

1. INTRODUÇÃO

Fonte: NASA, em <http://www.grc.nasa.gov/WWW/K-12/airplane/shortr.html>

1.1 FOGUETES A PROPELENTE SÓLIDO

Início: Idade Média, em guerras

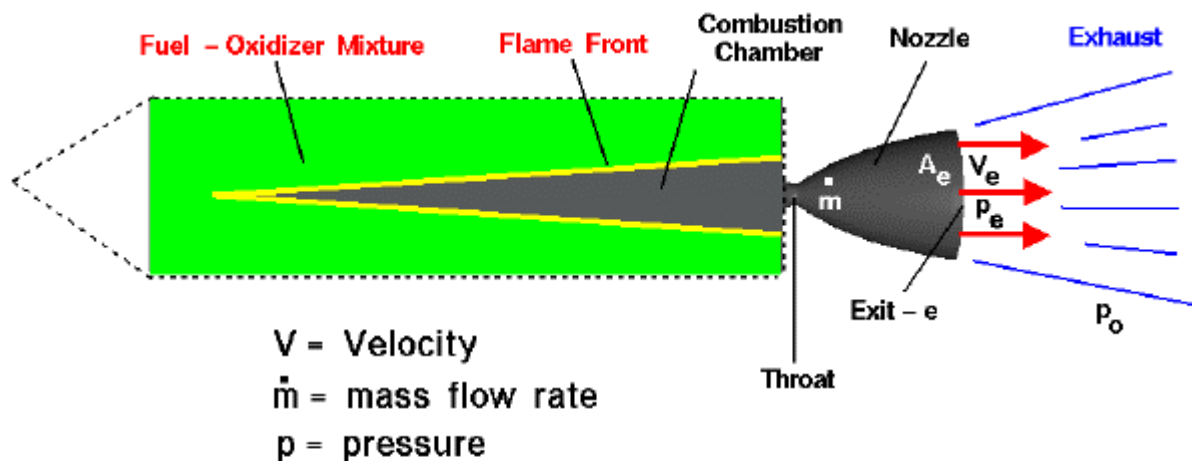


Chinese soldier launches fire-arrow



Solid Rocket

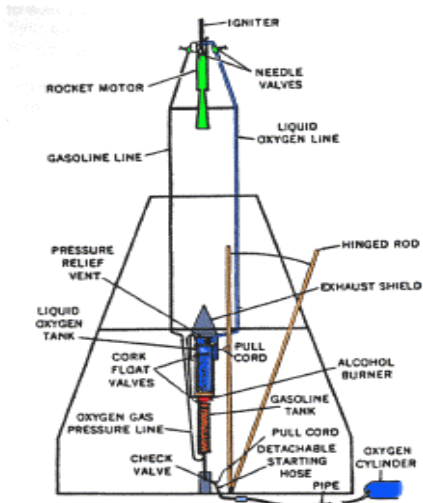
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$$\text{Thrust} = F = \dot{m} V_e + (p_e - p_0) A_e$$

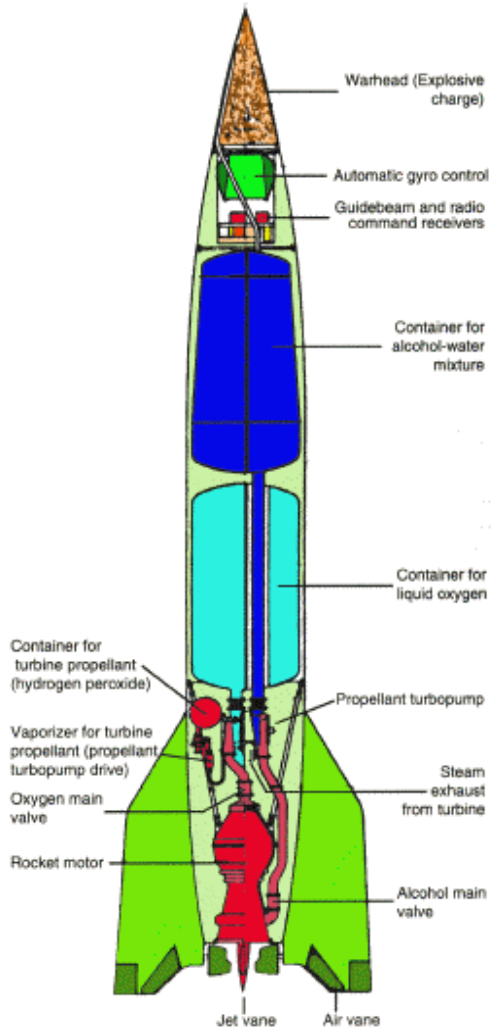
1.2 FOGUETES A PROPELENTE LÍQUIDO

Início: Robert Goddard, 1926



Dr. Goddard's 1926 Rocket

V-2, Von Braun, 2^a Guerra Mundial, 1942

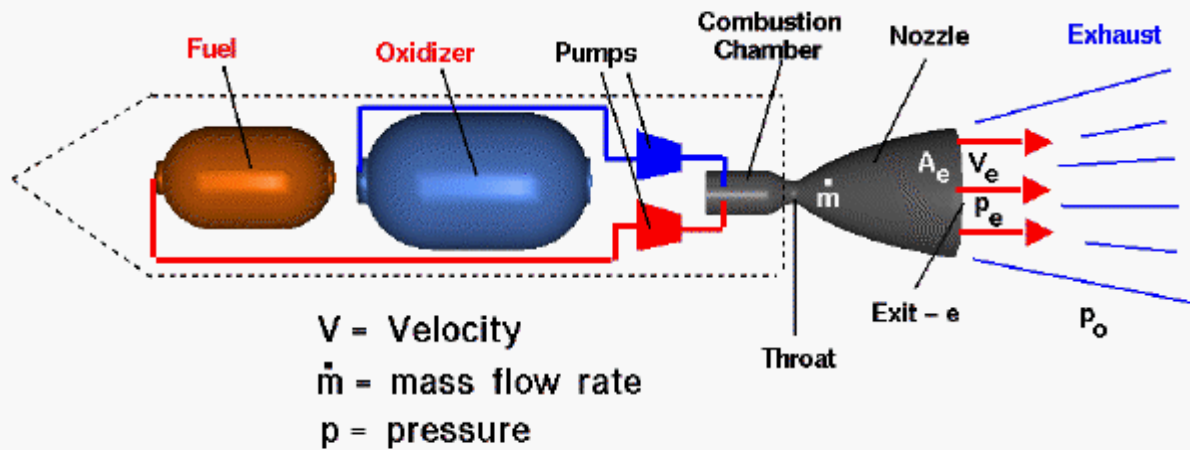


German V-2 (A-4) Missile



Liquid Rocket

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$$\text{Thrust} = F = \dot{m} V_e + (p_e - p_o) A_e$$

1.3 CÁLCULO DO EMPUXO DE UM MOTOR-FOGUETE

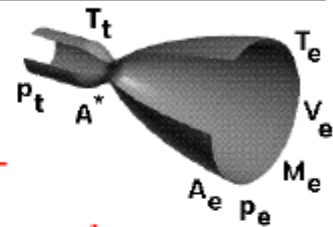


Rocket Thrust Summary

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Known:

p_t = Total Pressure R = Gas Constant
 T_t = Total Temperature A = Area
 γ = Specific Heat Ratio



Mass Flow Rate: $\dot{m} = \frac{A^* p_t}{\sqrt{T_t}} \sqrt{\frac{\gamma}{R}} \left(\frac{\gamma+1}{2}\right)^{-\frac{\gamma+1}{2(\gamma-1)}}$

Exit Mach: $\frac{A_e}{A^*} = \left(\frac{\gamma+1}{2}\right)^{-\frac{\gamma+1}{2(\gamma-1)}} \frac{\left(1 + \frac{\gamma-1}{2} M_e^2\right)^{\frac{\gamma+1}{2(\gamma-1)}}}{M_e}$


Exit Temperature: $\frac{T_e}{T_t} = \left(1 + \frac{\gamma-1}{2} M_e^2\right)^{-1}$

Exit Pressure: $\frac{p_e}{p_t} = \left(1 + \frac{\gamma-1}{2} M_e^2\right)^{-\frac{\gamma}{\gamma-1}}$

Exit Velocity: $V_e = M_e \sqrt{\gamma R T_e}$

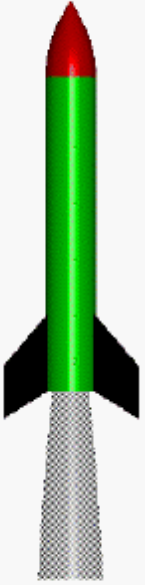
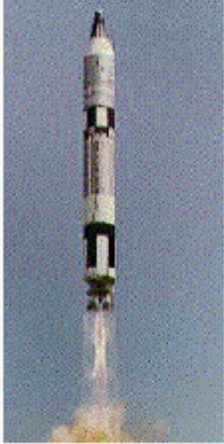
Thrust: $F = \dot{m} V_e + (p_e - p_0) A_e$

1.4 FOGUETES X MINIFOGUETES

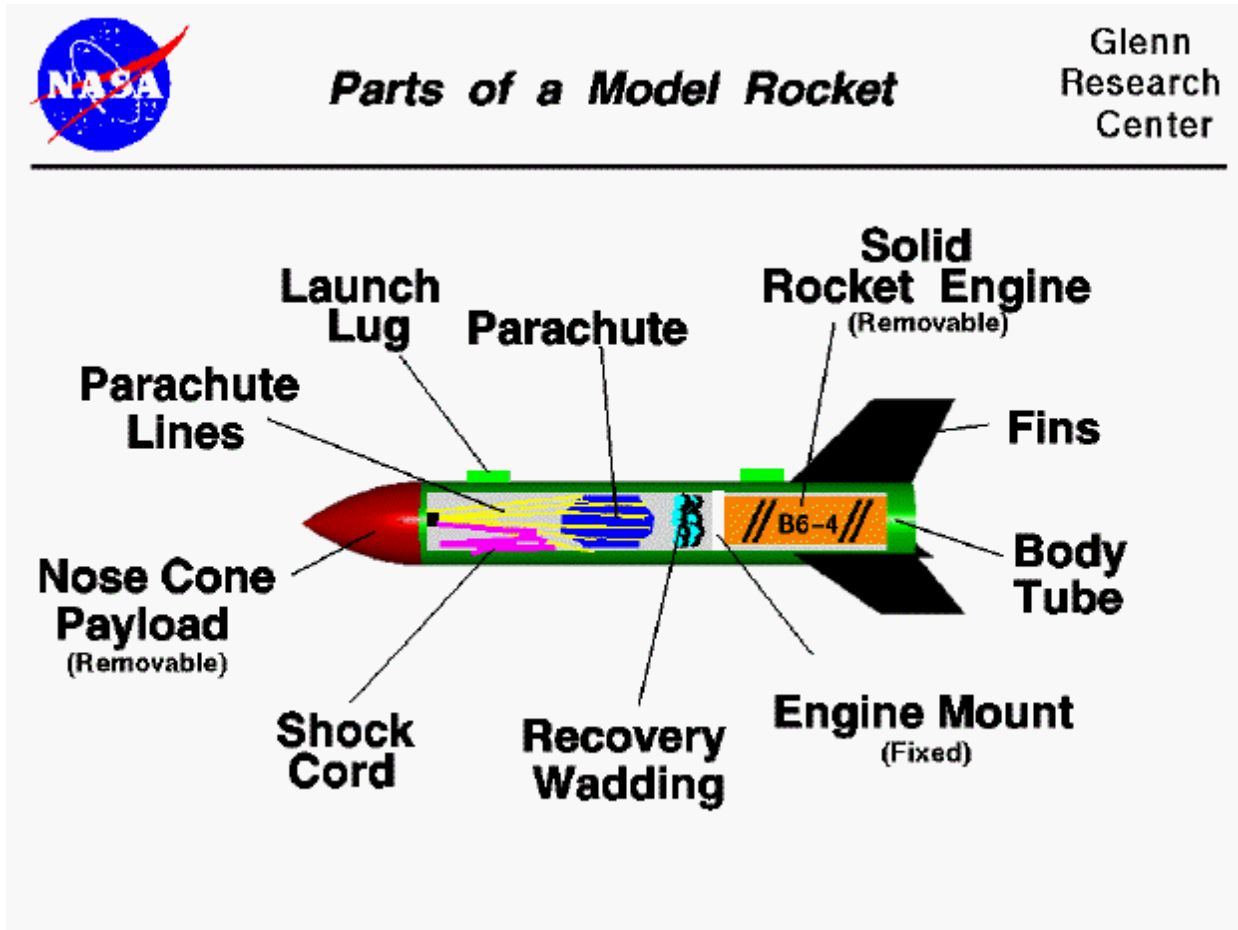


Model Rockets and Real Rockets
Compare and Contrast

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	Model Rocket	Real Rocket	
	<p>4 forces throughout flight</p> <p>all of flight in atmosphere aerodynamics very important</p> <p>very short powered flight</p> <p>solid rocket engine small propellant mass fraction</p> <p>passive stability no control</p> <p>low speed heating not important</p> <p>inexpensive materials balsa, cardboard, plastic</p>	<p>4 forces during atmospheric flight</p> <p>short time in atmosphere aerodynamics less important</p> <p>long powered flight</p> <p>liquid or solid rocket engine large propellant mass fraction</p> <p>passive stability active control</p> <p>high speed heating important</p> <p>expensive materials aluminum, titanium, nickel alloy</p>	 <p>Titan Booster</p>

1.5 COMPONENTES DOS MINIFOGUETES



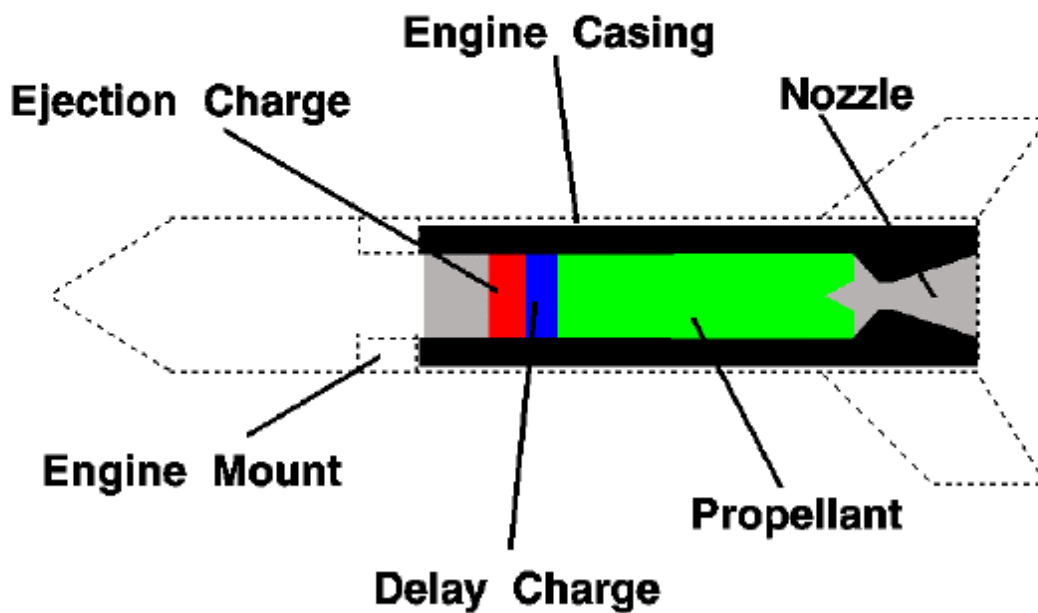
1.6 MINIFOGUETES MODELO OU ESPAÇOMODELOS

Kits, motores pré-fabricados



Model Solid Rocket Engine

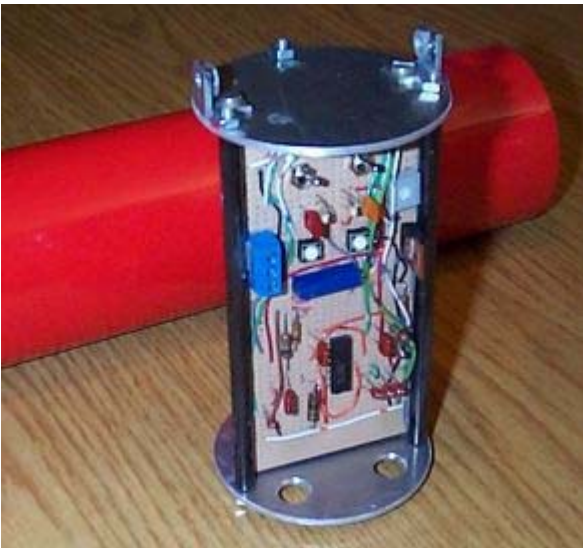
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1.7 MINIFOGUETES EXPERIMENTAIS

Projeto próprio

Fonte: Richard Nakka, <http://www.nakka-rocketry.net/>



Módulo do timer do pára-queadas



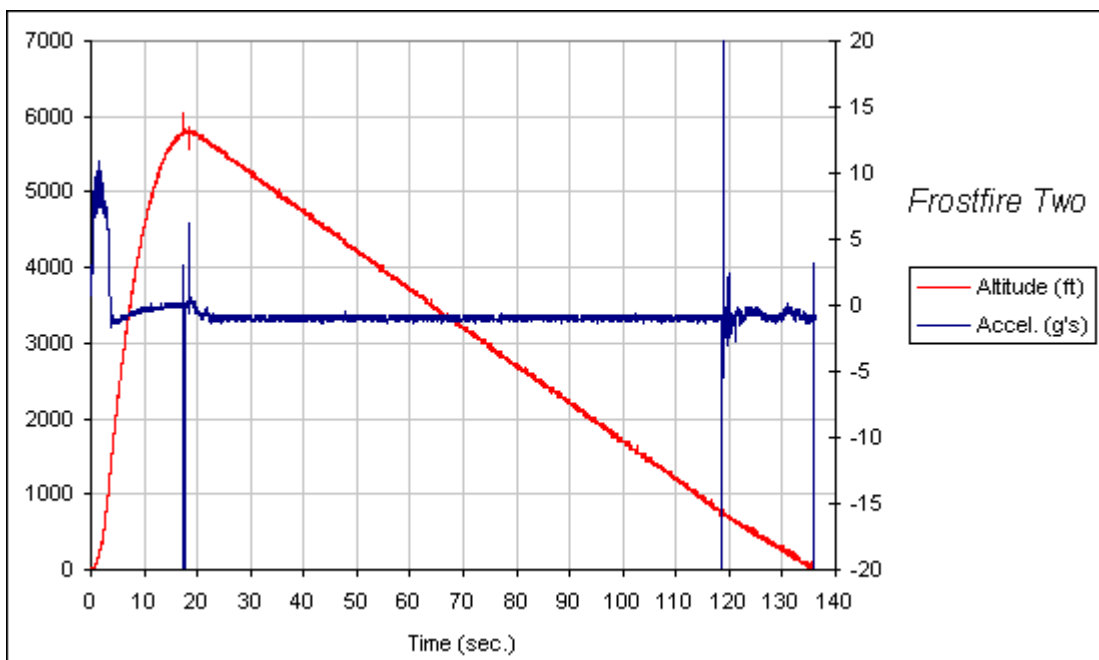
Minifoguete experimental de Nakka



Motor-foguete experimental



Grão-propelente



Altitude e aceleração medidos com equipamento a bordo do minifoguete