Clarkson UNIVERSITY

Deployment of an Interstellar Electromagnetic Acceleration System

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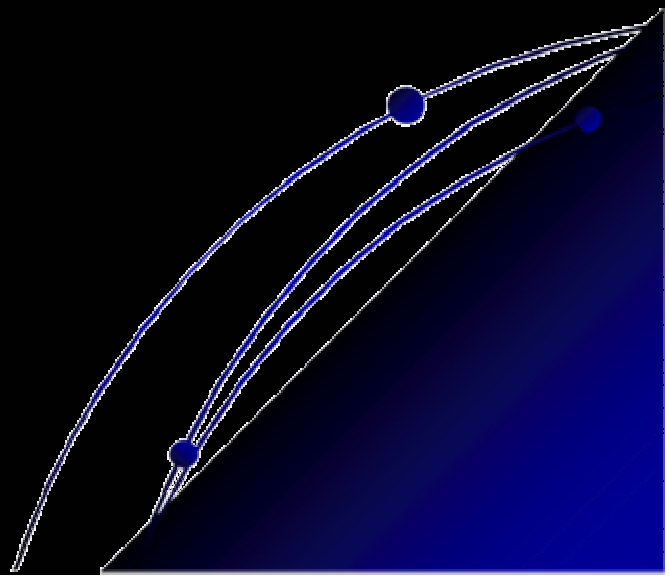
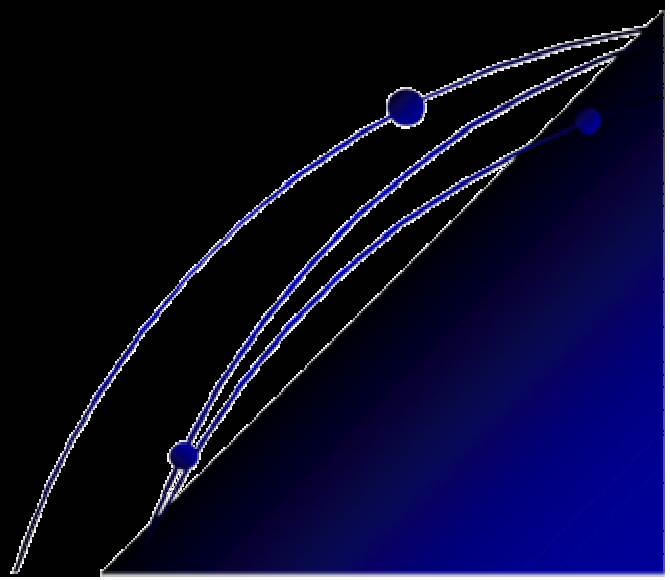
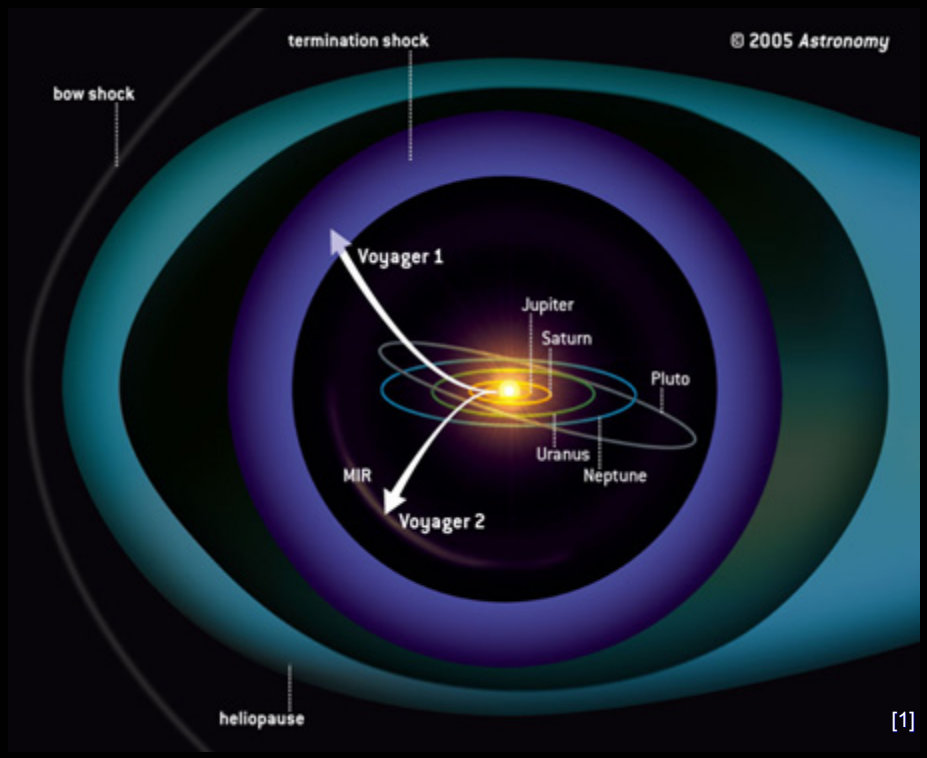


Outline

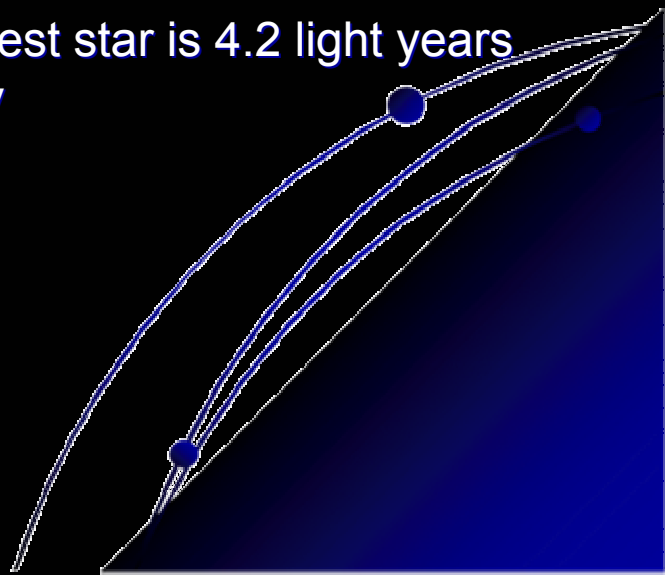
- Introduction to Interstellar Exploration
- Critical Questions
- Interstellar Electromagnetic Acceleration
- Further Research
- Conclusions



Beyond Sol



- The Sun moves through interstellar space at a speed of 25km/s
- Important features at the edge of the solar system
  - Termination Shock
  - Heliopause
  - Bow Shock
- Nearest star is 4.2 light years away



Interstellar Mysteries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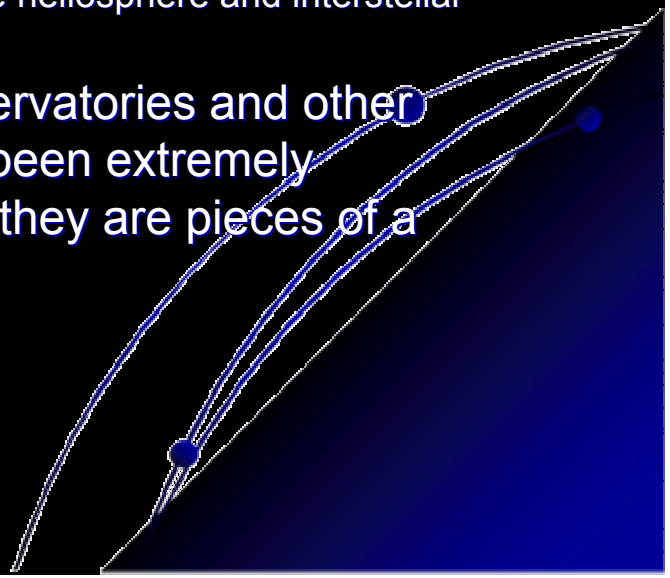
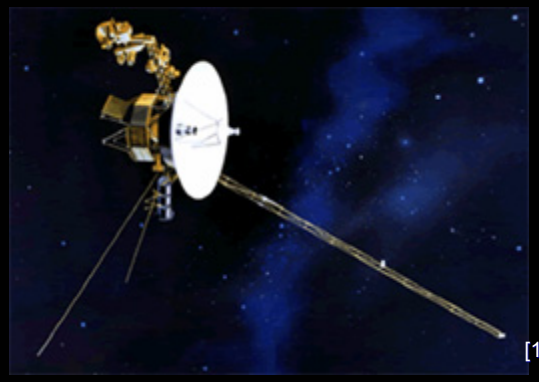
- Specific objectives have been identified for possible interstellar missions
  - Determine the nature of the interstellar medium and its implications for the origin and evolution of matter in the galaxy
  - Explore the structure of the heliosphere and its interaction with the interstellar medium
  - Study fundamental physical processes occurring in the heliosphere and interstellar medium
- The Great Observatories and other missions have been extremely successful, but they are pieces of a larger puzzle



Missions Past, Present, and Future

- Voyager 1 & Voyager 2
- Stardust
- Interstellar Boundaries Explorer (IBEX)
- No dedicated interstellar mission has ever been launched!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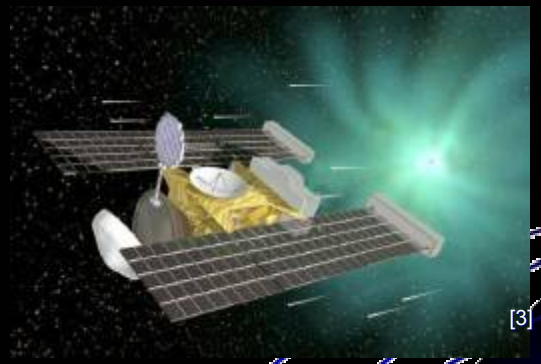
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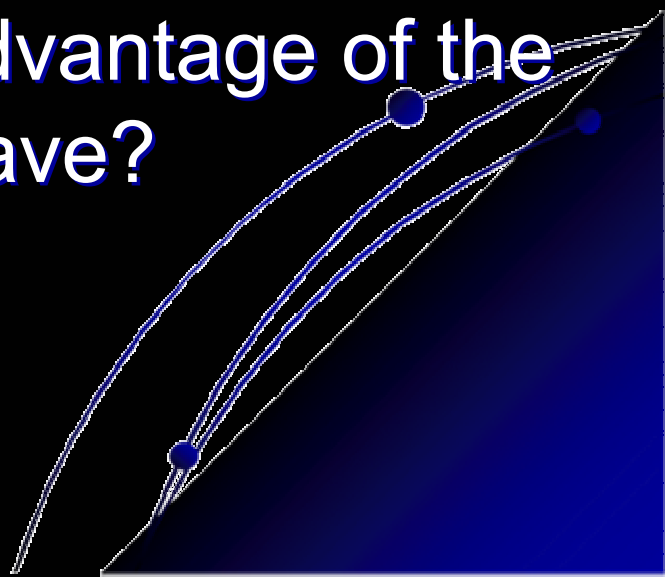
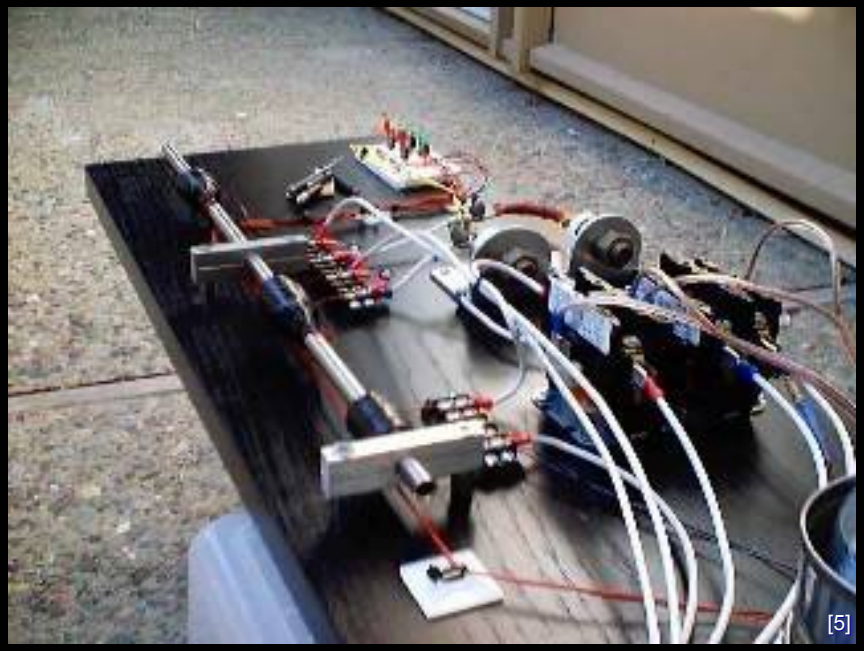
Critical Questions

- How can the propellant mass and propulsion system be moved off the spacecraft?
- How can a mission take advantage of the solar system it seeks to leave?



Electromagnetic Acceleration

- Uses interaction between magnetic field generated by an external station and much smaller magnetic field on spacecraft to exert an impulse on the spacecraft
- Similar to a coil gun or mass driver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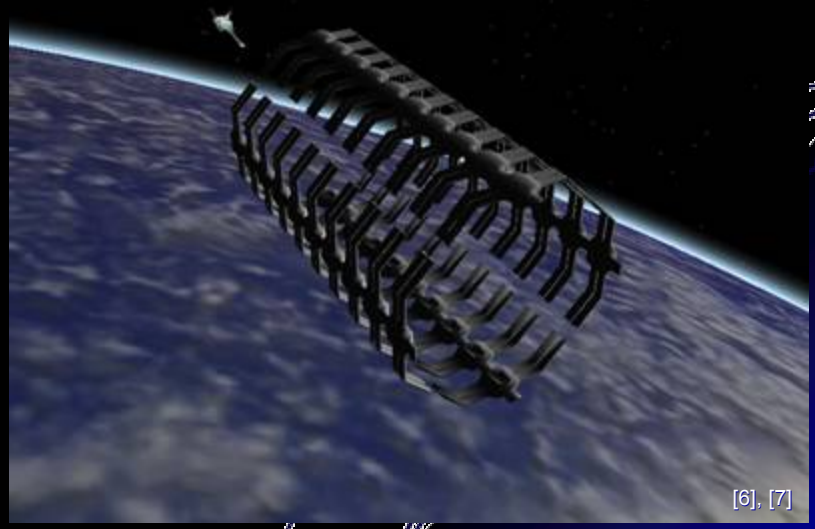
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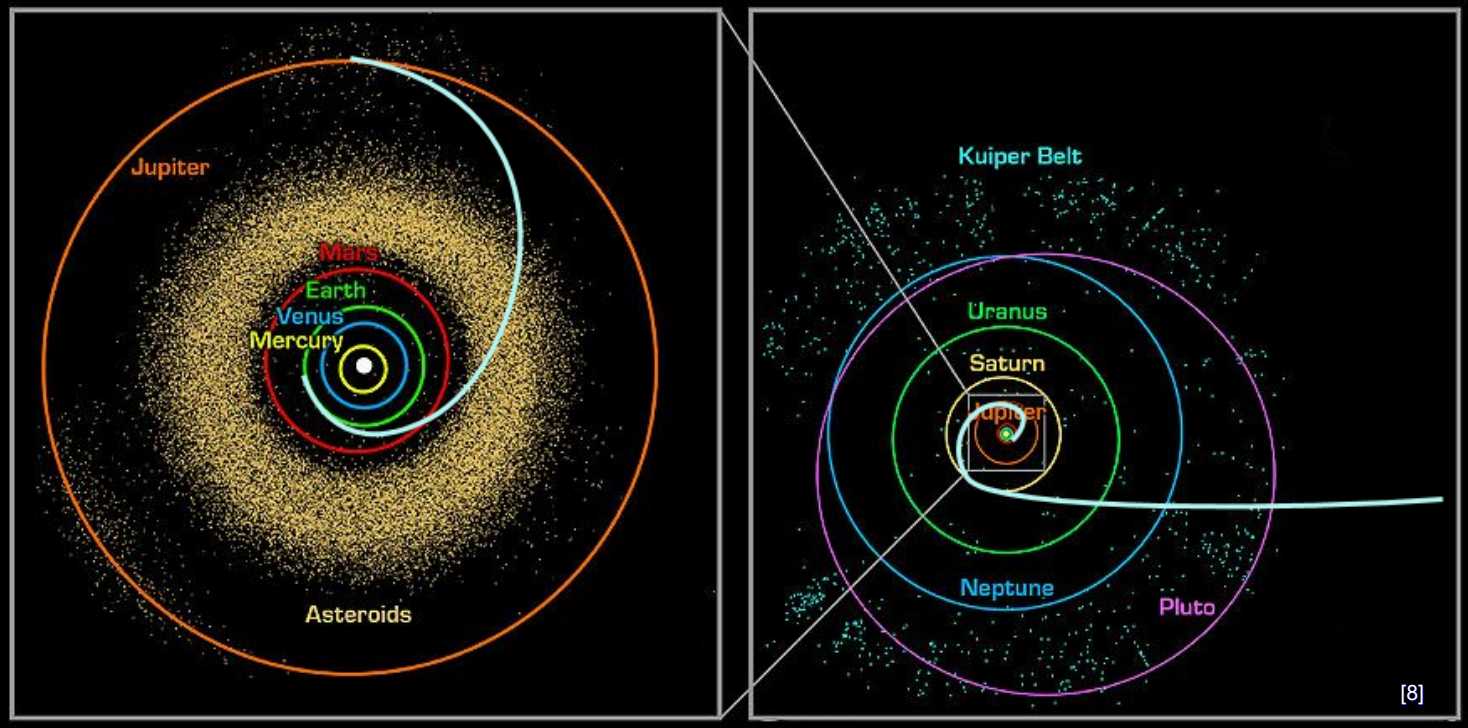
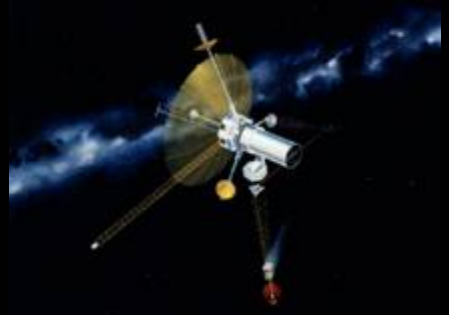
Solar System Sized Launch Strategy



- Multiple electromagnetic acceleration stations throughout the solar system
  - In orbit around planets, at Lagrange points, etc
- Spacecraft pass through multiple stations on the way out of the solar system
  - Gain energy from the gravity of each planetary body

Architectural Benefits

- Moves main propulsion system off the interstellar vehicle
  - Reduces spacecraft mass
  - Simplifies spacecraft configuration
  - Enables use of multiple microprobes
- Enables a range of trajectories with a single system
  - Spacecraft could pass through all stations or a subset of the system
- Reusable for multiple interstellar missions
  - Increased science return



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Hardware Requirements


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- Large scale source of electrical energy
- Electromagnetic acceleration system
- Propulsion system for stations
- Precision navigation for interstellar probes
- Heavy lift vehicle to launch stations
- Building on existing programs is cost efficient

Auxiliary System Uses

- Possible auxiliary uses for the stations:
  - Communications link with other spacecraft
  - Long term scientific observations
  - Movement of spacecraft and cargo within the solar system
- Supports and compliments the primary mission of launching interstellar probes
- Creates a long term infrastructure in space
  - Critical to future manned and unmanned exploration

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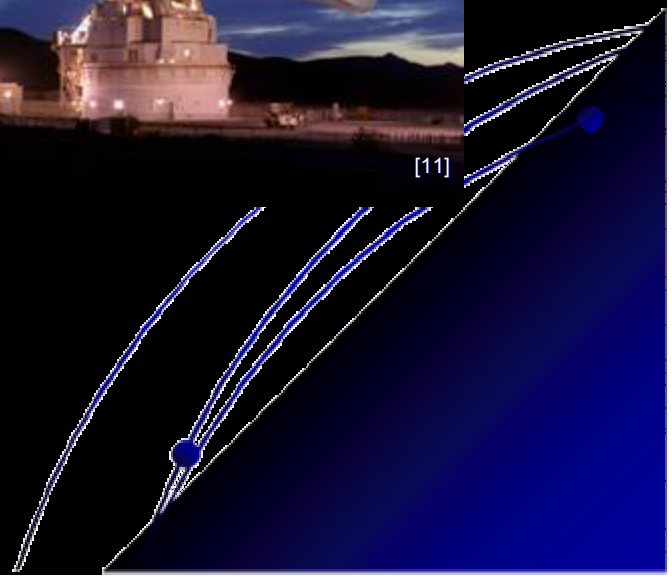
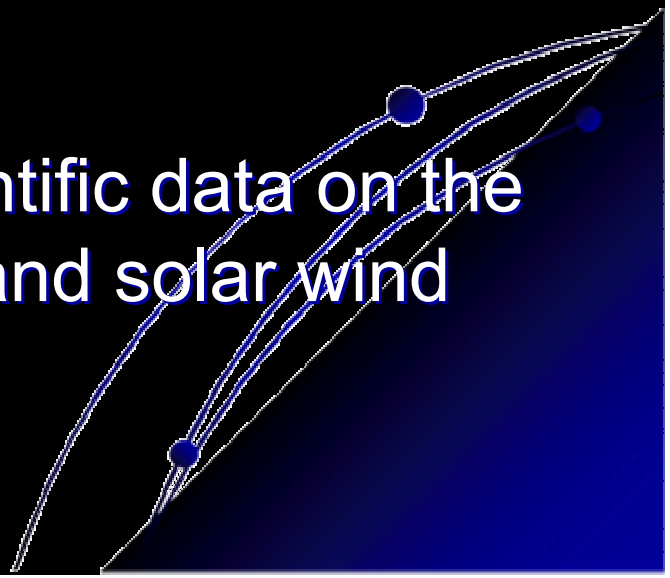


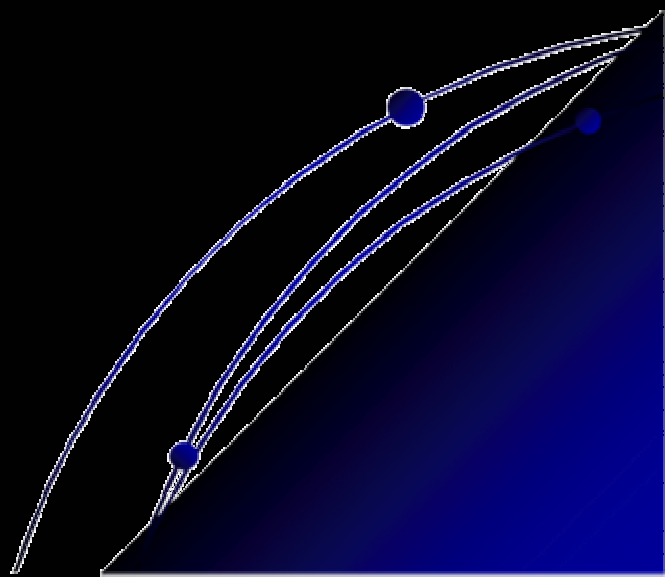
Initial Concept Conclusions

- Concept offers advantages over traditional systems
- Some of the required hardware is already under development
- Enables collection of direct scientific data on the interaction between interstellar and solar wind

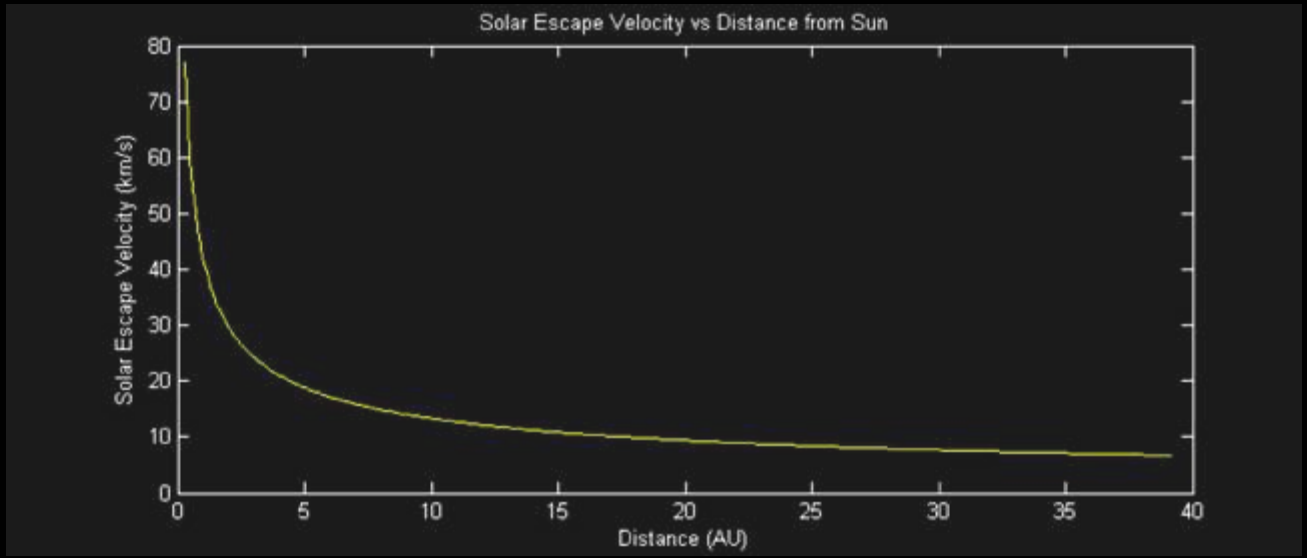


Where Do We Go From Here?

- Leaving The Solar System
- Advantages of Multiple Accelerators
- Trajectory Optimization
- Precision Navigation
- Spacecraft Loading
- Station Configuration
- Cost

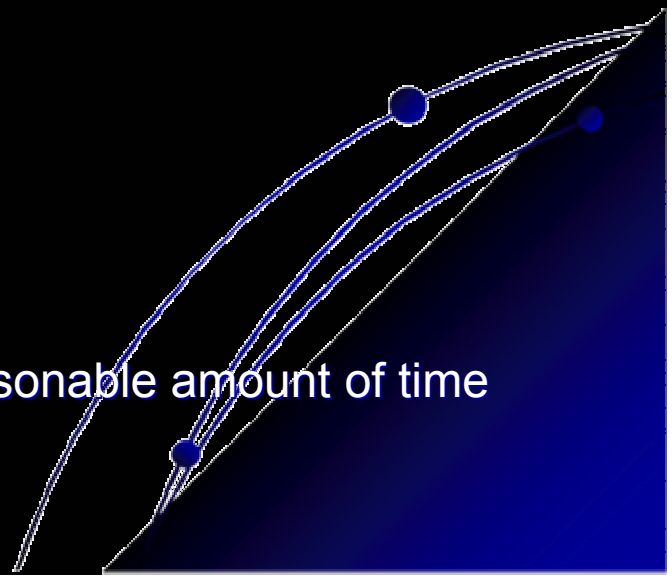


Escaping The Solar System



- Earth orbits the sun at 29.78 km/s
- Solar escape velocity of 42.12km/s
- Minimum ΔV of 12.25km/s

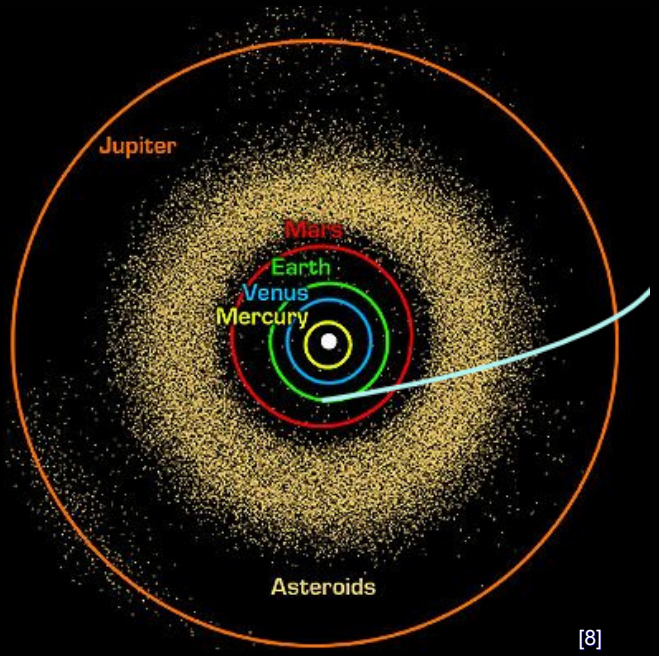
- Larger energy requirement to reach 200AU in a reasonable amount of time



Advantage of Multiple Accelerators

Single accelerator in Earth orbit

- Larger station size
- Larger power requirement
- Increased spacecraft loading
- LEO space debris hazard
- Not useful for cargo operations



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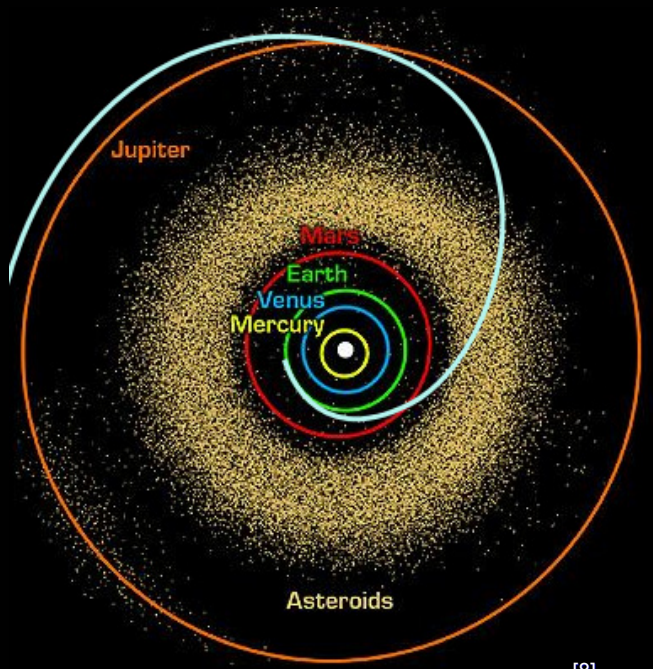

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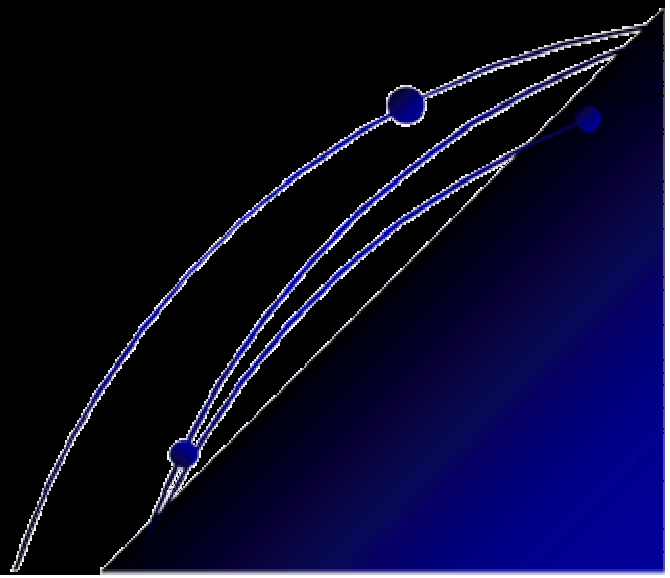
Multiple accelerators throughout solar system

- Use gravity assists
- Lower station power requirement
- Decreased spacecraft loading
- Useable for cargo operations

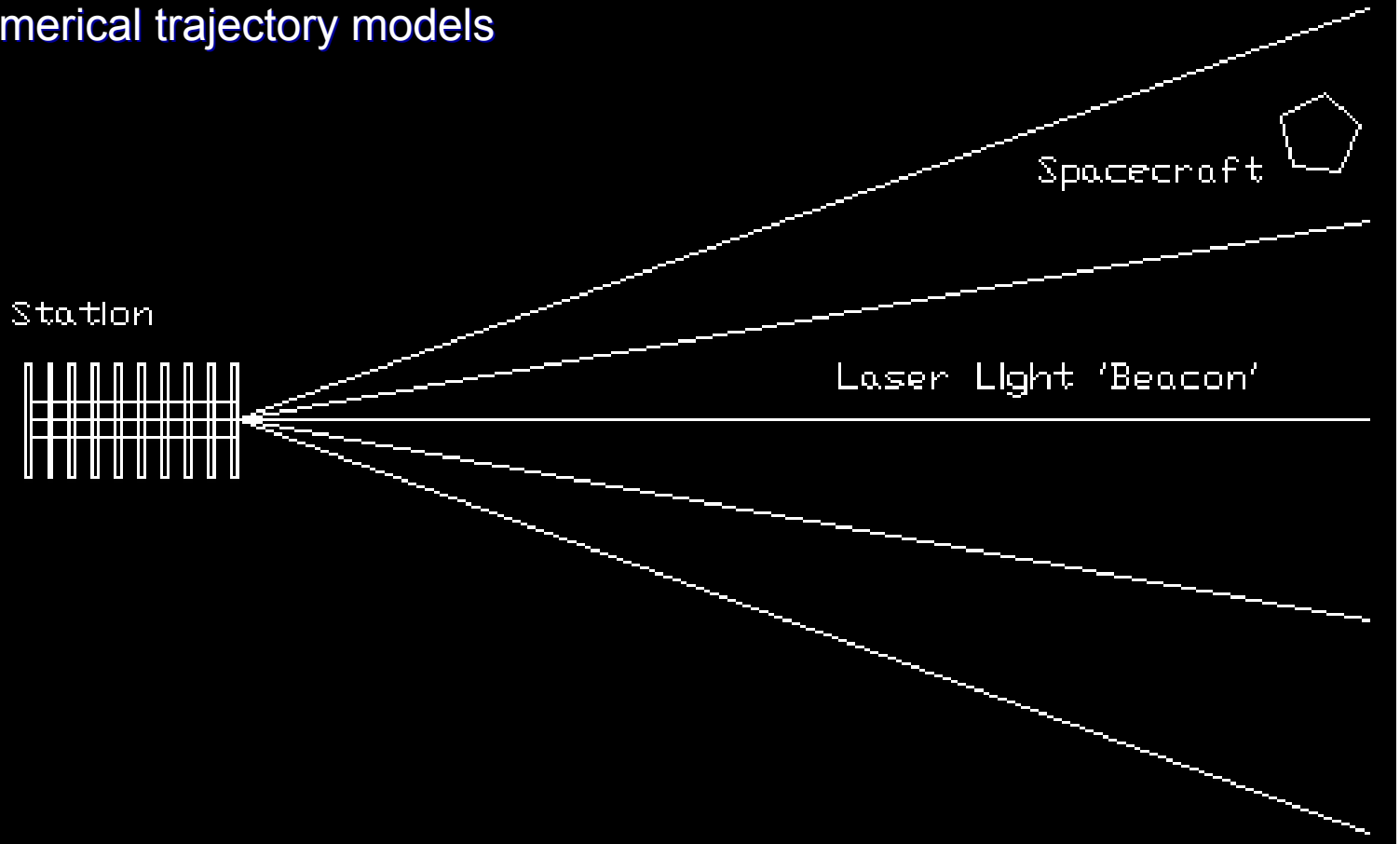
Trajectory Optimization

- Orbital period of outer planets is an issue
- Stations can be designed to vary their output
- Multiple-flyby trajectories have been used in the past
- Design for the maximum number of launch windows

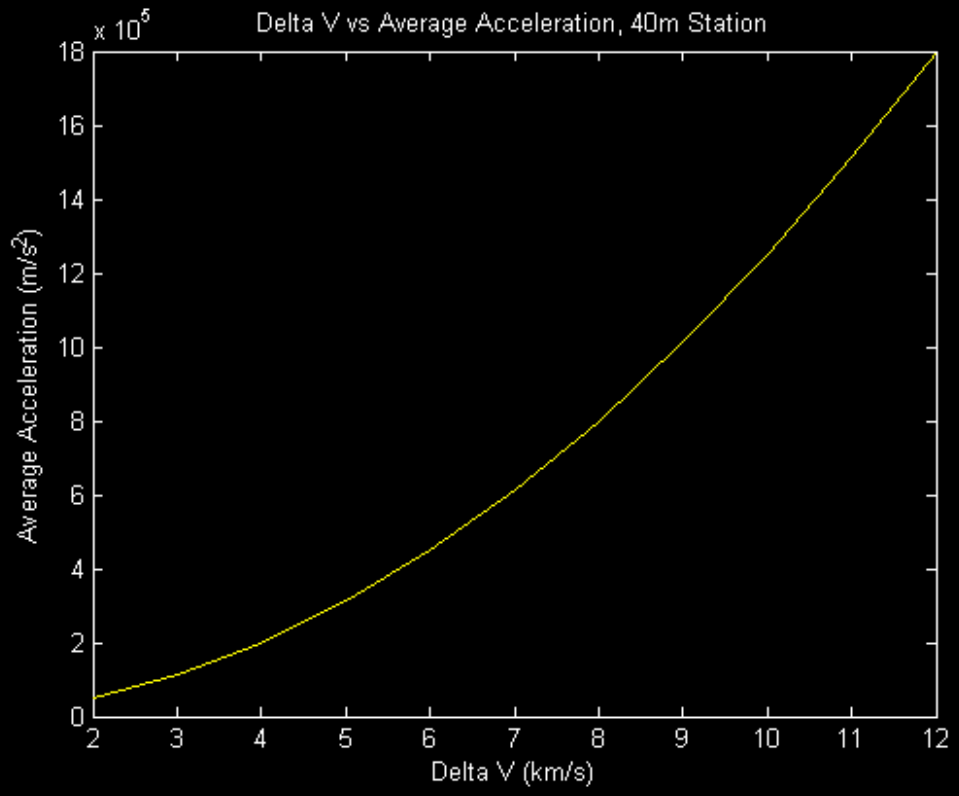


Precision Navigation

- Laser ‘Beacon’
- Doppler shift/triangulation from stations
- Refined numerical trajectory models

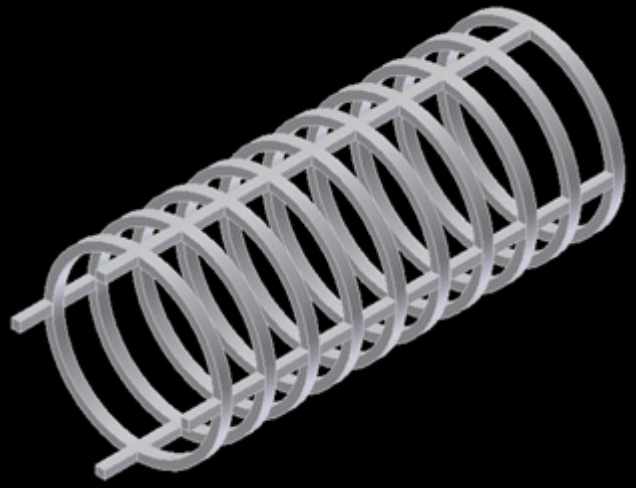


Spacecraft Loading



- 40m station length assumed
- Even small ΔV amounts require a large average acceleration
- Instantaneous accelerations will be even greater
- Spacecraft design for extremely high acceleration will be required

Station Configuration



Superconducting Coils

MagBeam

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What About the Cost?

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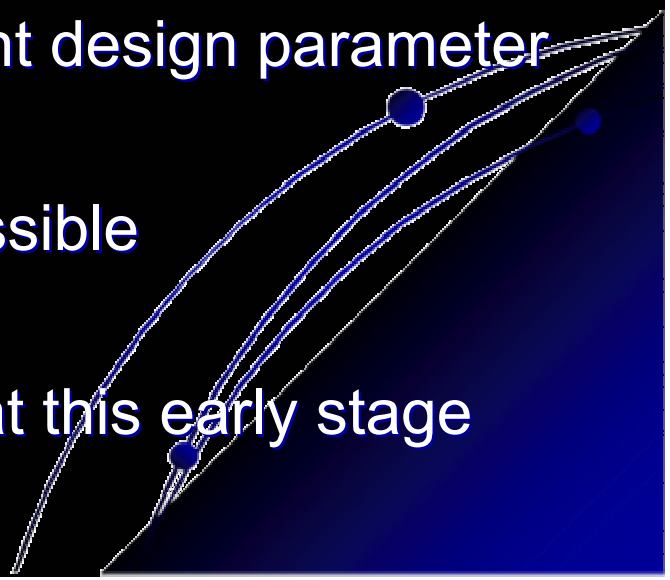
- ISS - $53-$92 billion (depending on who you ask)
- Hardware development in parallel with other projects
- Fulfill multiple science objectives
- Station architecture is an investment
- Interstellar probes are a fraction of the total cost

Conclusions

- Multiple stations represent a robust system for interstellar exploration
- Trajectory planning and optimization is a critical next step
- Spacecraft loading will be an important design parameter
- Multiple station configurations are possible
- Cost should not be a deciding factor at this early stage



Acknowledgements

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My family for teaching me to keep dreaming.

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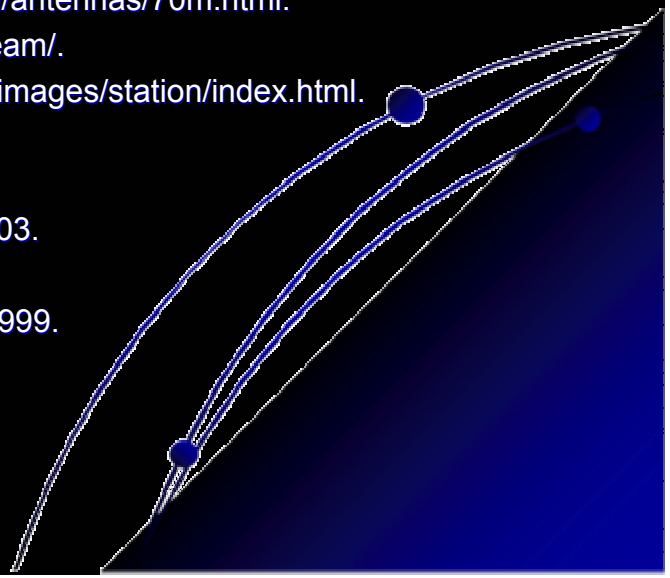

Questions?