The Tony Davies High Voltage Laboratory

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Mission Cost for GIEs using APs

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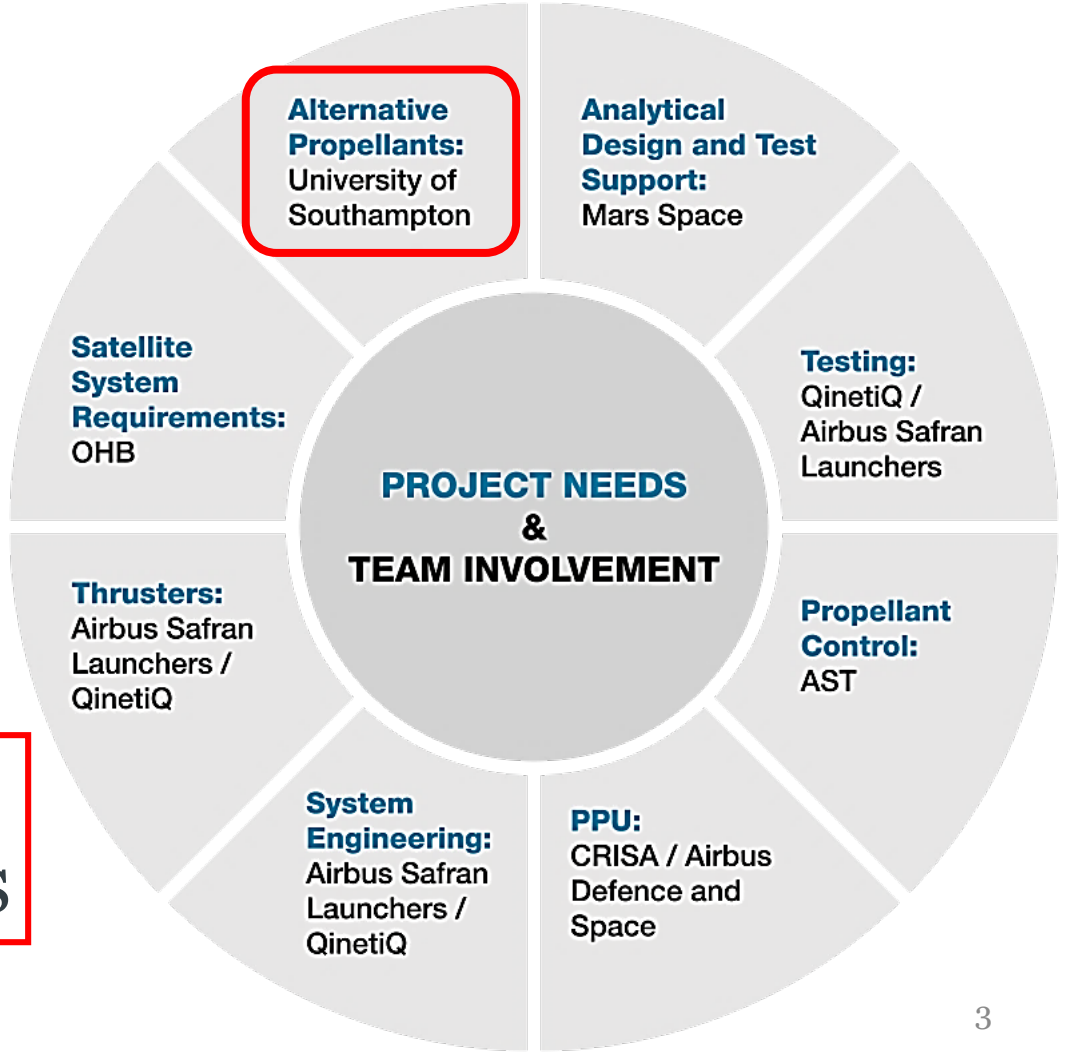
Agenda

- Introduction
  - GIESEPP Project
  - Motivation
- Spacecraft assumptions & Calculation procedure
- Results
- “New Space” approach
- Summary

GIESEPP Project

- It stands for Gridded Ion Engine Standardised Electric Propulsion Platform
- Consortium of the major European companies
- To develop, build and qualify GIE systems
- Commercial competitiveness
- Significantly reduce costs and increase production capacities



Motivation

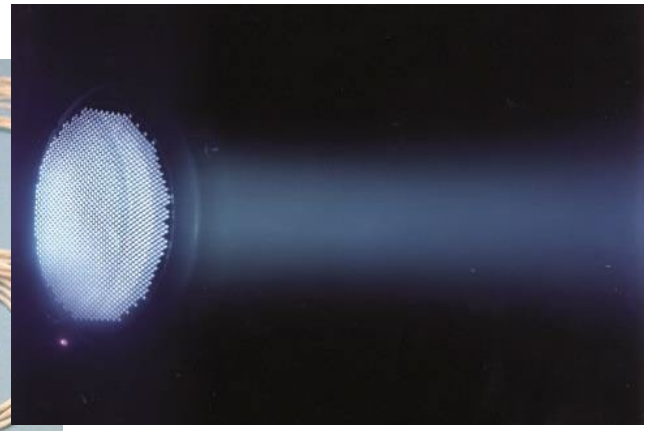
- Xenon is expensive and it has limited availability
- Investigated the impact of APs on existing GIESEPP systems
  - Krypton only viable alternative [1]
- Cheaper – how much in a typical mission?
- Krypton vs. Xenon:
  - Performance, Power, Discharge efficiency, Cathode
- Mitigation:
  - Xe/Kr mixture

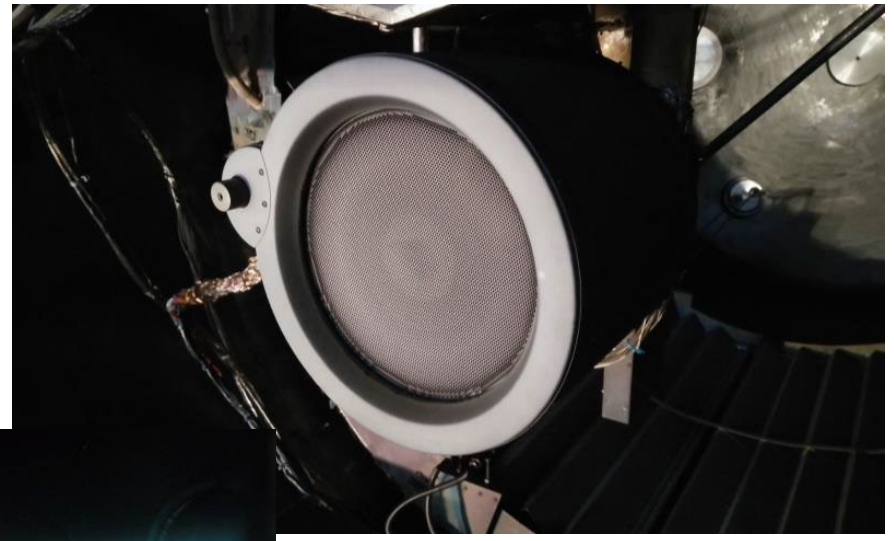
[1] N. Fazio, S. B. Gabriel, and I. O. Golosnoy, "Alternative Propellants for Gridded Ion Engines," in *6th Space Propulsion Conference*, 2018

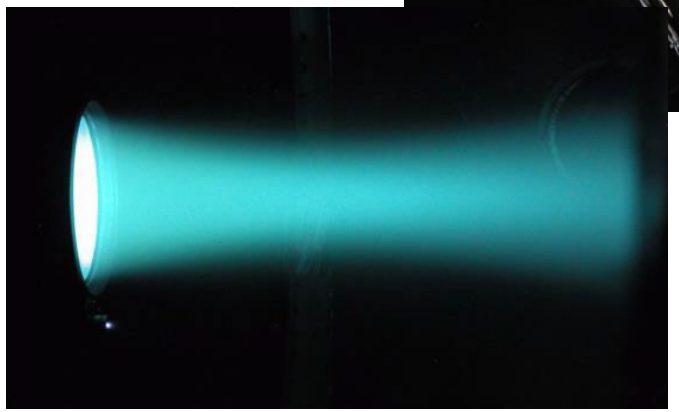
Typical Δv for low thrust missions

GEO station keeping	700 - 1000
Orbit raising GTO to GEO	2400
Orbit rising LEO to GEO*	4000
LEO applications (up to 1200 km)	800

GIESEPP thrusters







T5 – 700W class

- ø10cm active grid
- thrust: up to 25mN

T6 – 5kW class

- ø22cm active grid
- thrust: up to 230mN

Spacecraft assumptions – mission scenarios

- Three propellants: Xenon, Krypton and 1:4 Xe/Kr mixture
- Three cases:
  - CASE I – LEO satellite (GOCE-type):
    - Up to 1 kW EP power (=1 T5-type) and ~1 t (metric ton) dry mass
  - CASE II – medium size GEO satellite (ELECTRA-type):
    - Up to 10 kW EP power (=2 T6-type) and 2-3 t (metric tons) dry mass
  - CASE III – big size GEO satellite:
    - Up to 20 kW EP power (=4 T6-type) and 4-6 t (metric tons) dry mass
- Two Approaches:
  - Fixed thrust
  - Fixed EP power available on board

Calculation procedure – masses

- Rocket equation

$$m_p = m_0 \left[1 - \exp\left(-\frac{\Delta v}{g_0 Isp}\right)\right]$$

$$m_0 = m_{pl} + m_{S/C} + m_{prop} + m_{power} + (1 + tf)m_p$$

With:

m_{pl} = payload mass

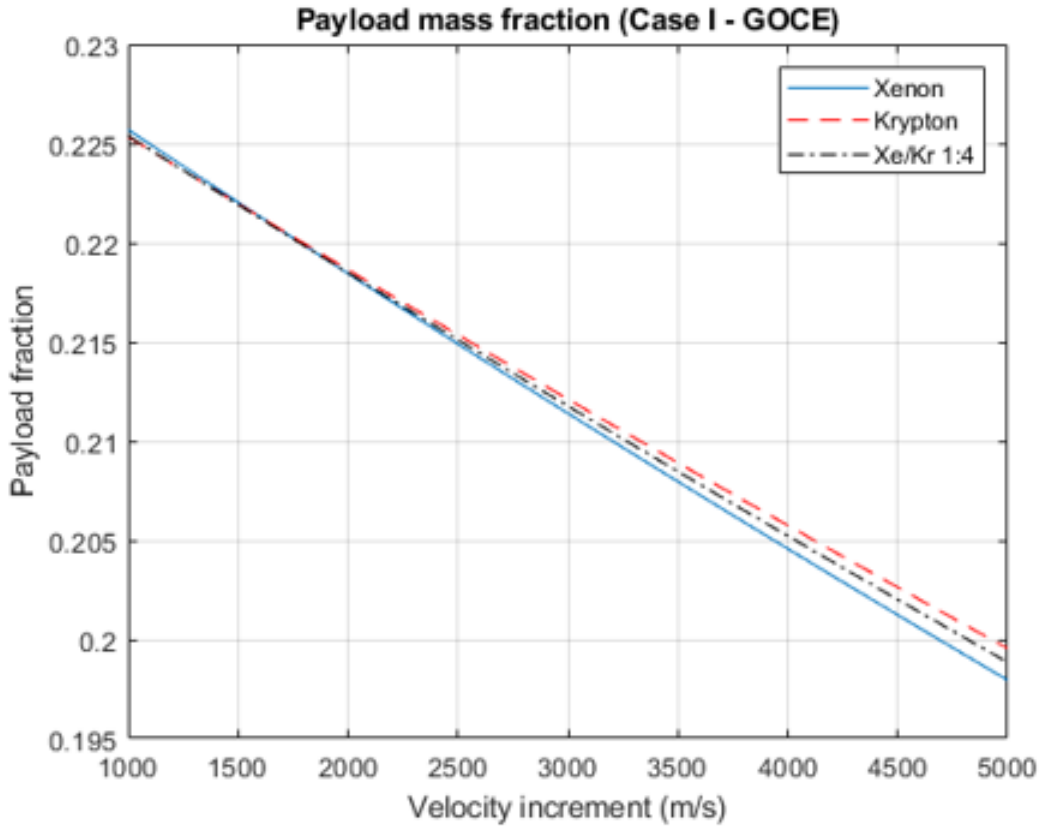
$m_{S/C}$ = S/C platform mass

m_{prop} = propulsion system

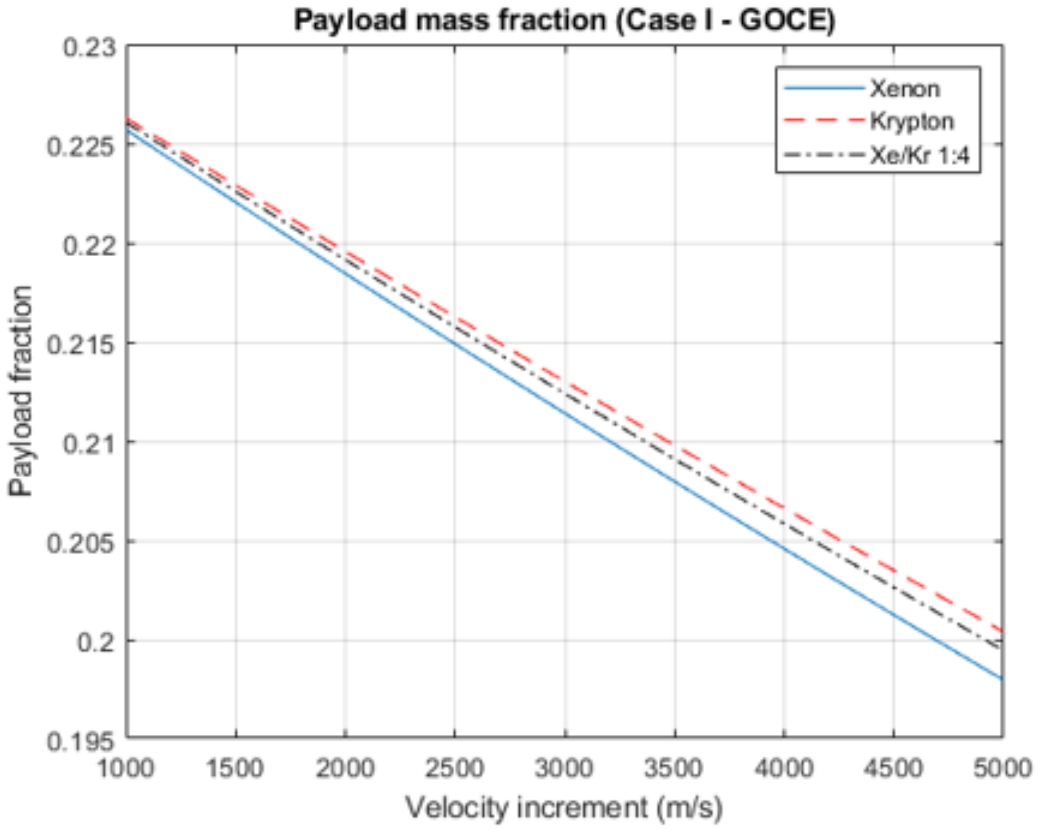
m_{power} = power generation

Results – Payload mass fraction = $\frac{m_{pl}}{m_0}$

FIXED THRUST APPROACH

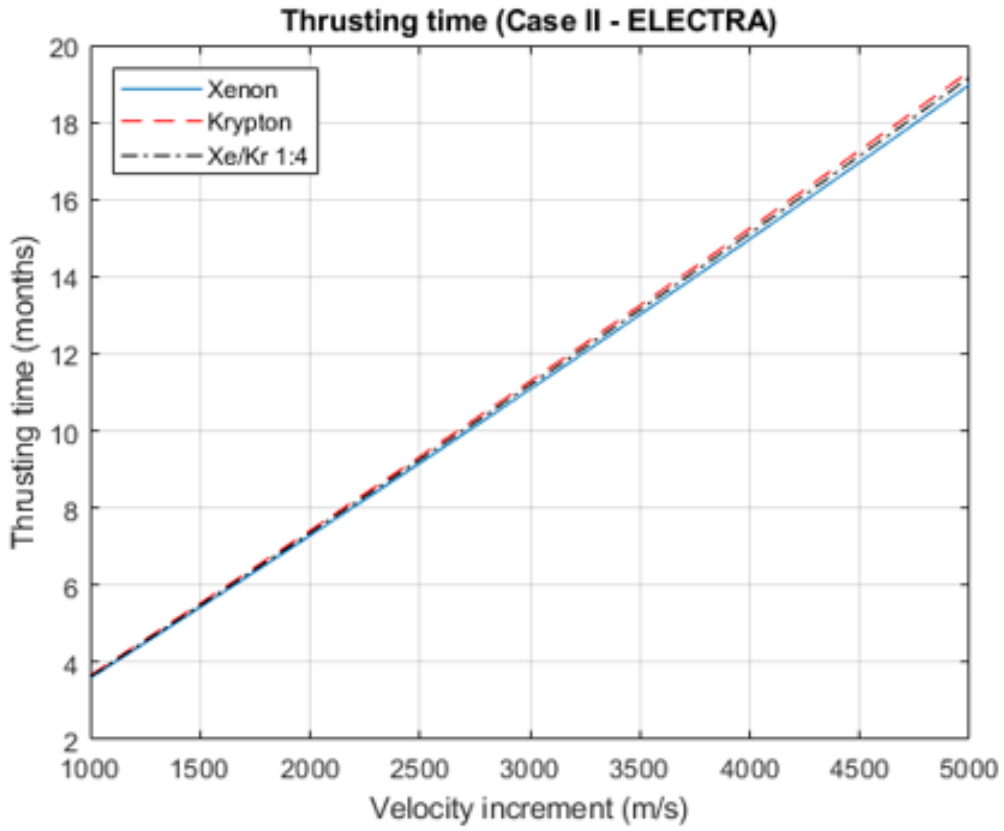


FIXED POWER APPROACH



Results – Thrusting time = $\frac{m_p}{\dot{m}}$

FIXED THRUST APPROACH



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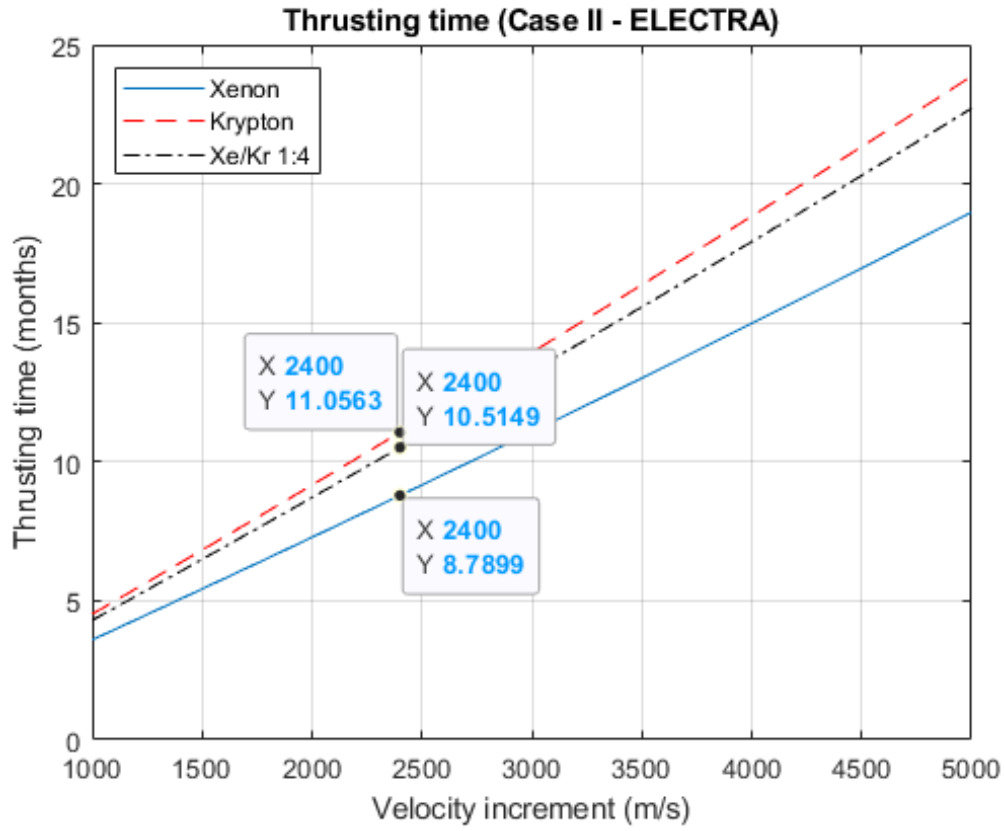


Calculation procedure – costs

- Rocket equation

$$m_p = m_0 \left[1 - \exp\left(-\frac{\Delta v}{g_0 Isp}\right)\right]$$

with $$m_0 = m_{pl} + m_{S/C} + m_{prop} + m_{power} + (1 + tf)m_p$$

~~➢ Payload mass fraction = $\frac{m_{pl}}{m_0}$~~

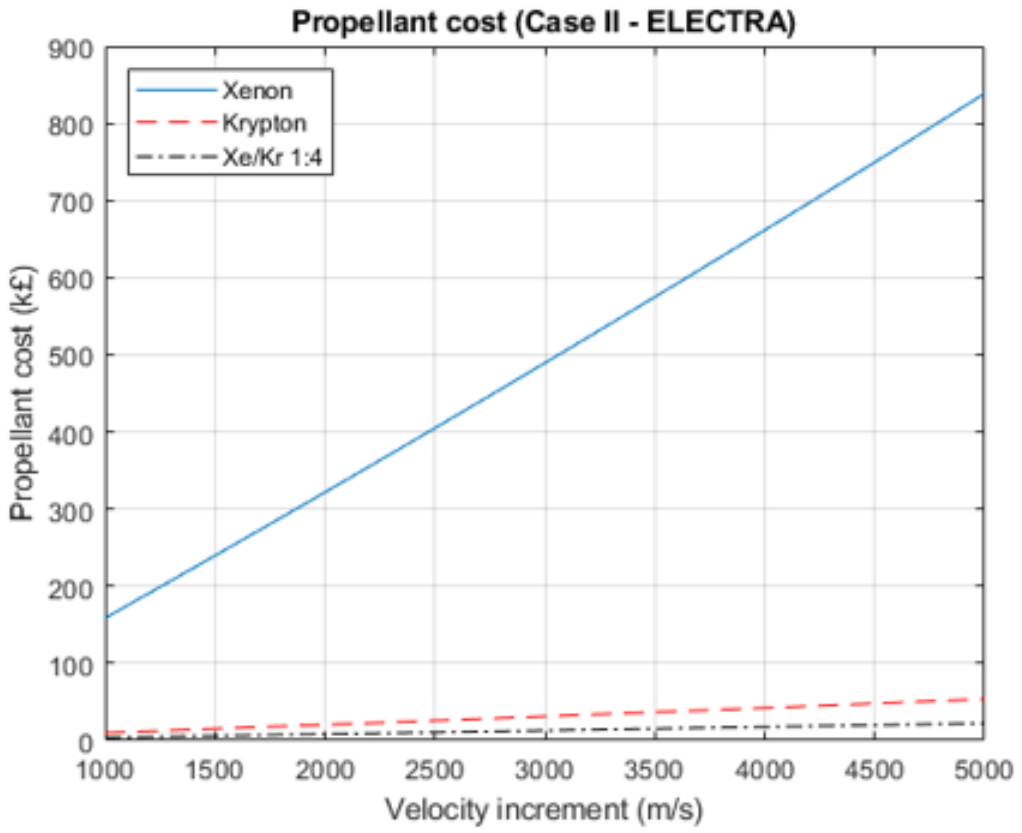
~~➢ Thrusting time = $\frac{m_p}{\dot{m}}$~~

➢ Costs: - propellant cost

- mission cost → propellant-related cost:
  - Propellant
  - Power generation
  - Tankage

Results – Propellant cost

FIXED THRUST APPROACH



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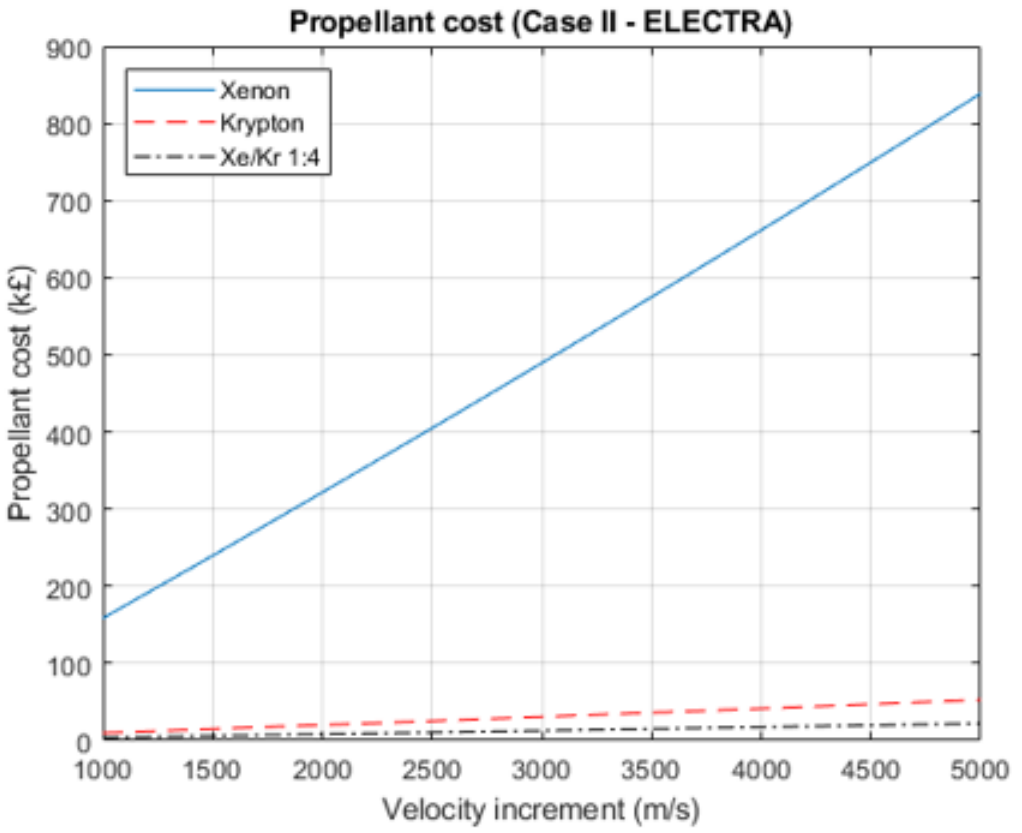
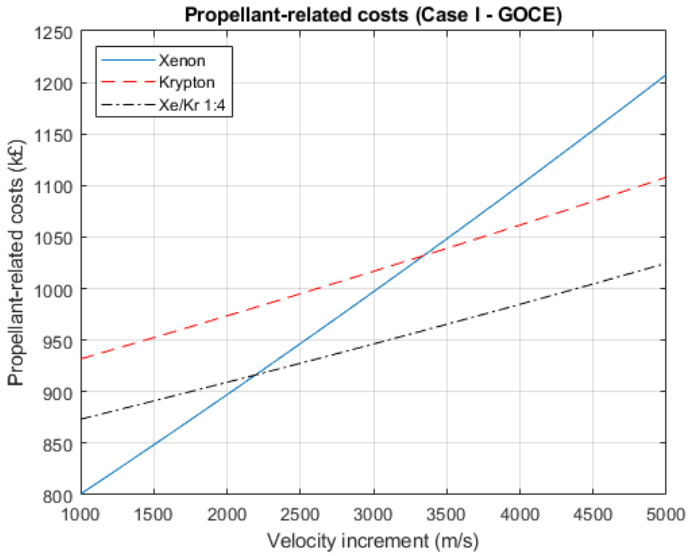
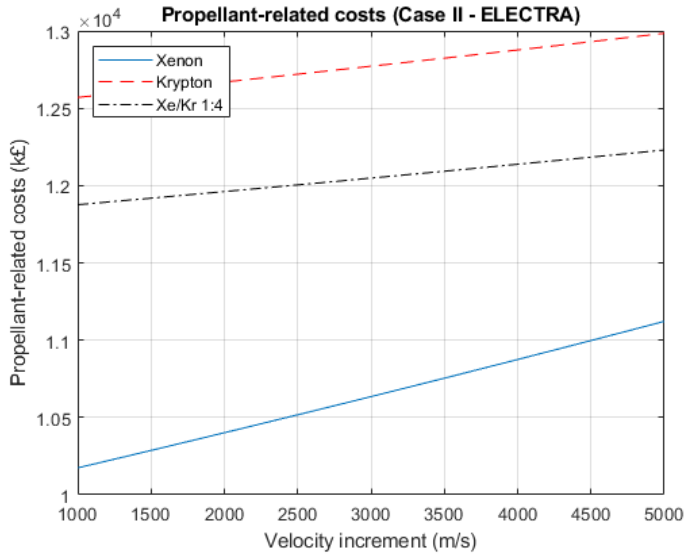


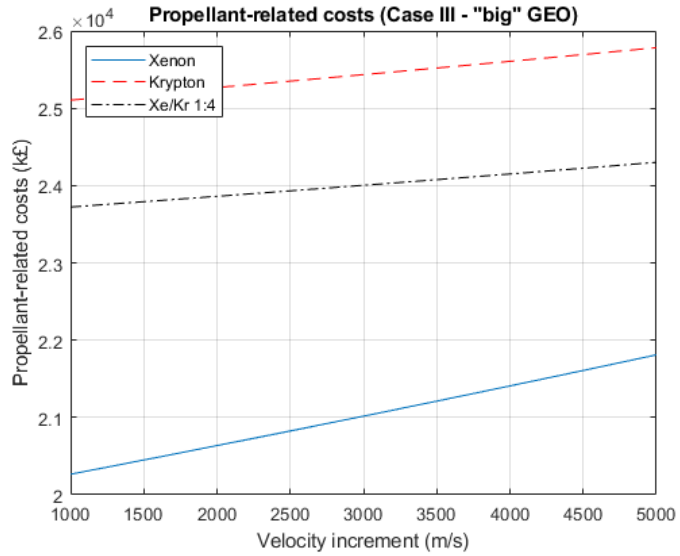
- Saving is up to **16x** for Kr and up to **38x** for Xe/Kr mixture over considered Δv range

Results – Propellant-related cost

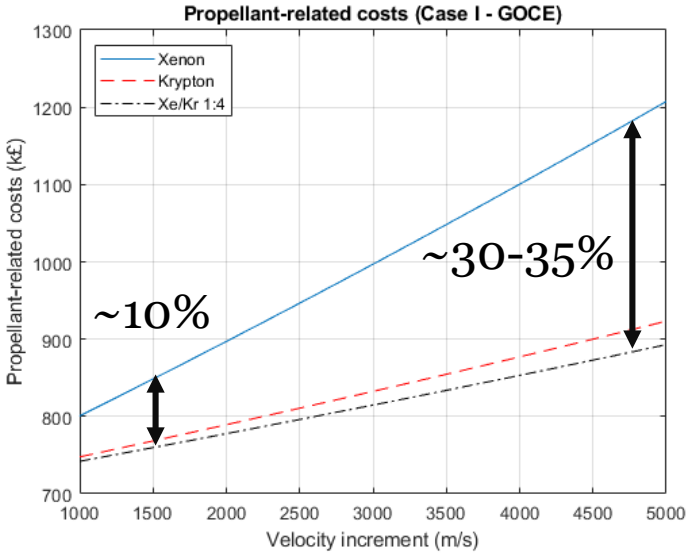
Fixed T

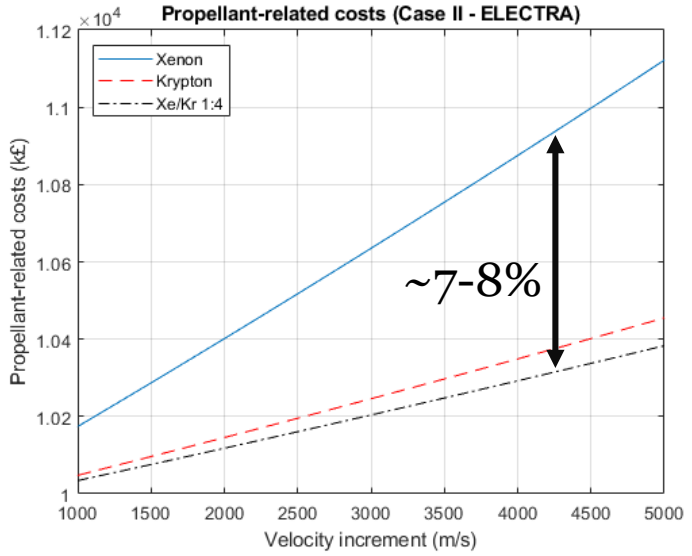


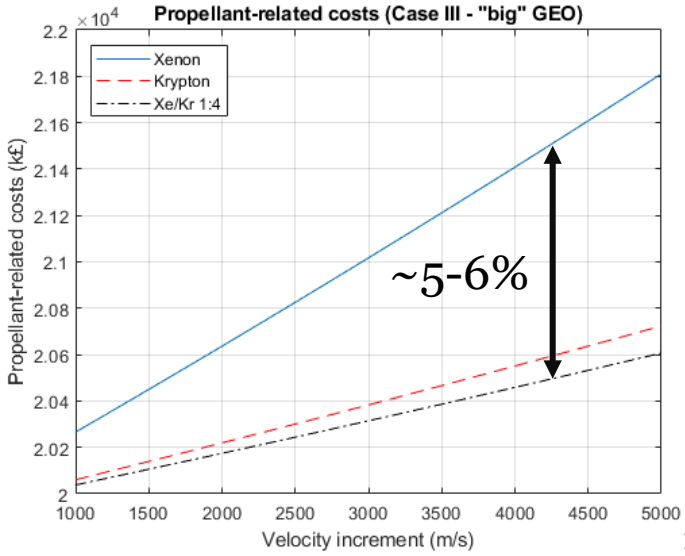




Fixed P





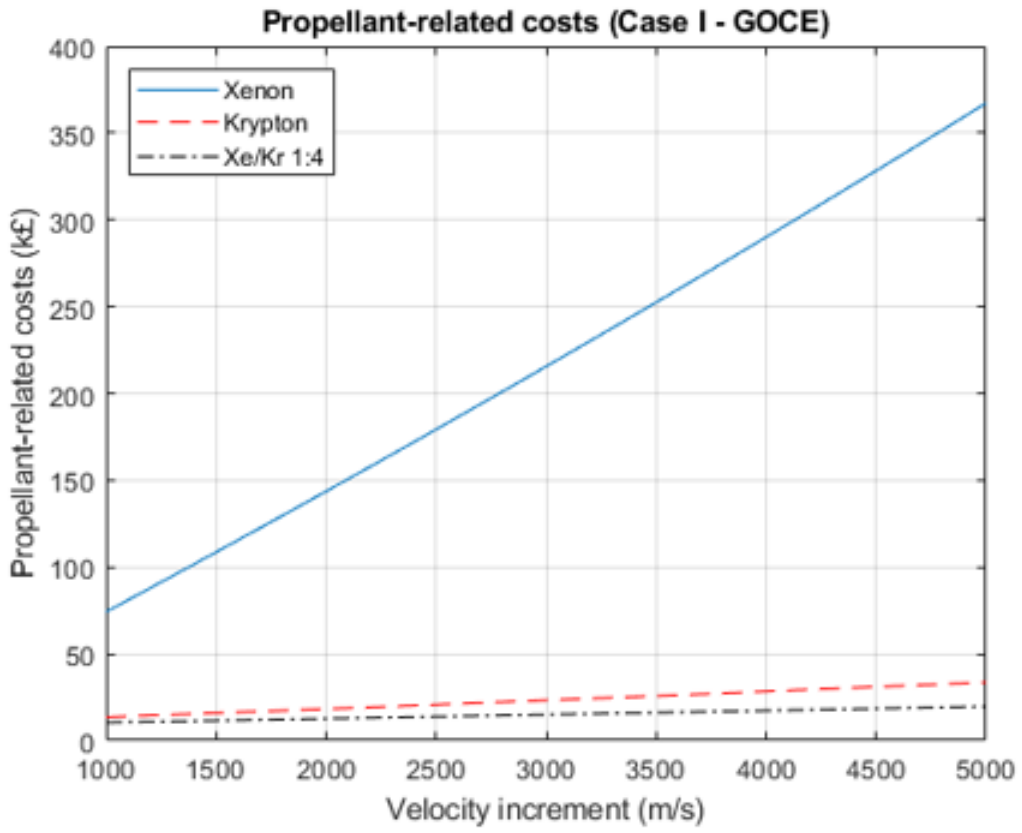


“New Space” approach: mega constellations

- Starlink case
  - 12000 satellites in LEO
  - HETs using Kr for OR and SK
- Why?
  - Cost: $500k-$1M vs $100M
  - Availability: 60 tonnes Xenon world production
- Solutions:
  - Much lower hardware cost
  - Alternative propellants

Results – “New Space”

FIXED THRUST APPROACH



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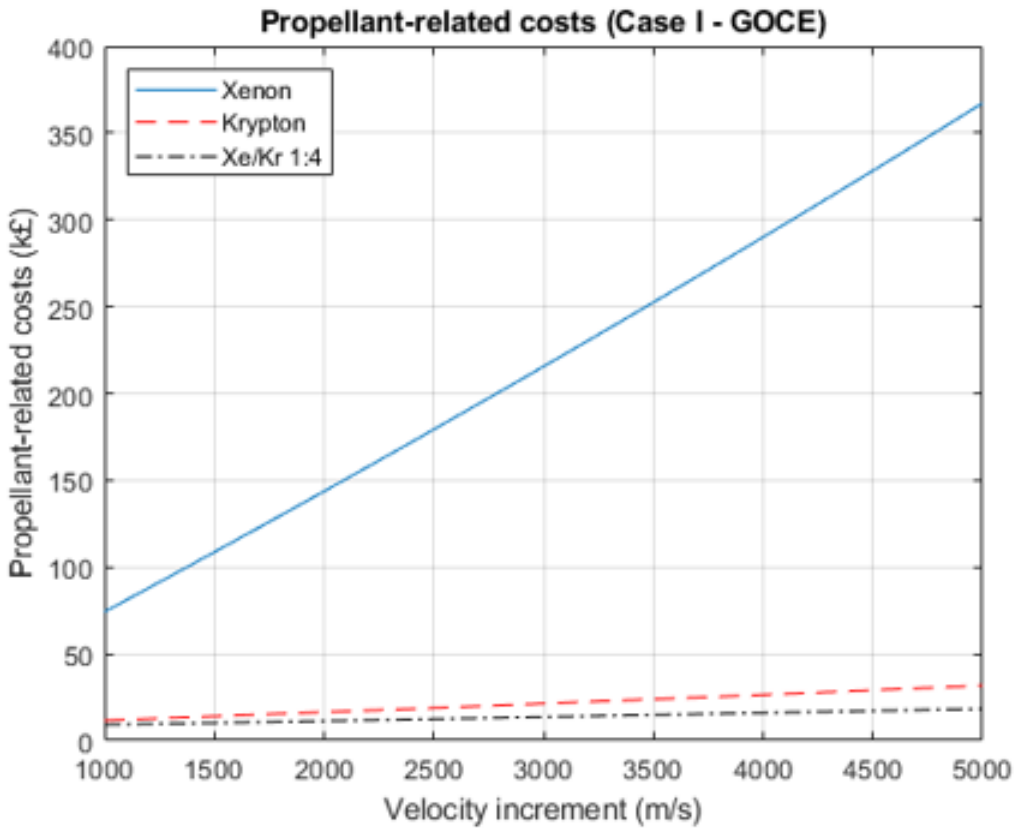

Hardware price – 100-fold reduction

Summary

CONCLUSIONS:

- Fixed thrust approach
  - no advantage for current missions
- Fixed EP power approach
  - Small savings
- “New Space” approach
- Pre-mission costs

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Thank you for your attention

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