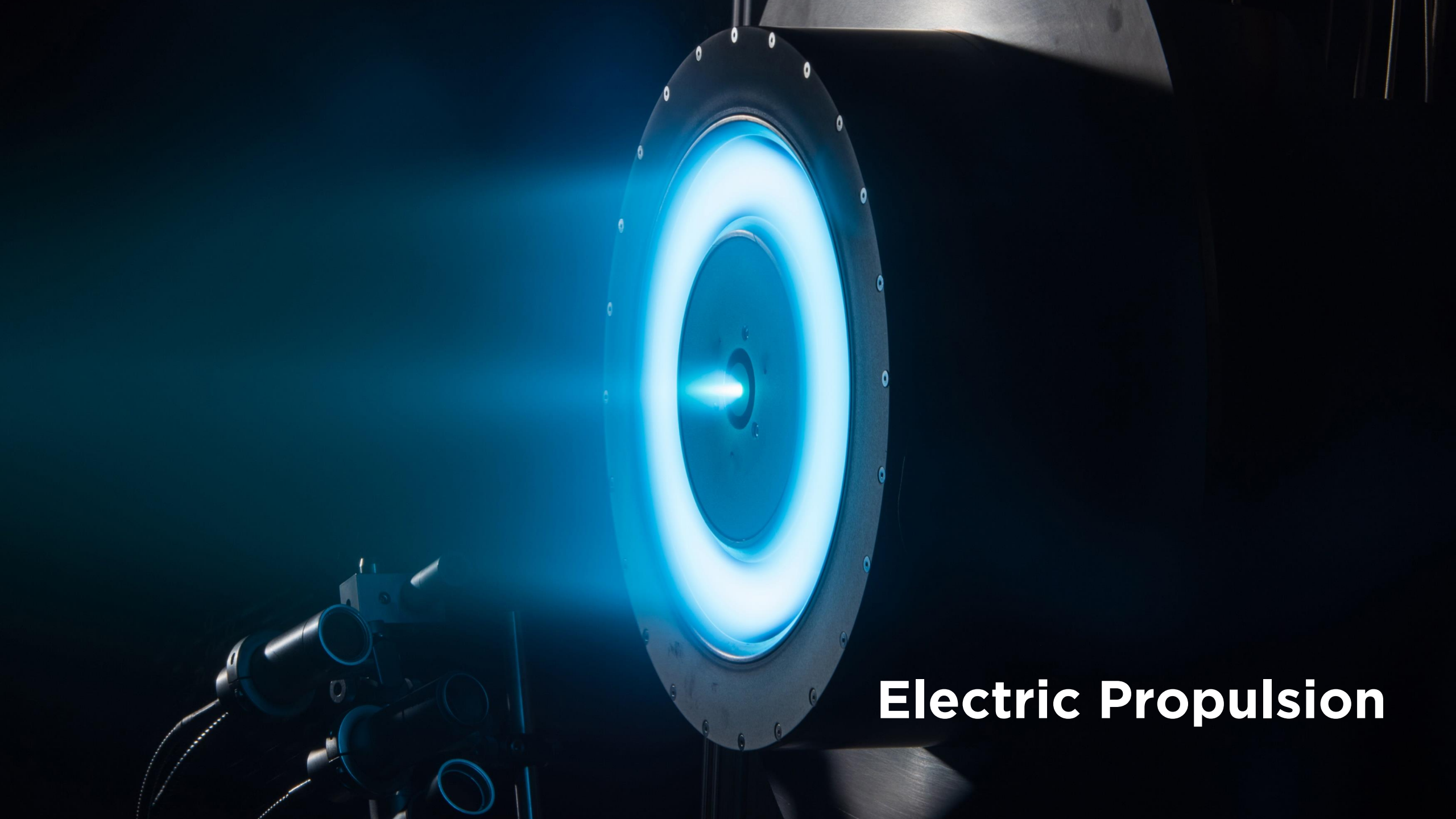

Electric Propulsion

Introduction to Advanced Propulsion

- Rockets do not have to be chemical, their energy supply can be separated from their propellant mass supply.

- Investing more in the development of chemical systems offers diminishing returns.

- SIs are already close to the max we can achieve chemically:
  - Materials and cooling systems cannot sustain much higher temperatures.
  - Molecular weight is limited by the propellants in the reactions and often higher than the minimum H2.

Eliott Wertheimer

Electric Propulsion

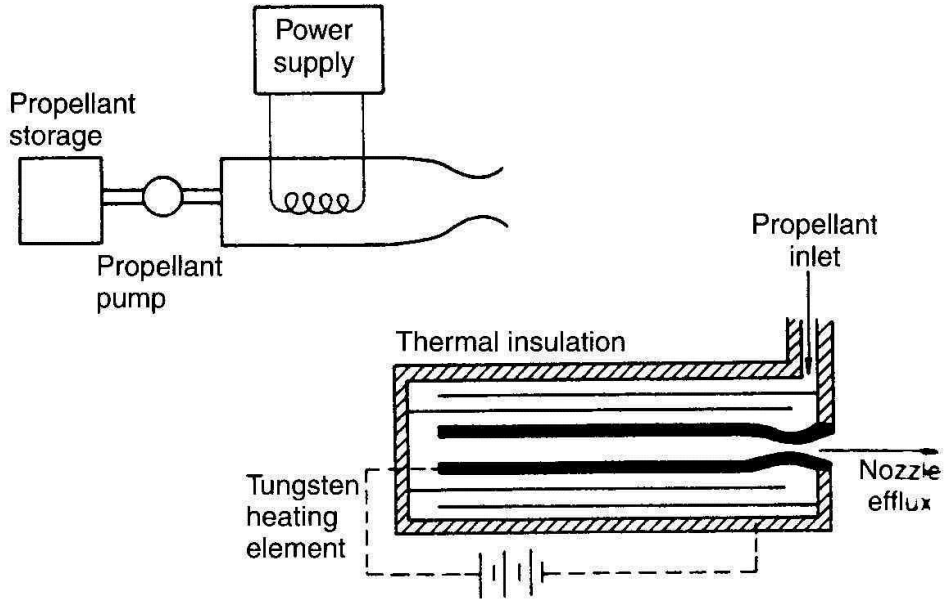
- Consists in the electrical heating of a working fluid or the electromagnetic acceleration of a conducting material and require an external source of electric energy (solar, chemical, nuclear).
    - Electrothermal: electrical energy is converted to heat in thermodynamic motors using ohmic heating, electric arcs, etc. Rocket laws still apply.
    - Electrodynamic: reaction masses are accelerated electrodynamically. The laws of electromagnetism apply. The reaction mass must be able to react with electric or magnetic fields, extra mass (e.g. reaction “trolley” for railgun) or extra energy input are required (e.g. ionisation of propellant for ion engine).

Eliott Wertheimer

Electrothermal Propulsion - Resistojets

- A working fluid is heated using electrical resistance (Ohmic heating).
- This system improves the performance of low impulse systems such as monopropellant motors.
- Particularly applies when excess electrical power is available which would otherwise be radiated to space through shunt resistors.

In advanced state of development



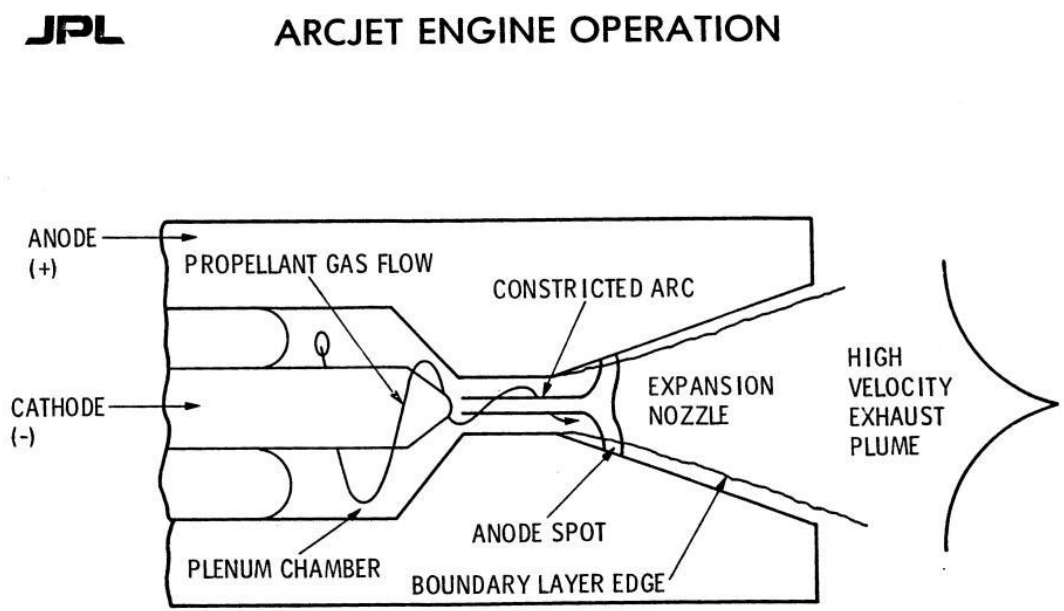
Eliott Wertheimer

Electrothermal Propulsion - Arcjets

- Heating of a working fluid through an electric arc which reaches up to 10,000˚K.

- Main problem is that high temperatures cause short circuits and shutdowns due to the movement of materials.

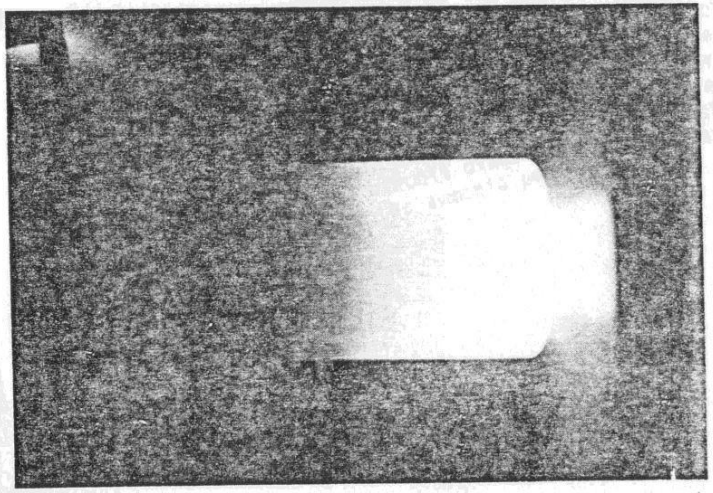
In advanced state of development

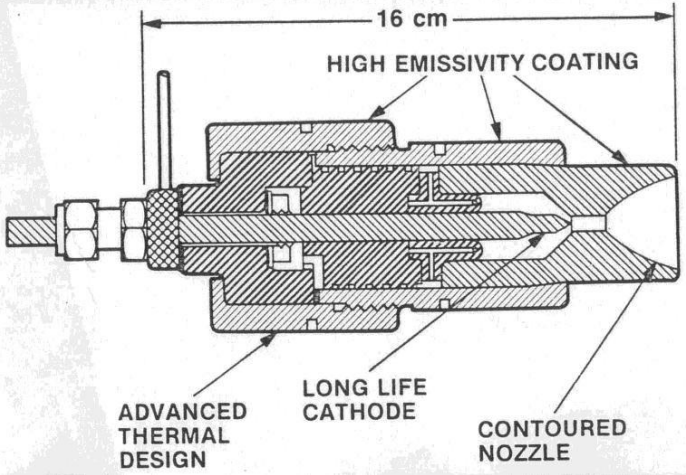


Eliott Wertheimer

Electrothermal Propulsion - Arcjets

ARCJET CHARACTERISTICS



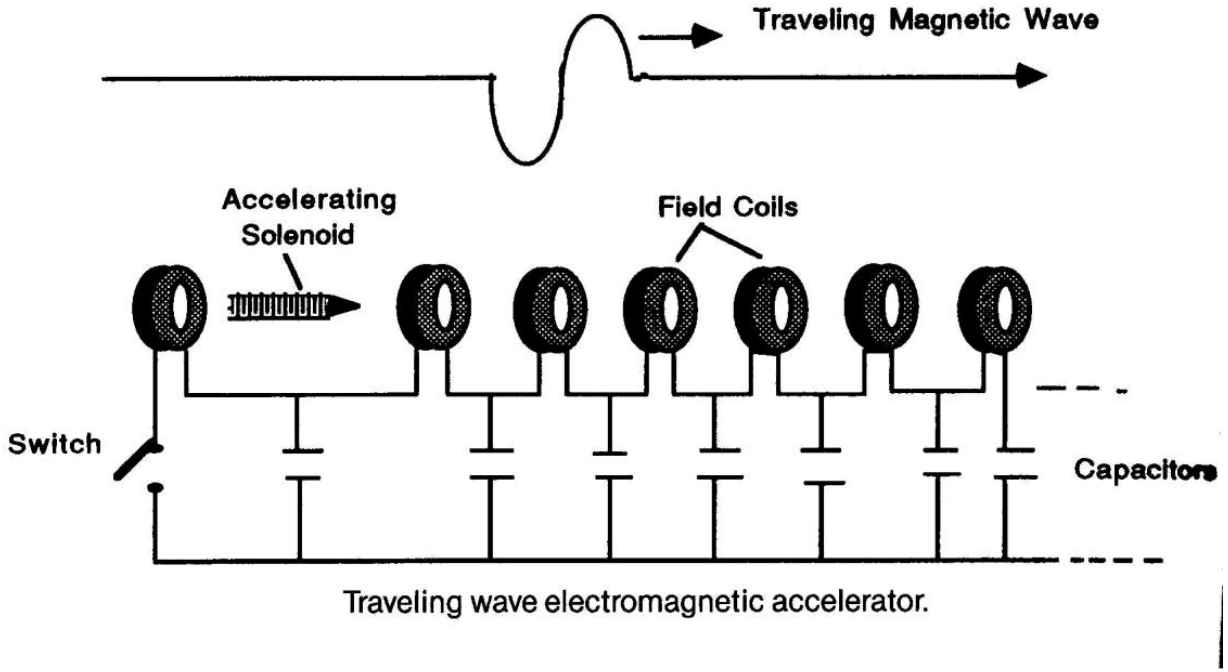


PARAMETER PER ENGINE	VALUE DEMONSTRATED	VALUE IST GOALS
PROPELLANT	NH_3	NH_3
ENGINE INPUT POWER	25 kW_e	30 kW_e
THRUST	2.4 N	2.6 N
SPECIFIC IMPULSE	870 s	1050 s
ENGINE EFFICIENCY	37%	45%
ARC VOLTAGE	109 V	120 V
ARC CURRENT	230 A	250 A
MASS FLOW RATE	0.27 g/s	0.25 g/s
ENGINE MASS	7 kg	7 kg
TEST DURATION	573 hrs	1500 hrs
TOTAL IMPULSE	5 x 10^6 N-S	1.4 x 10^7 N-S

Eliott Wertheimer

Electrodynamic Propulsion – Rail Guns

- Linear electric motors which are very attractive for example in the exploitation of lunar or asteroidal surface material.
- It is highly energy efficient (non thermodynamic), and can attain many km/s.
- Usually the larger the better.

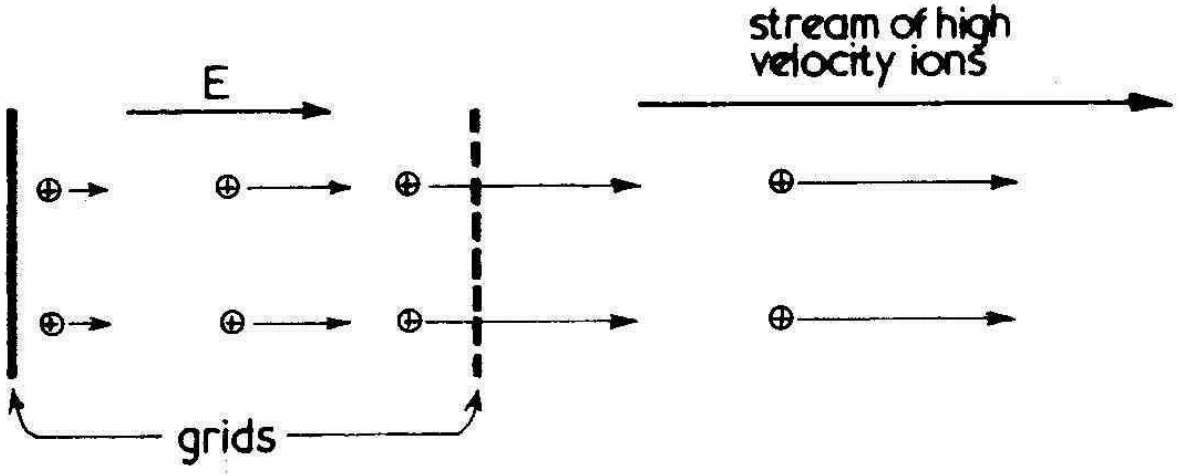


Traveling wave electromagnetic accelerator.

Eliott Wertheimer

Electrodynamic Propulsion – Ion Engines

- Charged atoms or ions are accelerated electrostatically to very high velocities (km/s).
- Current exhaust velocity record is owned by the Dawn spacecraft: 10km/s
- Ion engines can produce very low thrusts for very long times.



Eliott Wertheimer