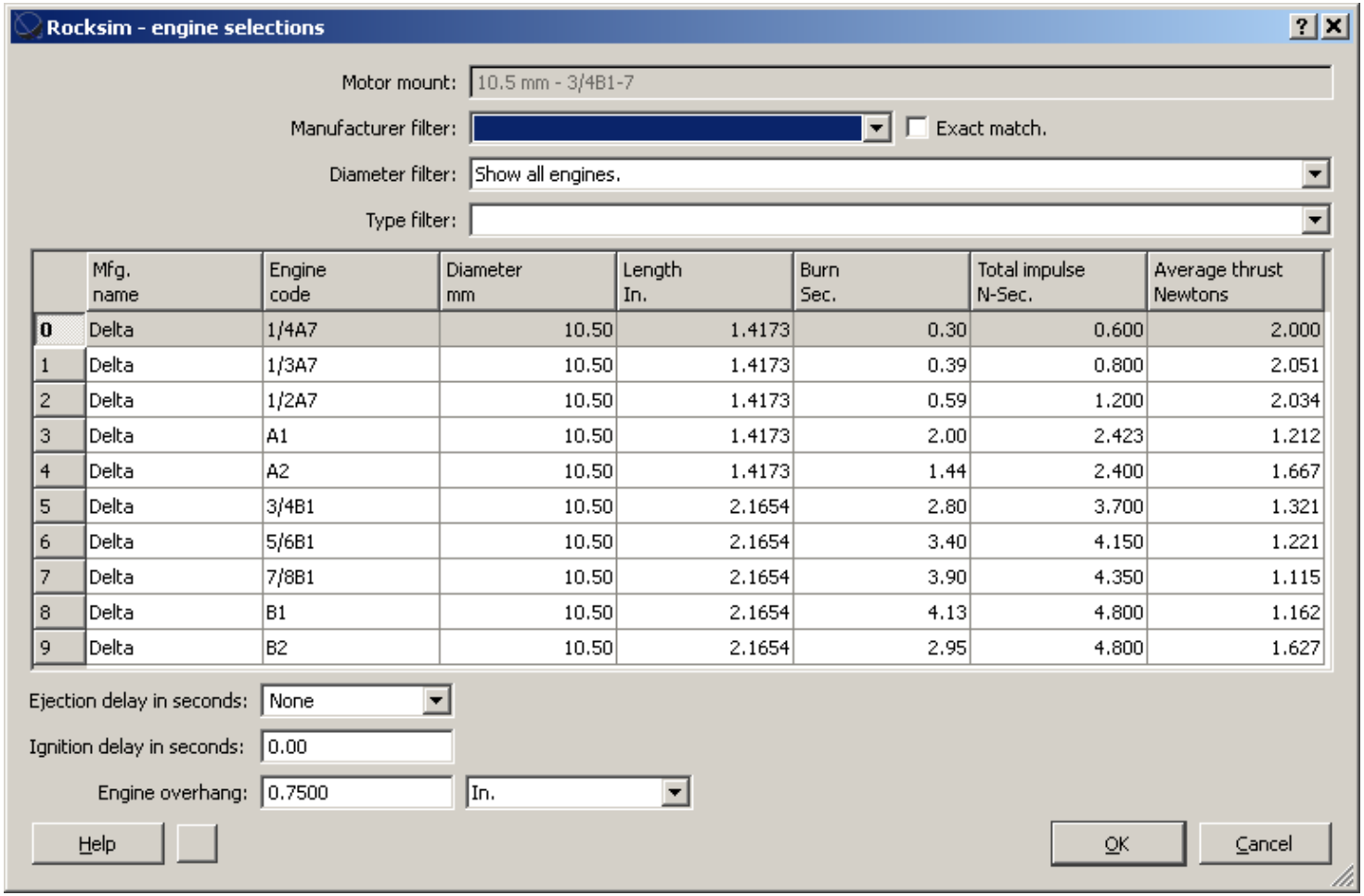
| Type | Designation | Manufacturer | Dimensions (mm) | Impulse (N-sec) | Propellant Mass (g) | Tested By | Contest Approved | Sport Use Ends |
|---|---|---|---|---|---|---|---|---|
| S | 1/2A3T-2,4 | Estes | 13 x 45 | 1.25 | 2 | NAR | Yes | |
| S | 1/2A6-2 | Estes | 18 x 70 | 1.25 | 2.6 | NAR | Yes | |

| Type | Designation | Manufacturer | Dimensions (mm) | Impulse (N-sec) | Propellant Mass (g) | Tested By | Contest Approved | Sport Use Ends |
|---|---|---|---|---|---|---|---|---|
| S | A3T-4 | Estes | 13 x 45 | 2.5 | 3.3 | NAR | Yes | |
| S | A6-4 | Quest | 18 x 70 | 2.5 | 3.5 | NAR | Yes | |
| S | A6-4 | Quest | 18 x 70 | 2.3 | 3 | NAR | Yes | |
| S | A8-3,5 | Estes | 18 x 70 | 2.5 | 3.3 | NAR | Yes | |
| S | A10T-3,P | Estes | 13 x 45 | 2.5 | 3.8 | NAR | Yes | |

| Type | Designation | Manufacturer | Dimensions (mm) | Impulse (N-sec) | Propellant Mass (g) | Tested By | Contest Approved | Sport Use Ends |
|---|---|---|---|---|---|---|---|---|
| S | B4-2,4 | Estes | 18 x 70 | 5 | 6 | NAR | Yes | |
| S | B6-0 | Estes | 18 x 70 | 4.9 | 5.6 | NAR | Yes | |
| S | B6-0,4 | Quest | 18 x 70 | 5 | 6.5 | NAR | Yes | |
| S | B6-2 | Quest | 18 x 70 | 5 | 6.5 | NAR | Yes | |
| S | B6-2,4,6 | Estes | 18 x 70 | 5 | 5.6 | NAR | Yes | |


***No "A" or "1/2A" booster engines***

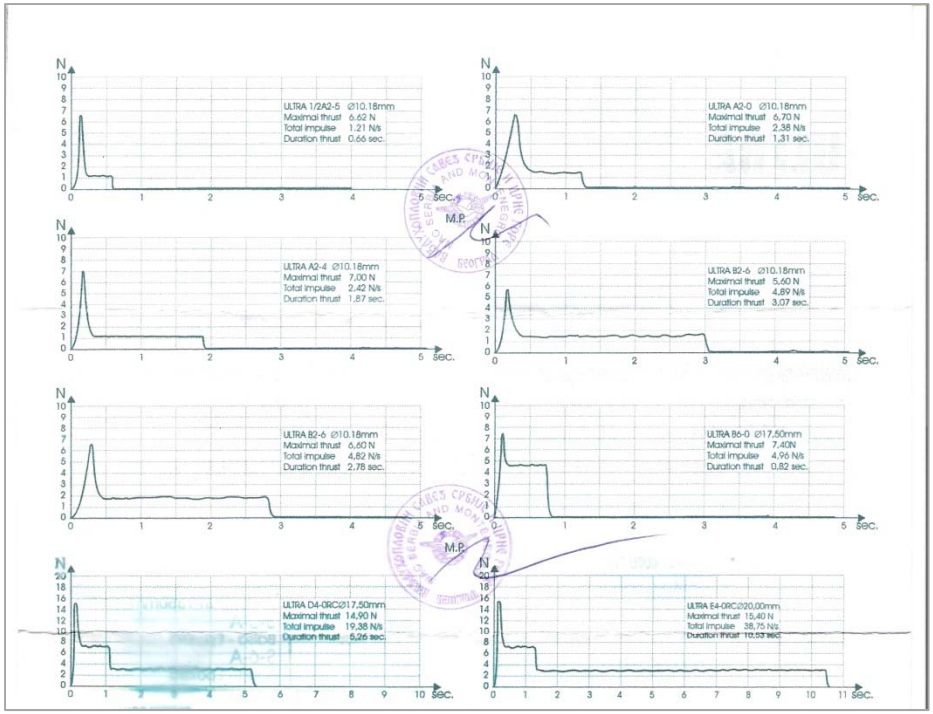
# “Delta” Engines Are Ideal for S1

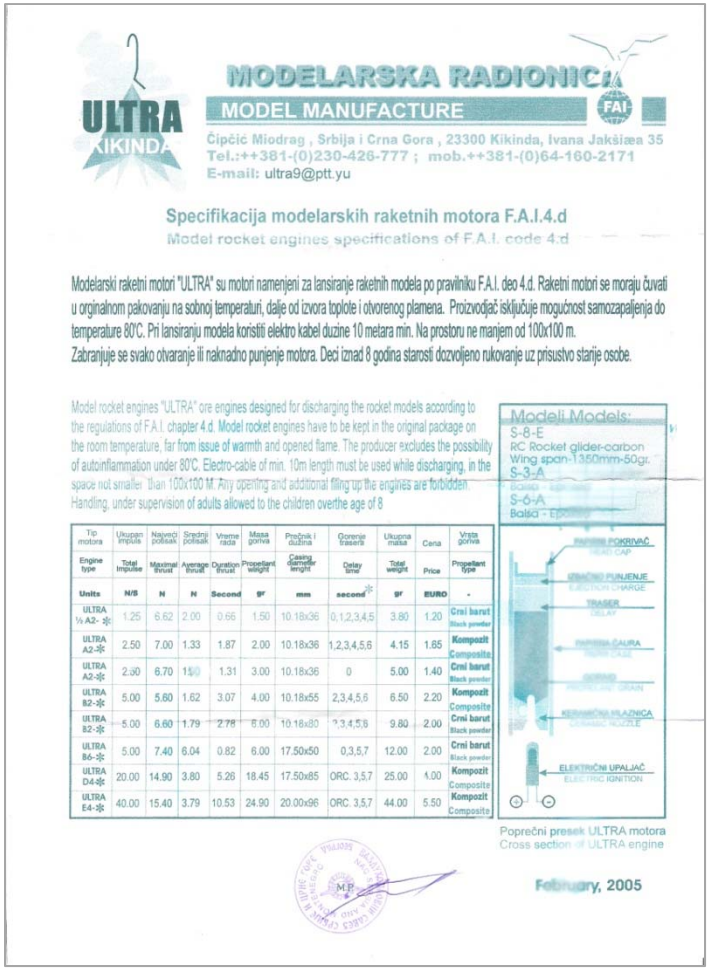



| | Mfg. name | Engine code | Diameter mm | Length In. | Burn Sec. | Total impulse N-Sec. | Average thrust Newtons |
|---|---|---|---|---|---|---|---|
| 0 | Delta | 1/4A7 | 10.50 | 1.4173 | 0.30 | 0.600 | 2.000 |
| 1 | Delta | 1/3A7 | 10.50 | 1.4173 | 0.39 | 0.800 | 2.051 |
| 2 | Delta | 1/2A7 | 10.50 | 1.4173 | 0.59 | 1.200 | 2.034 |
| 3 | Delta | A1 | 10.50 | 1.4173 | 2.00 | 2.423 | 1.212 |
| 4 | Delta | A2 | 10.50 | 1.4173 | 1.44 | 2.400 | 1.667 |
| 5 | Delta | 3/4B1 | 10.50 | 2.1654 | 2.80 | 3.700 | 1.321 |
| 6 | Delta | 5/6B1 | 10.50 | 2.1654 | 3.40 | 4.150 | 1.221 |
| 7 | Delta | 7/8B1 | 10.50 | 2.1654 | 3.90 | 4.350 | 1.115 |
| 8 | Delta | B1 | 10.50 | 2.1654 | 4.13 | 4.800 | 1.162 |
| 9 | Delta | B2 | 10.50 | 2.1654 | 2.95 | 4.800 | 1.627 |


***Small size (10.5mm diameter)***
***Unique fractional “A” and “B” engines***
***Long delay times***

# Serbian “ULTRA” Engines Are An Alternative

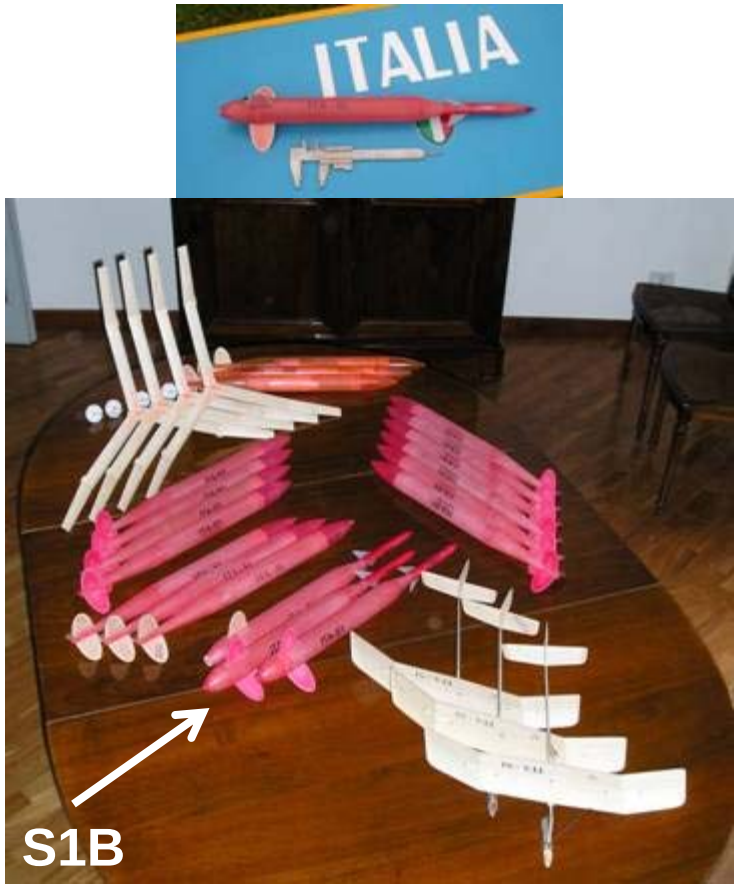



# VEHICLE SIZING OPTIMIZATION

# Considerations for an Optimum S1B Vehicle

- **Maximize altitude**
  - **Engines**
  - **Drag**
  - **Weight**
  - **Launcher & staging**
- **Satisfy requirements**
  - **≥ 500 mm length**
  - **≥ 40 mm diam for 50% of total length**
  - **≥ 18 mm diam for 75% of length of each stage**




***Competitive FAI models by Antonio Mazzaracchio***

***http://www.antoniomazzaracchio.it/index_file/Page1007.htm***

# The Fundamentals

- **Staging required for a high performance S1 vehicle**
  - **Drop the large 40mm booster stage as soon as possible**
- **Upper stage should be minimum size**
  - **Minimize drag**
- **Upper stage should have optimum weight**
  - **Tracking powder (if optical tracking)**
  - **Altimeter (if electronic tracking)**
- **Vehicle should use optimum engines**
  - **“Delta” engines: [1/4A + 7/8B] or [1/2A + 3/4B]**
- **Vehicle should have high but not necessarily ultimate reliability**
  - **Three opportunities to make a qualified flight**

# Use Excel Spreadsheet with "Solver" Optimizer to Minimize Surface Area

**CONSTRAINTS (REQUIREMENTS)**

- Smallest body diameter must be not less than 18 mm for at least 75% of the overall length of each stage (2.4.3)
- Minimum diameter = 40 mm for at least of 50% of the overall length (2.4.4)
- Minimum overall length = 500 mm (19.69 in) (2.4.4)
- Maximum weight = 60 gr (2.116 oz) (5.3)

| | Length | Diam - Aft | Diam - Fwd | Fraction | Area | Factor | Factored Area | Length (in) |
|---|---|---|---|---|---|---|---|---|
| STAGE 1 | | | | | | | | |
| Boattail | 81.43 | 10.5 | 40 | | 6,564.3 | | | 3.206 |
| Cylinder | 250.00 | 40 | 40 | 0.500 | 31,415.9 | | | 9.843 |
| Transition | 18.27 | 40 | 18 | | 1,943.2 | | | 0.719 |
| Subtotal | 349.7 | | | | 39,923.4 | 0.1 | 3,992.3 | 13.768 |
| STAGE 2 | | | | | | | | |
| Boattail | 0 | 18 | 18 | | 0.0 | | | 0.000 |
| Cylinder | 114.3 | 18 | 18 | 0.760 | 6,463.5 | | | 4.500 |
| Nose | 36.0 | 18 | 0 | | 1,049.2 | | | 1.417 |
| Subtotal | 150.3 | | | | 7,512.7 | 0.9 | 6,761.4 | 5.917 |
| TOTAL | | | | | | | | |
| Total | 500 | | | | 47,436.1 | | 10,753.8 | 19.685 |

denotes optimized cell

**Assume that weight and drag are proportional to surface area**

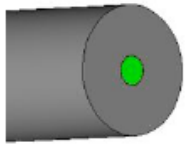
**Can try other values using *S1B_Optimization.xlsx***

**Note: solution says optimum Stage 2 has no boattail**

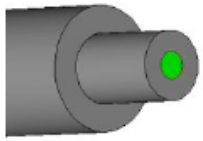
# DRAG REDUCTION

# Bob Parks Examined Extending the Engine to Reduce Base Drag

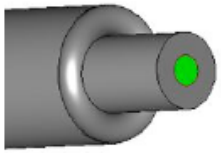
Configurations analyzed



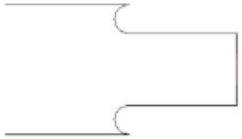
Standard 18mm base
The green dot is the nozzle exit area



Engine extended 15mm
From base



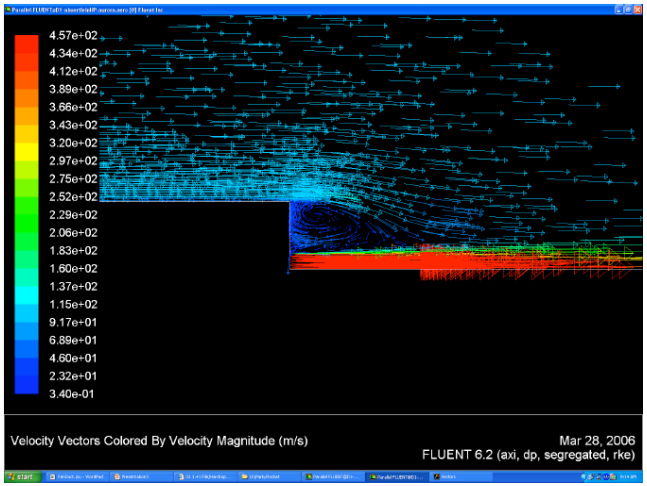
15mm extension with “wave”



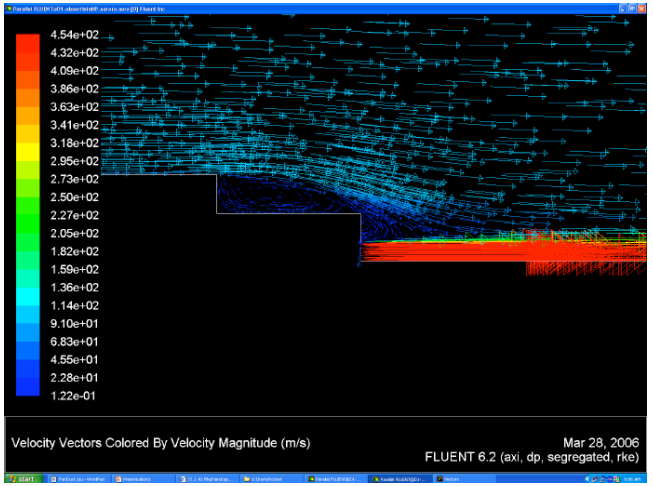
Wave base cross section

# Bob's CFD Analysis Using FLUENT

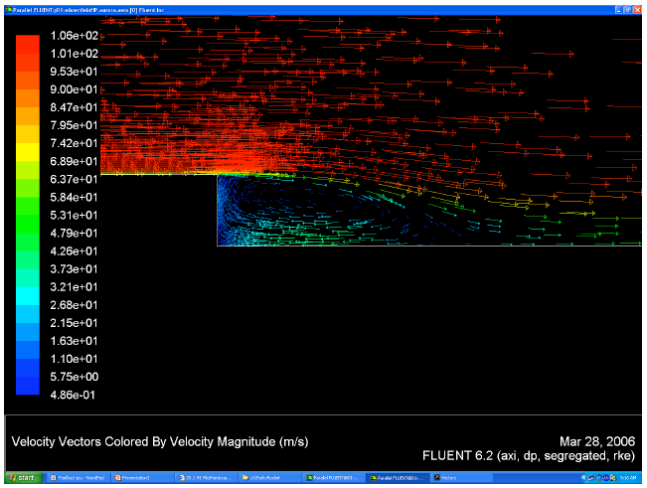
**Basic Configuration, Plume On**



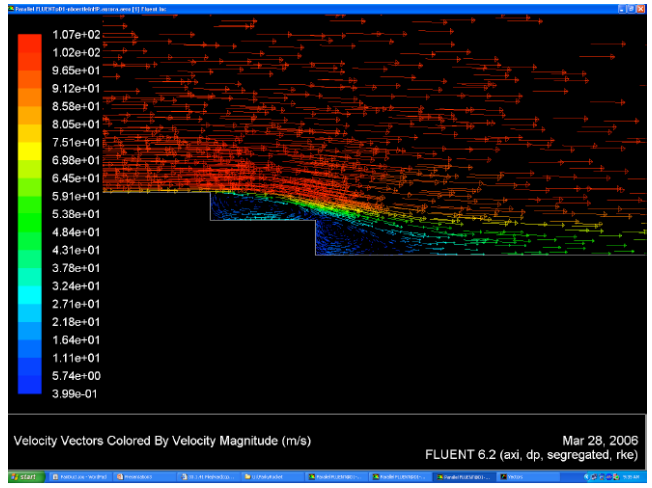

**Extended by 15 mm, Plume On**




**Basic Configuration, No Plume**




**Extended by 15 mm, No Plume**





**100 m/s flight speed**
**4 mm diameter exit plume**

# Extended Engine Reduced Base Drag

| Case | Base Drag (N) | Base Cd |
|---|---|---|
| Basic, with plume | 0.554 | .355 |
| Basic, no plume | 0.285 | .183 |
| Extended, plume | 0.325 | .208 |
| Extended, no plume | 0.239 | .153 |
| Wave, plume | 0.323 | .207 |
| Wave, no plume | 0.237 | .152 |


**Extended engine produces a boattail-like effect**

# Comments by Bob Parks

The non thrusting base drag Cd of .18 is right in the middle of the test data in "Fluid Dynamic Drag" by Hoerner. Having analysis match test data is always encouraging!

With the engine thrusting, the base drag nearly DOUBLES. With the typical Estes engine base shape, it could be even worse due to the recessed nozzle. I don't know what current 10mm competition engines look like… but expect similar problems.

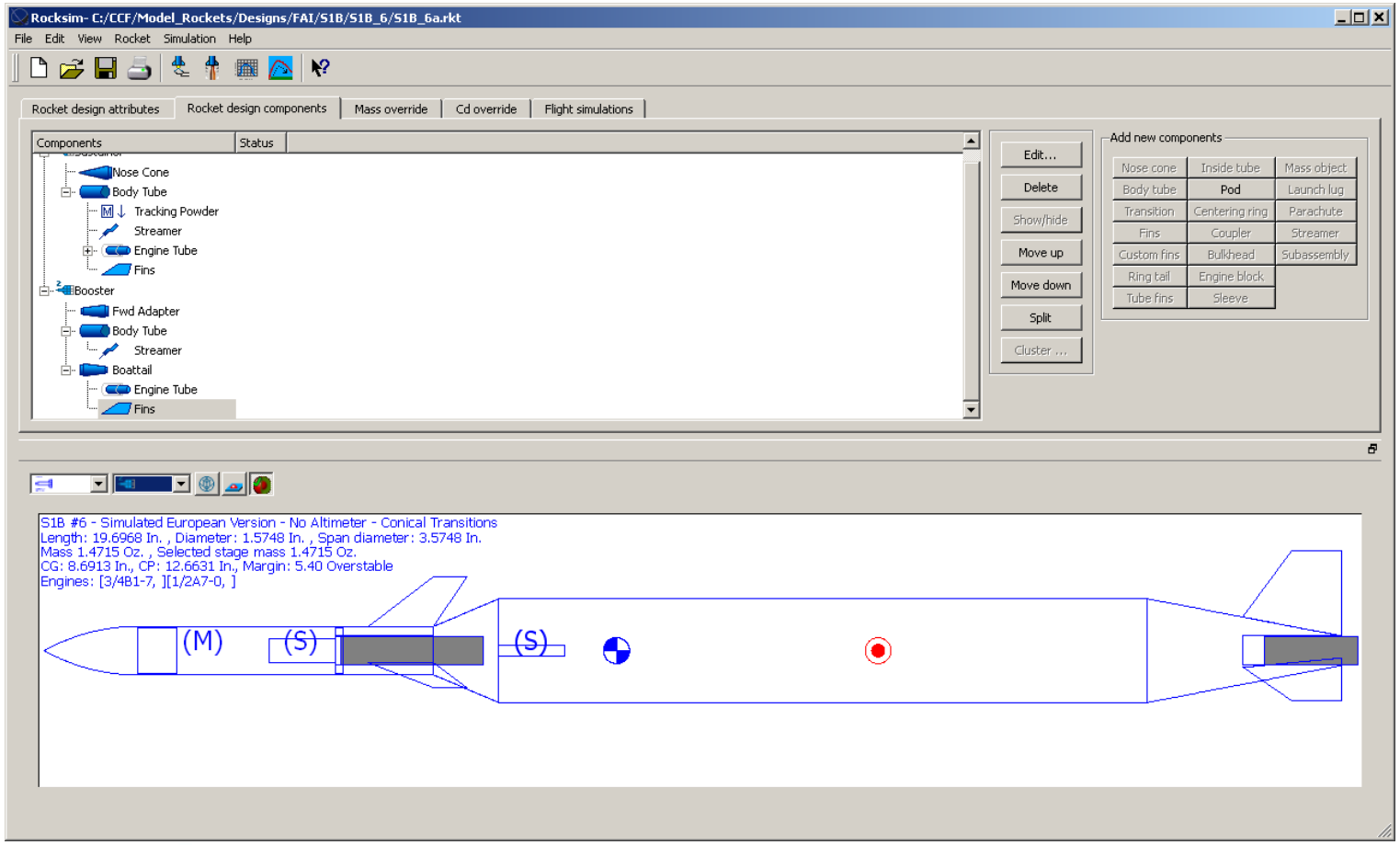
Extending the engine isolates most of the base area from the plume jet pumping effect, which gives a substantial drag reduction when thrusting. There is a slight reduction in coast drag.

The engine was extended 15mm aft of the base for this. From the flow pattern images, if a 20mm extension is possible, it might work even better. I do not know how long the motors are.

The aft engine location means that larger fins are needed, but the fin drag penalty is very small compared to the base drag decrease

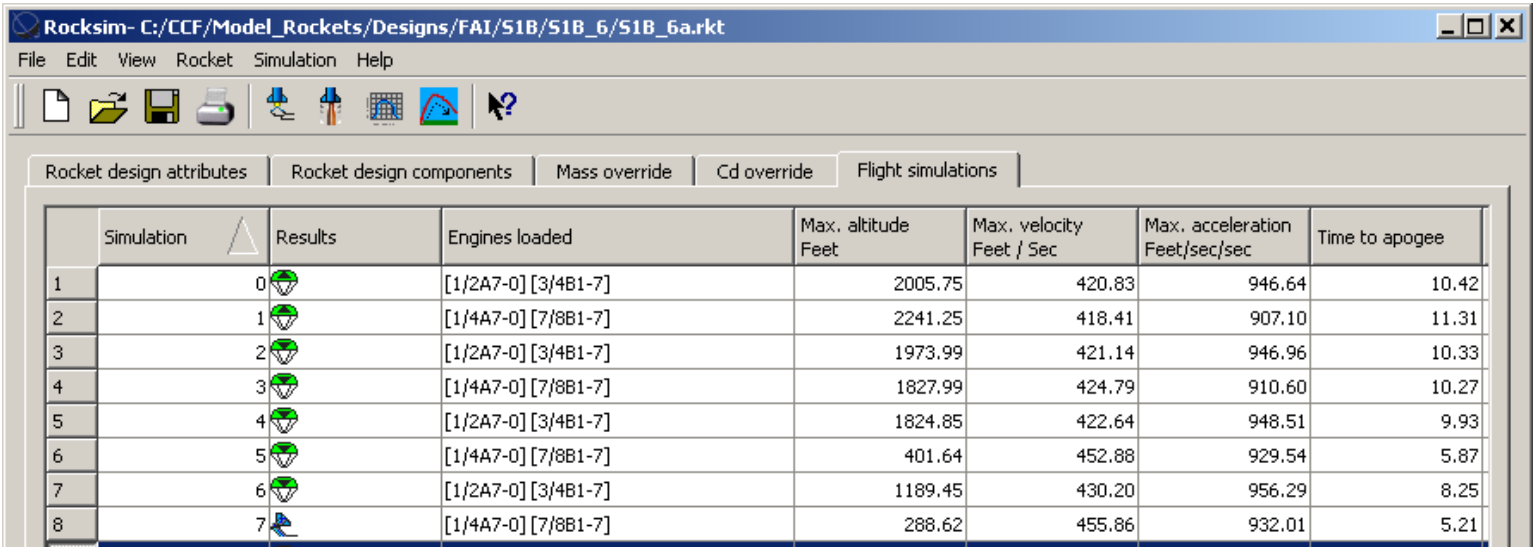
# ROCKSIM RESULTS

# Use RockSim to Simulate European S1B Results




**Used program defaults for weight and drag calculations**

# RockSim Results




| | Simulation | Results | Engines loaded | Max. altitude Feet | Max. velocity Feet / Sec | Max. acceleration Feet/sec/sec | Time to apogee | Altitude (m) |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | | [1/2A7-0] [3/4B1-7] | 2005.75 | 420.83 | 946.64 | 10.42 | 623.3 |
| 2 | 1 | | [1/4A7-0] [7/8B1-7] | 2241.25 | 418.41 | 907.10 | 11.31 | 689.8 |
| 3 | 2 | | [1/2A7-0] [3/4B1-7] | 1973.99 | 421.14 | 946.96 | 10.33 | 599.5 |
| 4 | 3 | | [1/4A7-0] [7/8B1-7] | 1827.99 | 424.79 | 910.60 | 10.27 | 641.0 |
| 5 | 4 | | [1/2A7-0] [3/4B1-7] | 1824.85 | 422.64 | 948.51 | 9.93 | 516.3 |
| 6 | 5 | | [1/4A7-0] [7/8B1-7] | 401.64 | 452.88 | 929.54 | 5.87 | 489.2 |
| 7 | 6 | | [1/2A7-0] [3/4B1-7] | 1189.45 | 430.20 | 956.29 | 8.25 | 439.8 |
| 8 | 7 | | [1/4A7-0] [7/8B1-7] | 288.62 | 455.86 | 932.01 | 5.21 | 202.4 |
| | | | | | | | | 371.9 |

- **Simulations look at engine combinations and wind**
  - **Simulations 1+2 = no wind**
  - **Simulations 3+4 = light wind (3-7 MPH)**
  - **Simulations 5+6 = slightly breezy (8-14 MPH)**
  - **Simulations 7+8 = breezy (15-25 MPH)**


**Note: Using U.S. engines (A10T and A3-4T), altitude is only ~1,200 ft (~370 m)**

# Discussion of RockSim Results

- **Rerunning the simulations provided similar results**
  - **More variation in the high wind conditions (as expected)**
- **1/4A with 7/8B provided highest altitude**
  - **Needs very low winds to avoid weathercocking of booster**
- **1/2A with 3/4B provides better reliability across wide range of wind conditions**
- **Aerodynamic stability margin varied <u>widely</u> depending if Barrowman or RockSim method used**
  - **Interference effects, fins on a boattail**
- **Additional weight in booster had small effect on maximum altitude**
  - **Consider electronic ignition of upper stage?**

# SUMMARY AND DISCUSSION

# Summary and Discussion

- **It's feasible to achieve 600+ meter altitudes (*)**
  - **Need "Delta" motors and optimized upper stage**
  - **Optimized booster not as critical**
- **Weathercocking critical for two stage vehicle**
  - **Select motors based on wind conditions**
  - ***Consider bringing a single stage vehicle as a backup in case of high winds***
- **Consider extended engine in upper stage**
  - **May reduce base drag by boattail-ish effect**
- **Results based on 0.25 oz "payload"**
  - **Tracking powder or lightweight altimeter**
  - **Effect of heavier altimeter unknown**


**(*) Assumes that RockSim calculation of drag coefficient is correct**

# S1 Might Be An Opportunity for the U.S.

- **Reviewed issues of *Interspace* newsletter from January '06 through Autumn '09**
- **S1 is only reported for two European contests**
  - **2006 WSMC S1B: 1st = 622 m, 2nd = 601 m, 3rd = 575 m**
  - **Other contest lists winners but not their altitudes**
- **Perhaps S1 isn't flown very often "over there"**
  - **Like in U.S., tracking events can be a lot of work**
  - **Timing events are easier**
- **The big challenge for U.S. will be practicing without having European engines available**
  - **Perhaps using electronic staging might be a good idea unless old stocks of A3-0 engines can be found**


**Note: old A3-0 engines can be legally flow via special process from NAR**

# Altimeters Might Be a Wild Card

- **It appears probable (but not certain) that some kind of electronic altimeter will be used for S1 (and S5?) at the 2010 WSMC**
- **We'll have to wait to see what is decided**