PERSPECTIVES ON PROPULSION FOR FUTURE SPACE MISSIONS

Keynote, NIAC Fellows Meeting

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By

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First Task: Earth to Orbit

(1) Existing Expendable Launch Vehicles: Atlas-V, Delta-4

(2) Shuttle-Derived Vehicles: Shuttle-C, Shuttle-Z, Shuttle-B, Ares, Wingless Orbiter, Flyback Booster, Liquid-rocket Boosters

(3) New Reusable Vehicle: Rocket, Rocket-based Combined Cycle

(4) Advanced Concepts: Tethers, Laser-powered rockets, Guns, etc.

Basic Problem: Achieve Orbital Speed (~7.5 km/s)

- V = Ve (ln Mo/Mf) – gravity – drag
- Best Ve ~ 3.5 – 4.0 km/s
- Hence Mo/Mf > 9

  (> 89% expendables)

Shuttle-Derived Vehicles:

A Launch Option for Space Exploration

A New Beginning?

Change Factors:

- China in Space
- Columbia Tragedy
- Shuttle Orbiter being phased out
- Space Station operational
- Orbital Space Plane: Dead
- Project Constellation

Basic change in space philosophy since 1981.

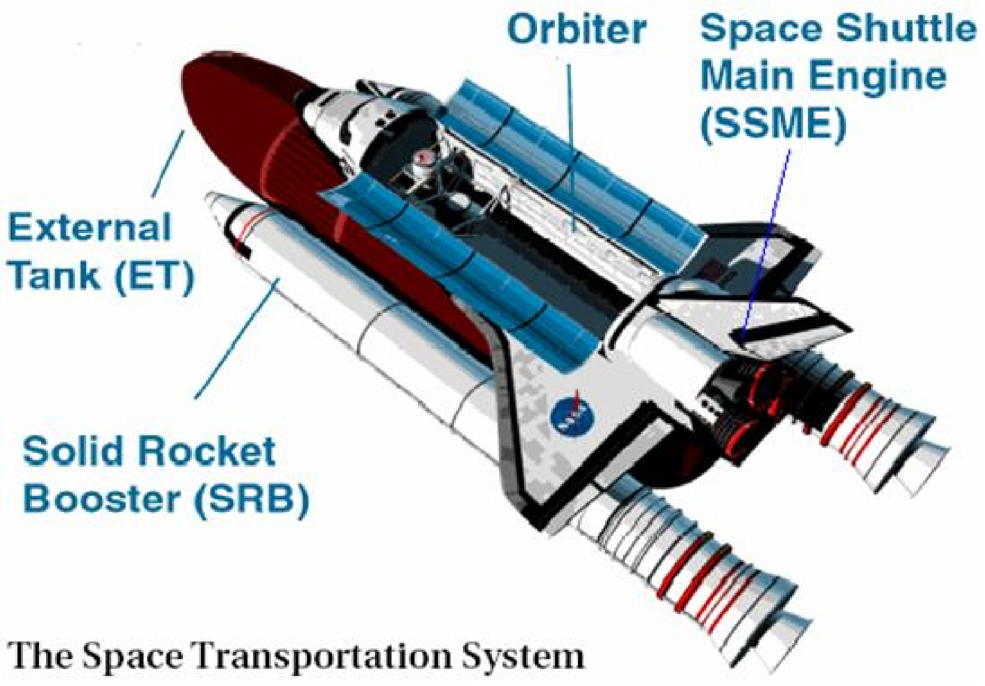
Now have “destination” in LEO, Orbiter phasing out, new competition.

What is a Shuttle-Derived Vehicle (SDV)?

- New vehicle using major components of NASA's Space Transportation System (STS).
- Modified and/or replaced:
  - Orbiter
  - Solid Rocket Boosters
  - External Tank
  - Engines (SSMEs)
- May be Piloted or Unpiloted

STS Components

- Orbiter
  - Crew, cargo, engines
  - 1.5 M-lb thrust
- Solid Rockets
  - Main liftoff thrust (5.2 M-lb)
  - "Pillars" on launch pad
- External Tank
  - 2 tanks: LOX, LH2
  - STS structural backbone
  - Brought almost to orbit, discarded



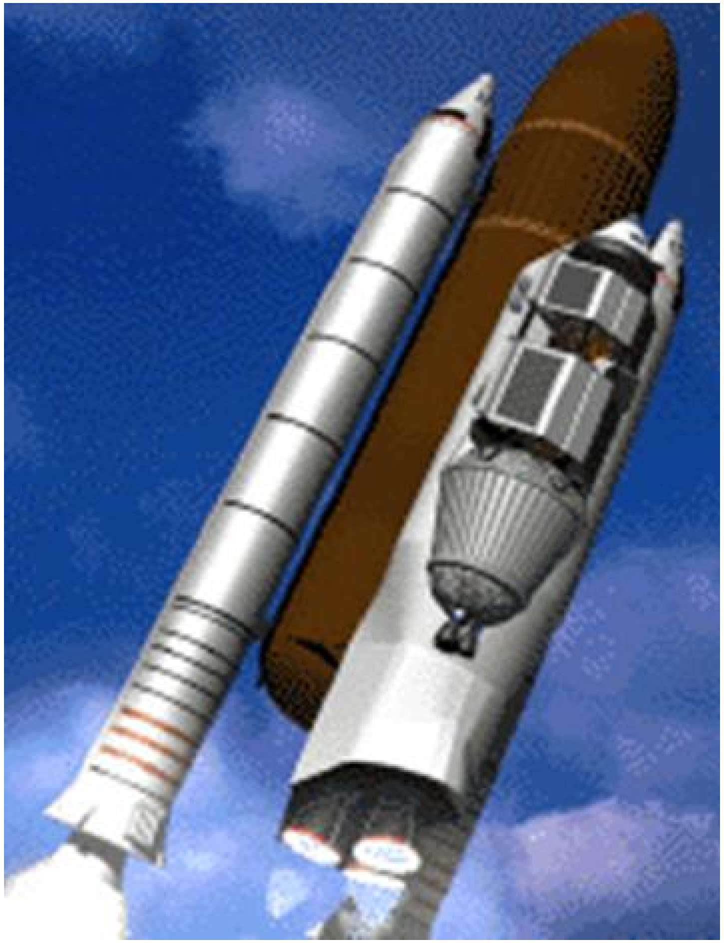
Why an SDV?

- **New missions**
  - **Cargo to LEO and beyond**
  - **New piloted-vehicle launcher**
  - **Large lunar/planetary missions**

- **Cargo versions: 2x-3x Orbiter**
  - **80 to 150 klb to LEO**
  - **Shuttle Orbiter: 50 to 65 klb**

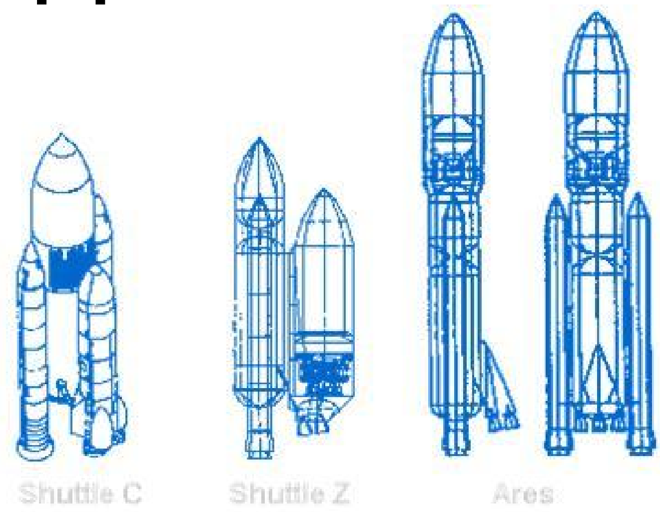
- **Reduced development costs**

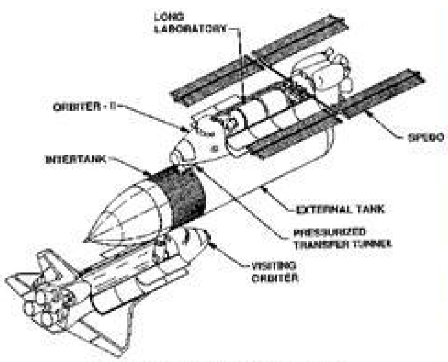
- **Use of STS infrastructure**
  - **Launch facilities**
  - **Ground support and processing**
  - **Design and production heritage**



Some SDV Approaches

- **Shuttle-C, Shuttle-Z, Shuttle-B**
  - Replace Orbiter with cargo module, upper stage, etc.
- **Inline HLLVs (e.g. Ares)**
  - Adapt engines, tankage, solids for new launch vehicle
- **New Booster Rockets**
  - Liquid, Flyback, Hybrid
- **Wingless Orbiter**
  - ET reaches orbit with non-returning piloted vehicle
- **SRB-X**
  - All-solid launcher using Shuttle Solid Rocket Boosters

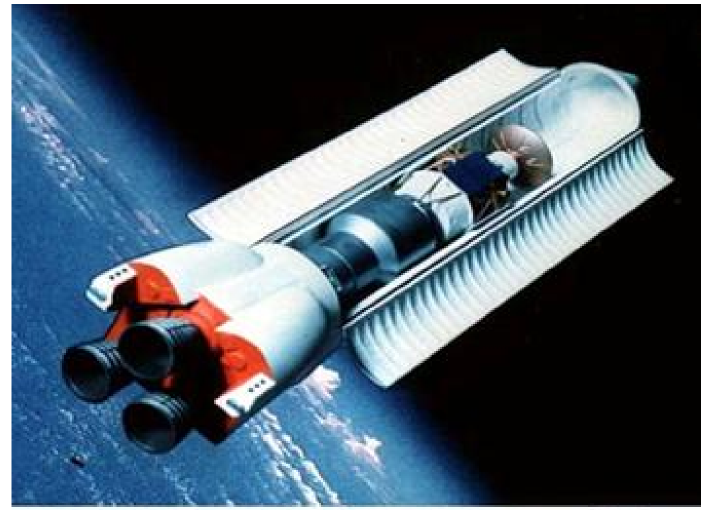




Side view of STS-Lab with a visiting Orbiter docked to it

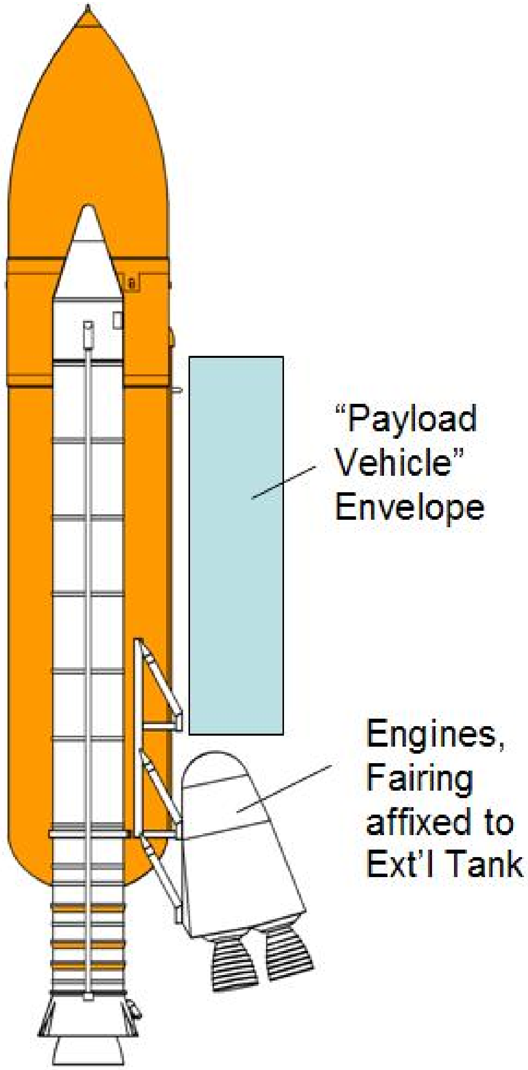
Shuttle-C

- Cargo canister replaces Orbiter
  - 2-3 SSMEs in Orbiter "boat-tail"
  - Engines, canister destroyed on re-entry
- 100 – 150 klb to LEO
- Closest SDV to reality
  - NASA-funded 1987-91
  - Killed by other Space Station Freedom needs



New Concept: Shuttle-B

- Use new expendable engines
  - Boeing RS-68, now used on Delta-IV
  - Northrop Grumman TR-106, ground tested
- Engines fixed to, discarded with ET
- Launcher-independent "payload vehicles"
  - Attached to ET above engines
    - Cargo Carrier
    - Space Exploration Vehicle
    - Payloads / Upper Stages
- Configuration shown is "schematic"

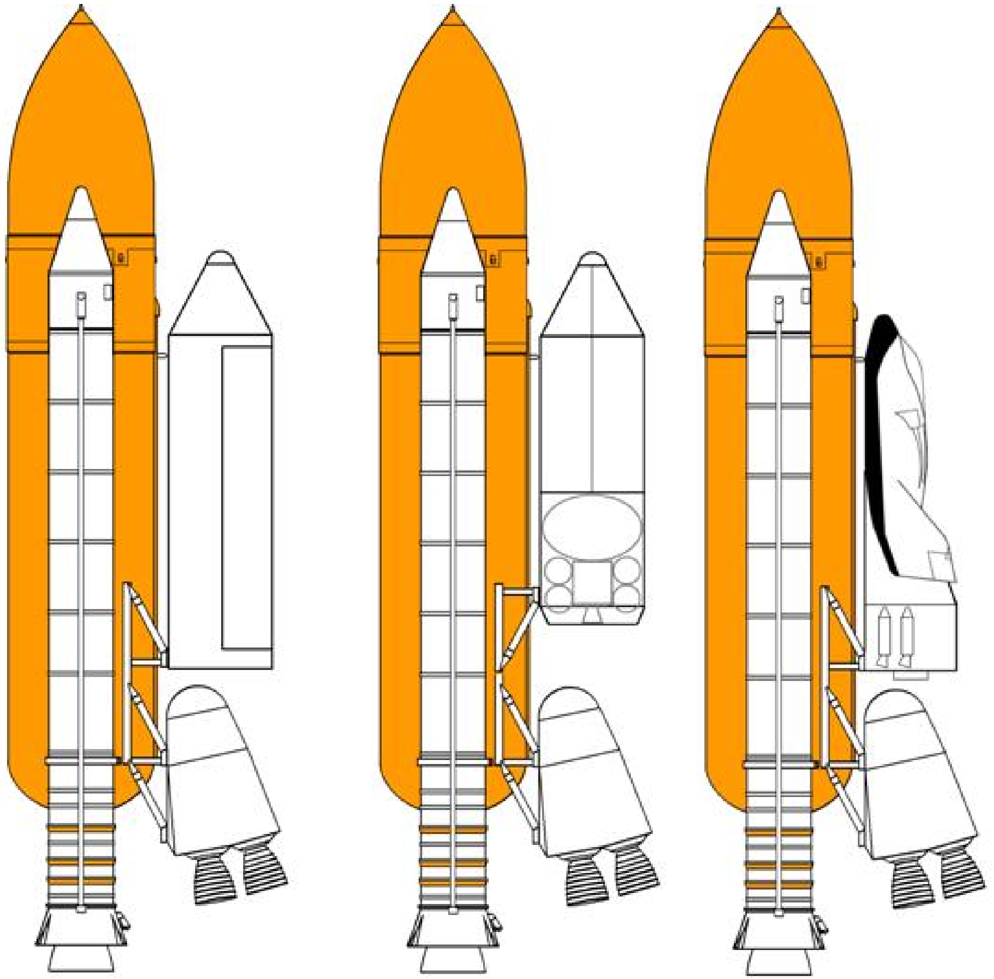


Shuttle-B Configurations

- •Cargo
- •Upper Stage
- •Space Exploration Vehicle

NOTE:

Configurations, payloads shown are speculative.



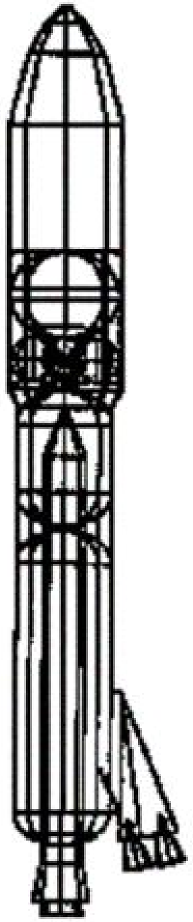
Shuttle-B Expendable Engines

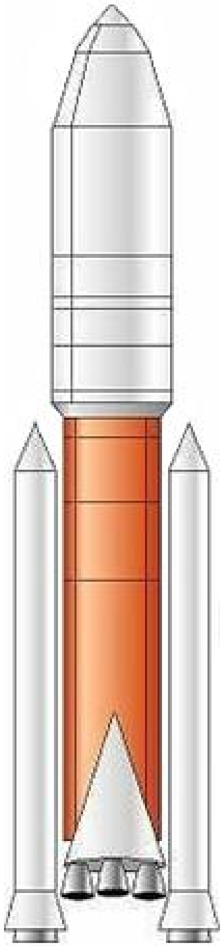
- **Boeing RS-68**
  - 750 klb thrust (vs 500 klb SSME)
  - Two RS-68s at 100% rated thrust match three SSMEs at 109% rated thrust
  - Some payload penalty: Isp 410 sec (vs 452 sec for SSME)
  - Reduced parts count, not man-rated.
  - Now flying, on Delta-IV Evolved Expendable Launch Vehicle (EELV).

- **Northrop Grumman (TRW) TR-106**
  - Pintle-injection (similar to LEM descent engine)
  - 650 klb thrust
  - Northrop Grumman claims one-half to one-fourth cost of RS-68 due to simplicity.
  - Limited test-firings in 2000; would require development, man-rating

Ares Launcher

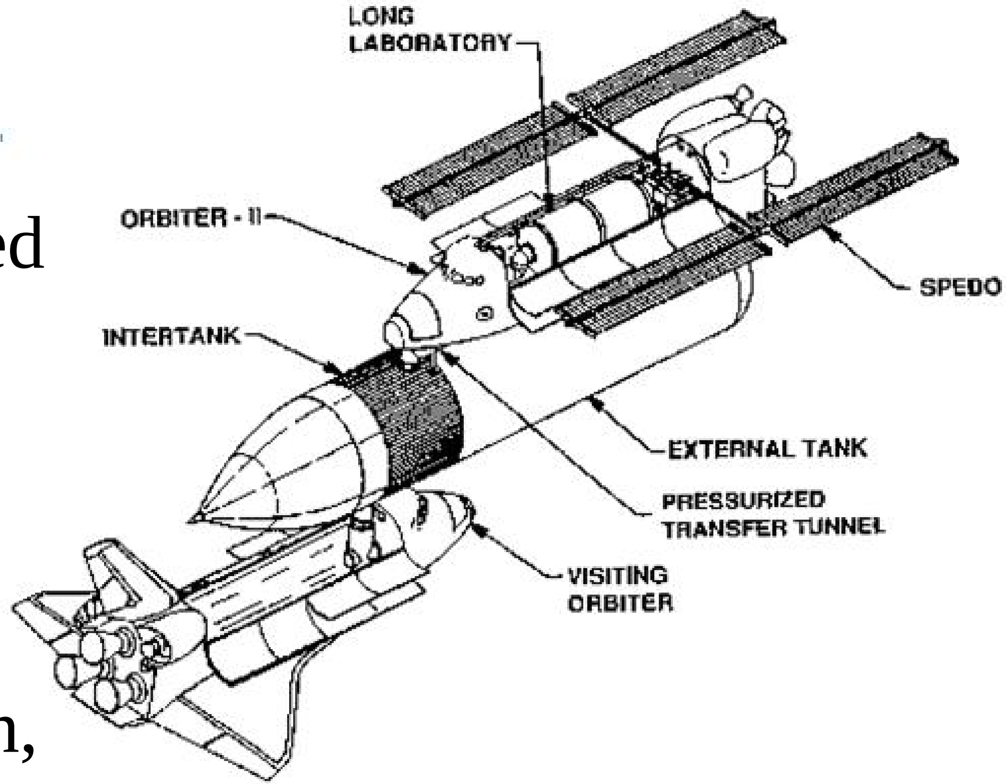
- **Direct ascent for “Mars Direct”**
  - Robert Zubrin, David Baker, Owen Gwynne
  - Circa 1991, Lockheed Martin
- **Semi-Inline Concept**
  - Use ET, SRBs
  - Side-mounted engines
  - Top-mounted cryogenic upper stage and payload
- **Payload: 104,000 lb to Mars**
  - Earth Return Vehicle
  - Habitation Module & Crew





Wingless Orbiter

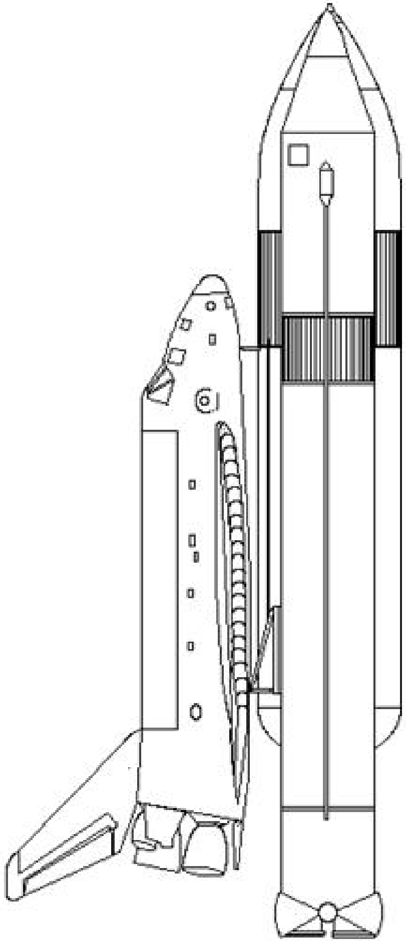
- General Dynamics, External Tanks Corp.
- Orbiter w/o wings lofted (no return)
- Connected to emptied External Tank
- Large-volume station with Orbiter crew cabin, payload bay



Side view of STS-Lab with a visiting Orbiter docked to it.

Liquid Rocket Boosters

- <u>Advantages</u>
  - Throttleable
  - Handling
- <u>Issues</u>
  - Complexity
  - Thrust
  - Cost
  - Reusability



Flyback Booster Concept

- Replace SRBs with liquid boosters that fly back to launch site.
- Jet engines for powered landing. Unpiloted.
- Flyback boost part of many early STS designs.
- Probably dead issue for STS following Columbia, Orbiter phase-out.
- May be an element in future SDV concepts.

SSTO: The “Holy Grail”

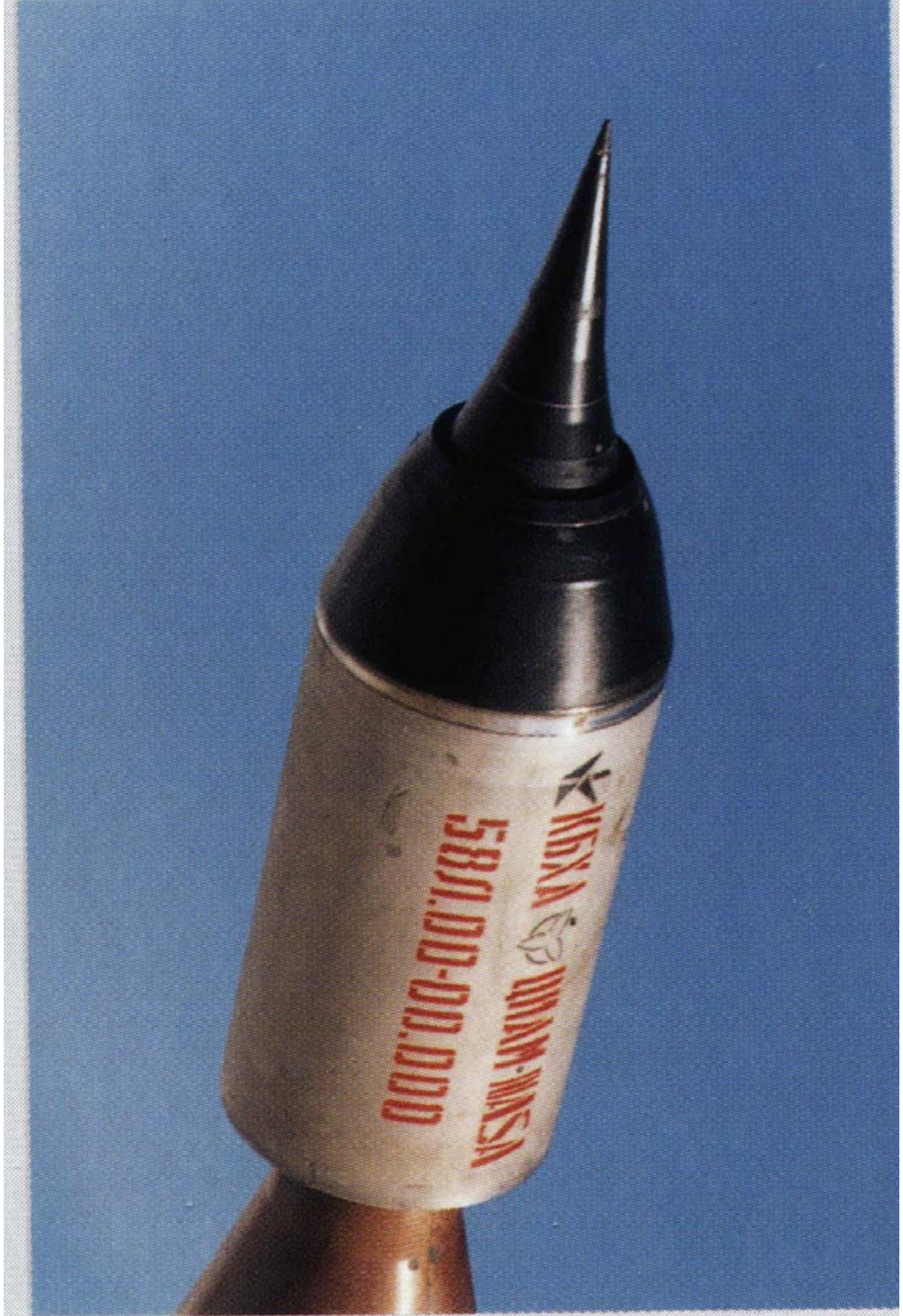
- Recent program: X-33 -> Venturestar
- Fully Reusable
- Propulsion: Hydrogen/Oxygen Aerospike Rocket
- Space Launch Initiative (NGLT): Two-Stage-to-Orbit (TSTO) using Kerosene and Oxygen
- Hyper-X; HyTech: Scramjet Technology
- No current large reusable LV development

Advanced-technology chemical rockets

- Solid/liquid hybrid rockets
- High thrust/weight, “Russian” cycles
- Gelled and metallized propellants
- High energy density materials

Generation-3 Technologies

- Combined-cycle engines
- Pulse-detonation engines
- Launch assist
- Gun launch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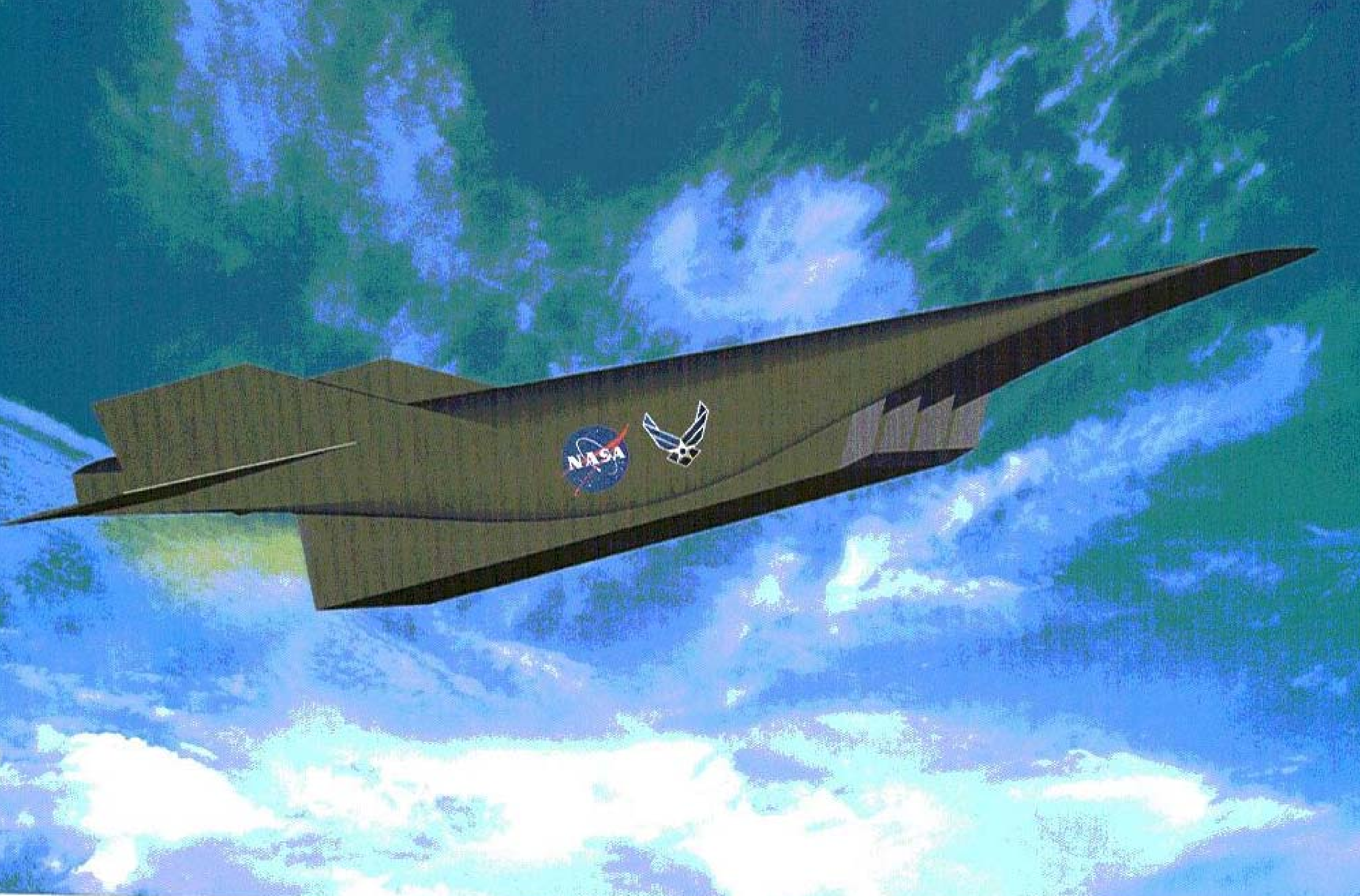


X-43C Hypersonic Flight Demonstrator

Once in Earth orbit, what next?

Space Exploration Vehicle (Project Constellation): Undefined; likely to be a modular set of Apollo-derived capsule-based vehicles

Project Prometheus: Nuclear-reactor powered electric thruster; new radioisotope powerplants for spacecraft

Nuclear thermal rocket: NERVA-based (solid-core reactor), particle-bed reactor, gas/plasma core, nuclear pulse (Orion)

Advanced concepts: Solar sails, laser-driven sails, tethers, M2P2, fusion-based rockets, antimatter propulsion, etc.

In-Space Propulsion- Currently Operational

- Chemical rockets (solid-propellant, liquid monopropellant, liquid bipropellant
- Arcjets
- Electromagnetic and electrostatic thrusters (all solar powered)
- Aerobraking and aerocapture (for planetary insertion)

Project Prometheus

Originally in Code S, Office of Space Science, now in Code T: Office of Space Exploration

(1) Performance upgrades to radioisotope power systems

(2) Development of a nuclear reactor, *ca* 100 kWe, to power an electric propulsion system and to provide large amounts of onboard power for scientific and exploration spacecraft.

(3) Development of a 100 kWe electric propulsion system

(4) Does not include nuclear thermal propulsion

Prometheus Heritage

(1) Current RTG powerplants (Galileo, Cassini): ca 250 We

(2) SP-100 reactor-powered thermoelectric: canceled 1992

(3) SNAP program (1950s, 1960s, 1970s):

- SNAP-8: 30,000-hr test
- SNAP-10A orbited 1964 (500 We SERT)
- SNAP-20 design: 20 MWe

(4) Electric thrusters for Deep Space 1; long-term testing at GRC; XIPS at Hughes

Prometheus Isotope Power Research

(1) Thermoelectric Conversion

- MIT: SiGe nanocomposites
- Hi-Z Technology: Quantum-well thermoelectrics
- Teledyne: segmented BiTe/PbTe-BiTe/TAGS/PbSnTe
- Teledyne: superlattice BiTe-PbTe/TAGS

(2) Thermophotovoltaic Conversion

-Creare, EDTEK, Essential Research

(3) Stirling-Cycle Conversion

- Sunpower, Cleveland State University (microfabrication)

(4) Brayton-Cycle Conversion

- Creare: Microfabrication and Demo

Prometheus Nuclear-Electric Power/Propulsion System Development

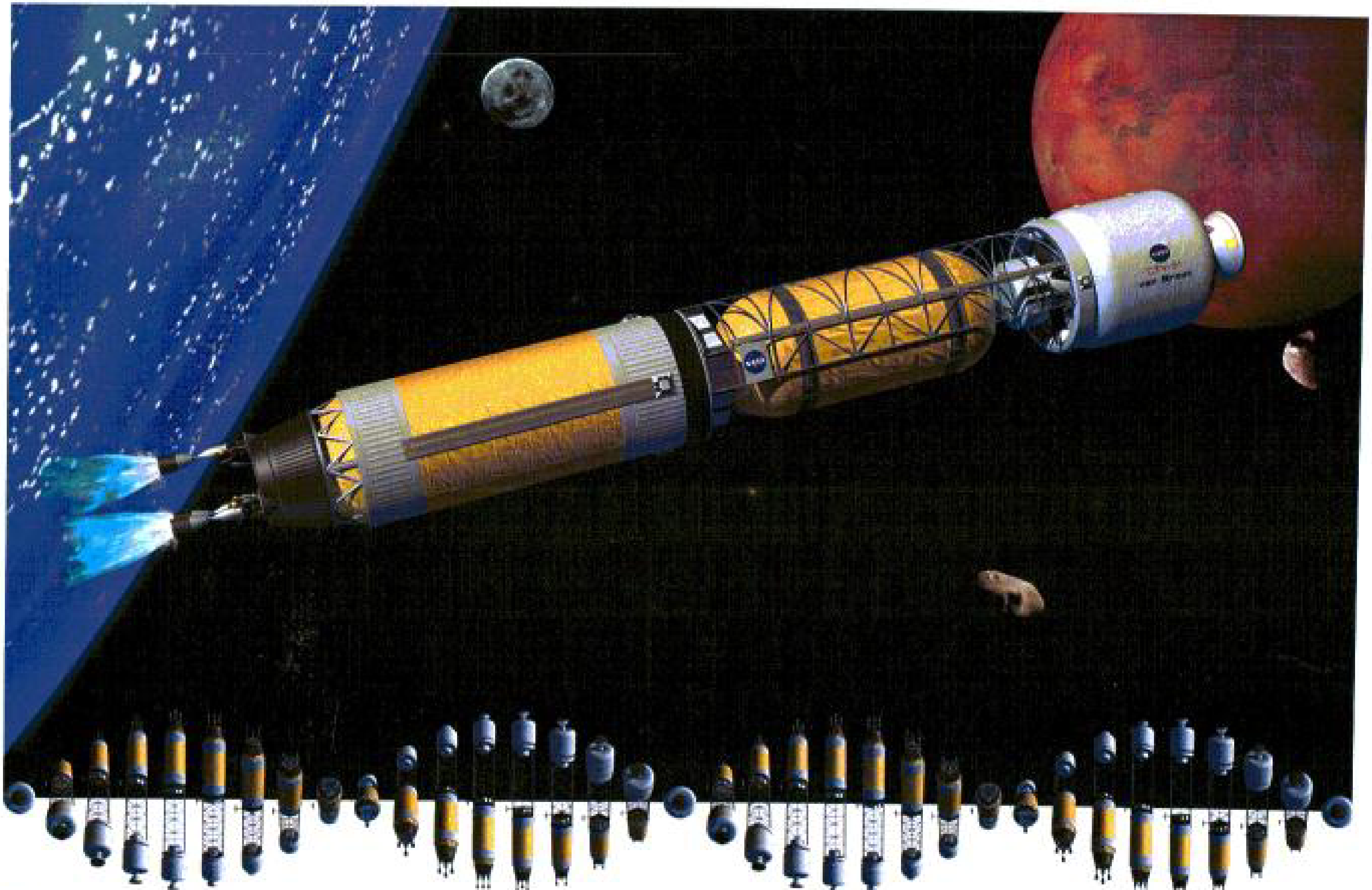
(1) Reactor Development: U.S. Department of Energy (Los Alamos)

(2) Power Conversion System and JIMO Spacecraft: ($50-million contracts awarded May 2003):

- Boeing Phantom Works
- Lockheed Martin
- Northrop-Grumman

(3) Ion Propulsion Thruster: JPL and NASA-GRC

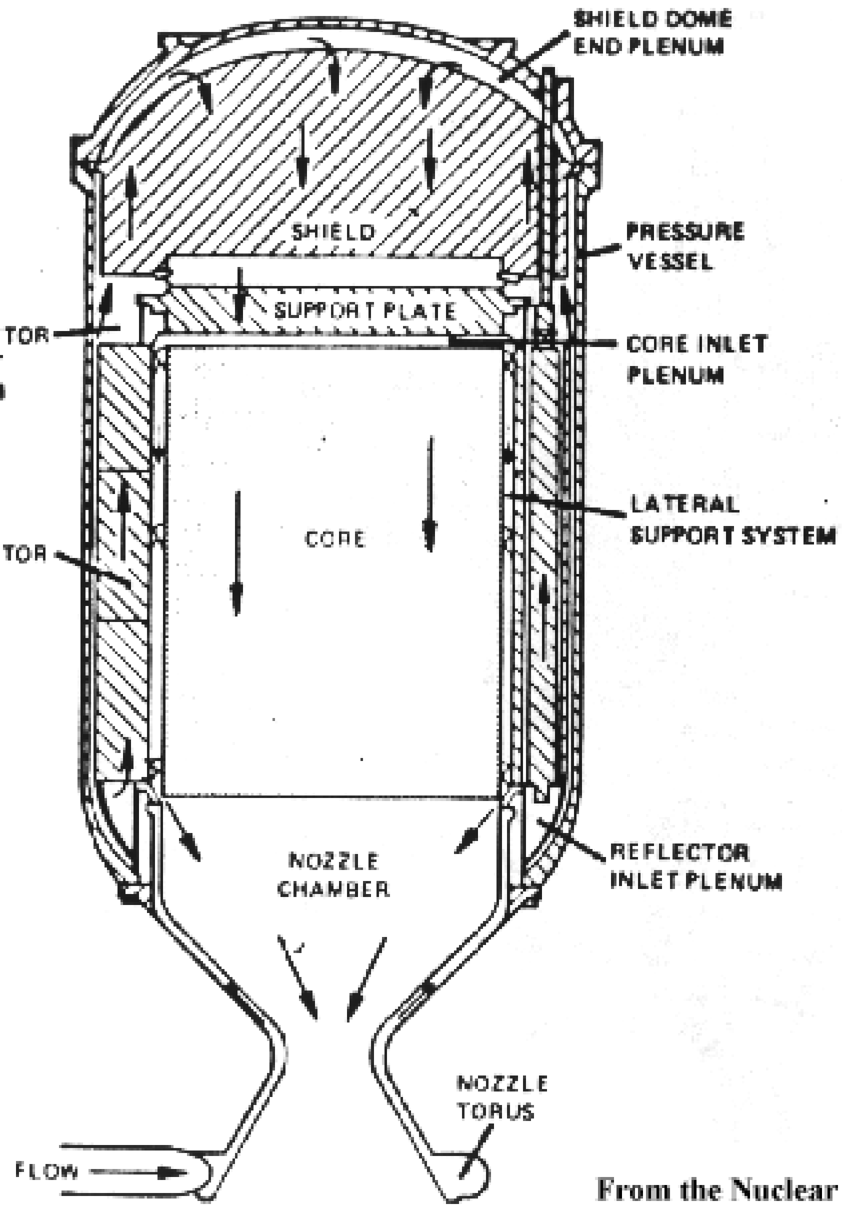
Bimodal Nuclear Thermal Rocket Propulsion



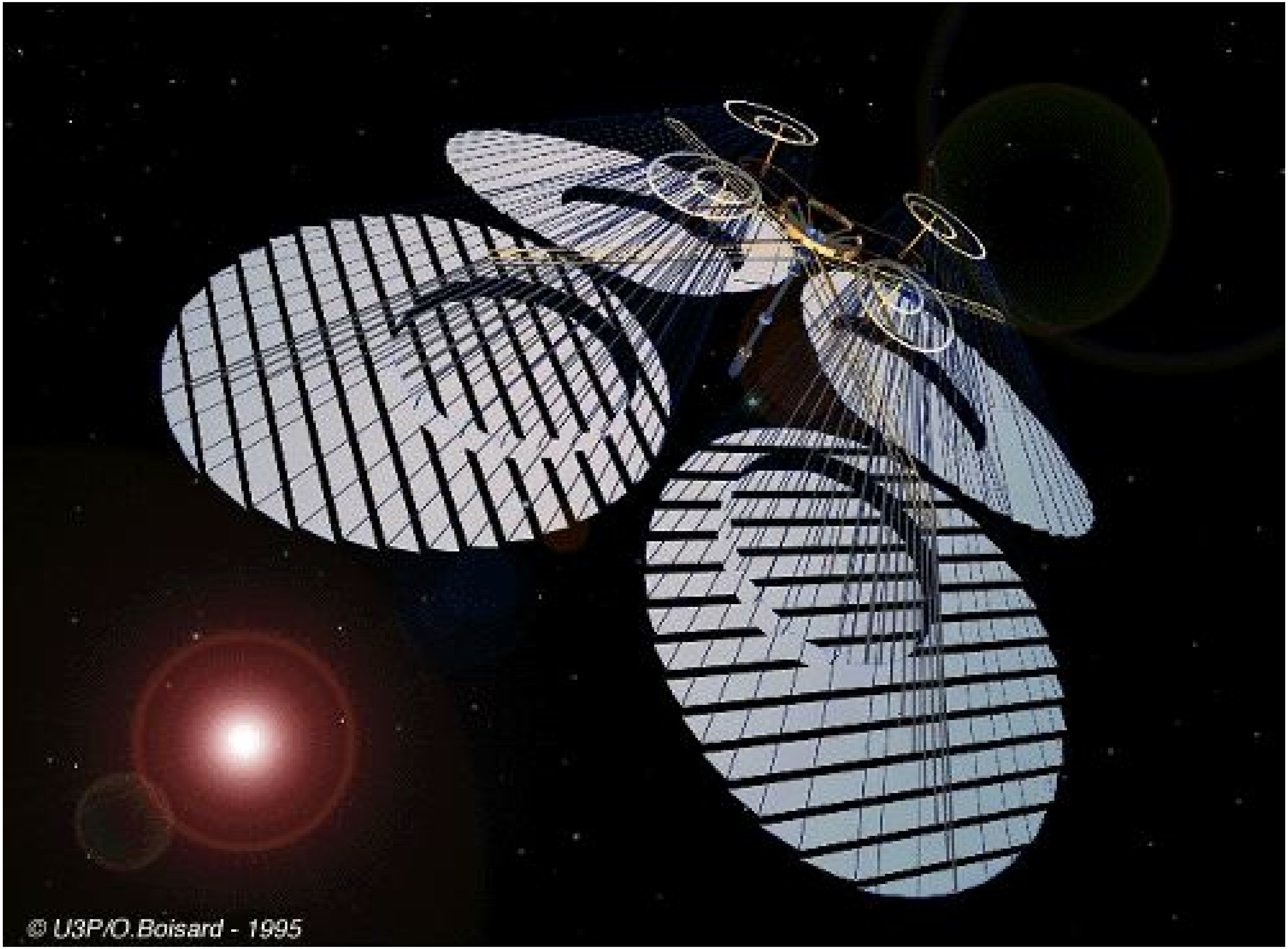
Blueprint for 21st Century Space Travel

For further information contact: Stanley K Borowski @grc.nasa.gov

TYPICAL ROCKET PROPULSION REACTOR



From the Nuclear Rocket Technologies web site.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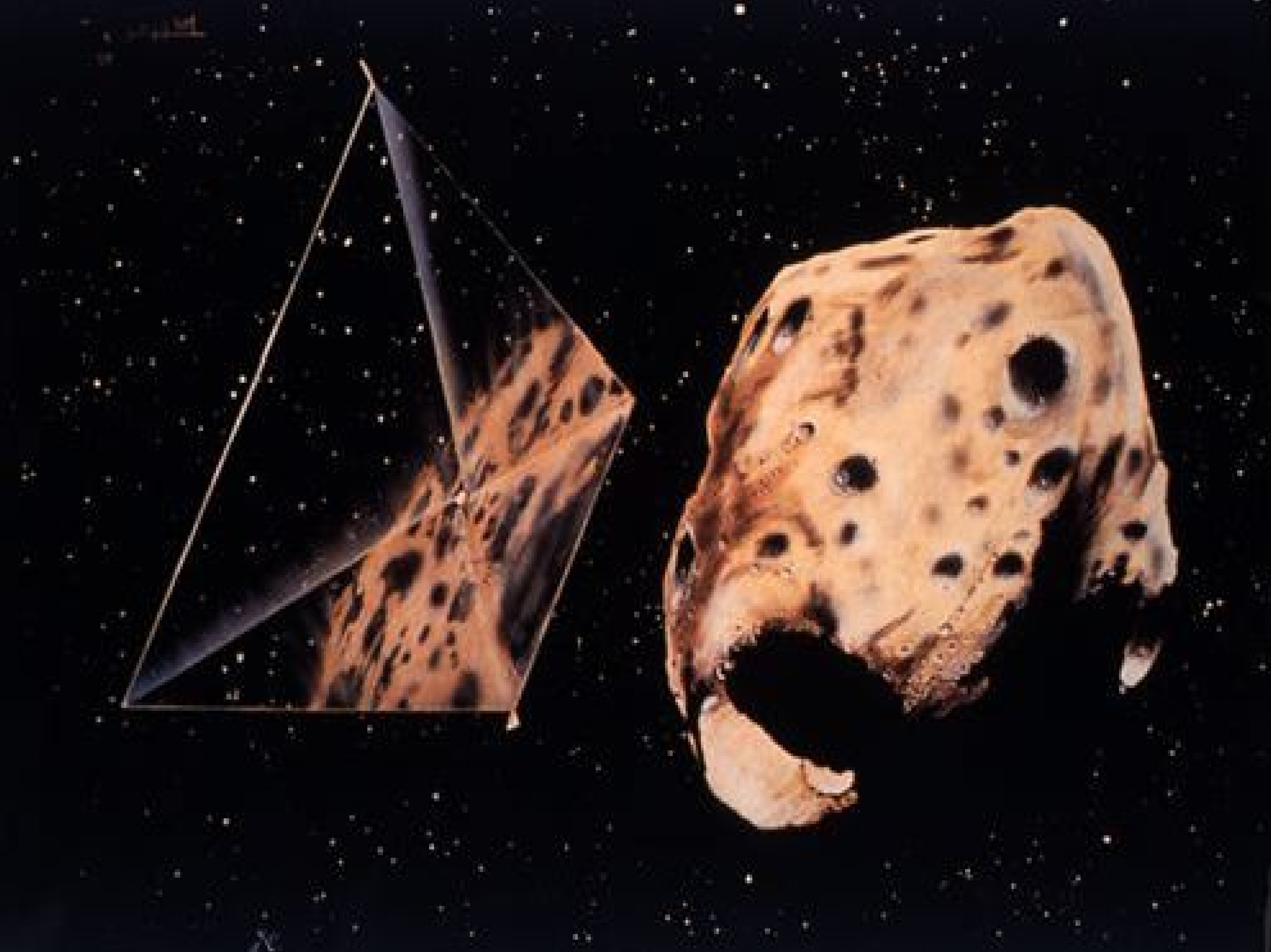
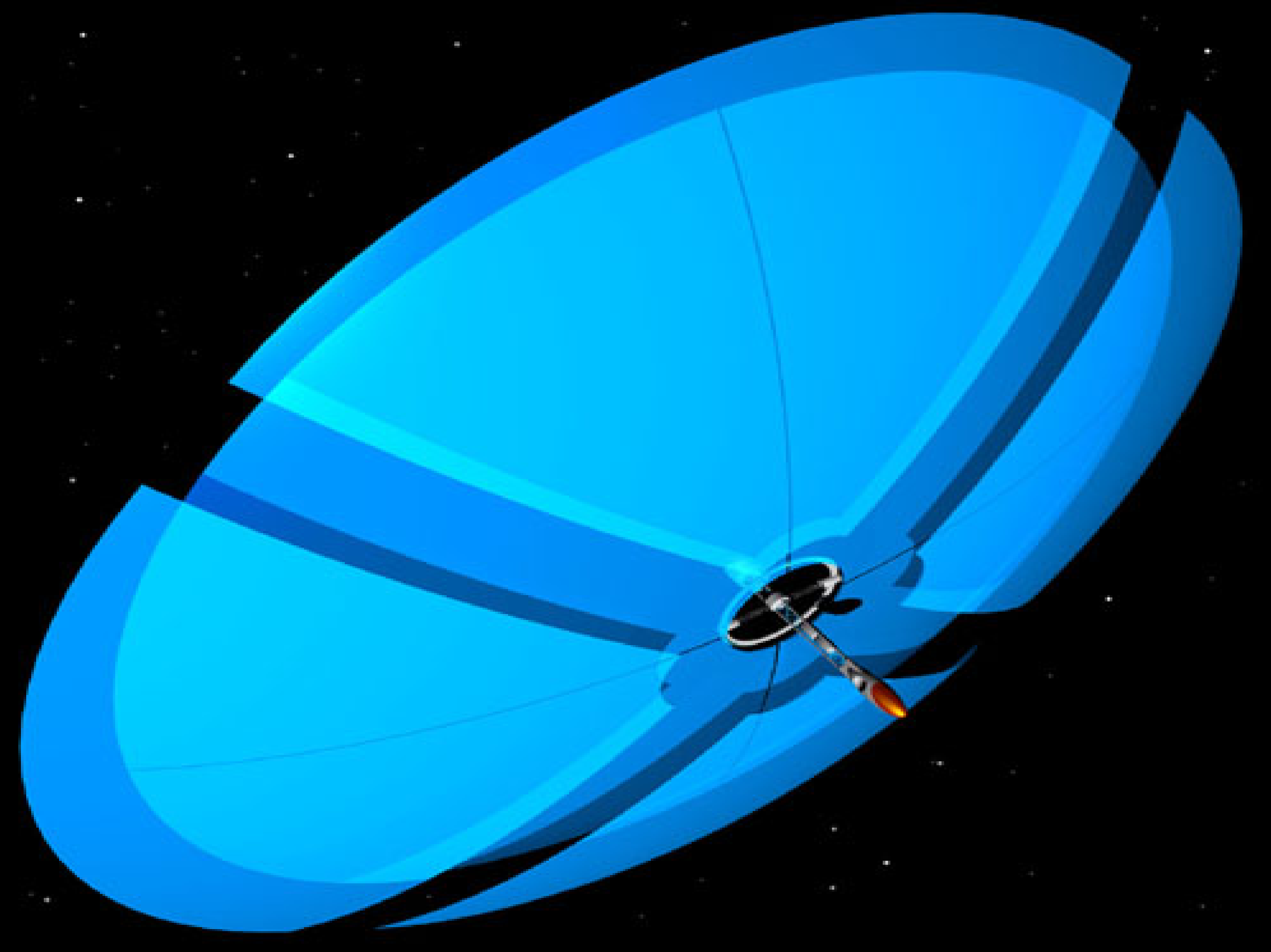
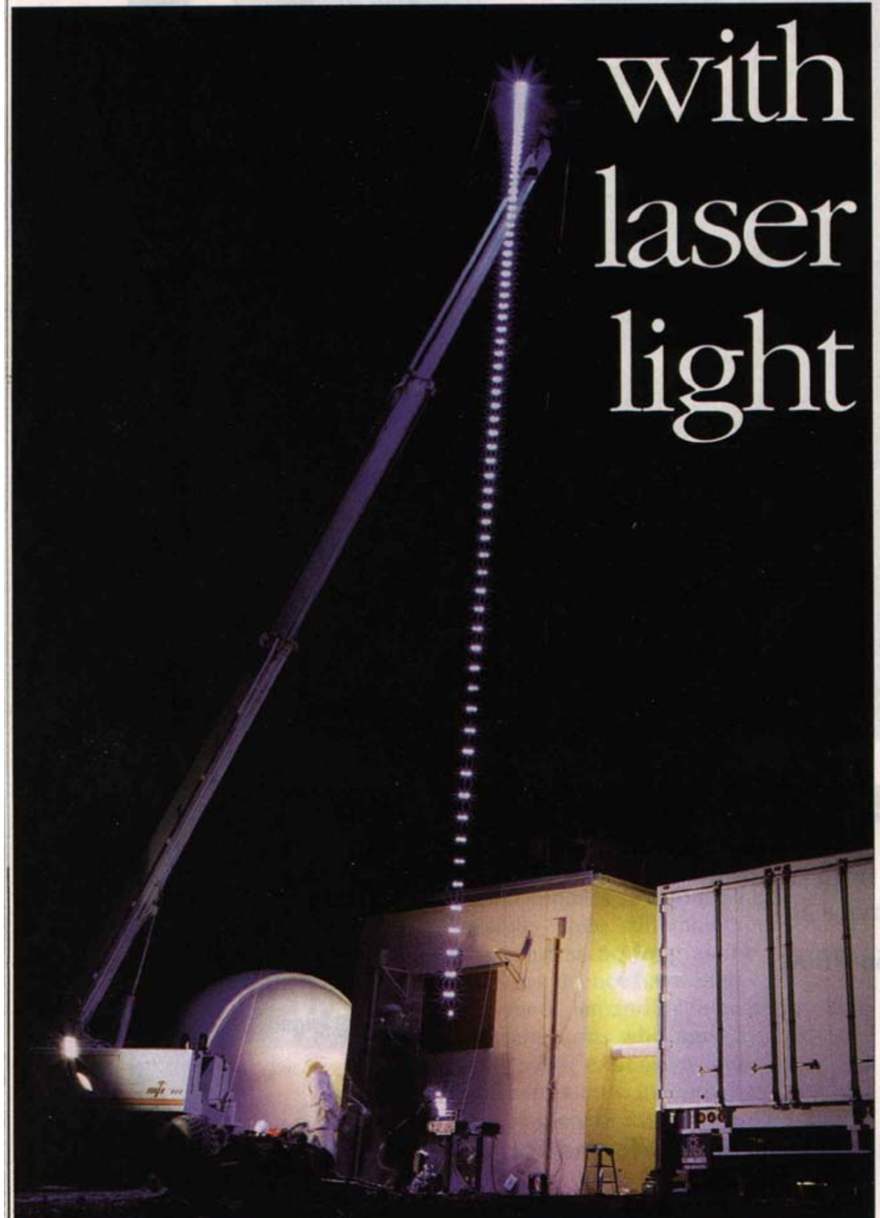


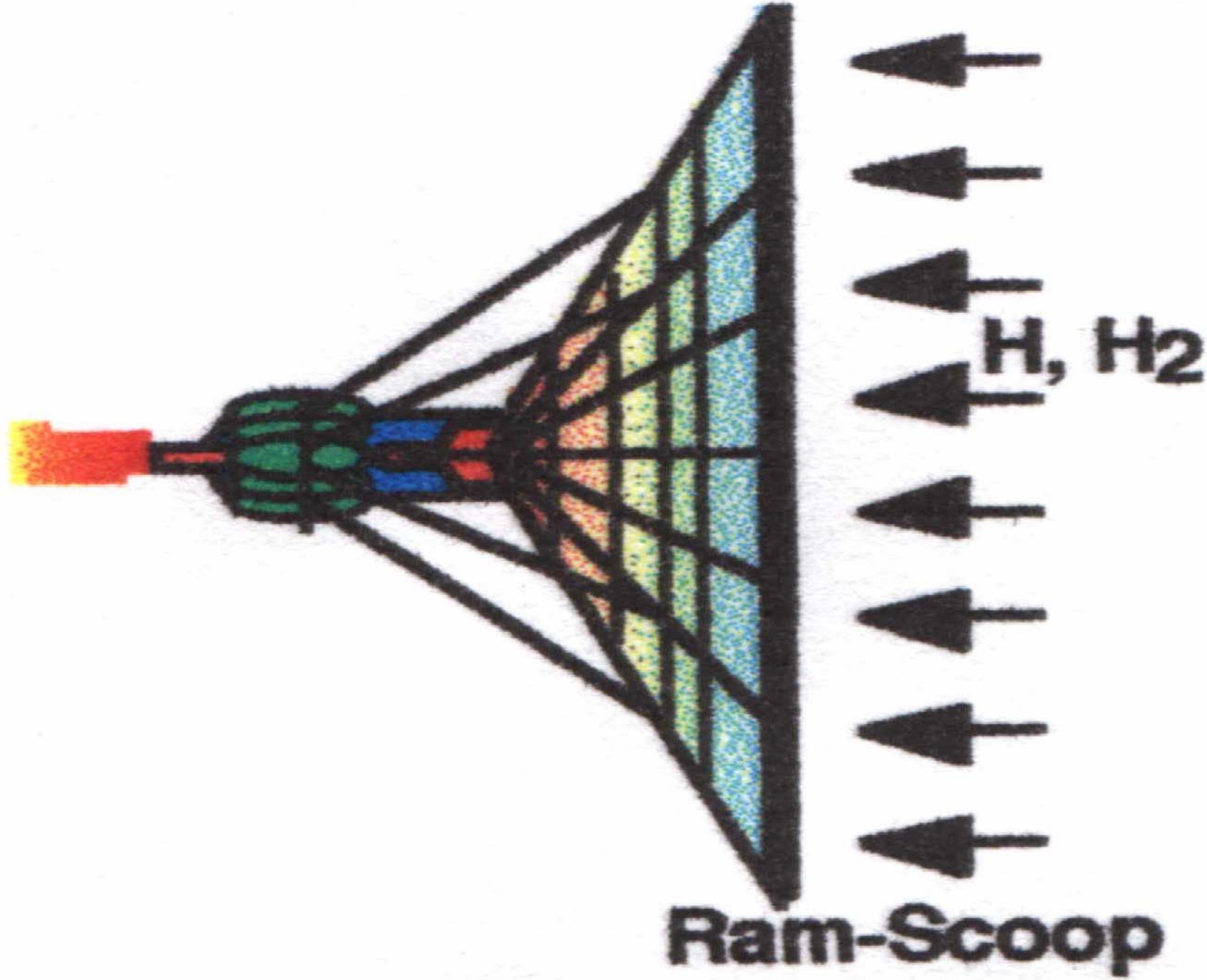


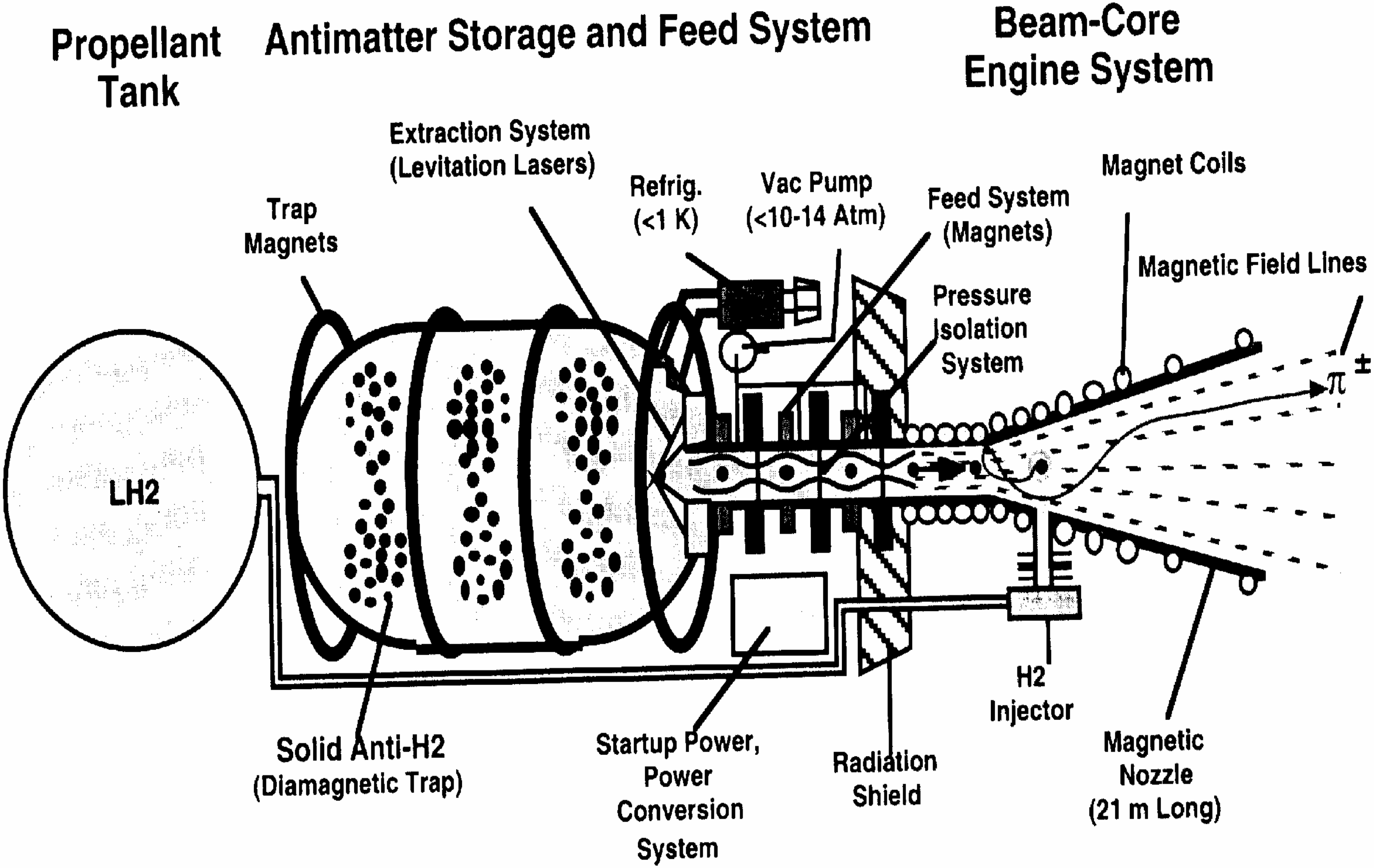
Launching with laser light



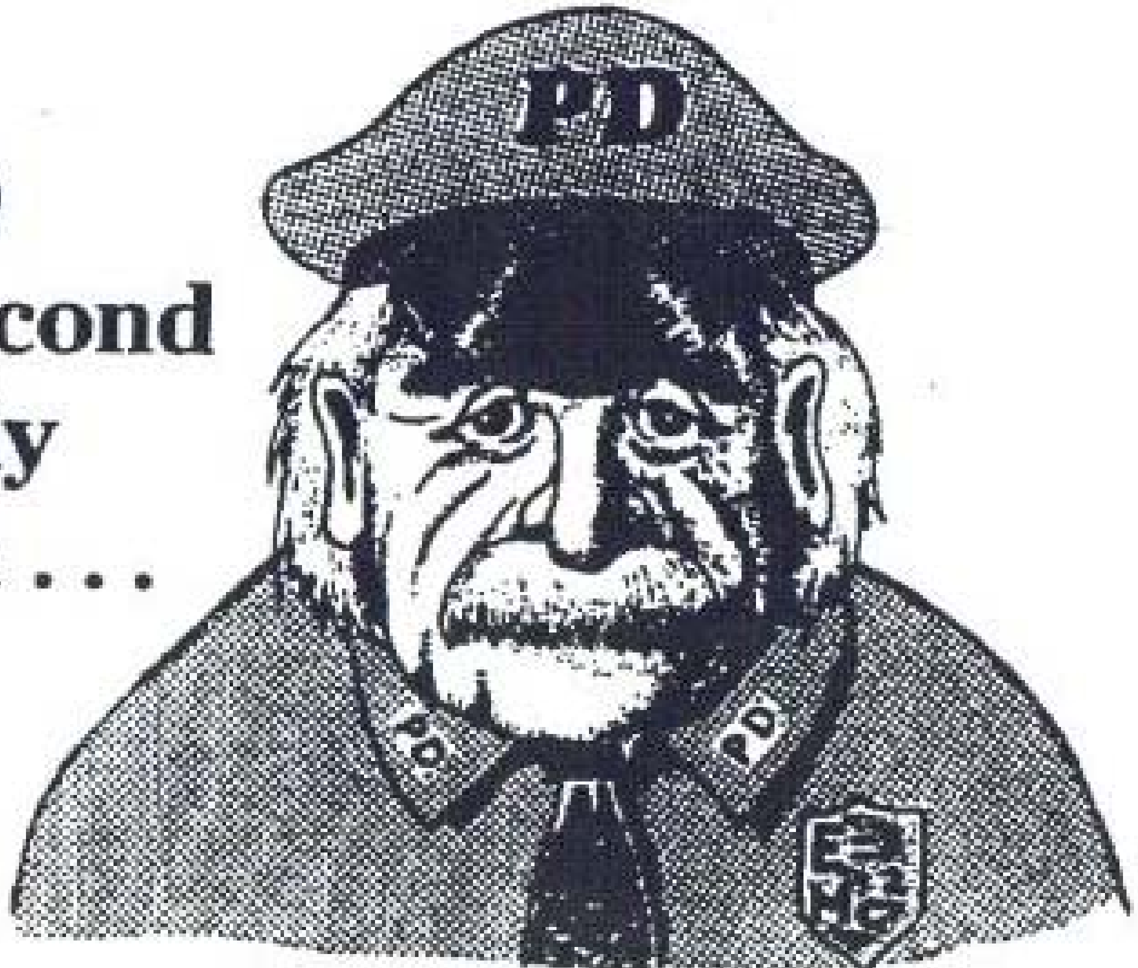
In-Space Propulsion: “Breakthrough” Concepts

- Nuclear fusion
- Interstellar ramjet
- Antimatter
- Breakthrough physics:
    - Wormholes
    - Warp drive
    - Antigravity


H, H_2
Ram-Scoop


Propellant Tank
Antimatter Storage and Feed System
Beam-Core Engine System
Extraction System (Levitation Lasers)
Trap Magnets
Refrig. (<1 K)
Vac Pump (<10-14 Atm)
Feed System (Magnets)
Magnet Coils
Magnetic Field Lines
Pressure Isolation System
LH2
π±
π
Solid Anti-H2 (Diamagnetic Trap)
Startup Power, Power Conversion System
Radiation Shield
H2 Injector
Magnetic Nozzle (21 m Long)

186,000
miles per second
is not only
a good idea . . .



IT'S THE LAW!