



Advanced Propulsion Systems -Beyond Rocket Science - An Overview

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Orange County Computer Society

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Alternatives Beyond Chemical Rockets

- It's a grand time to be an Engineer
- Challenges
 1. Exit from this Gravity Well
 2. Travel Time
Interplanetary and Interstellar
- Examine traditional technologies
Throw, Sail, Rocket
- Explore Novel Strategies
Nuclear, Mega-structures, Ion & Plasma, Exotic Physics

Propulsion Power Sources

- Chemical Rocket (160M hp)
- Nuclear Fission, Fusion, Thermal, Fragment
- Beamed Laser, Maser, Particle, Magnetic
- Space Sails Kites: Solar, Light, Beams
- Exotic Physics Anti-matter, Fusion, ...

Alternatives Beyond Chemical Rockets

- **Rockets & Jets**

Chemical, Nuclear, Ramjet

- **Launch Structures**

Catapults, Elevators, Fountains, Loops, Tethers ,Piers

- **Sails**

Laser, Maser, Particle, Light

- **Hybrids**

Catapult, Scramjet, Nuclear

- **Exotic Physics & Reactionless Drives**

Field Drives, Warps & Wormholes, GR/EMF Couplings, (A-word)

Alternatives Beyond Chemical Rockets

Rockets & Jets

- Chemical (Apollo – 160M hp for a few minutes)
- Nuclear (200 Men to Mars & Back in 4 weeks)
- Ion & Plasma (Continuous Thrust for Months & Years)
- Interstellar Ramjet

Rockets & Jets - Chemical

- We know the technology, its efficient, we have the infrastructure, and it works (most of the time).

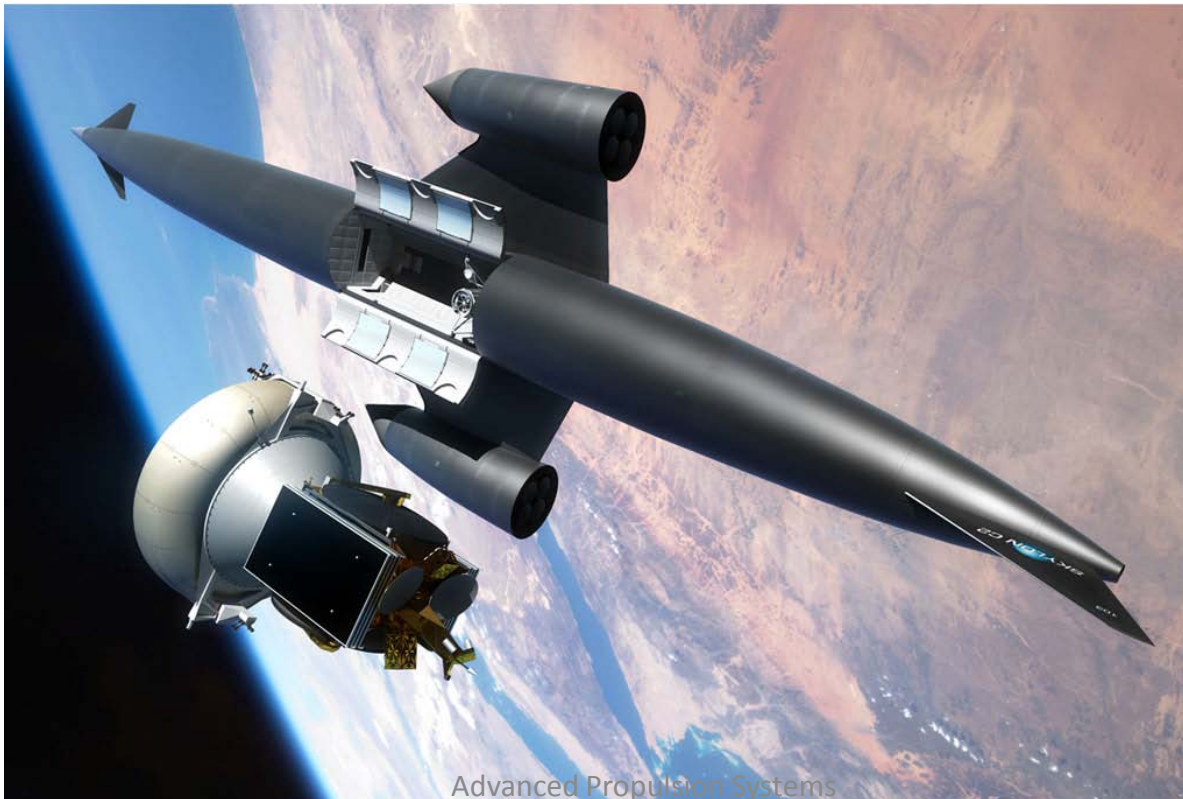


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Advanced Propulsion Systems

Rockets & Jets - Chemical

Skylon – Privately funded, single-stage-to-orbit (SSTO) vehicle designed to take off and land from a runway, delivering up to 16.5 tons to orbit.





Rockets & Jets – Chemical

10 Commercial Spacecraft

- Dragon SpaceX cargo & crew capsule for SSI atop Falcon 9 ('12)
- CST-100 Boeing Apollo-like space capsule for ISS ('16)
- Dream Chaser Sierra Nevada's space plane ('16)
- Space Vehicle Jeff Bezos' secretive Blue Origin 7-pax Crew Capsule ('18)
- Liberty Launch ATK's booster ('15)
- Stratolaunch Air-launch venture by Paul Allen & Burt Rutan ('16)
- Space Habitat Bigelow Aerospace space stations w/ Boeing and SpaceX
- Suborbital Craft Armadillo Aerospace (John Carmack) @\$110,000 /seat.
- SpaceShip Two Virgin Atlantic's suborbital tourist plane ('14)
- Lynx XCOR Aerospace suborbital craft @ \$95,000/seat

Alternatives Beyond Chemical Rockets

Rockets & Jets

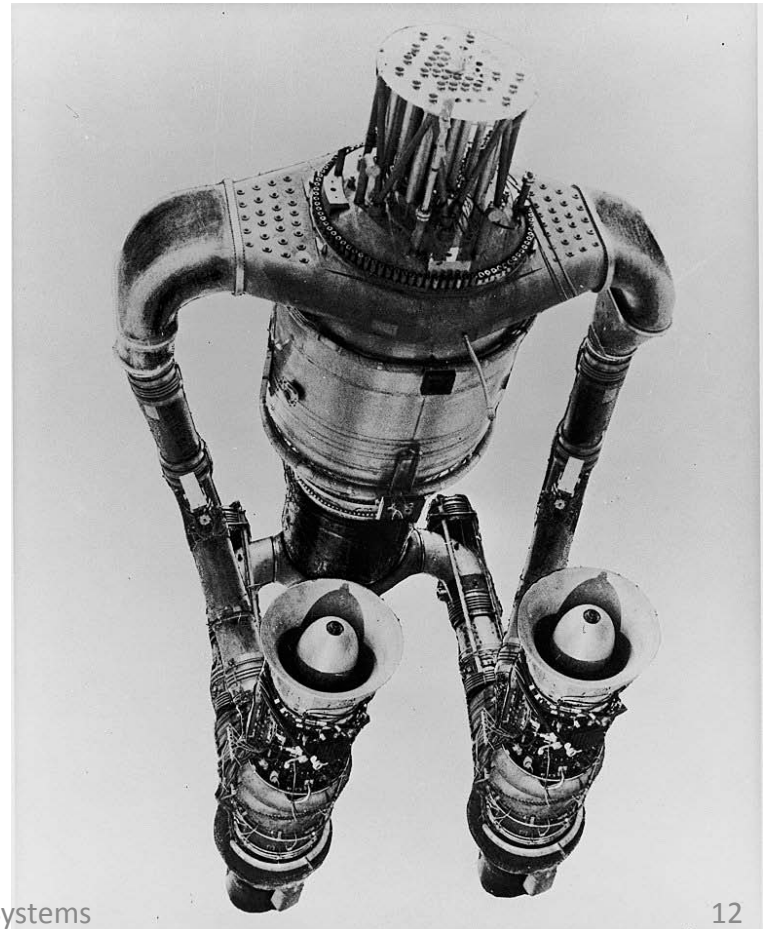
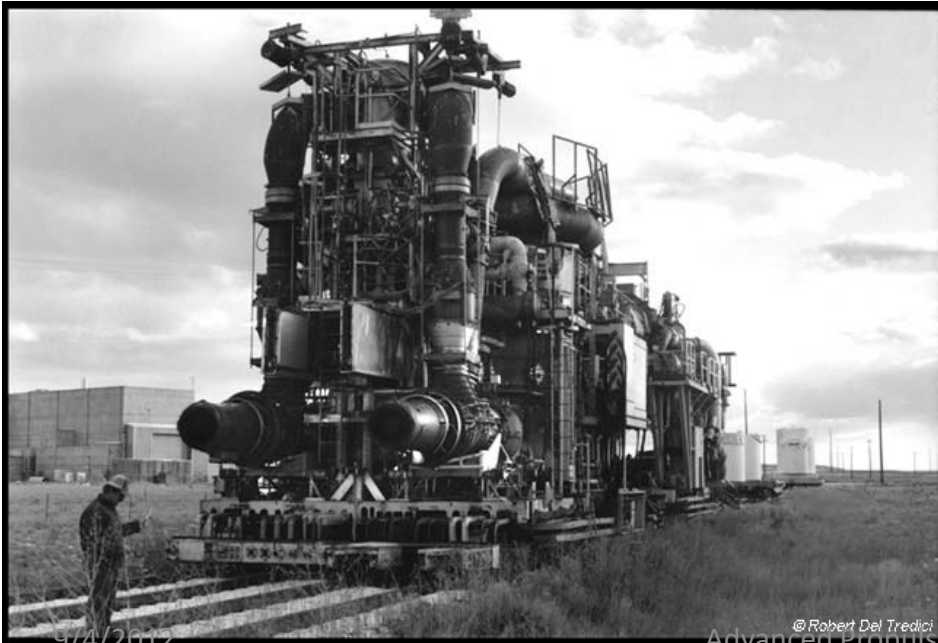
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Rockets & Jets - Nuclear

- USAF Nuclear Jet Engines
 - NEPA: Nuclear Energy for the Propulsion of Aircraft (USAF)
 - Convair X-6 (USAF-1950's) Nuclear Jet Engine tested in bomb bay
 - Project Pluto (USAF,AEC-'57..64) Nuclear ramjet powered cruise missile
- Nuclear Rocket Engines:
 - Nuclear Pulse Propulsion (NPP)
 - Nuclear Thermal – Fission
 - Nuclear Thermal – Fusion (ICF & MCF)
 - Multi-modal Nuclear Thermal (Electric Power & Thrust)

Nuclear Jets: NEPA

- NEPA Proof-of-Concept
 - Fission Propulsion in an USAF Aircraft in the 1950's. The Convair X-6, a B-36 Peacemaker with a Nuclear Jet Engine



Nuclear Jets: NEPA & Pluto

Convair X-6
(B-36 Peacemaker)



Project Pluto Nuclear Ramjet
Cruise Missile Proof-of-Concept

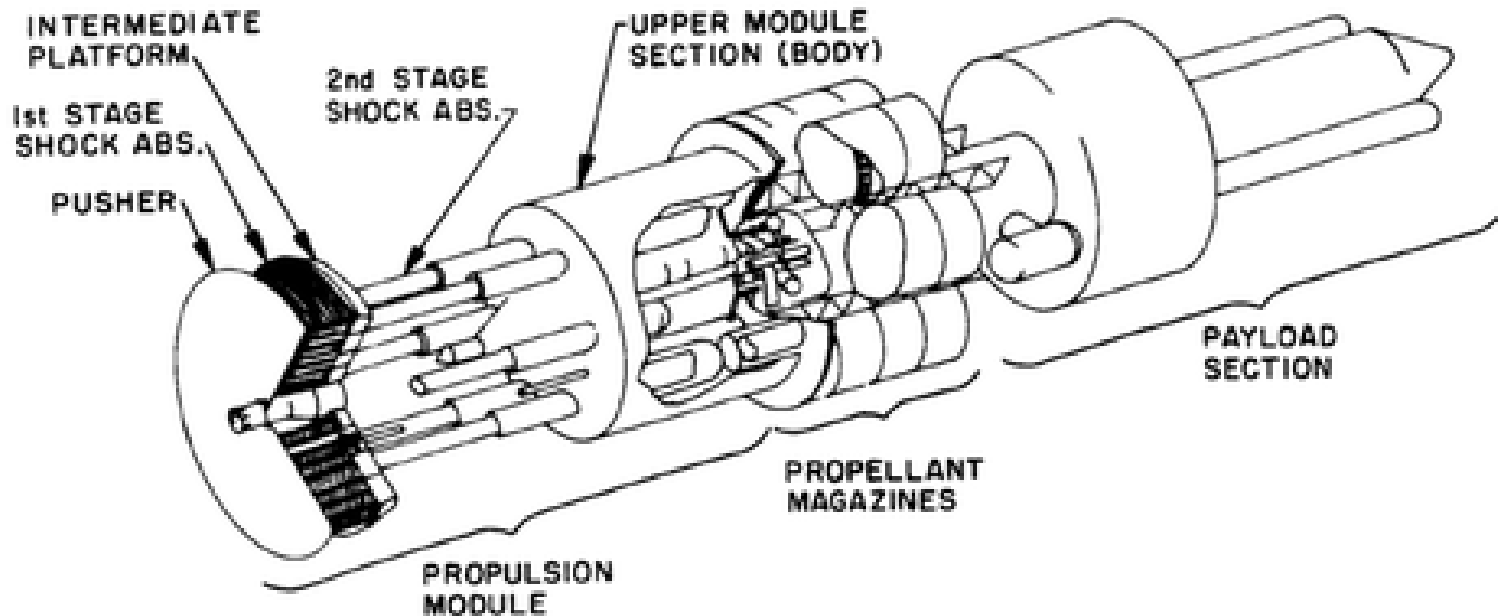


Nuclear Rockets

- Nuclear Pulse Propulsion (NPP)
 - **Project Orion** (-'47,ARPA, AEC, G.A.-'58) F. Reines; F. Dyson
 - Project Longshot (NASA-'87..88, US Nav Acad) Unmanned probe, ICF ?
- Nuclear Thermal – Fission
 - Project Rover (NASA,AEC-'55..70) {Kiwi, Phoebus-63..68 (-> Nerva), Pewee}
 - Nerva (NASA, US Nav Acad-..'72)
 - Project Prometheus (NASA-'03..'05) {power for Jupiter type missions}
- Nuclear Thermal - Fusion
 - Project Daedalus (Brit Interplanetary Soc-'73..78) {ICF, Self-replicating}
 - Project Icarus (Brit I'plan. Soc.-'09..2014) {design exercise for morale}
- Multimodal Nuclear Thermal Power & Thrust

Nuclear Rockets: Orion

- Project Orion - Nuclear Fission Pulse Drive
- Project Orion – Nuclear Fusion Pulse Drive



Nuclear Rockets: Orion

- **Project Orion - Nuclear Fission Pulse Drive**
Nobel Laureate F. Reines: Fission (1947) Orbital Craft.
800 0.15 Kt shaped nuclear fission bomblets focused on the
pusher plate would raise a 4,000 ton ship to orbit.

Nuclear Rockets: Orion



4,000 ton Cruise Ship Celia II

Nuclear Rockets: Orion

- Project Orion – Nuclear Fusion Pulsed Drive

Freeman Dyson: Fusion 1958 Interstellar Transport;
1Mt deuterium fusion;
8,000,000 ton (8Mt) vessel;
20 km diameter pusher plate w/ 1mm copper plating;

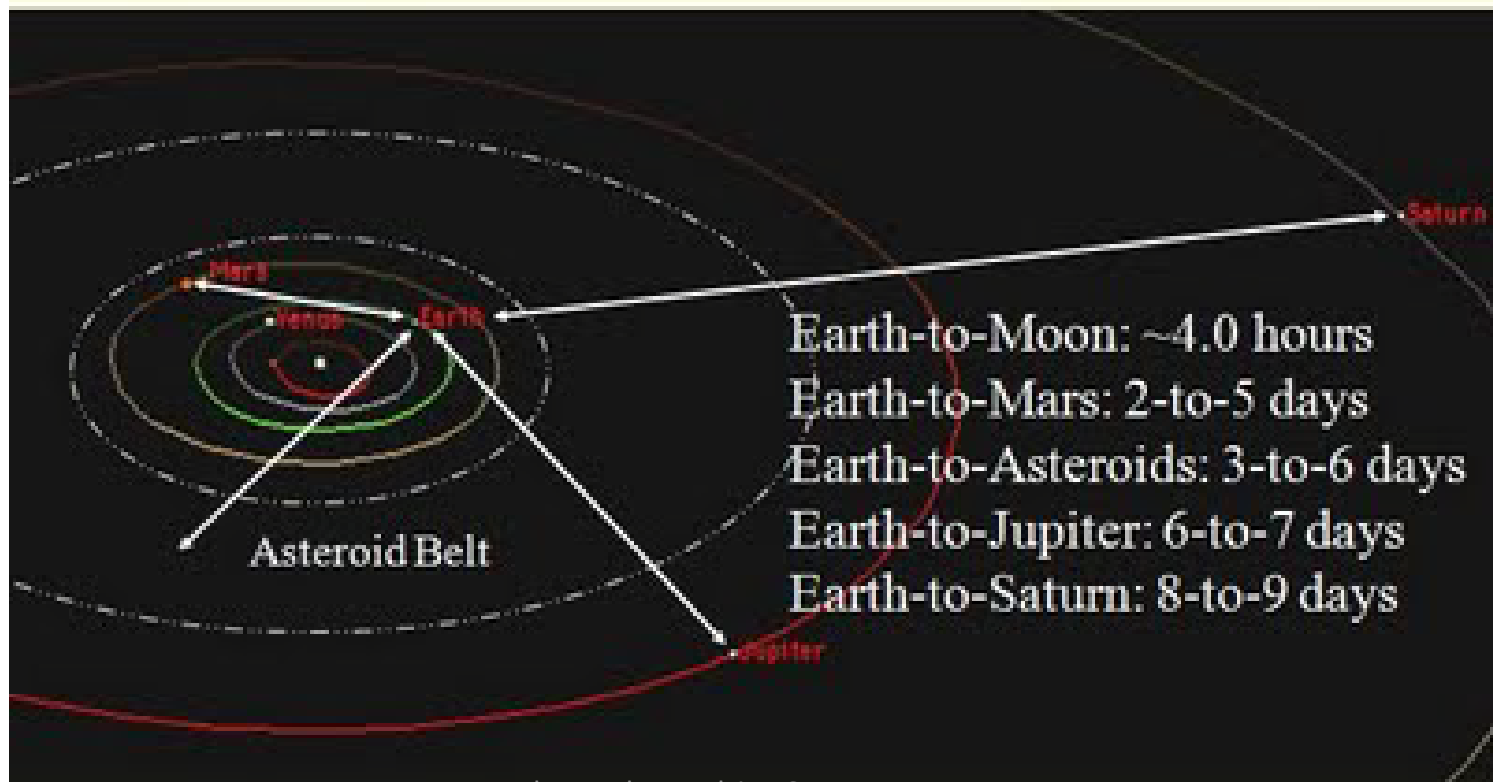
Nuclear Rockets: Orion



Star Wars Imperial Star Destroyer

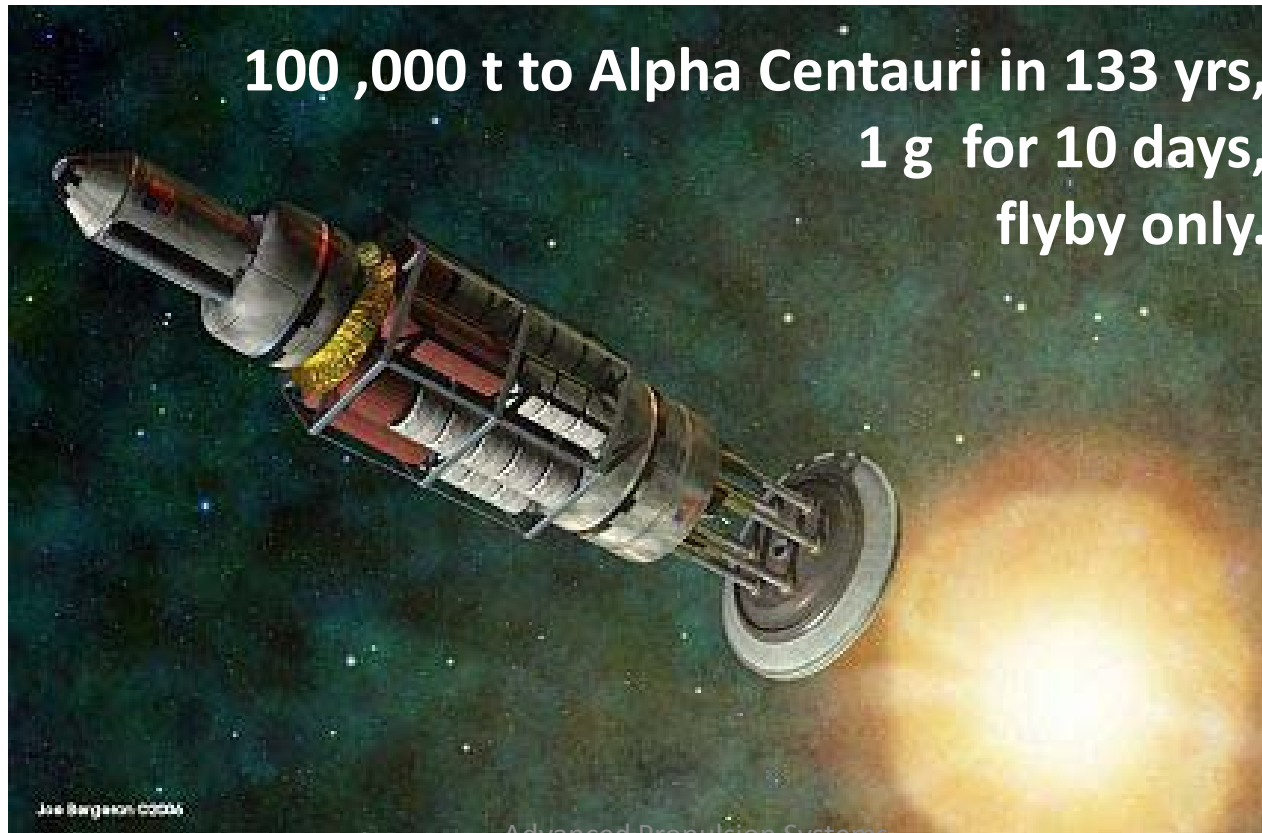
Trip Times at one Earth gravity Acceleration

One-Way Trips Times at 1.0-g ($9.81\text{m}/\text{sec}^2$)
Acceleration from Earth to “Inner” Solar System



Nuclear Rockets: Orion

- **General Atomics Interstellar Arks:**
Small 20m diameter 300 ton ship to 400m dia. 8Mt.

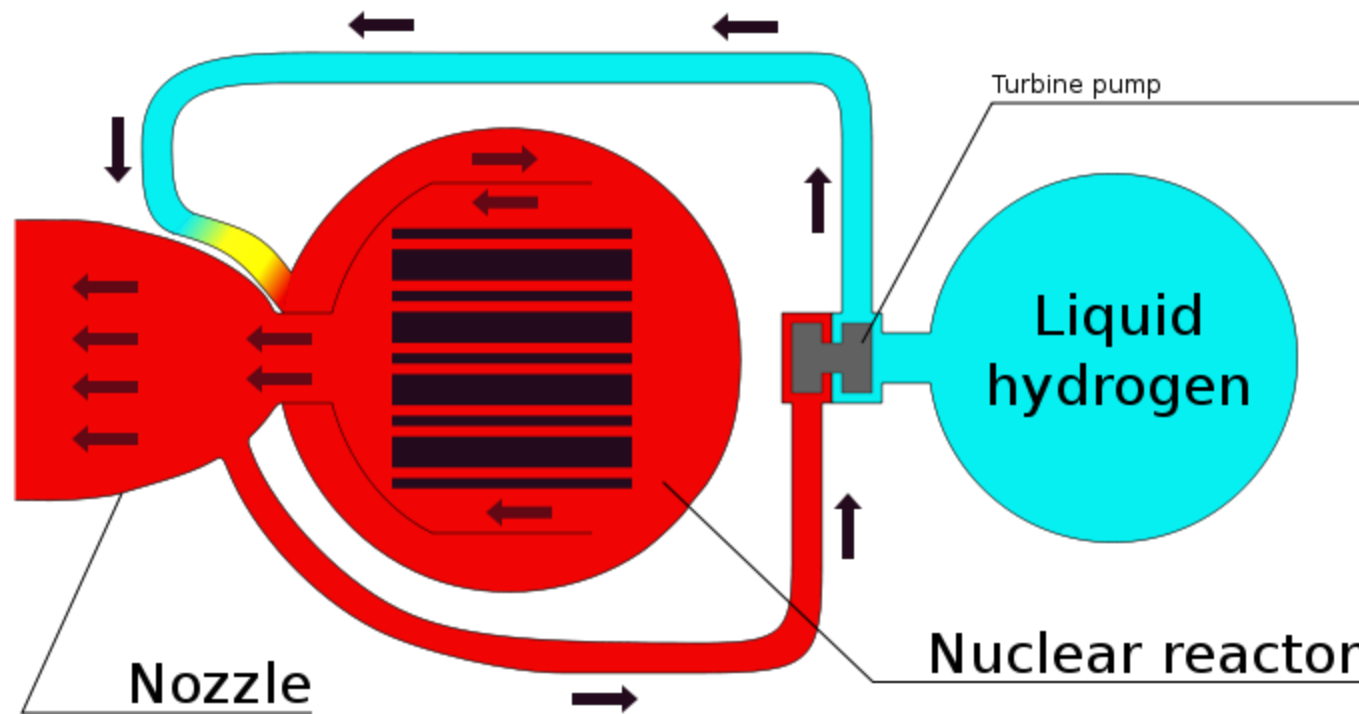


Nuclear Rockets

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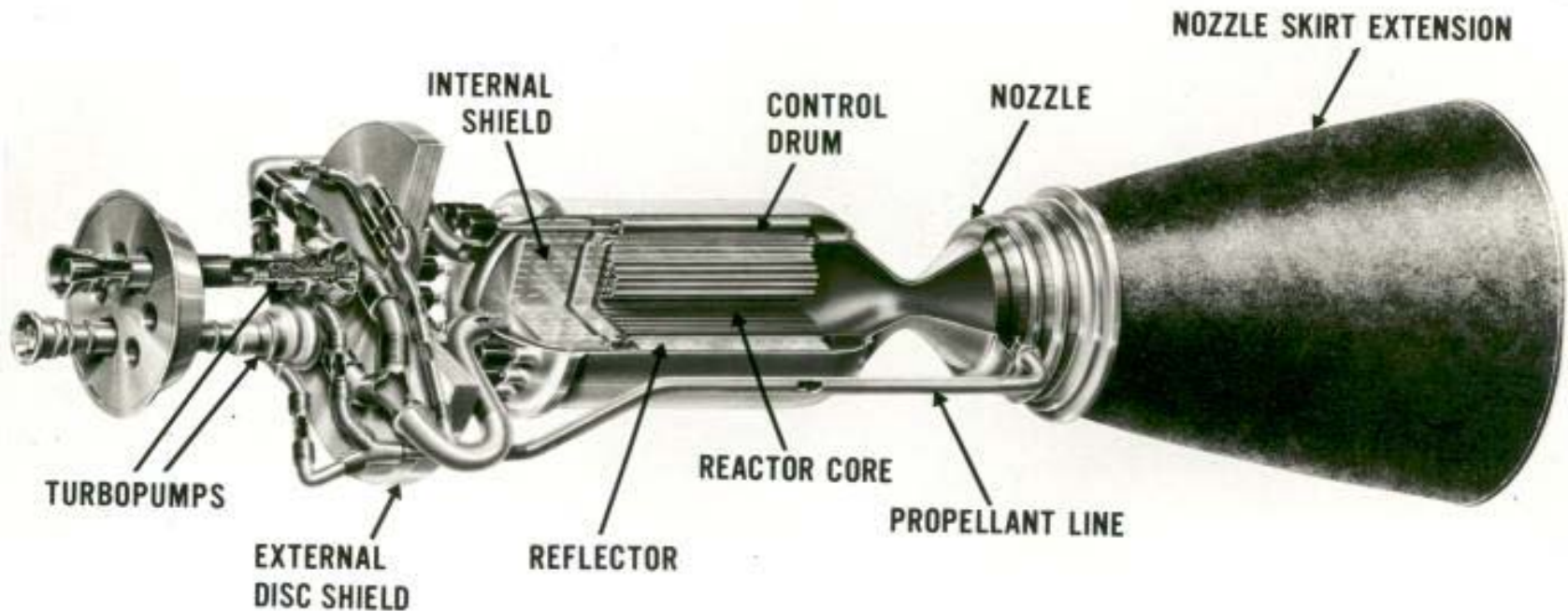
Nuclear Rockets: Nerva

Nuclear Engine for Rocket Vehicle Application



Nuclear Rockets: Nerva

Nuclear Engine for Rocket Vehicle Application



Nuclear Rockets

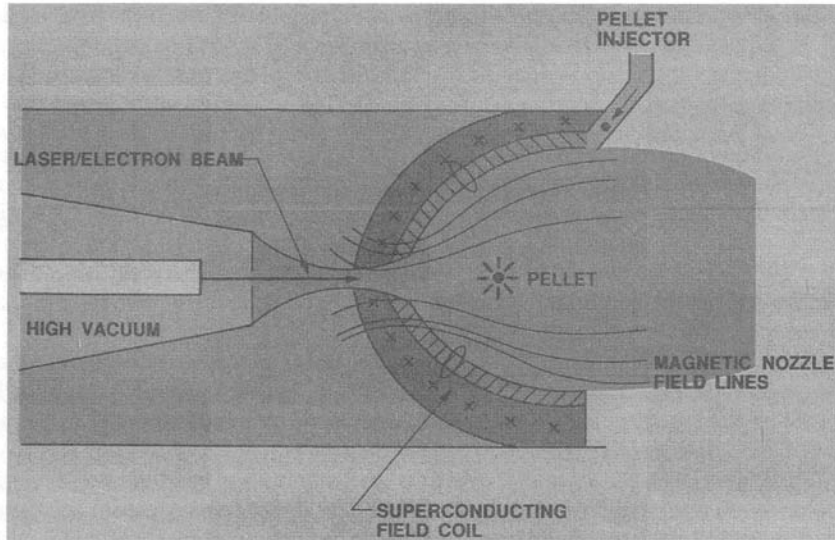
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Nuclear Rockets: Fusion

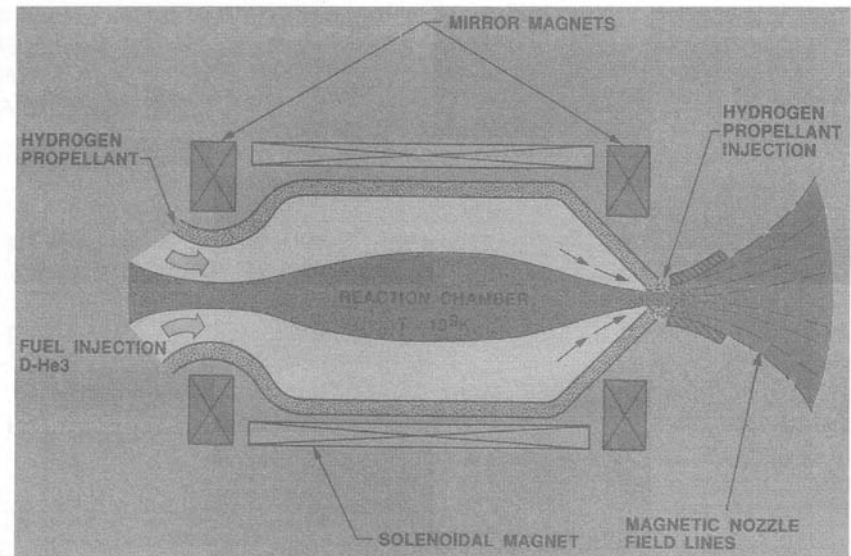
Nuclear Engine for Rocket Vehicle Application

- Fusion Propulsion (Rocket or Ramjet) via ICF or MCF

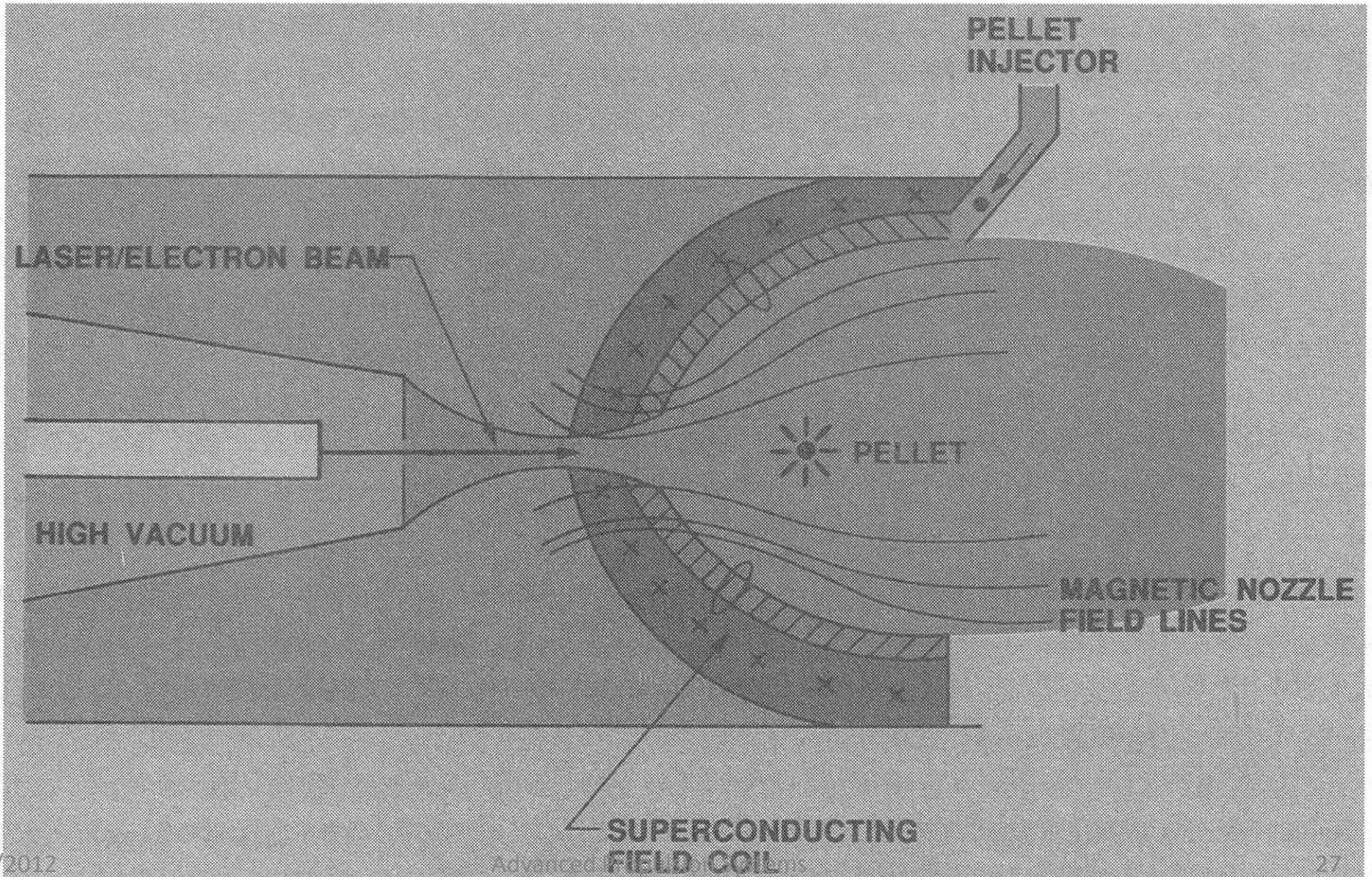
Inertial Confinement Fusion (ICF)



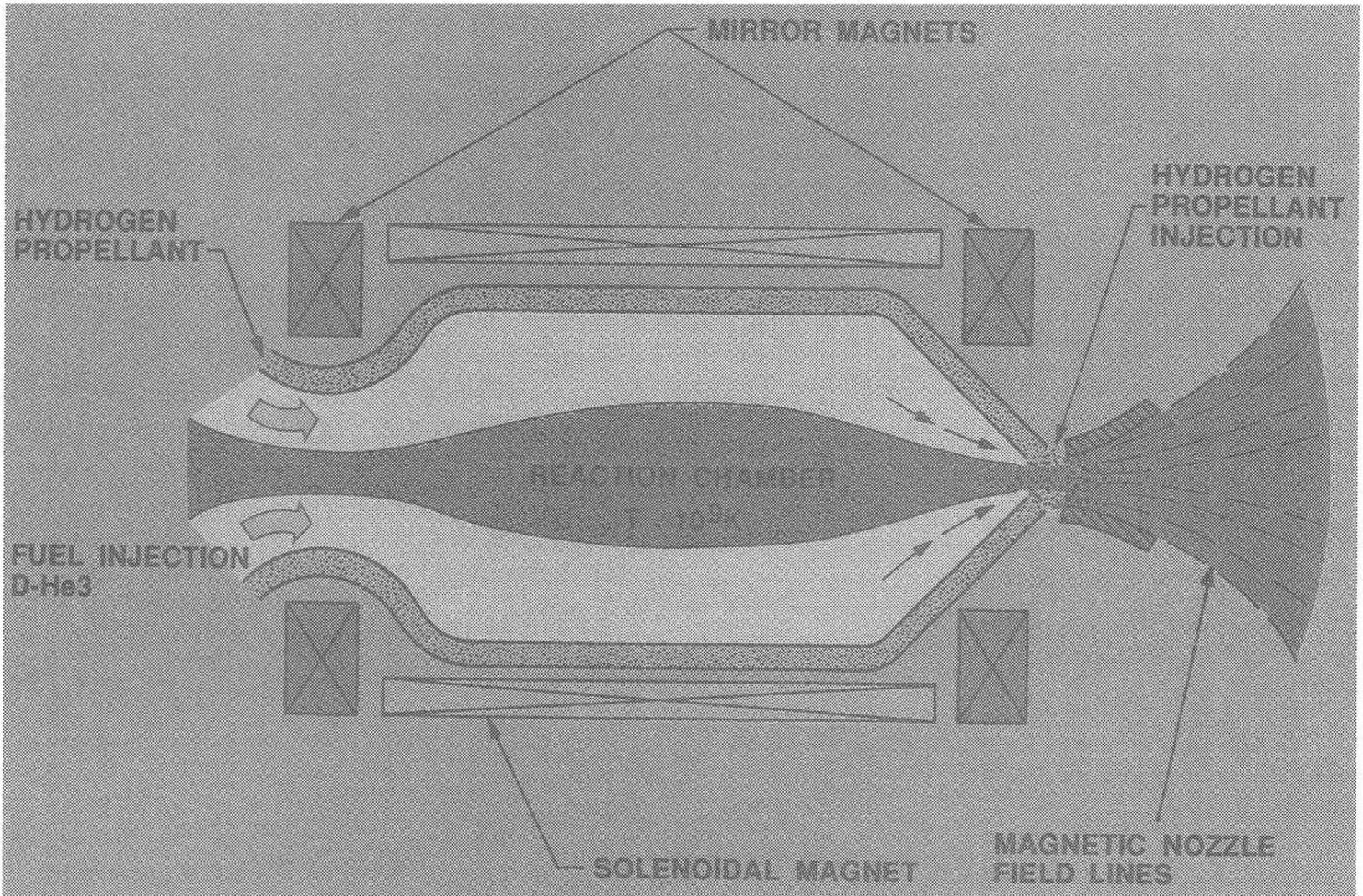
Magnetic Confinement Fusion (MCF)




Inertial Confinement Fusion (ICF)



Magnetic Confinement Fusion





Nuclear Rockets: 10 Fusion Projects

- Project Orion [npp] (USAF-'58) {8Mt to proxima in 133 yr. Mars RT in 4 wks}
- VISTA [ic] {Mars & return in 5 mos.}
- HOPE [mtf]
- ICAN II [acmf]
- Discovery II [mcf] (NASA-GRC) {alpha-centari in 125 yr. Jupiter in 118 dy}
- Fusion Ship II [iec]
- Project Daedalus [icf] (BIS-'73-'78) {self-replicating}
- Project Longshot [npp,icf] (NASA..88)
- Project Prometheus (NASA-'03..'05) {power for outer planets}
- Icarus (BIS-'09-'14) {morale booster}

Alternatives Beyond Chemical Rockets

Rockets & Jets

- Chemical (Apollo – 160M hp for a few minutes)
- Nuclear (200 Men to Mars & Back in 4 weeks)
- **Ion & Plasma** (Long duration and variable thrust)
- Interstellar Ramjet

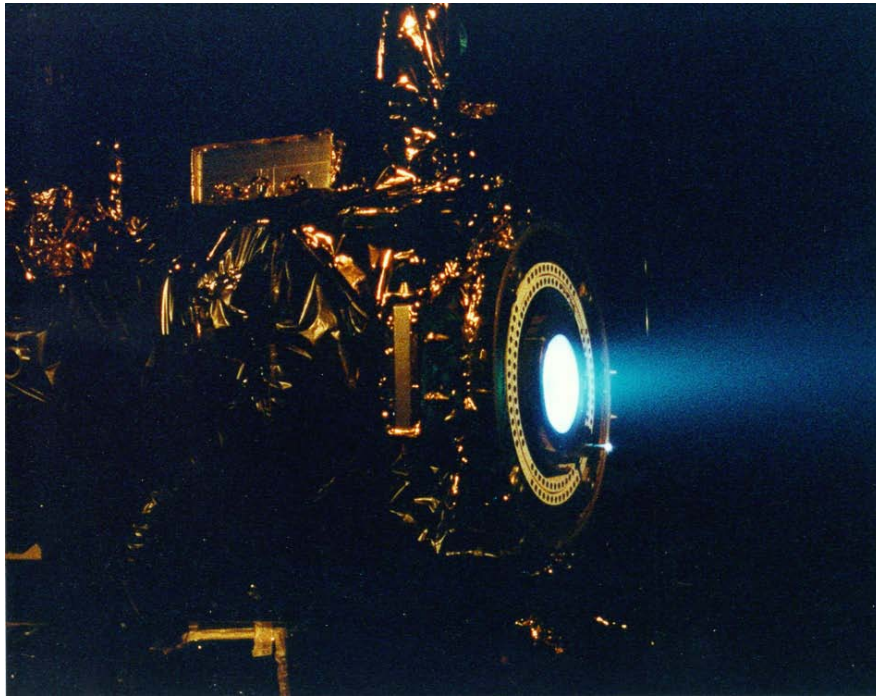
Ion & Plasma Thrusters

- **Project Prometheus** (NASA-'03..'05) CANCELLED
Nuclear Electric Propulsion (NEP) powered system for long-duration space missions beyond RTG capabilities. Evolved NStar Engine used in Deep Space I and Dawn Mission.
- **Dawn Mission** (NASA-'07..'15) Ongoing
Exploration of asteroid Vesta and dwarf planet Ceres.
- **nanoFET** (UofM-'10..)
Nano-particle field extraction thruster
- Electrostatic (Coulomb) vs. Magnetic (Lorentz)
- VASIMR, DS4G, MPD, PIT

Ion & Plasma Thrusters

Dawn Mission (now at Vesta)

Launched in 2010 by NASA to the asteroid Vesta.
Now departing Vesta for the dwarf planet Ceres.



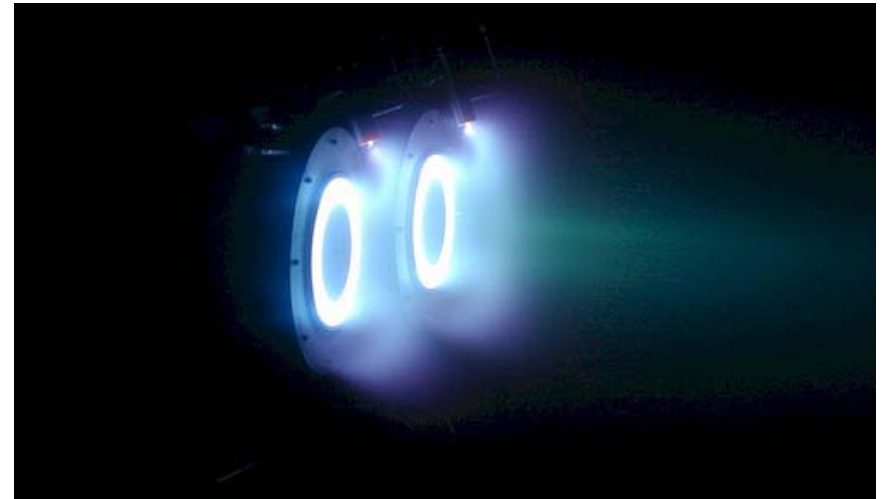
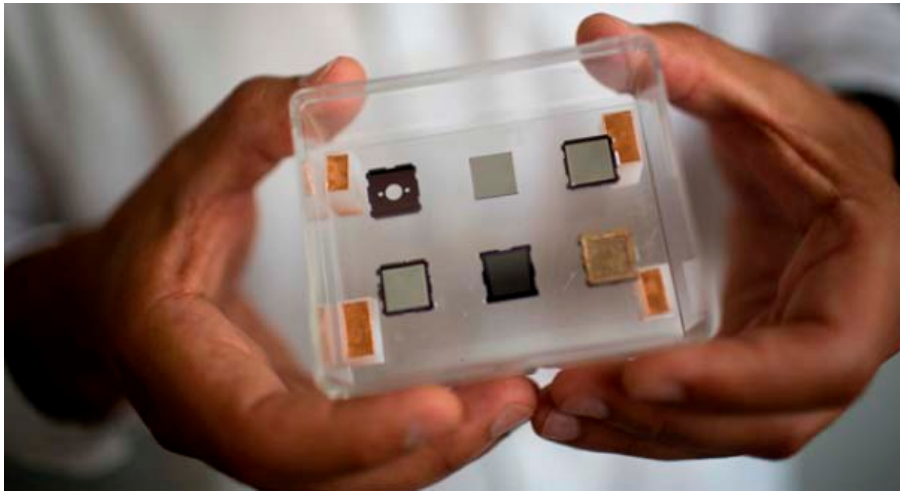
See online Vesta rotation video here:

<http://www.jpl.nasa.gov/video/index.cfm?id=1009>

Ion & Plasma Thrusters

nano-particle field extraction thruster (nanoFET)

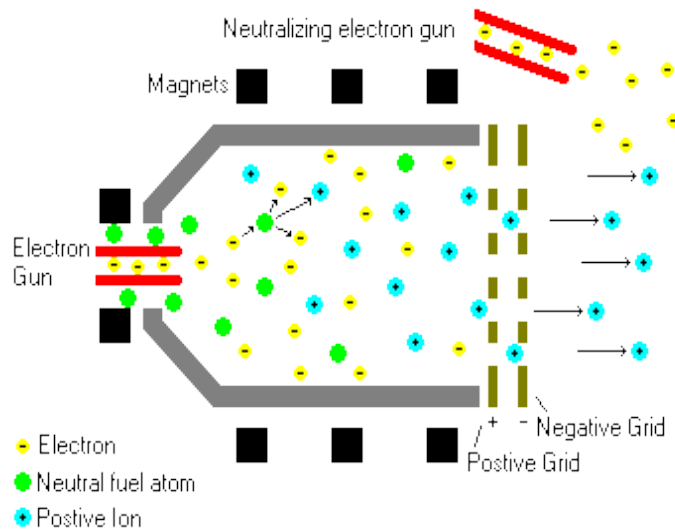
- **nanoFET** (UofM – AIAA 2012)
Nano-particle field extraction thruster
(seed interplanetary or interstellar space w/ ad hoc microchip network)



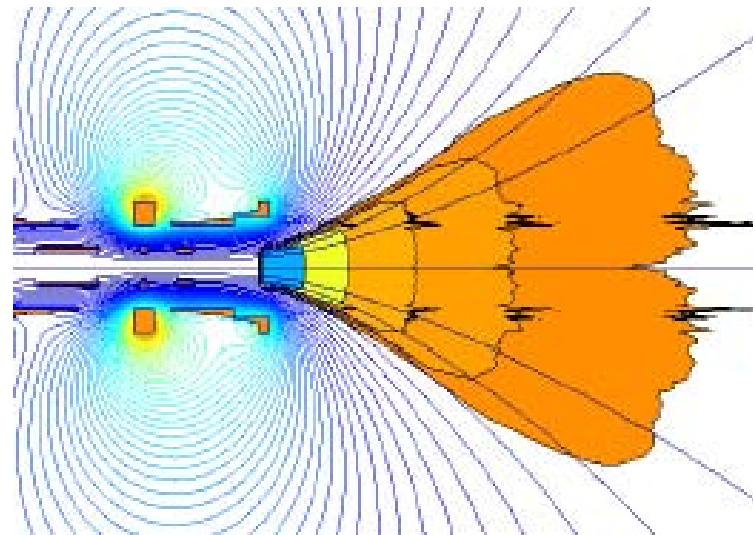
Ion & Plasma Thrusters

Electrostatic (Coulomb) vs. Magnetic (Lorentz)

- Advanced Nuclear Electric Propulsion (NEP)
Coulomb Force vs. Lorentz Force



Electric Ion Propulsion (EIT)
Asteroid Deflection Tool



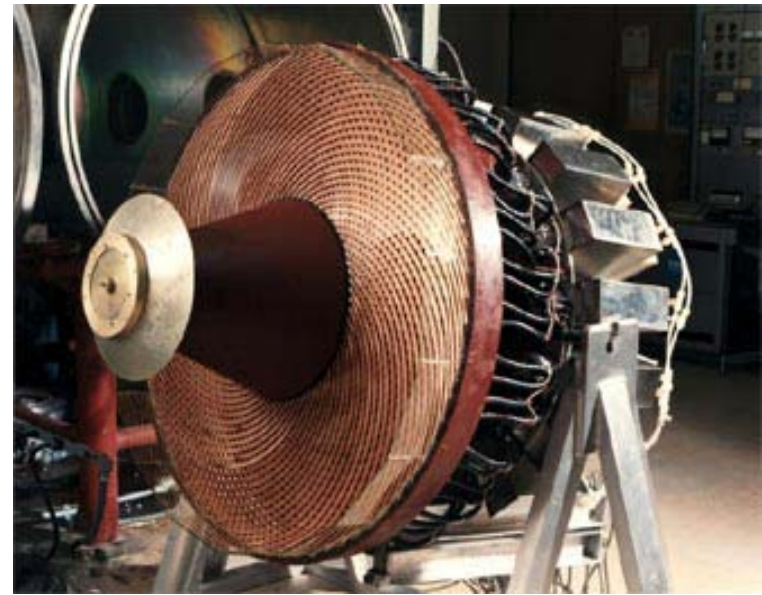
Variable Specific Impulse
Magnetoplasma Rocket
(VSIMR)



Ion & Plasma Thrusters

High Power Electromagnetic Thrusters

- Magnetoplasmadynamic Thruster (MPD)
- Pulsed Inductive Thruster (PIT)



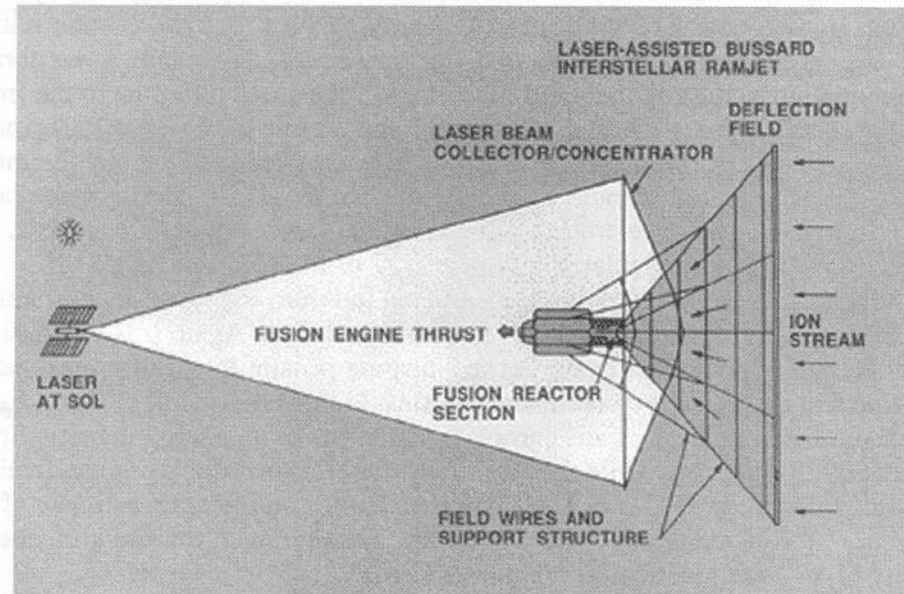
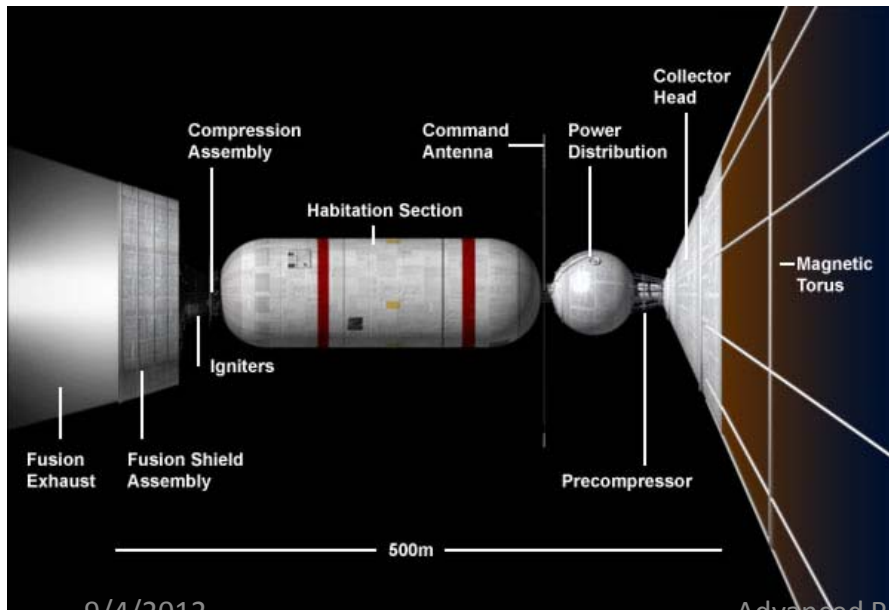
Alternatives Beyond Chemical Rockets

Rockets & Jets

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- **Interstellar Ramjets**

Rockets & Jets – Interstellar Jets

- Bussard Ramjet – Scoop drag greater than thrust?
 - A magnetic field a few miles to hundreds of miles in diameter directs interstellar hydrogen into a constriction to compress as propellant.
 - Beamed energy, Fission, Fusion, or Antimatter collecting and heating the propellant which then ignites in a fusion reaction.



Alternatives Beyond Chemical Rockets

- **Rockets & Jets**
Chemical, Nuclear, Ramjet
- **Launch Structures**
Catapults, Elevators, Fountains, Loops, Tethers ,Piers
- **Sails**
Laser, Maser, Particle, Light
- **Hybrids**
Catapult, Scramjet, Nuclear
- **Exotic Physics & Reactionless Drives**
Field Drives, Warps & Wormholes, GR/EMF Couplings, (A-word)

Launch Structures

- Space Guns, Catapults, & Mass Drivers
- Space Elevators
- Orbital Rings & Tethers (Tesla-1870's)
- Space Fountains
- Launch Loops

Meta-material technology breakthroughs will drive the engineering of these mega-structures.

Launch Structures

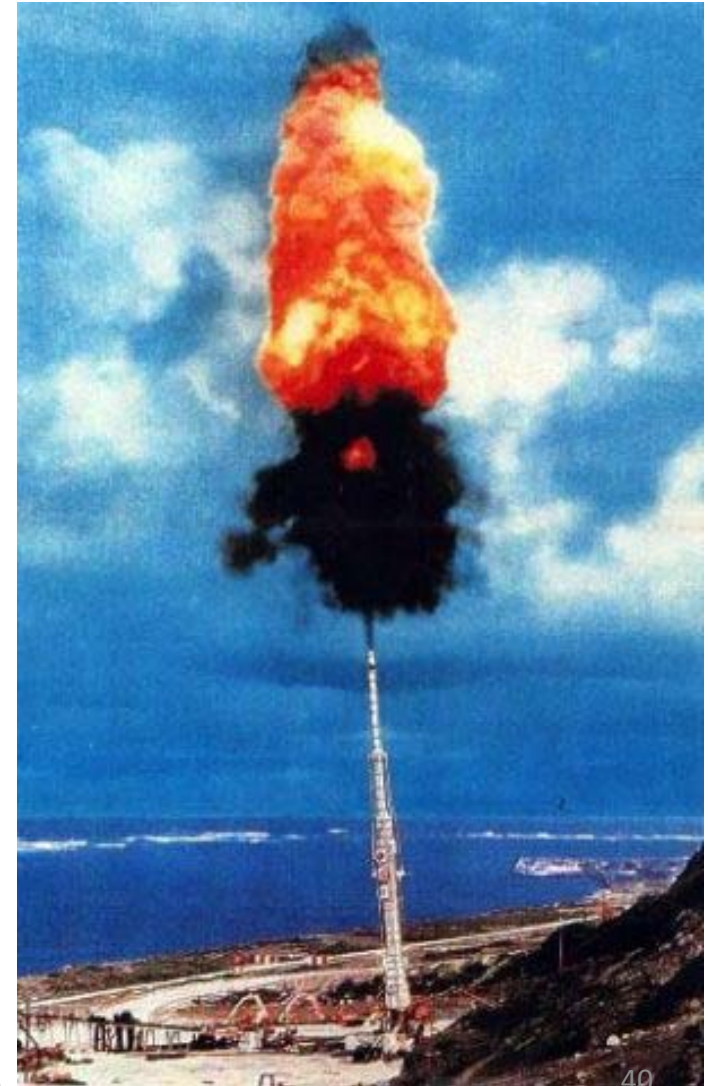
Space Guns, Catapults & Mass Drivers

- Space Gun - Chemical

High Altitude Research Project

HARP 16 inch 20m gun shown. The 40m version lofted 180 kg to 112 mi.

Escape velocity from a 60 km barrel requires 100 g's for about 10 secs.



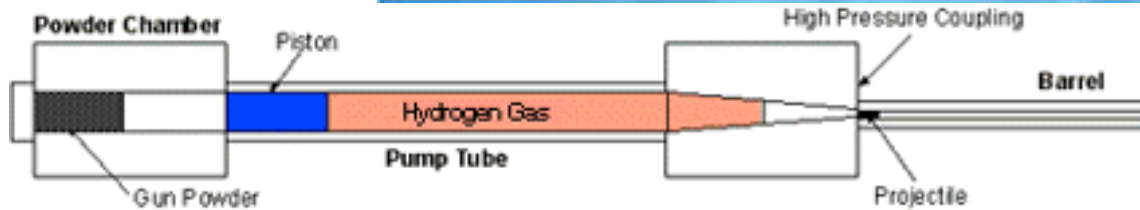
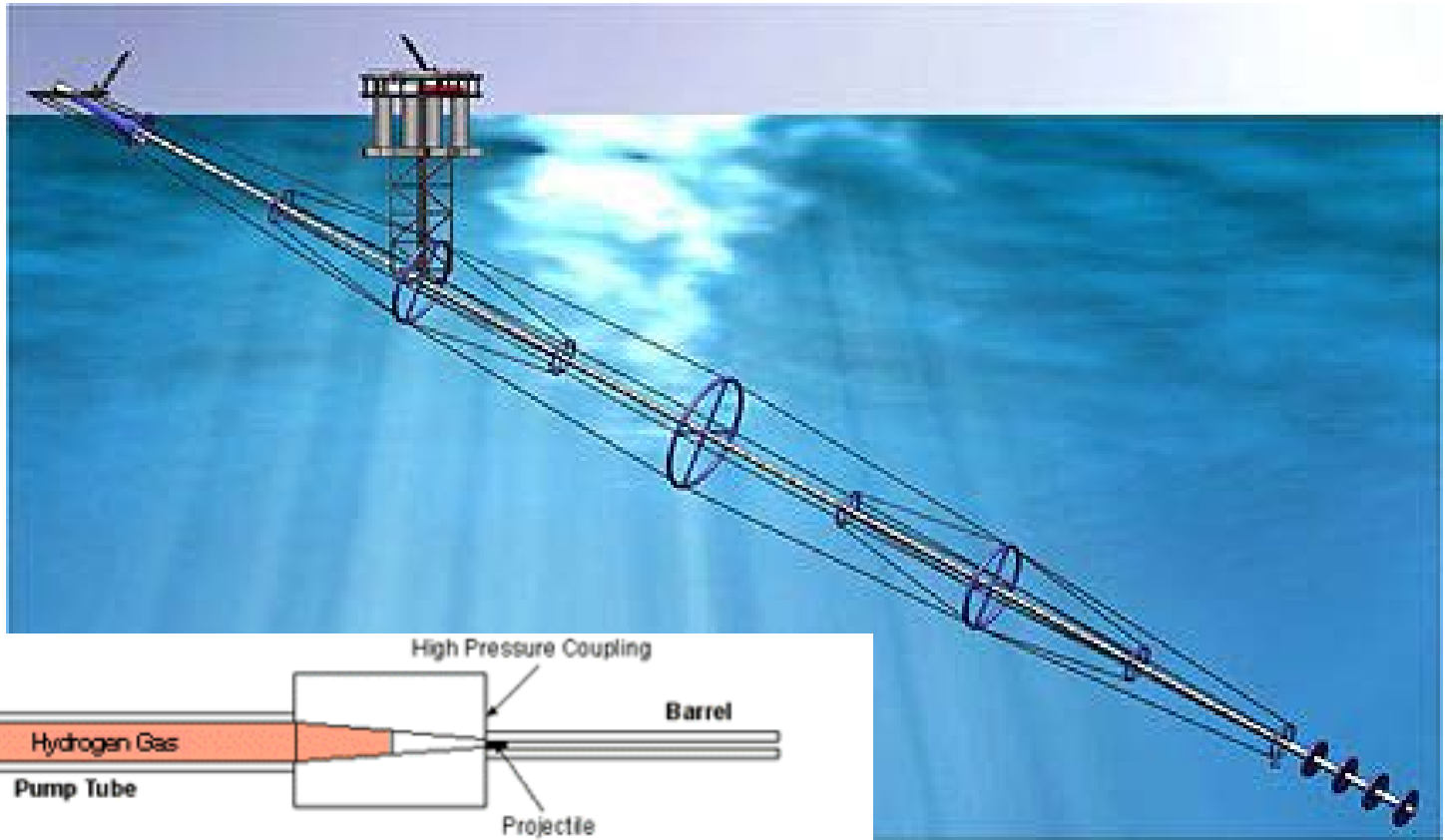
Launch Structures

Space Guns, Catapults & Mass Drivers

- **Space Gun – Light Gas (Hydrogen)**

Quicklaunch Commercial Space Gun. Launch at \$500 / lbs

\$600/kg
@ 7 km/s

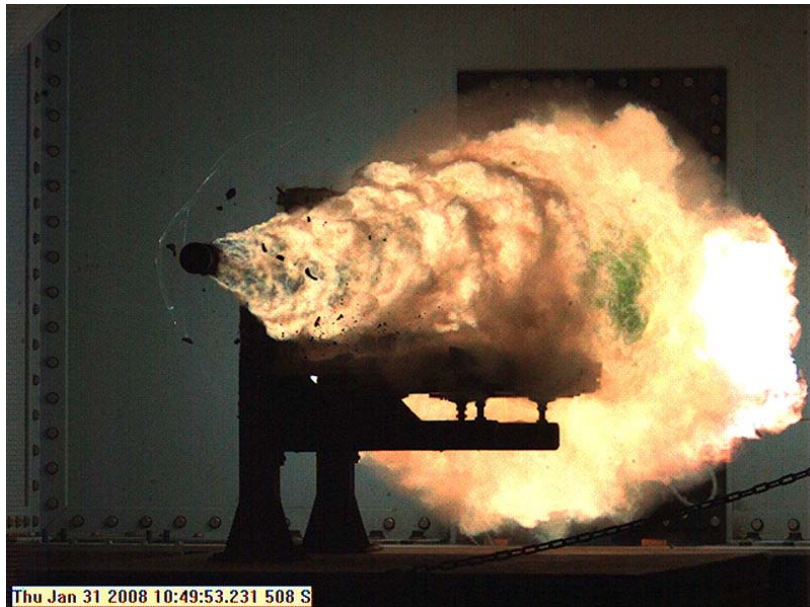


Launch Structures

Space Guns, Catapults & Mass Drivers

- Mass Driver, Spacegun, Coilgun, Railgun
Chemical or EM catapult (<12 Km/s)

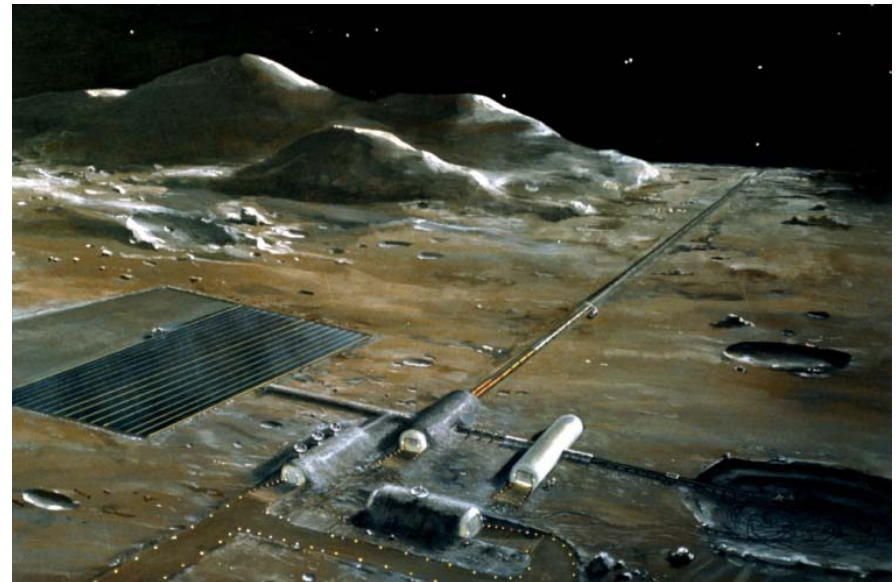
Navy EM Rail Gun
2 – 3.5 km/s



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Proposed Lunar Catapult



Advanced Propulsion Systems

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Launch Structures

Space Guns, Catapults & Mass Drivers

- StarTram Maglev Mass Driver

Electromagnetic launch with Rocket Assisted orbital insertion.

Gen 1: 130 km at 30 g.

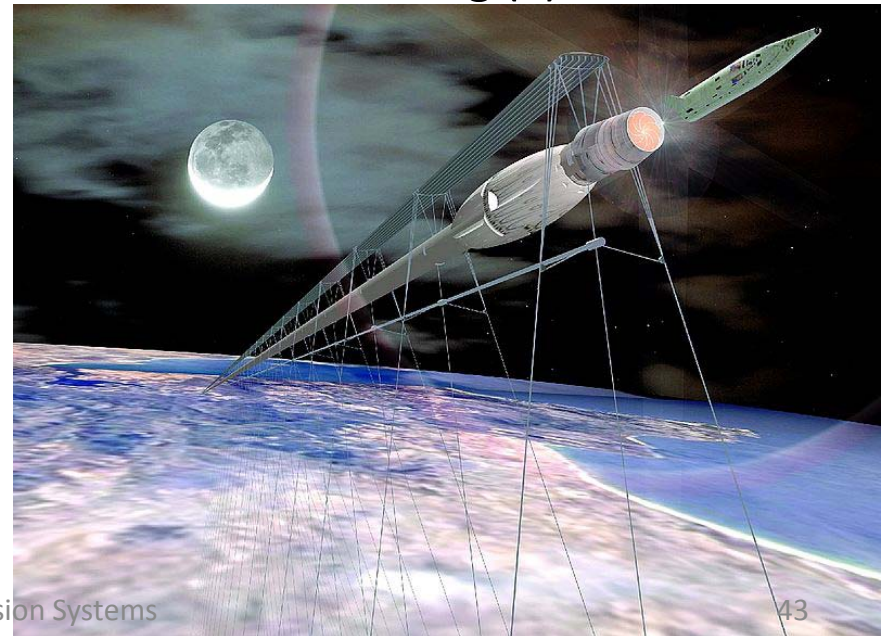
$V_m = 8.78 \text{ km/s}$ at 10°

6 km ASL. \$43/kg

Gen 2: 1,500 km at 2-3 g.

$V_m = \sim 8 \text{ km/s}$ at 10° (?)

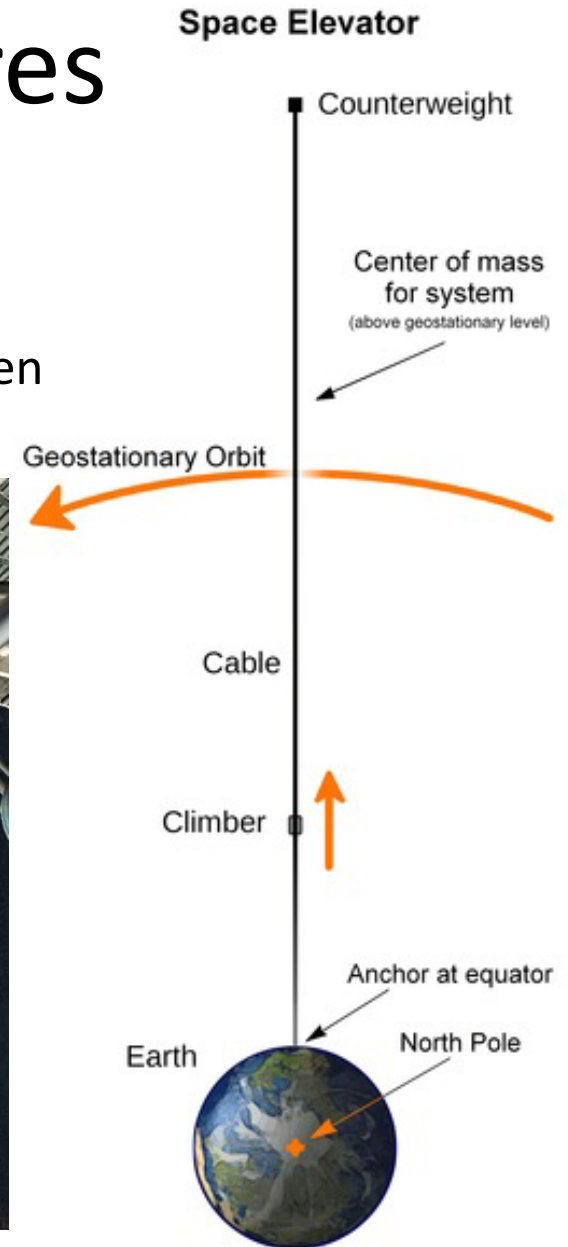
22km ASL. \$43/kg (?)



Launch Structures

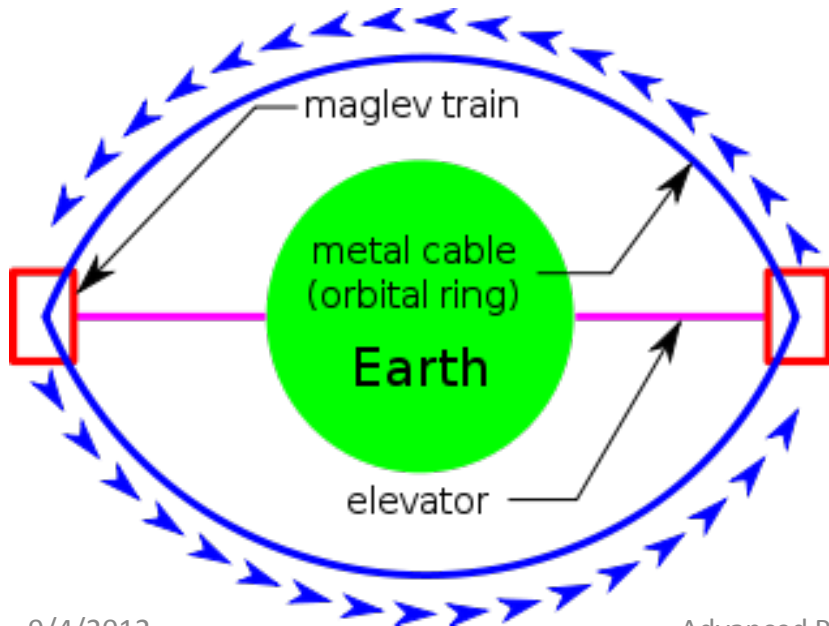
- **Space Elevator**

Obayashi Corp. plans to build one by 2050 for 1T Yen
7.5 day travel time for 30 pax to GEO.



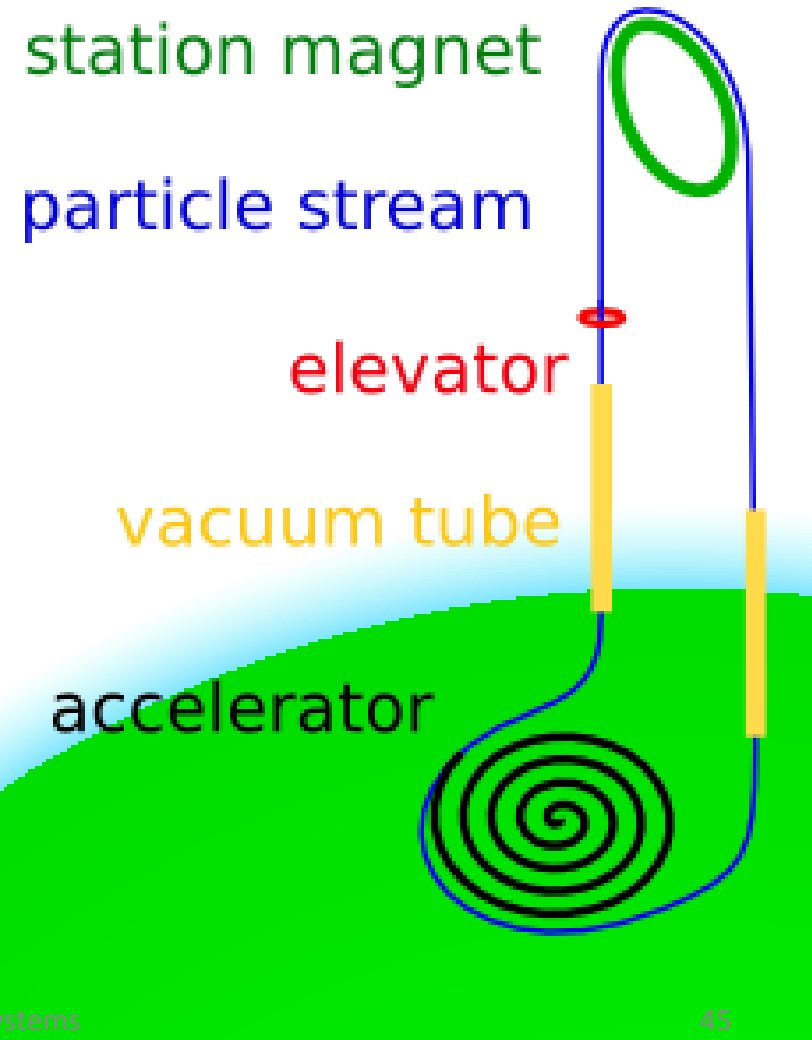
Launch Structures

- Space Fountain
- Tesla Orbital Ring
\$0.05/lbs after \$31T investment
or launch of 18 Kt of steel in one
Project Orion type craft.



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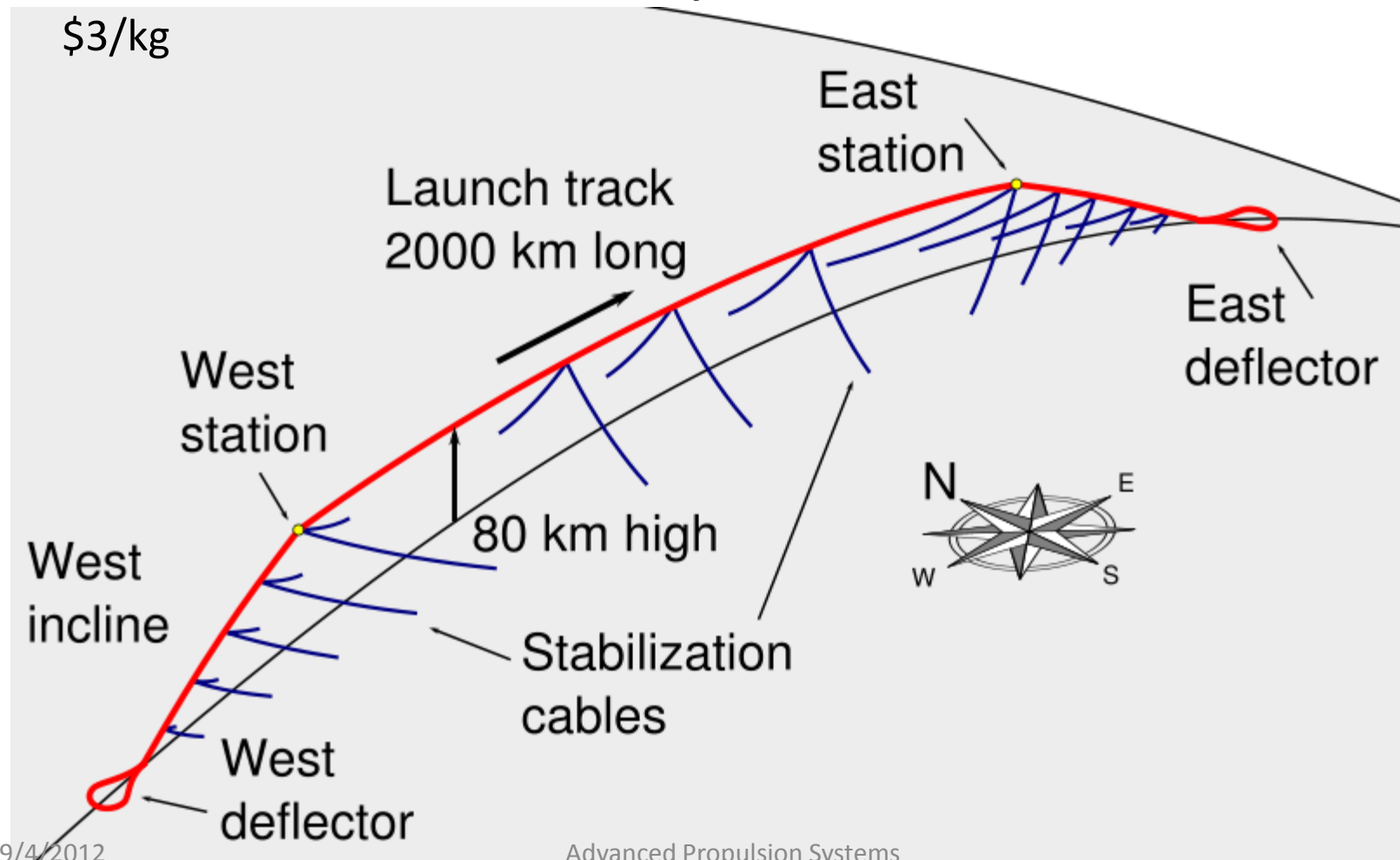
Advanced Propulsion Systems



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Launch Structures

- Lofstrom Launch Loop



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Space Sails

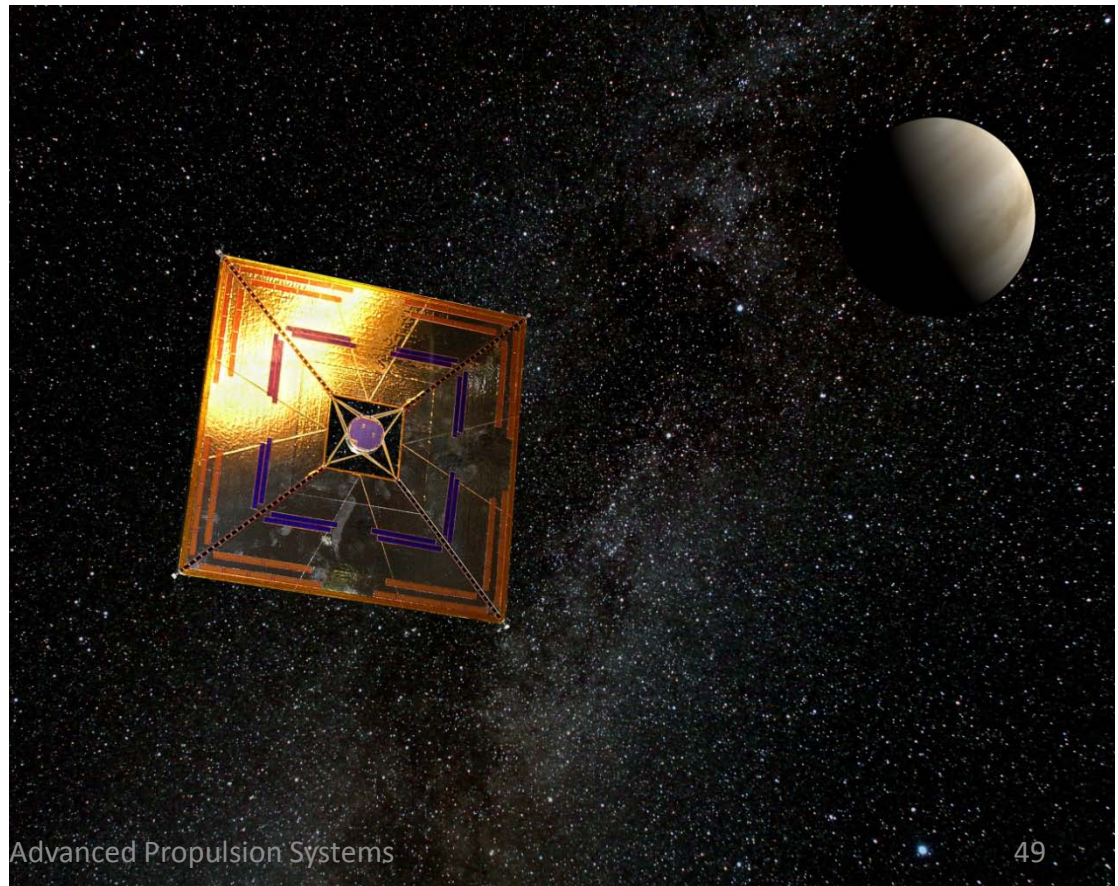
Laser, Maser, Particle, Light

- Solar Sails & Light Sails
- Magnetic Sails & Particle Beam Sails
- Fission Fragment Sails
- Interstellar Sails
- Exotic Meta-material Sails

Space Sails – Solar & Light

- **IKAROS** - Interplanetary Kite-craft Accelerated By Radiation of the Sun
Launched in 2010 by the Japanese Aerospace Exploration Agency (JAXA)

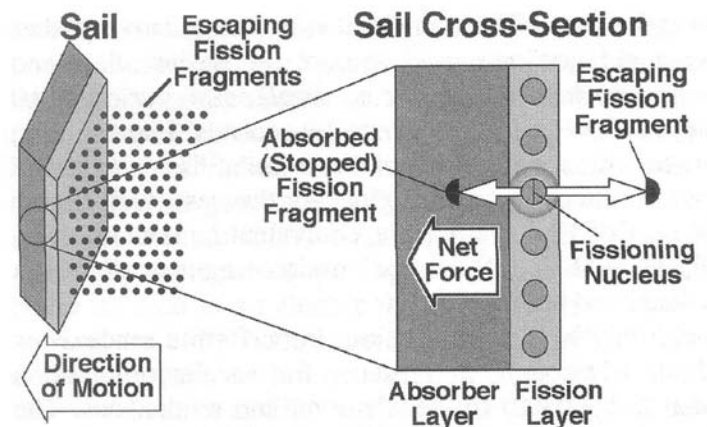
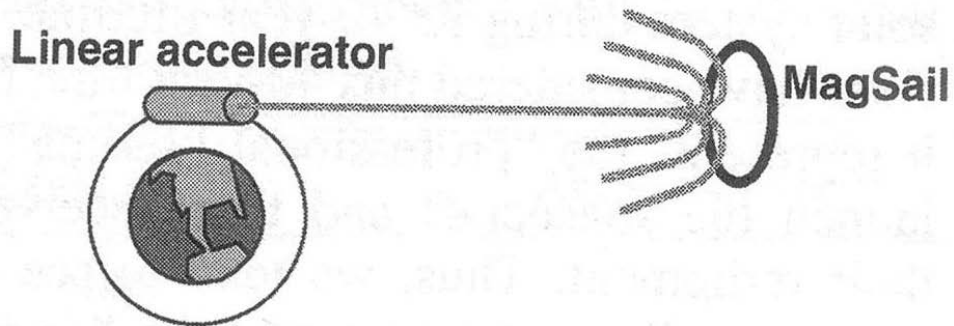
The adjustable reflectance of the LCD's embedded in the 200 m² polyimide sail controls the craft's attitude as it sails to Venus then the far side of the Sun.



Space Sails

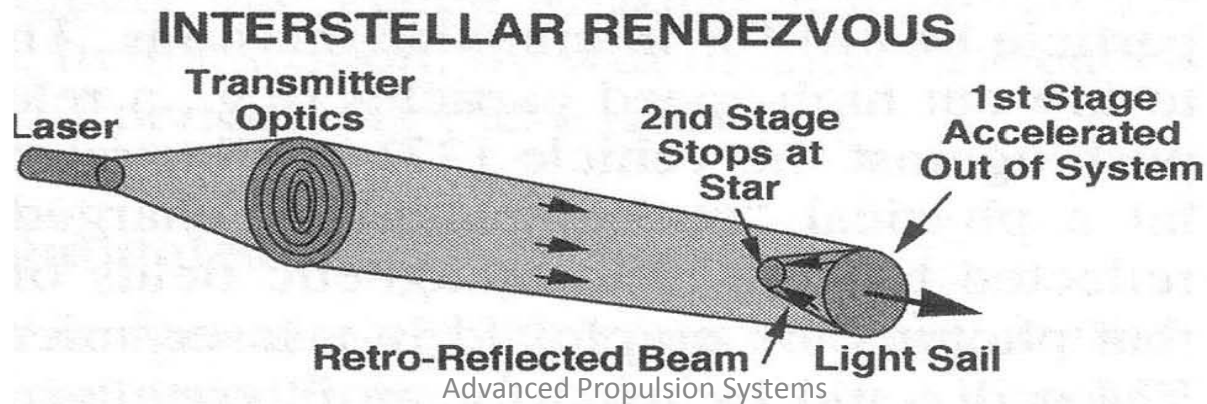
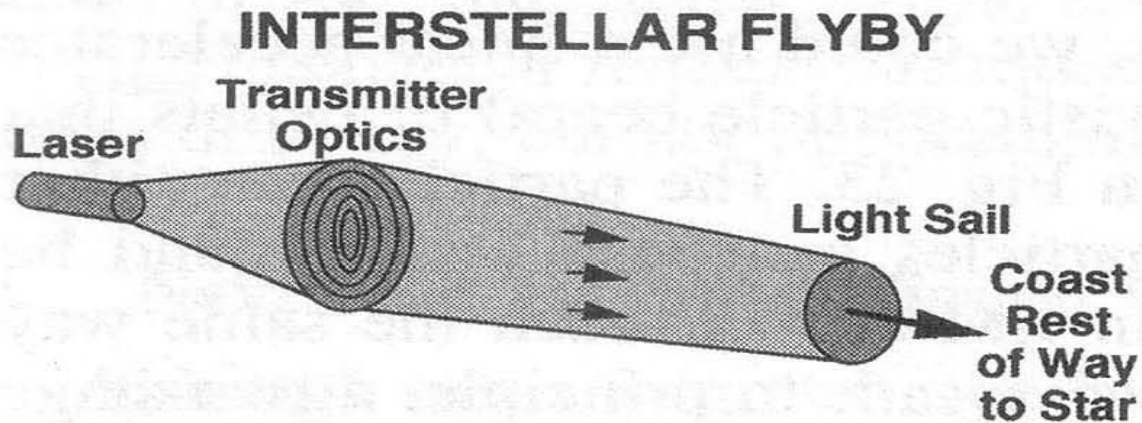
Laser, Maser, Particle, Magnetic

- Magnetic Sails & Particle Beam Sails
- Fission Fragment



Space Sails

Interstellar Photon Sails



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Hybrid Mass Driver – Scramjet - Nuclear Rocket



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Exotic Physics & Reactionless Drives

**There are more things in heaven and earth, Horatio,
than are dreamt of in your philosophy.**

– Shakespeare, Hamlet Act II, Scene V



Exotic Physics & Reactionless Drives

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“It’s theoretically impossible.”

“Perhaps .. [they] have .. different theories.”

- Larry Niven, *Ring World*

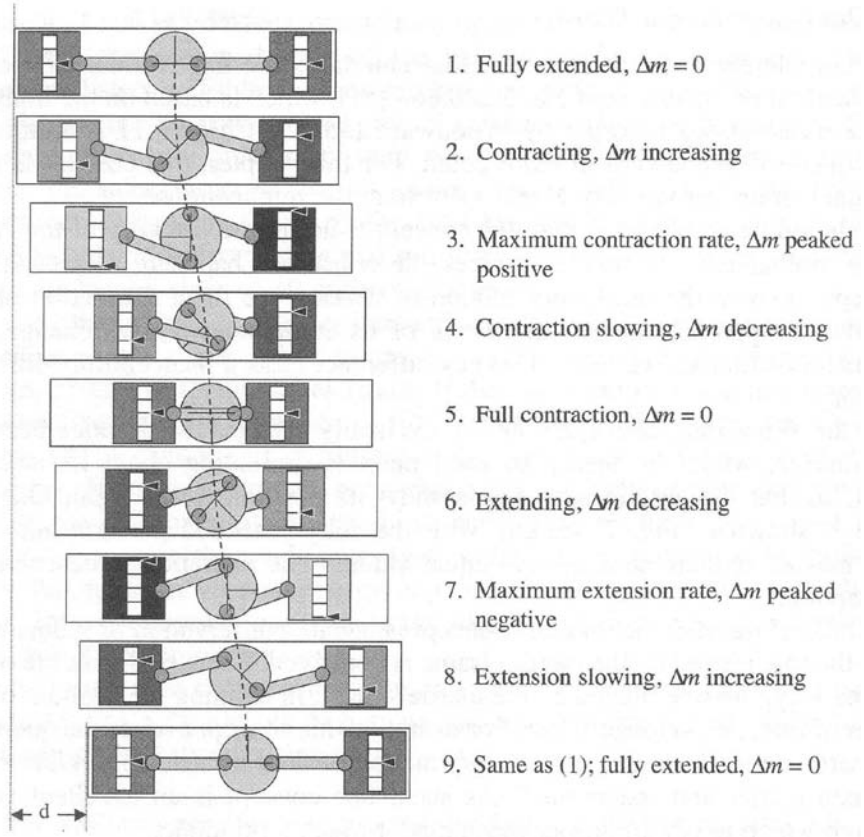
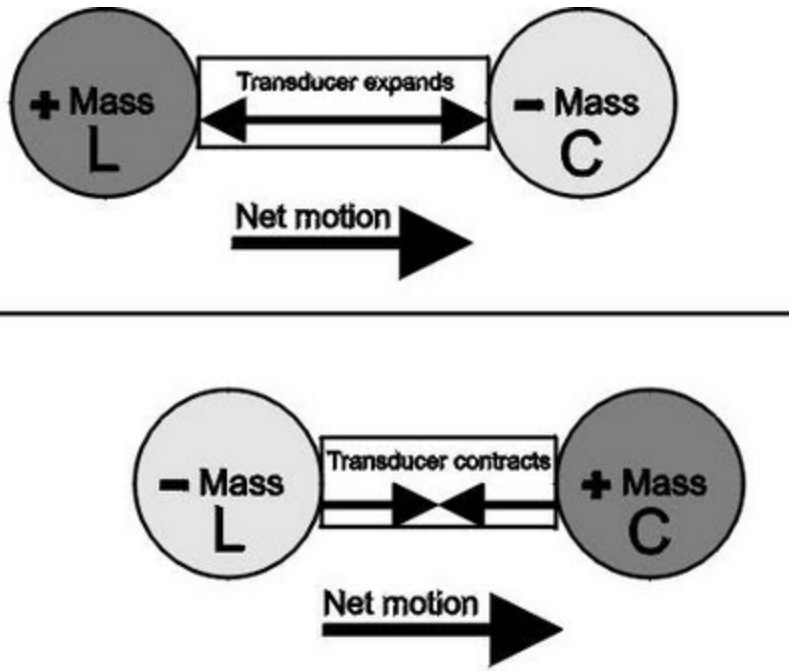
Clarke's Three Laws of prediction

- When a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he is very probably wrong.
- The only way of discovering the limits of the possible is to venture a little way past them into the impossible.
- Any sufficiently advanced technology is indistinguishable from magic.

Exotic Physics & Reactionless Drives

Inertial Modification

- Theoretical Mach-Lorentz Thruster (MLT)
(Woodward Effect)





Exotic Physics & Reactionless Drives

Space Drives Swim in the 'Aether'

- Quantum Vacuum $(10^{-26} \text{ .. } 10^{98} \text{ Kg/m}^3)$
- Spacetime $(10^{-26} \text{ .. } 10^{25} \text{ kg/m}^3)$
- Galactic* Hydrogen $(3.3 \times 10^{-21} \text{ Kg/m}^3)^{(b)}$
- Dark Energy $(6.9 \times 10^{-27} \text{ Kg/m}^3)^{(a)}$
- Dark Matter $(2.1 \times 10^{-27} \text{ Kg/m}^3)^{(a)}$
- CMB Photons $(10^{-31} \text{ Kg/m}^3)$

* Hydrogen density only within our galaxy, not intergalactic space where it is $\sim 3.8 \times 10^{-28} \text{ kg/m}^3$.

Exotic Physics & Reactionless Drives

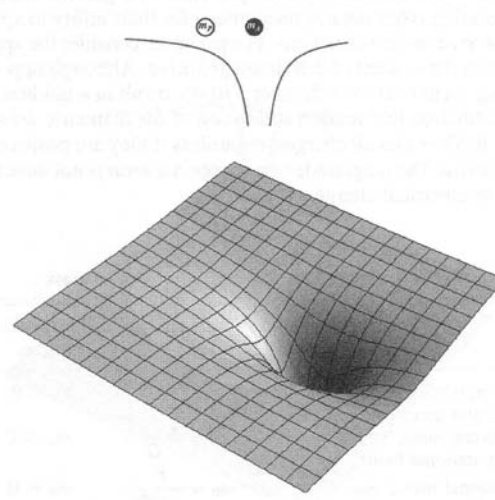
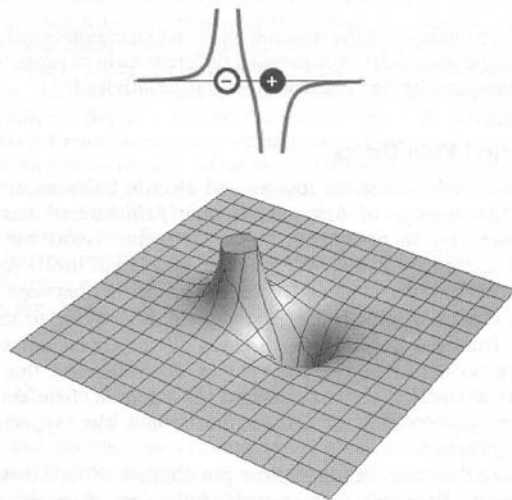
Modify the Geodesic (Engineer Spacetime)

- **Field Drives** (Diametric, Disjunction, Gradient, Bias) >
- **Negative Matter & Negative Energy** >
(Everything not forbidden is compulsory – Gel-Mann)
- **Warp Drives & Worm Holes** >
- **Gravity Control** >

Exotic Physics & Reactionless Drives

Hypothetical Field Drives

- Diametric Negative Inertia / Negative Mass
- Disjunction ($Mass_{passive}$, $Mass_{active}$, $Mass_{inertial}$)

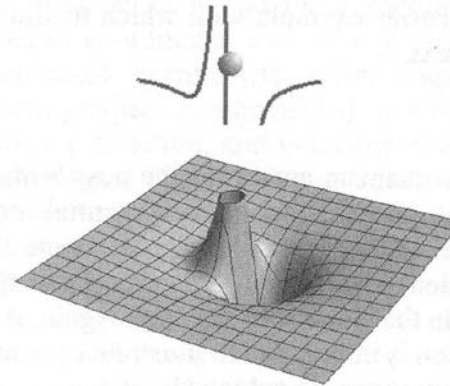
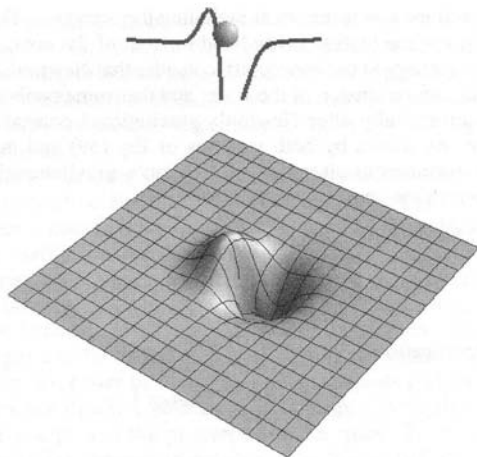


Disjunction contradicts the Weak Equivalency Principle (WEP)

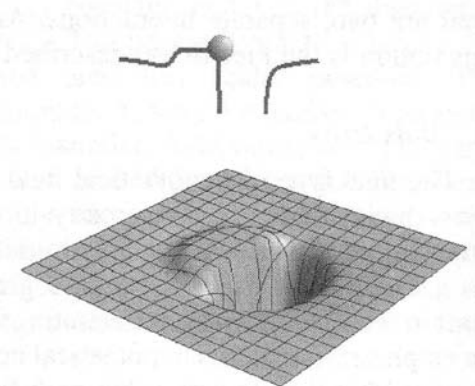
Exotic Physics & Reactionless Drives

Hypothetical Fields Drives

- **Localized Gradient in the Gravitational Potential**
Superimpose a localized gradient on the G potential along the craft's x-axis causing it to 'fall' forward.
- **Locally Bias Newton's Gravitational 'Constant', G**
Asymmetrically distort G along the craft's x-axis.



a) Multiplicative modification, B , Eq. (39a)

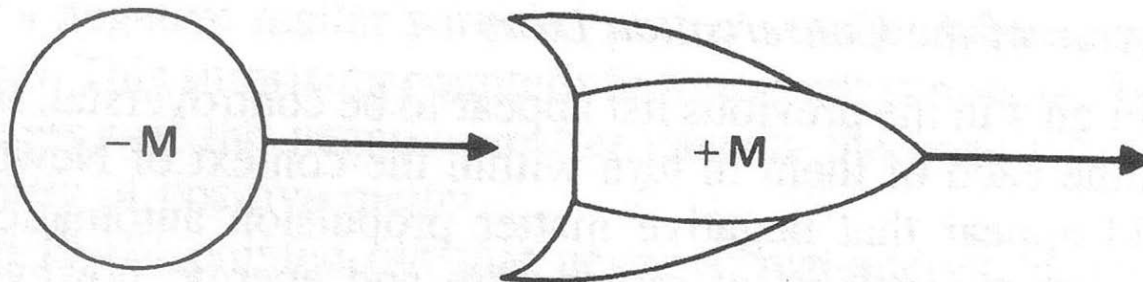


b) Exponential modification, b , Eq. (39b)

Exotic Physics & Reactionless Drives

Hypothetical Negative Mass & Energy

- Does negative mass exist?
(Everything not forbidden is compulsory – Gel-Mann)
- Is anti-matter same as Negative Matter? (UCR research)
- Does Negative Mass imply negative inertia?
- Does Negative Mass attract? Repel?

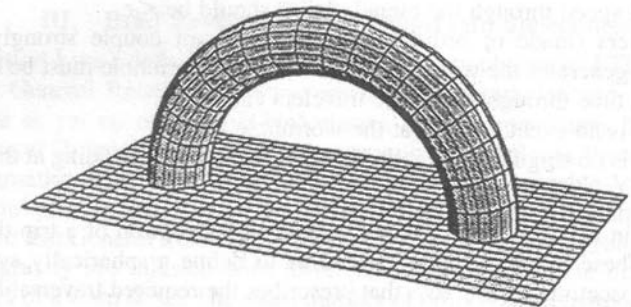
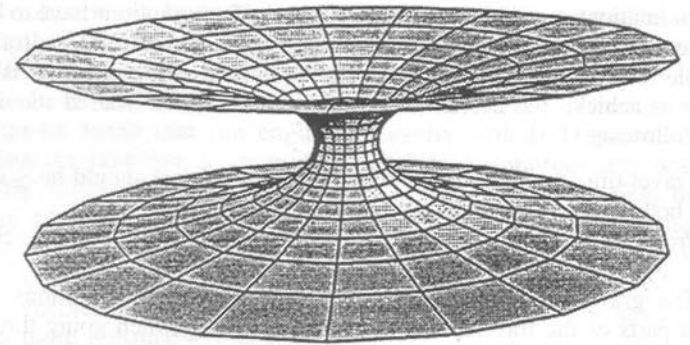
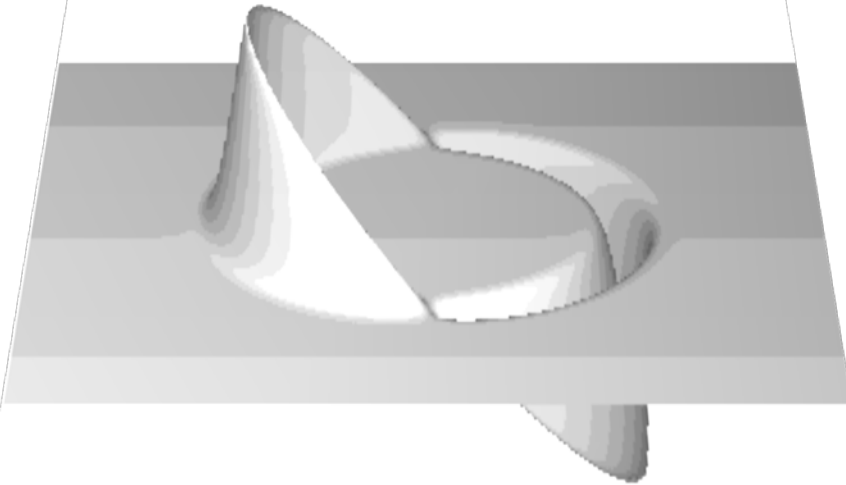


Negative Mass is such a Handy Tool

Exotic Physics & Reactionless Drives

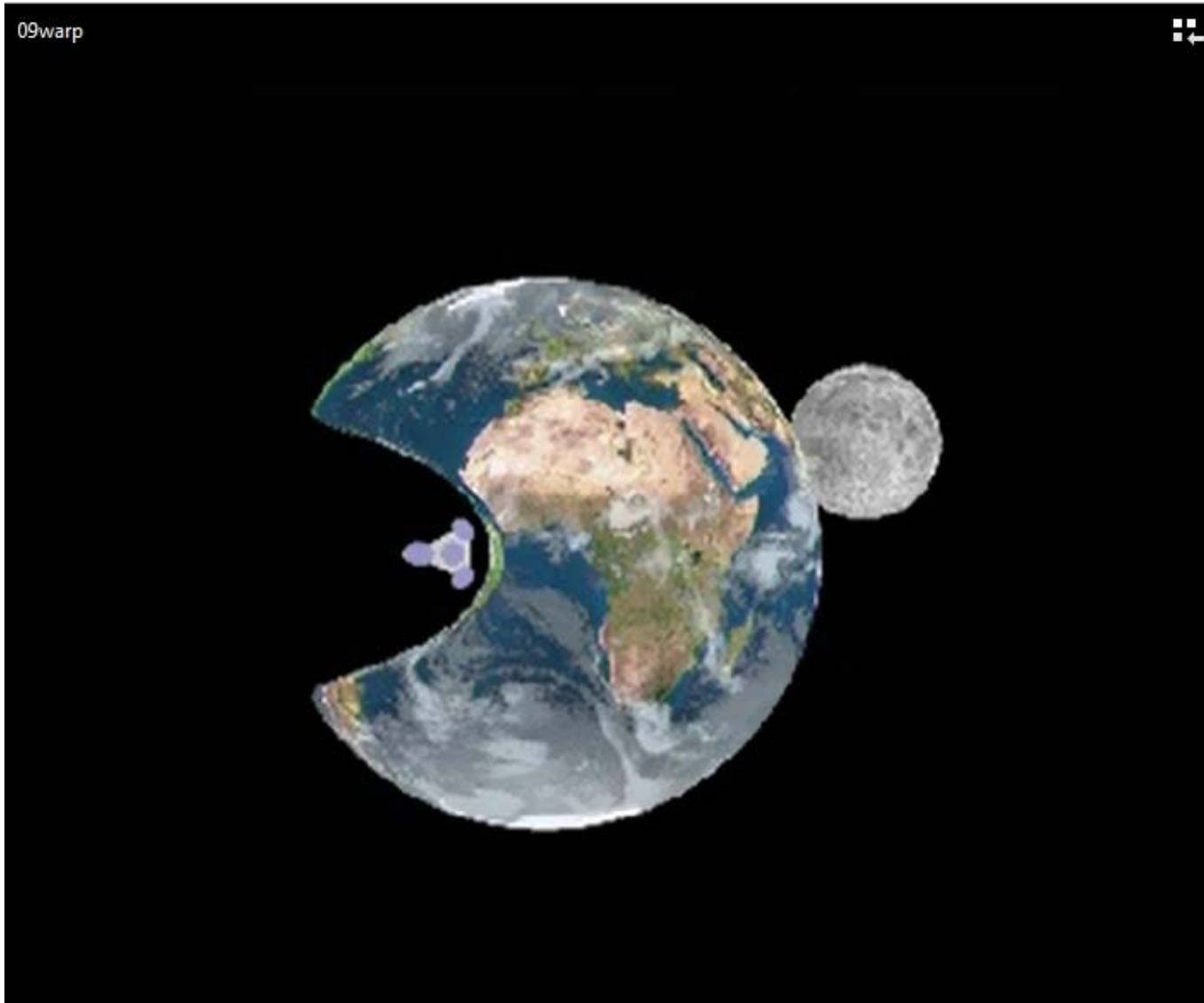
Warp Drives and Wormholes

- Warp Drives & Wormholes
(need Negative Mass)



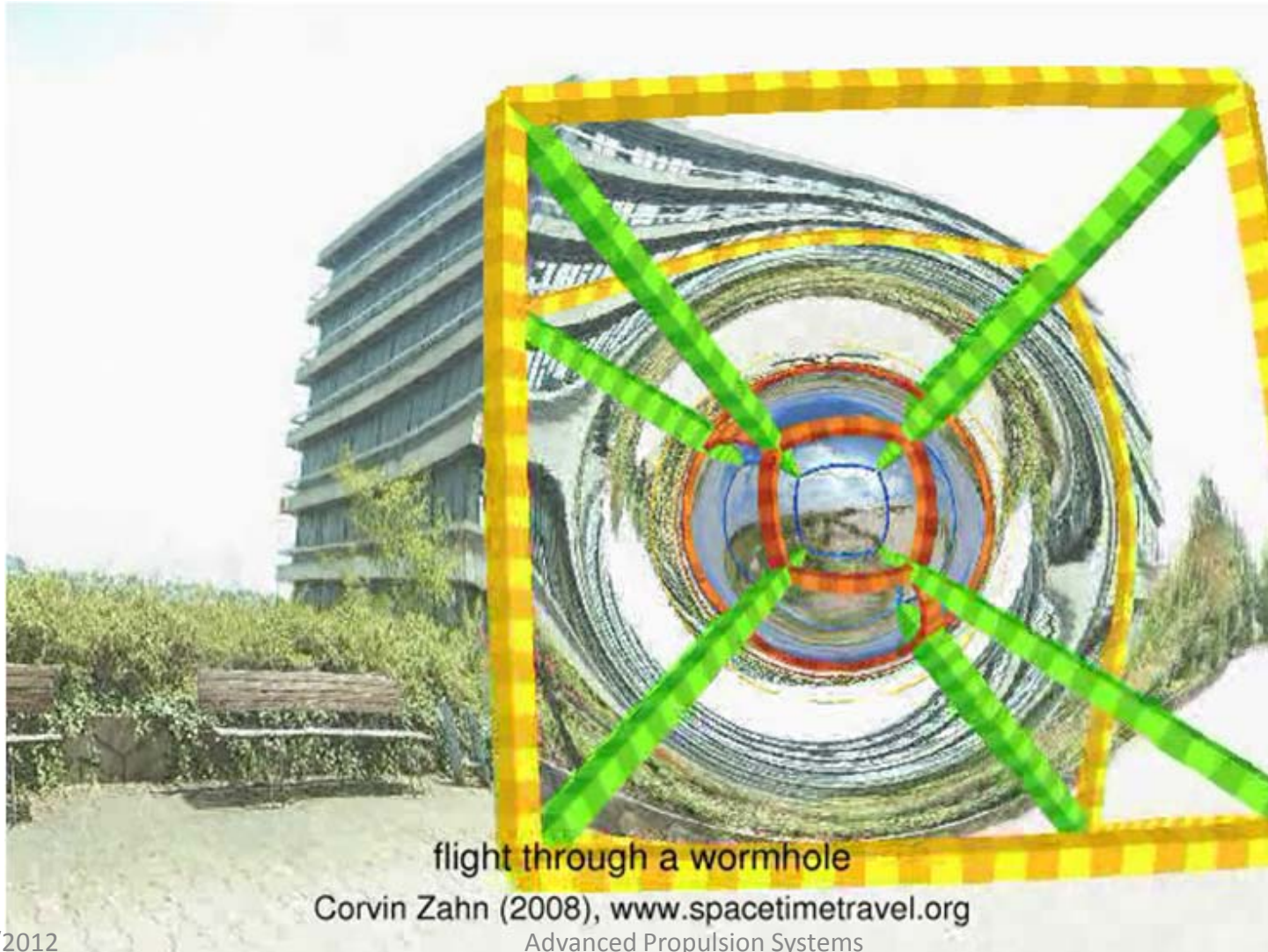
Exotic Physics & Reactionless Drives

Alcubierre Warp Drive



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Warp Drives and Wormholes



flight through a wormhole

Corvin Zahn (2008), www.spacetime-travel.org

Advanced Propulsion Systems



Exotic Physics & Reactionless Drives

Miscellaneous Hypothetical Effects

- **Gravitomagnetic Forces** (GR Frame Dragging)
- **Negative Energy and Inverse Gravity Fields**
(GR negative energy density & negative pressure are EFE solutions)
- **Cosmological Gravitational Inverses**
(Energy Density Pressure, Vacuum Energy of Λ , Dark Energy, Inflation)
- **Levi-Civita & Gertsenshtein Effects**
(Possible EMF GR interactions shown in EFE & EMF Eqns)
(Levi-Civita: Gravitational field induced by EMF - Pauli)
(Gertsenshtein: EMF resonance phenomena that produces an EFE Wave)
- **Inverse Gravity Solutions in Quantum Gravity Theories**

Our Future is Writ in the Stars

We are a great people

Our ancestors, our families, braved oceans, frozen wastes, and deserts.

They walked, swam, flew, and sailed here, to America.

We are Wanderlust.

It is in our blood, in our genes,
to explore new lands, new worlds.
We have taken our first small step.

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