Introduction to the economics of asteroid resources

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Outline

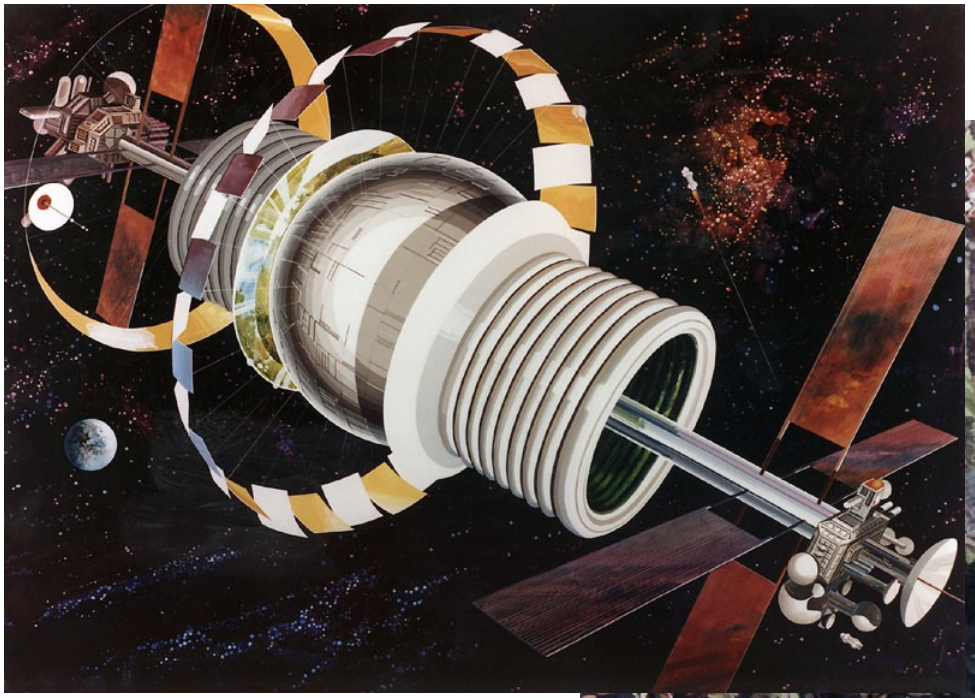
- Why asteroid resources?
- Connection of motivations to economics
- Economic considerations for early options
  - In-space uses
  - Terrestrial uses
- Common misconceptions
- Final thoughts

Why asteroid resources?

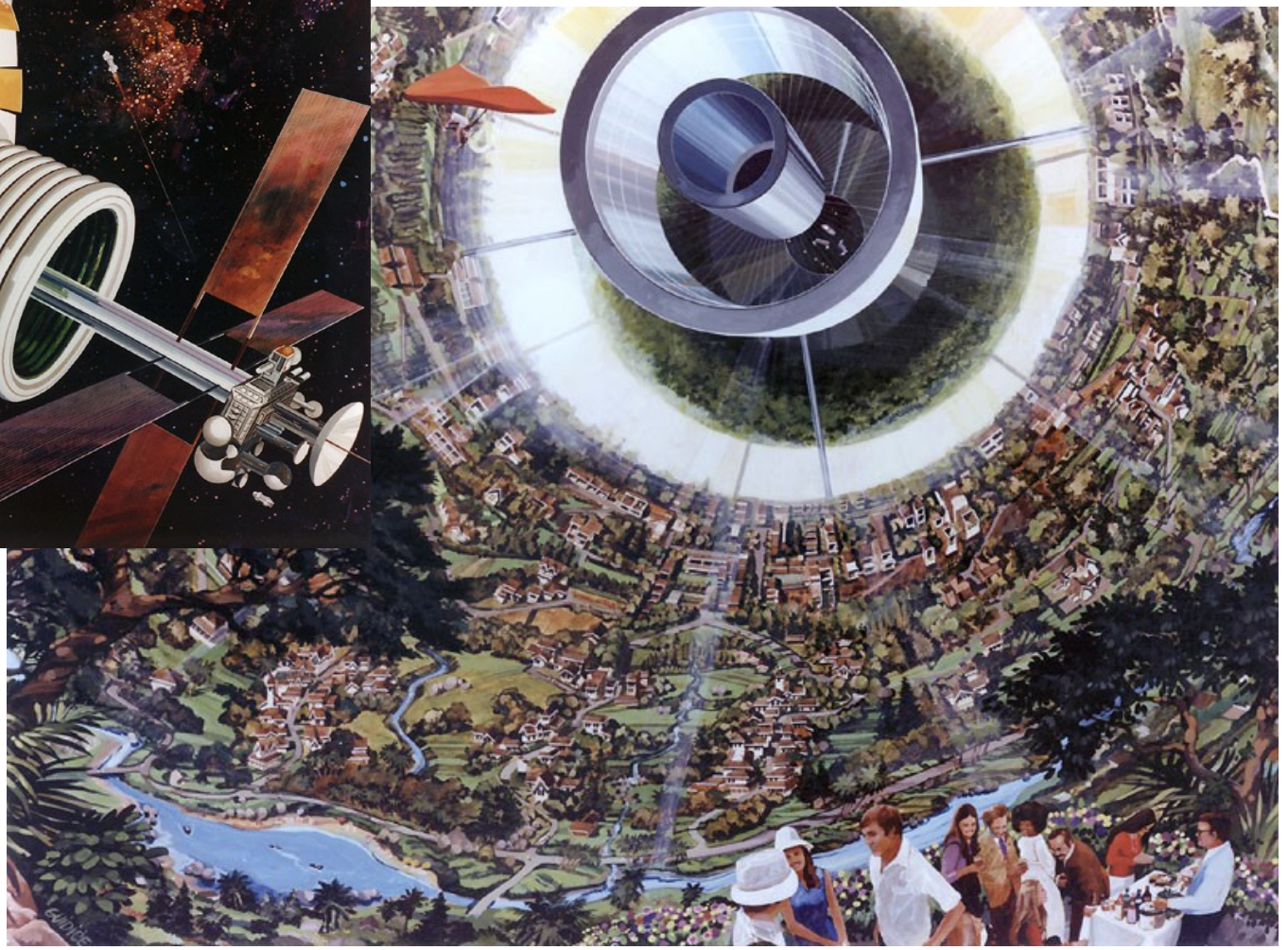
- Short-term
  - Reduce cost of traveling far from Earth and operating there
  - Return some resources back for use on Earth
- Long-term
  - Reduce latency of distant activity by fabricating tools, instruments, etc. close to their point of use
  - Develop thriving in-space human activity largely dependent on in-space resources

Motivations are driven by and/or dependent on economics

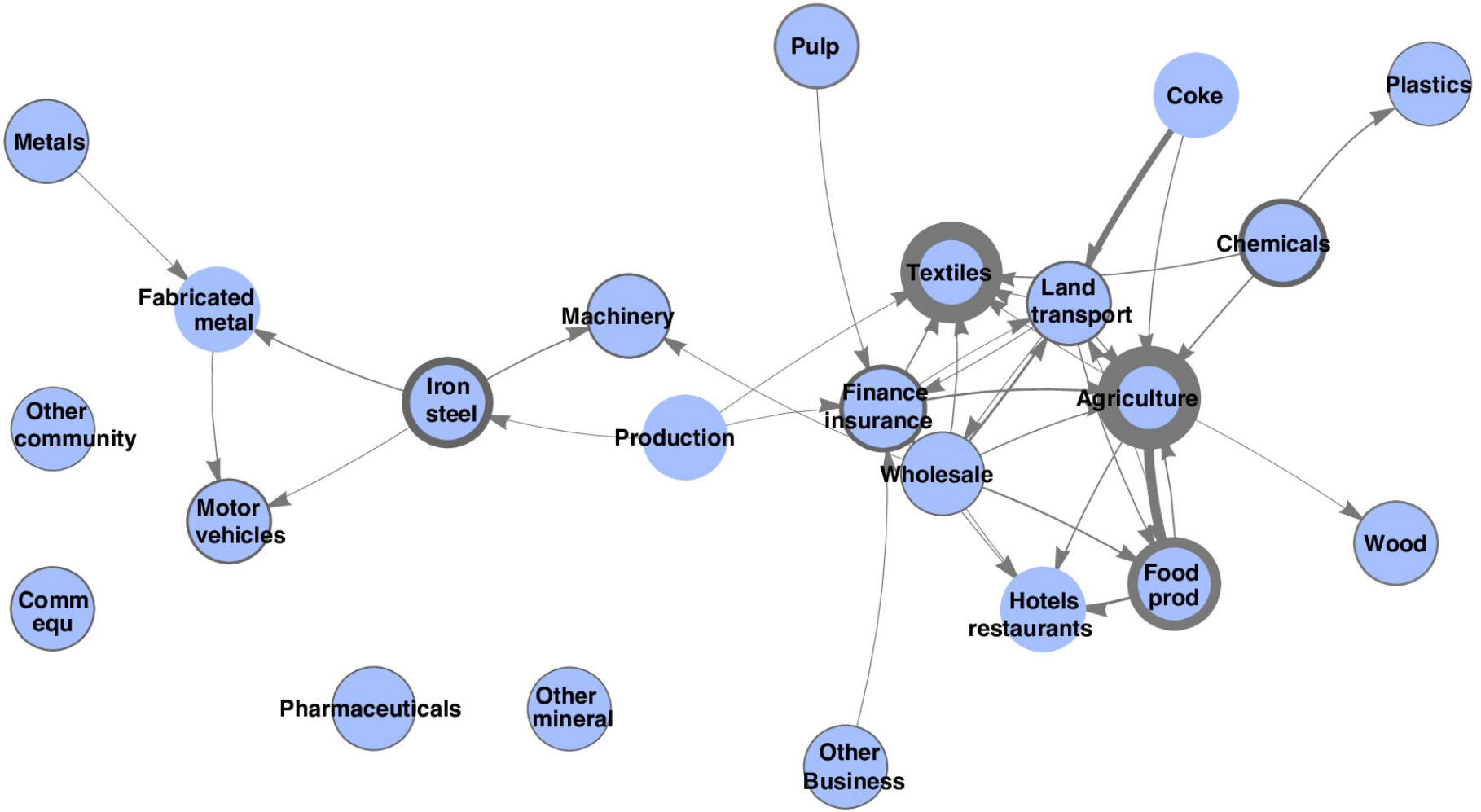
Long-term: Diverse human activity



Rick Guidice



Long-term: Diverse activity



Turkey

Bloechl et al. (2010)

General considerations

- Economics <=> scarcity?
  - Oversimplification for space
  - Potential resources / raw materials are common

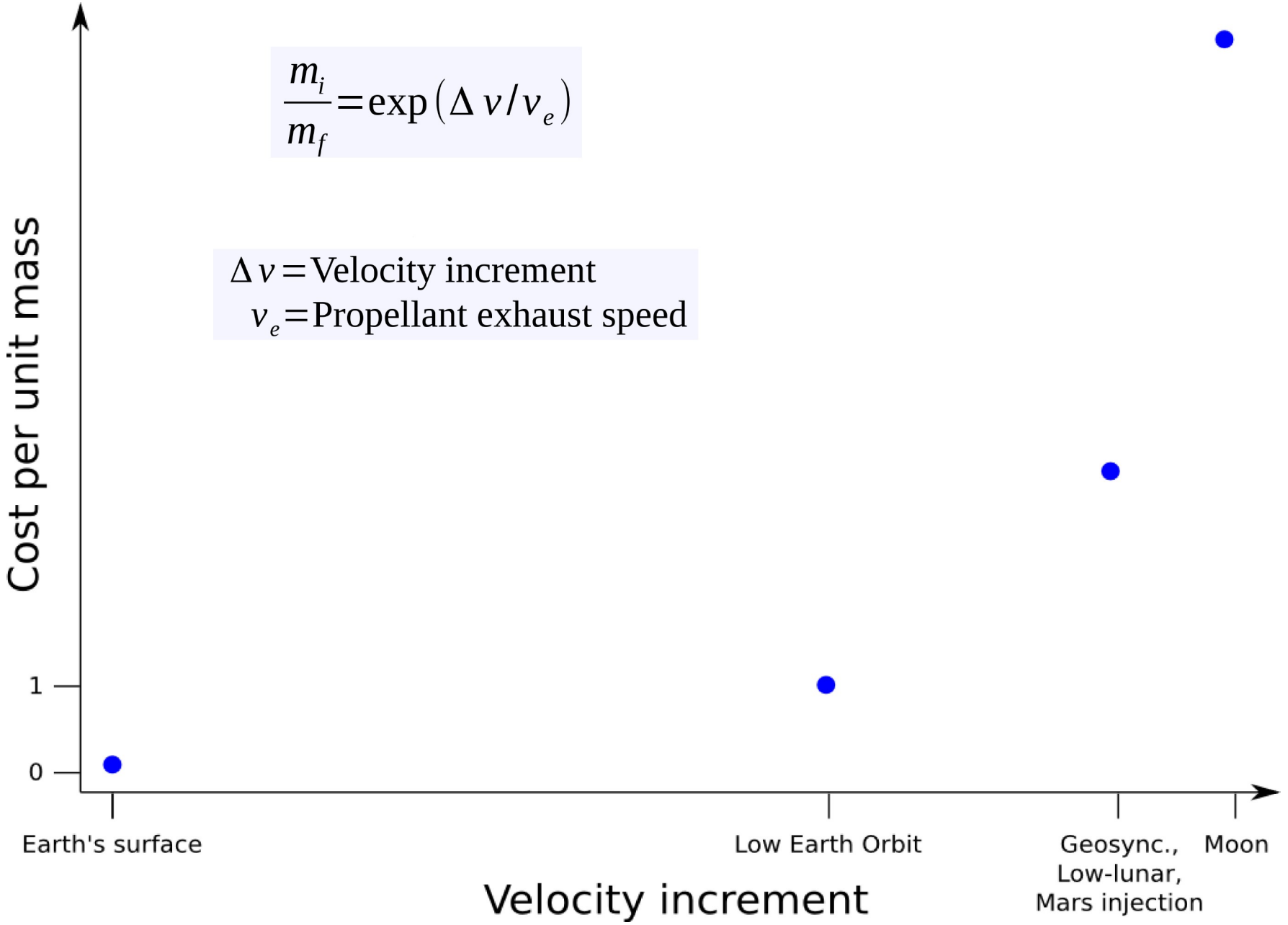
But:

- **Transportation often hard (need lots of energy and propellant)**
- **Infrastructure / industrial base is nonexistent yet**

Transportation: Propellant mass

$$\frac{m_i}{m_f} = \exp\left(\Delta v / v_e\right)$$

Δv = Velocity increment
v_e = Propellant exhaust speed



Transportation: Long trips

- One-way trip times measured in months
- Need to be a bit careful about time-value of assets

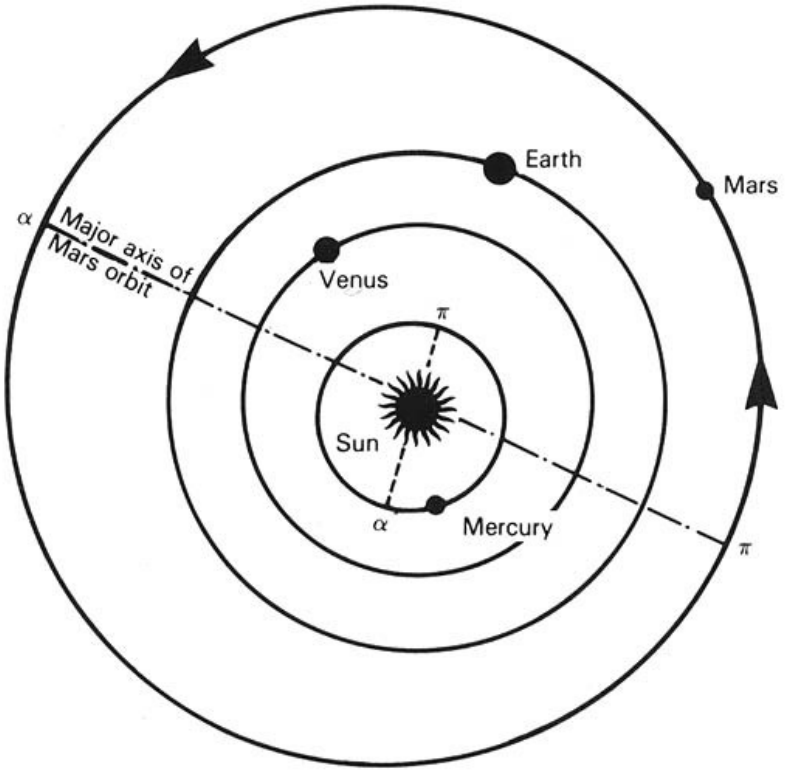
- More broadly, like any investment, time value must be understood

$$\text{Net present value} = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t}$$

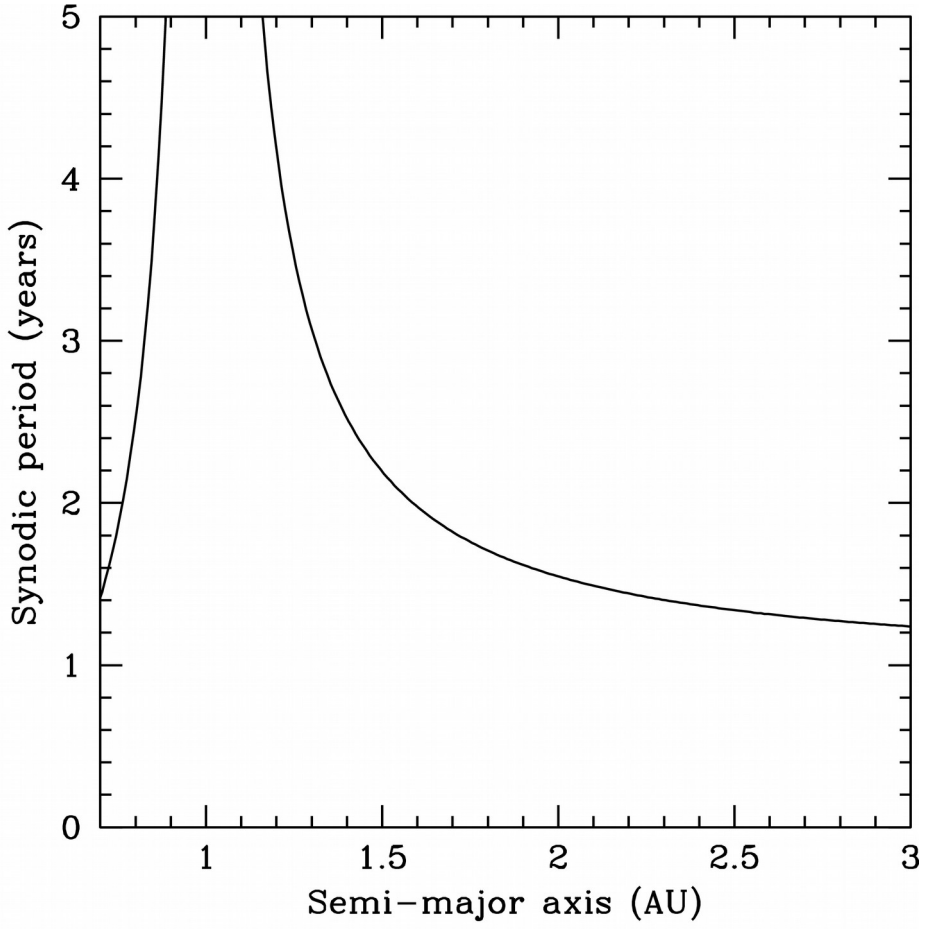
$C_t = \text{Cash flow for a time period}$

$r = \text{Discount rate}$

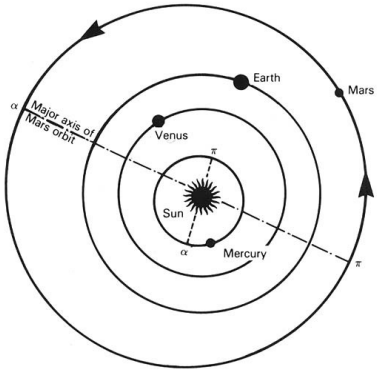
Transportation: Synodic periods



NASA SP-4212

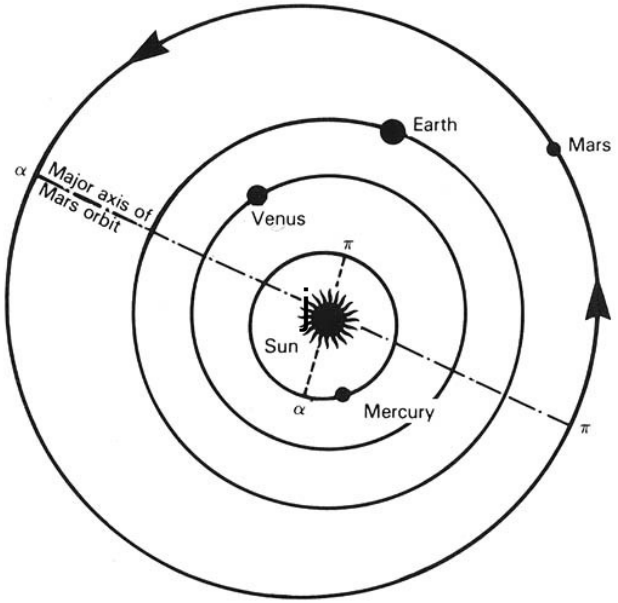


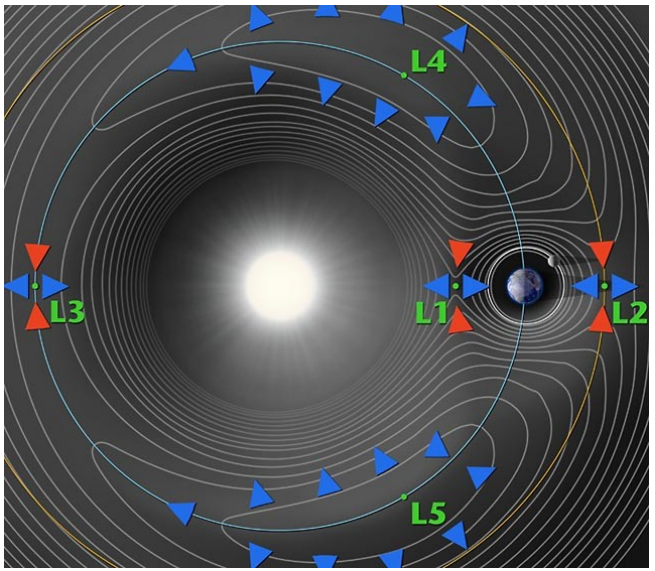
Early resource options



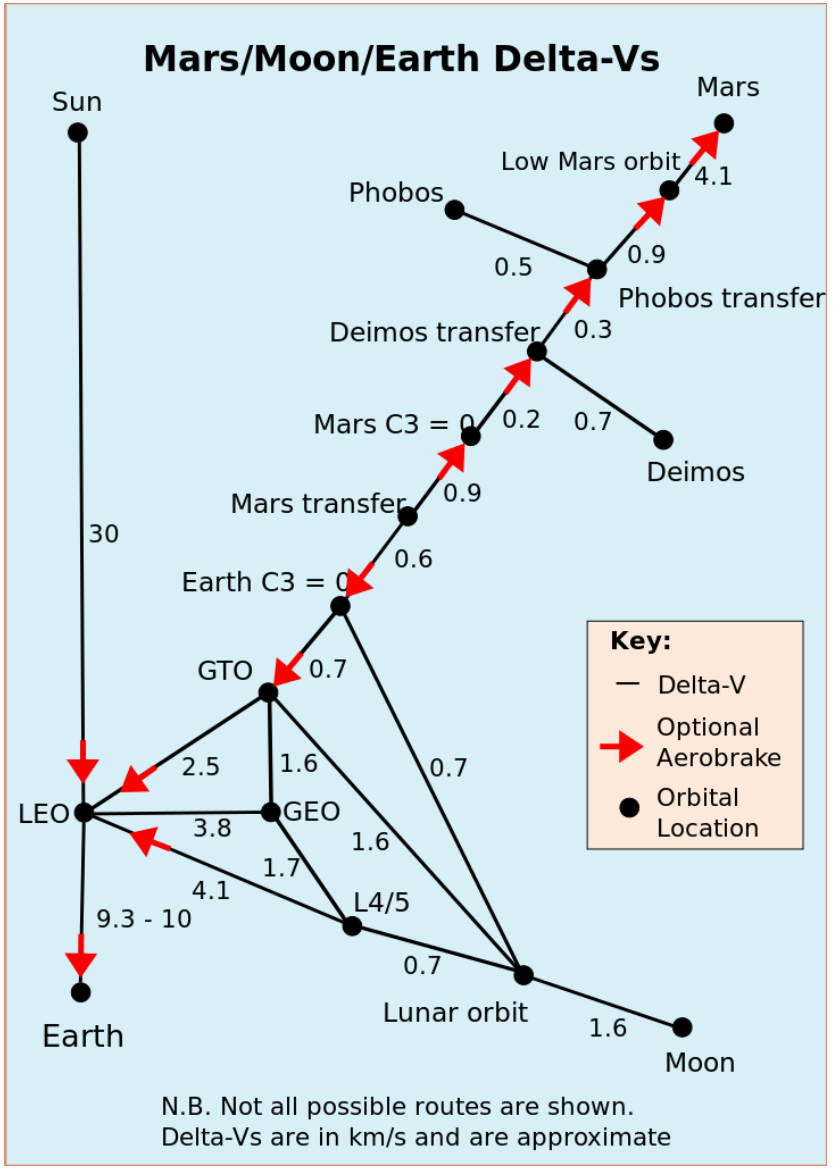
- **Regolith** (radiation shielding) & **water** (propellant & rad. shielding)
  - No customers / infrastructure yet
  - Easy-ish extraction
- **Precious metals** (platinum group)
  - Existing customers
  - Difficult extraction / refining

In-space uses: Propellant





NASA / WMAP Science Team



Wikipedia (Seriously. Best I've seen.)

Characteristic numbers for human spaceflight

Quantity	Scale
LEO launch cost (bulk, unpress.)	~ $ 5 M / tonne
Crew consumable mass	~ 3 t / person / year
International Space Station mass	500 t
Amortized ISS mass	~ 4 t / person / year

Mass payback

- Out & back trips to obtain bulk commodities are only worth doing if they bring back more mass than they use.

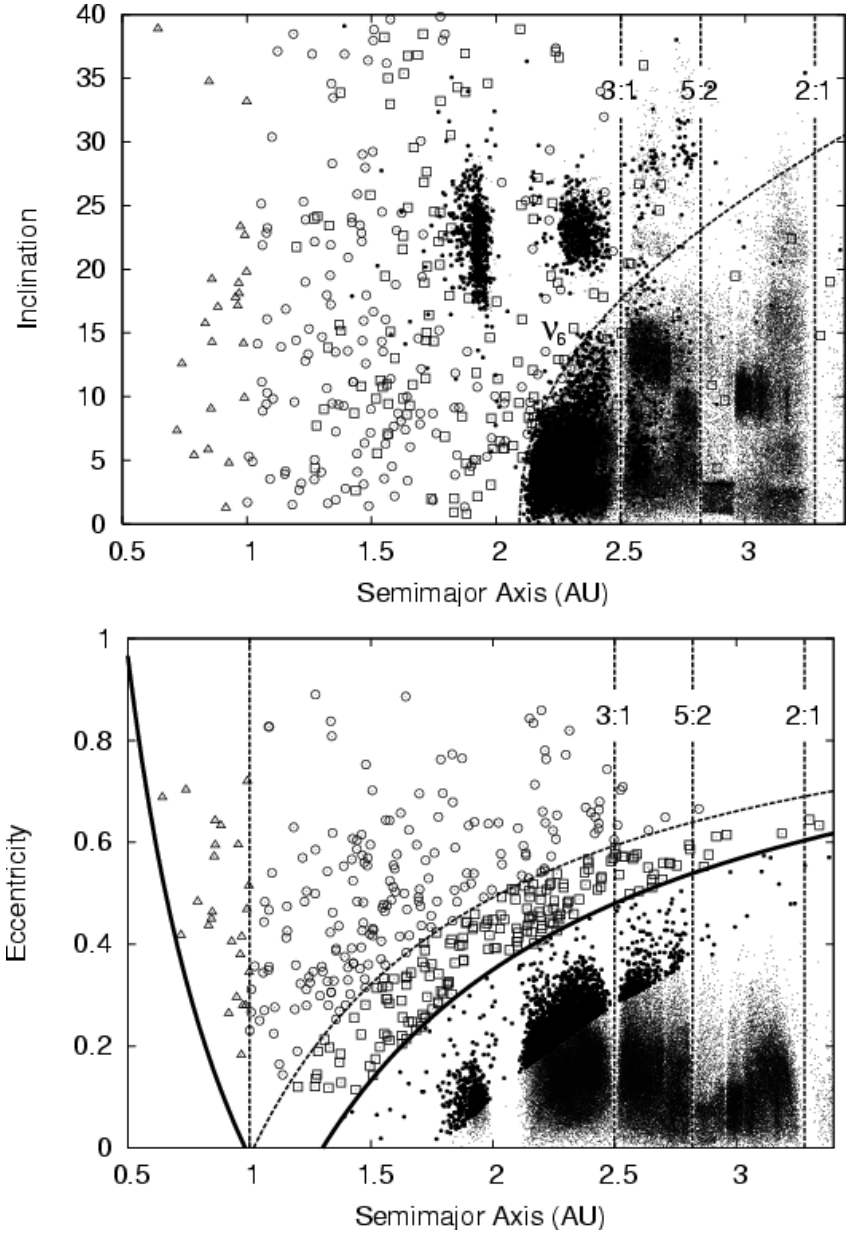
$m_{\text{returned}} = \text{Mass of useful, refined product returned to departure point}$

$m_{\text{consumables}\,i} = \text{Propellant from depot, spare parts, reagents, etc.}$

$$m_{\text{cost}} = \sum_i m_{\text{consumables}\,i}$$

- Need $m_{\text{returned}} / m_{\text{cost}} > 1$
- Want $m_{\text{returned}} / m_{\text{cost}} \gg 1$

Accessibility of asteroids



Elia et al. 2007

Precious metals

Element	Specific price ($ M / tonne)	Worldwide mined production (tonnes / year)
Platinum	50	200
Palladium	30	200
Rhodium	46	25
Iridium	20	3
Osmium	14	0.06
Ruthenium	2	10–20
Nickel	0.02	2,000,000

The competition

	Asteroids	Moon	Earth
Near-term transport options	**Small chemical Δ*v*. Low-thrust possible for entire trips**	High thrust (chemical) necessary to / from surface	**Reusable launch soon**
Access constraints	Long synodic periods	**Windows any time. Driving constraints?**	**None**
One-way trip times	Months to year	Few-day chemical for destinations near Earth	Few days near Earth, several months to Mars
Power	**Constant solar nearby**	Long nights / seasonal dark periods	**Abundant and cheap**
Existing industrial capacity	Nothing. Nada.	Not even crickets.	**Vast, low-cost, highly-advanced**

Misconceptions

(Mass of resource in asteroid) x (Market price)

= Value of asteroid

- Potential *revenue*, not profit—need to factor in risks and subtract costs
  - Extraction, mining, transportation, capital, etc.
- Plus, need to discount future revenue
- Ask yourself how much you'd be willing to bid to buy the asteroid.

Misconceptions

You'll flood the platinum market.

- Maybe eventually.
- But, will probably take a long time.
  - 200 t / year is a lot of platinum.
  - Just a far-future term in estimates of net present value?

Misconceptions

The value of asteroid water at (LEO/GEO/EM-L1) is the launch cost avoided.

- Cost of shipment from Earth is the absolute highest someone should pay.
  - High-grade, excellently characterized commodities
- Value will be set by supply, demand, incentives, etc. at the particular location.
- If the market value would be the same as the cost if shipped from Earth, why bother with space resources?

Misconceptions

I don't know how to make a profit => No one can make a profit

- People tend to hold good ideas close
  - Will gladly tell you bad ones, though.

Final thoughts