

The vehicle

Launch mass ⁹	2.0e3 kg
Vehicle diameter ⁴⁰	0.64 m
Motor type ⁵¹	Hybrid
Grain geometry ^{6,3}	Wagon wheel
Grain ports ^{6,3}	9
Throat diameter ⁶ d_t	200 mm
Combustion chamber pressure ⁶ P_c	16 bar or 1.6 MPa at lift-off
Thrust coefficient ⁶ C_f	1.3
Throat area ^{6,7} A_t	314 cm ² or 31.4e-3 m ²
Pressurization system ⁵¹	Pressure-fed
Ignition system ¹	Consumable catalyst bed
Ignition system ²	Pellet KMnO ₄ catalyst bed
Oxidizer tank wall thickness ⁴⁷	3.0 mm if steel

Table continued at the next page.

Fuel ^{5,2943}	Solid polyurethane "Edulan Purteknik 1133 sort"
Fuel tensile strength ²⁹⁴²	7.9 MPa according to ISO 527
Fuel density ²⁹⁴²	1 110 $\frac{\text{kg}}{\text{m}^3}$ according to ISO 2781
Fuel ⁶	168 kg
Oxidizer ⁵¹	80 per cent H ₂ O ₂
Oxidizer ⁶	840 kg
Expected ISP ^{6,40}	180 s to 190 s
Expected exhaust velocity ⁸	1.76 $\frac{\text{km}}{\text{s}}$ to 1.86 $\frac{\text{km}}{\text{s}}$
Oxidizer flow at lift-off ⁶	29 $\frac{\text{kg}}{\text{s}}$
Propellant flow at lift-off ⁶ $\frac{dm}{dt}$	34.8 $\frac{\text{kg}}{\text{s}}$
Thrust at lift-off ^{6,7,8} F	62 kN

Notes on the next page.

1. The consumable catalyst bed was the ignition device to be used in the beginning of the project. After the problems on August 27, 2014, it seems less likely this type of ignition device will be used.

2. It is not quite right to call a catalyst bed an ignition system, so here is an explanation.

The idea is that ignition will occur automatically if the 80 per cent H_2O_2 is decomposed in a $KMnO_4$ catalytic pellet bed before it is injected into the combustion chamber with solid polyurethane.

The temperature of the mixture of H_2O gas and O_2 gas is about 750 K or 480 C. The melting point of polyurethane vary considerably with the kind of polyurethane. One kind of polyurethane melts at 564 K or 291 C. See the polymer data handbook¹⁷² page 879, pdf page 969. The warm H_2O and O_2 gas is therefore about 200 K above the melting point of the polymer. Therefore the polymer will melt in the surface layer.

This kind of polymer begins to decompose when it melts. It does not become liquid. So it gives off various gases, presumably mostly made of carbon and hydrogen. The question is now if some of those substances can be ignited.

The autoignition temperature of some of the organic substances given off by the decomposing polyurethane is less than 750 K, for instance 638 K or 365 C for ethanol⁴.

3. The center of mass stability of the vehicle in relation to the grain geometry has not yet been addressed.

4. Wikipedia: Ethanol.

5. Peter Madsen: Email 2014-09-03.

6. Peter Madsen: Email 2014-08-26.

7. The rocket engine thrust is

$$F = C_f * A_t * (P_c - P_a)$$

where C_f is the thrust coefficient, A_t is the throat area, P_c is the combustion chamber pressure and P_a is the ambient pressure.

With $C_f = 1.3$, $A_t = 314 \text{ cm}^2$, $P_c = 16 \text{ bar}$, and $P_a = 1.0 \text{ bar}$ we get $F = 61 \text{ kN}$.

With $C_f = 1.3$, $A_t = 31.4e-3 \text{ m}^2$, $P_c = 1.6 \text{ MPa}$, and $P_a = 0.10 \text{ MPa}$ we get $F = 61 \text{ kN}$.

8. The exhaust velocity is $V_e = g * ISP$ where g is the acceleration of Earth. The engine thrust is

$$F = V_e * \frac{dm}{dt}$$

With $V_e = 1.76 \frac{\text{km}}{\text{s}}$ and $\frac{dm}{dt} = 34.8 \frac{\text{kg}}{\text{s}}$ we get $F = 61 \text{ kN}$.

9. The launch mass is calculated from the an assumption of a geometrical lift-off acceleration of $20 \frac{\text{m}}{\text{s}^2}$. We have

$$F = m * (ag + g)$$

where F is the engine thrust at lift-off, ag is the geometrical acceleration, and g is the acceleration of gravity on the planet. We find the launch mass is

$$m = \frac{F}{ag + g}$$

With $F = 61 \text{ kN}$, $ag = 20 \frac{\text{m}}{\text{s}^2}$ and $g = 9.8 \frac{\text{m}}{\text{s}^2}$ we get $2.0e3 \text{ kg}$.

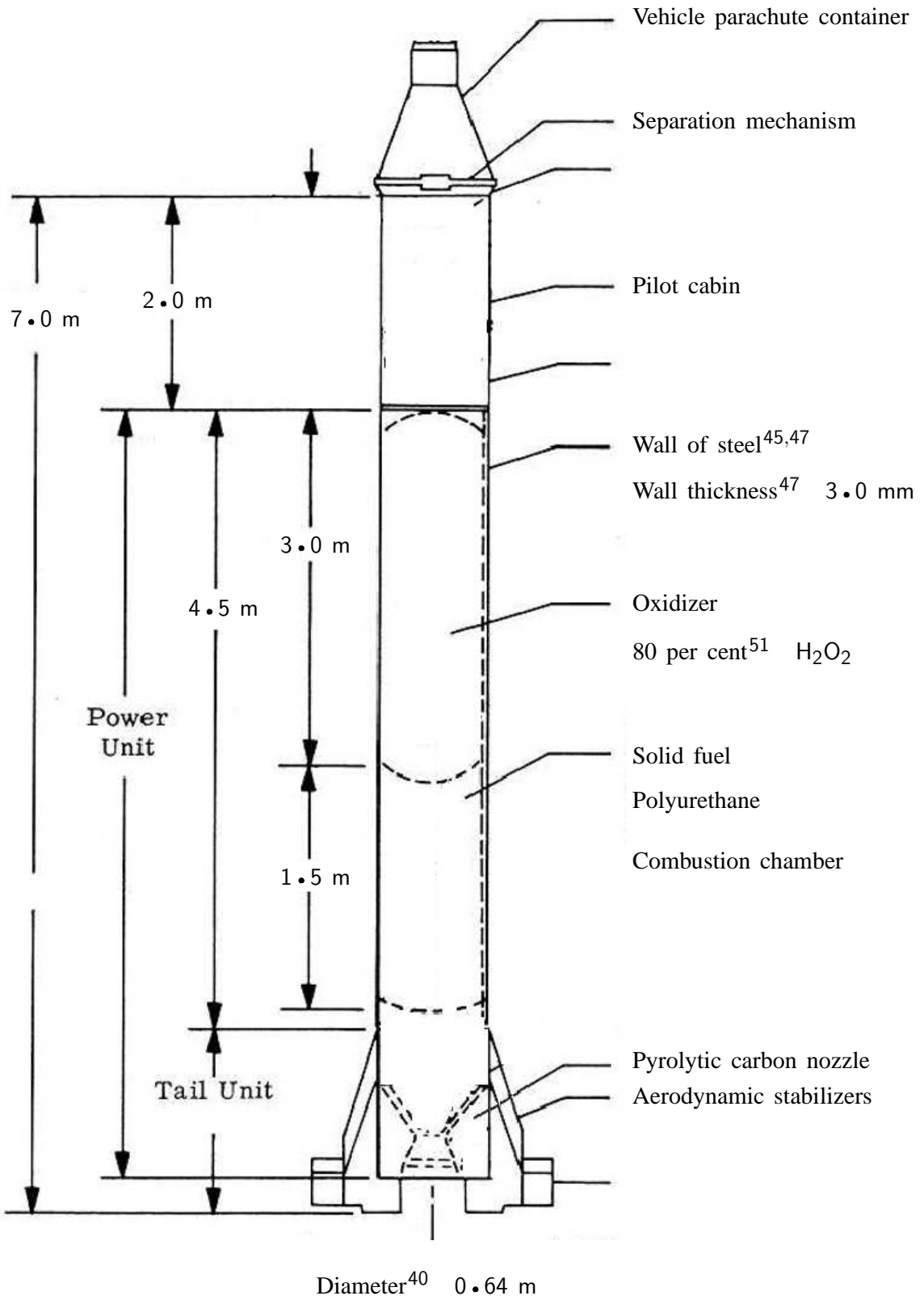
40. Peter Madsen: "Ny hybrid motor, nu med Fessor II katalysator". In English, "New hybrid motor, now with Fessor

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2943. Sikkerhedsdatablad. Edulan
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40. Peter Madsen: "Ny hybrid motor, nu med Fessor II katalysator". In English, "New hybrid motor, now with Fessor II catalyst bed". Published by ing.dk 2014-09-02 13:43.

45. Peter Madsen: "Kan man have T-stoff i en ståltank?" In English, "Will it work with T-stoff in a steel vessel?" Published on ing.dk 2014-08-17 18:36.

47. Peter Madsen: "Der regnes, tegnes og bygges på livet løs!" In English, "Calculation, drawing, and fabrication at full power!" Published on ing.dk 2014-08-02 01:47.

51. Peter Madsen: "Her er rumplanen!" In English, "Here is the spaceflight plan!" Published on ing.dk 2014-06-17 13:11.