# EmDrive Efficiency

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# Introduction

The efficiency of an EmDrive thruster depends on the application.
Each Thruster is designed specifically for the vehicle it will be propelling.
This is illustrated in section 6 of the following paper:

*Second Generation EmDrive Propulsion applied to SSTO launcher and Interstellar Probe.*
*Roger Shawyer*
*SPR Ltd UK*
*Acta Astonautica 116 (2015) 166-174*

The following presentation gives a simple explanation of how EmDrive efficiency is calculated.

# Energy Flow

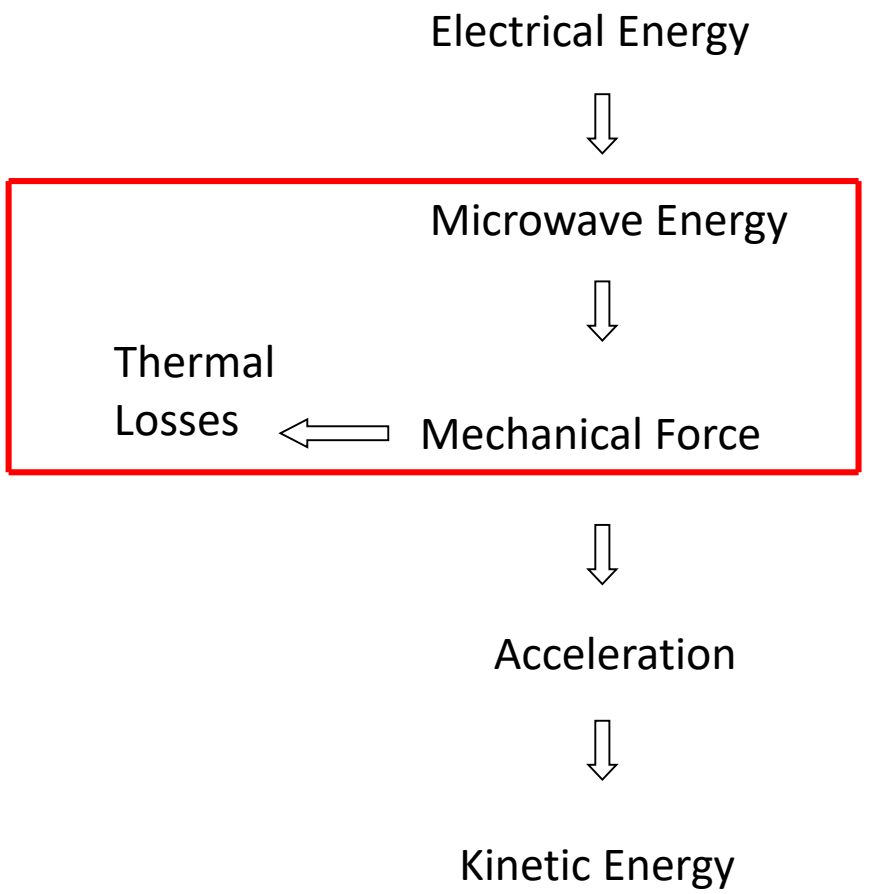
Efficiency is a measure of Energy out divided by Energy in

The Energy flow through a vehicle propelled by an EmDrive thruster is shown opposite

The efficiency of an EmDrive thruster is assumed to be the efficiency of the conversion of microwave energy into a mechanical force

The process is shown within the red box and accounts for the thermal losses

Overall mission efficiency must account for the efficiency of the electrical generation system, the conversion to microwave energy, and the mechanical losses due to aerodynamic or hydrodynamic drag.



# EmDrive Efficiency Theory 1

EmDrive Thruster operation is determined by:

- Input Power P (in kW)
- Specific Thrust Ts (in N/kW)
- Overall Vehicle Mass M (in kg)

The static propulsion force $F_s$ (in N) of an EmDrive thruster is given by $F_s=PT_s$

However once the vehicle is allowed to accelerate, some of the stored energy is converted to Kinetic energy, therefore the Q decreases and the propulsive force decreases to the dynamic force $F_d$

For constant dynamic force over time period t, Input Energy $E_{in}$ (in Joules) is given by
$E_{in} = F_s V_{av} t$

$V_{av} = (V_t - V_o)/2$ where $V_t$ is terminal velocity and $V_o$ is initial velocity.

Assume initial velocity is zero, then $V_{av} = V_t/2$

Then $E_{in} = PT_s t V_t/2$

# EmDrive Efficiency Theory 2

The period t (in seconds) is given by $t = V_t/a$

Then $E_{in} = PT_s V_t V_t/2a = PT_s V_t^2 /2a$

The Mechanical Energy output $E_{out}$ (in Joules) is the Kinetic Energy gained by the vehicle.
$E_{out} = MV_t^2 /2$

Then efficiency $e = E_{out}/E_{in} = \dfrac{MV_t^2\, 2a}{2PT_sV_t^2}$

Therefore $e = Ma/PT_s$ But from Newtons 2nd law $F_d=Ma$ Therefore $e = F_d /PT_s$

Then EmDrive efficiency = $F_d/F_s$

# Conclusions

- The efficiency of an EmDrive thruster accelerating a vehicle is equal to the Dynamic Force divided by the Static Force.
- The Static Force is the Microwave Input Power times the Specific Thrust
- The Dynamic Force is the Mass of the vehicle times the acceleration achieved
- The efficiency cannot be 100%, as then all stored energy would be transferred to kinetic energy, and the thrust would fall to zero
- In hover flight, thruster efficiency is zero, as there is no vehicle acceleration
- Typical 3G thruster efficiencies are between 20% and 70%, in order to optimise the flight envelope for each application