

# Exploration of Jovian Atmosphere Using Nuclear Ramjet Flyer

by

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# Characteristics of Nuclear Ramjet Flyer:

- Jovian atmosphere is an unlimited source of propellant.
- MITEE compact nuclear reactor is (nearly) unlimited source of heat.
- There are virtually no moving parts to wear out.

# MITEE Nuclear Engine

- MITEE (**M**iniature **R**ea**T**or **E**ng**E**)  
Ref.: *Acta Astronautica*, Vol. 44, No.2-4,  
1999
- Derivative of Ultra-Light Particle Bed  
Reactor (PBR) Developed for SDIO (1985 -  
1993)
- MITEE is lighter and more compact than  
PBR.

# MITEE Nuclear Engine (Contd.)

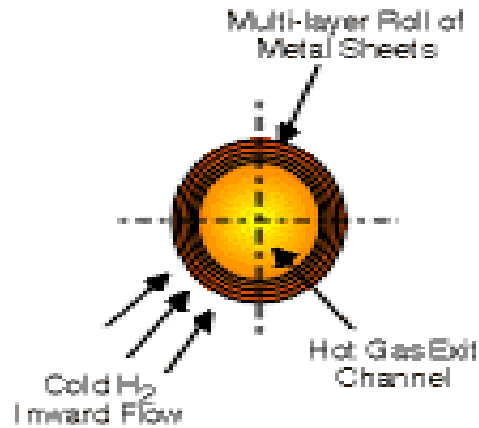
- Have Proposed MITEE-Based Rocket Engine for Solar System Exploration Missions:
  - Jupiter Orbiter: 2 Years
  - Europa Lander/Sample Return: 5 Years
  - Pluto Lander/Sample Return: 24 Years
  - Gravitational Lens at 550 AU: 30 Years

# MITEE Nuclear Engine (Contd.)

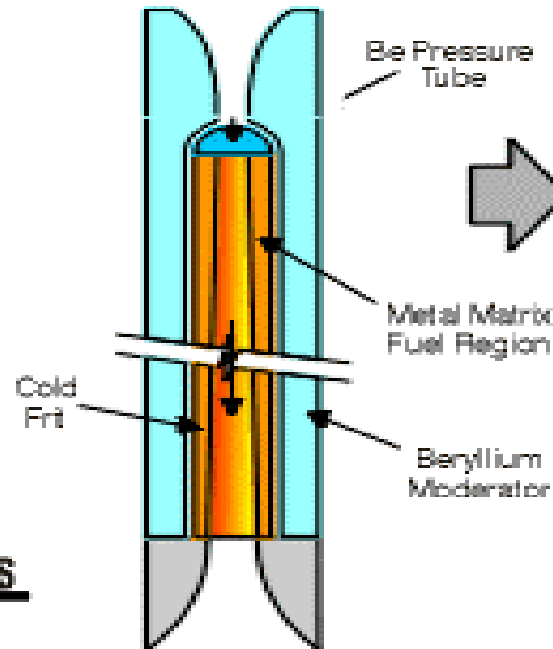
- MITEE can be adopted for ramjet application:
  - Replace  $H_2$  propellant supply system by inlet and diffuser.
  - Reduce power density from 10 MW/liter to 2 Mw/liter
  - Reduce outlet temperature from 3000 K to 1500 K
  - Increase operating life from ~1 hr to months.

# MITEE Nuclear Engine

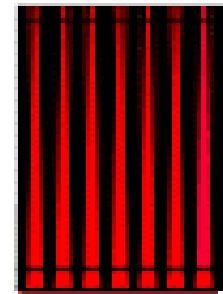
## MITEE FUEL REGION



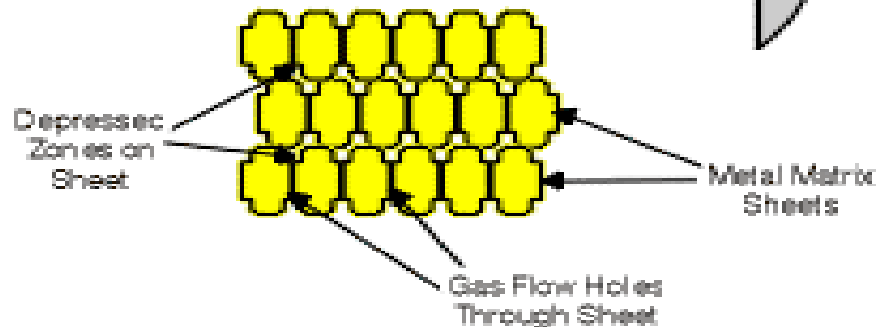
## FUEL ELEMENT



## REACTOR



## MULTIPLE SHEET LAYERS



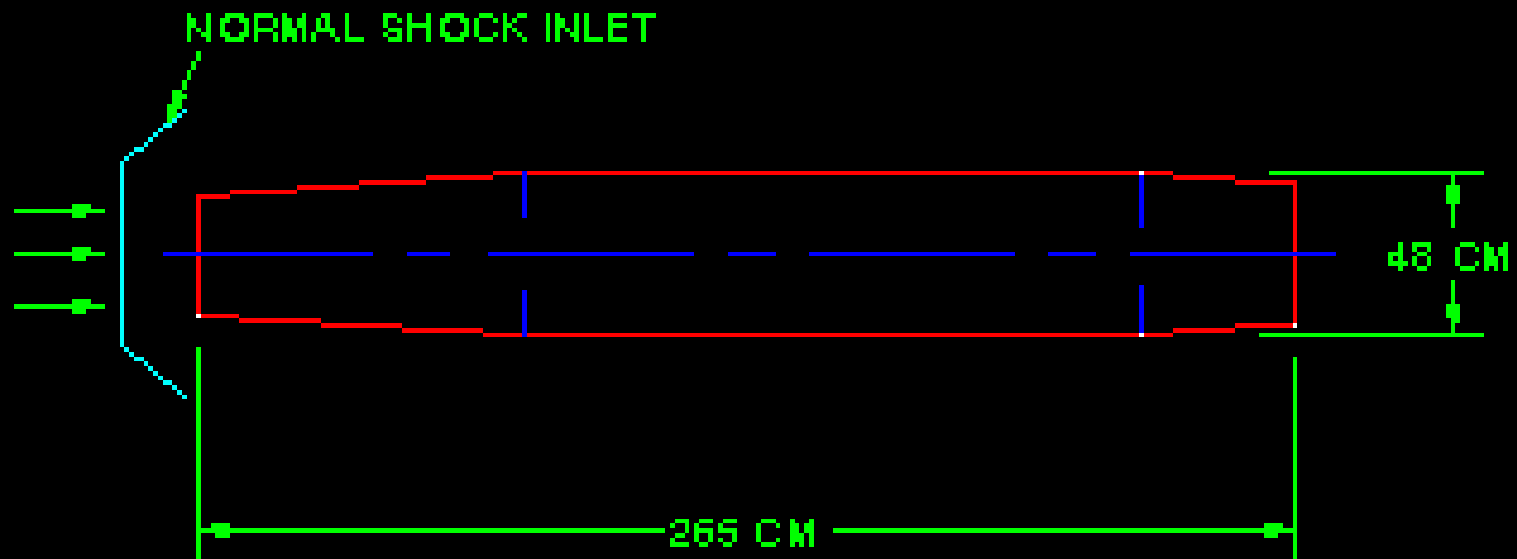
# Radiation Safety

- Before reactor startup nuclear fuel is not hazardous.
- Reactor will start operation after Jovian entry.
- During launch phase (from Earth) safety systems prevent criticality for all conceivable accidents.

# Ramjet Performance in Jovian Atmosphere

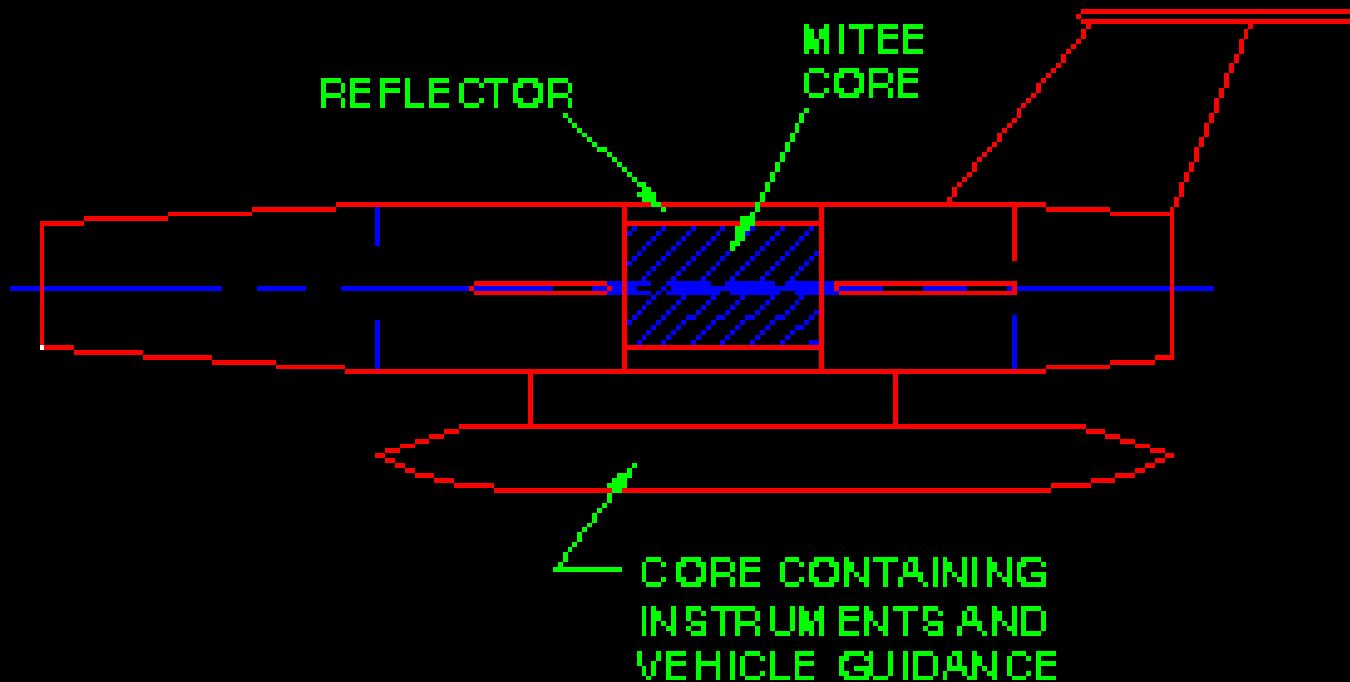
- Aerodynamic forces  $\sim \rho V^2$
- Assume perfect gas,  $\rho = pm_0/RT$
- $V = Ma = M(\gamma RT/m_0)^{1/2}$
- Then,  $\rho V^2 = \gamma p M^2$
- T and  $m_0$  cancel; To first order, performance of ramjet is same in Jovian atmosphere as on Earth, for same p and M.

# Marquardt Ramjet Engine

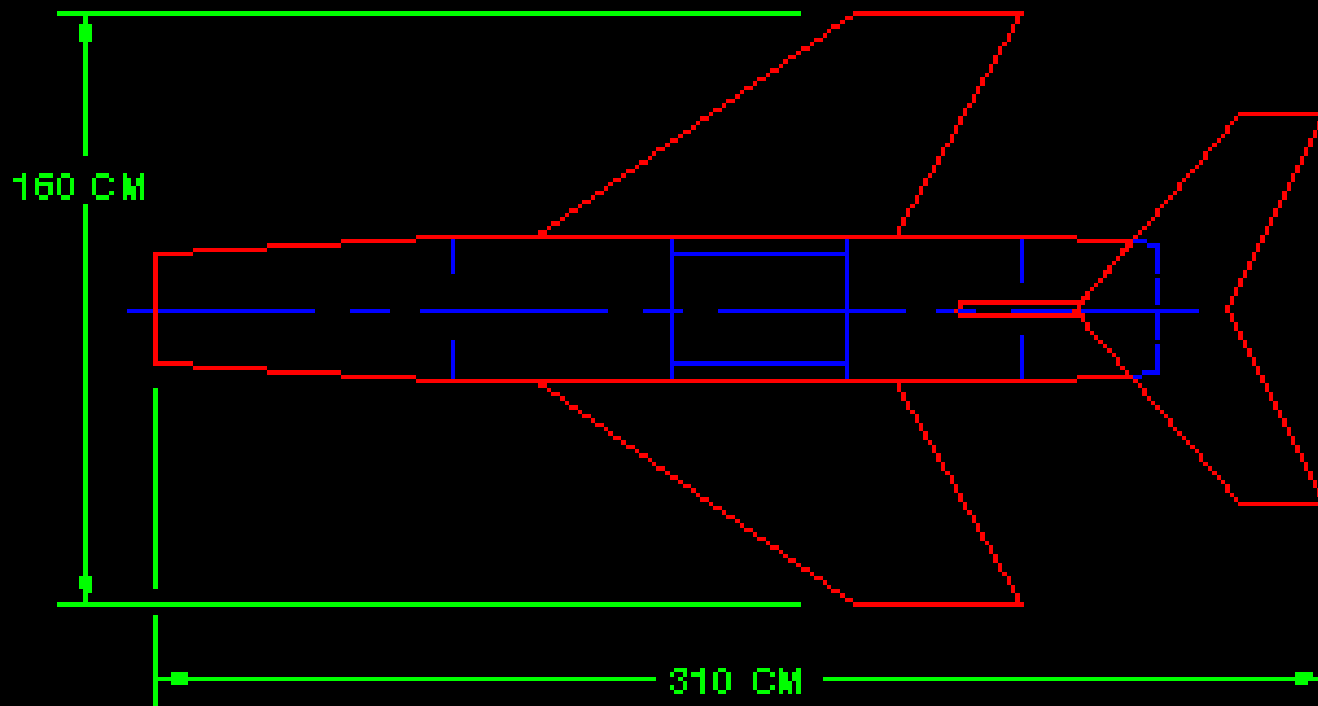


ENGINE MASS = 75 Kg  
ENGINE THRUST = 102,000 N @ S.L.  
                  2,600 N @ 18,000 M  
M RANGE = 0.9 TO 2.1

# Conceptual Design of Ramjet Flyer



# Conceptual Design of Ramjet Flyer (Contd.)



# Mass Budget of Ramjet Flyer

Component	Mass, kg
MITEE Engine	100
Ramjet Engine Encl.	75
Wings & Control Surf.	50
Pod Containing Instruments Vehicle Guidance	50
Total Mass:	275

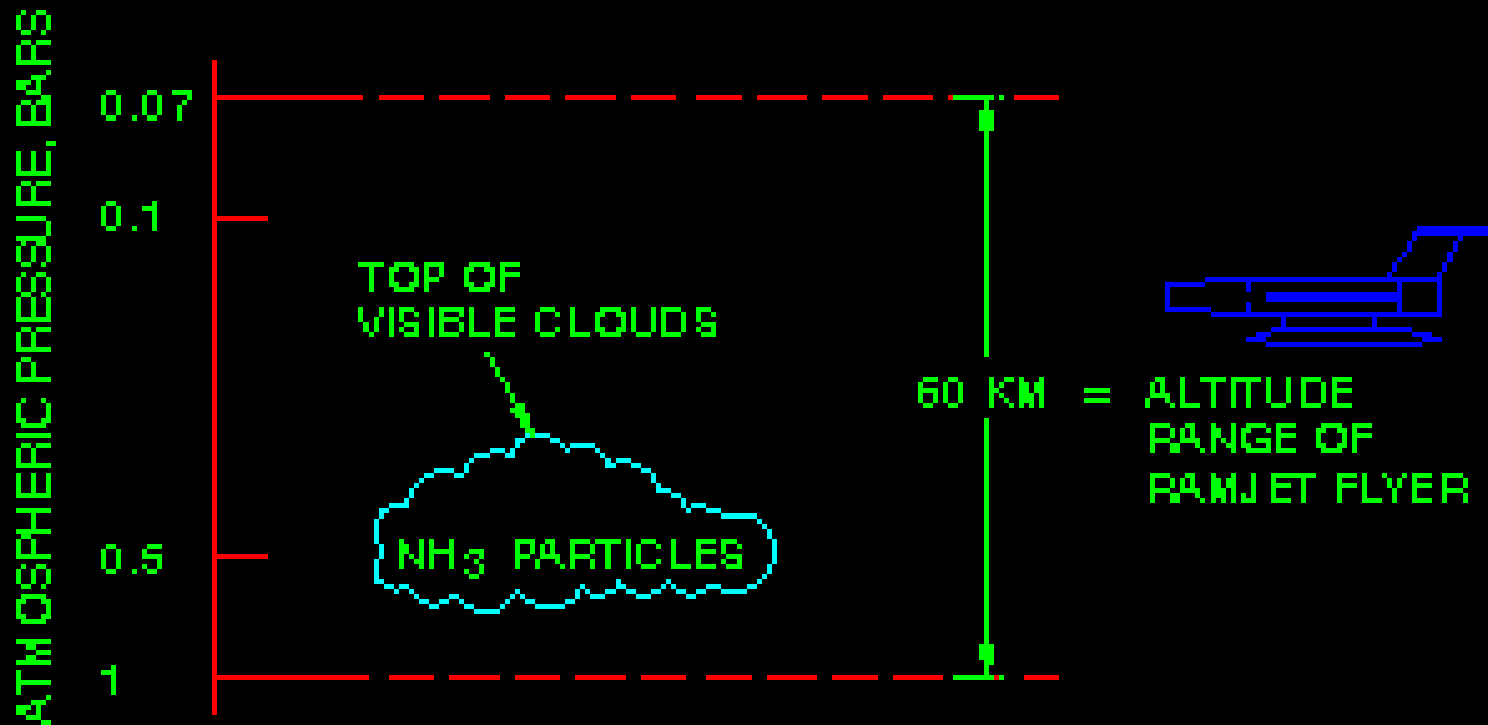
# Mission Characteristics

- Payload of 750 kg, comprised of
  - Ramjet Flyer 275 kg
  - Thermal Shield 275 kg
  - Companion Orbiter 200 kg
- Launch into LEO w. chemical rocket (Atlas IIAS).
- From LEO, fly to Jupiter using:
  - Chemical rocket with GA's: ~ 6 years
  - MITEE Nuclear rocket (if available): 2 years

# Mission Characteristics (Contd.)

- Deployment of Companion Satellite.  
Jovian entry profile similar to Galileo.
- When entry package has slowed to Mach ~1.5, flyer separates from thermal shield.  
Nuclear engine starts.
- Flyer commences atmospheric mapping operation.

# Flight Envelope in Jovian Atmosphere



# Atmospheric Properties Measured

- Pressure
- Temperature
- Chemical Composition
- Wind Velocity
- Cloud Particles and Size Distribution
- Lightning Frequency and Energy
- Energy Flux From Sunlight
- Energy Flux from Deep Interior

# Development Work Plan

- Task 1 : Preliminary Design of Engine
  - Thermal-Hydraulic Design
  - Neutronic Analysis
- Task 2: Preliminary Design of Flyer
  - Aerodynamic Configuration
  - Packaging for Jovian Entry
  - Detachment and Transition into Flight Mode

# Development Work Plan (Contd.)

- Task 3: Design Instrument Package
- Task 4: PD of Data Storage and Transmission
- Task 5: Mission Analysis
- Task 6: Establish Flight Envelopes in on Jupiter, Saturn, Neptune and Uranus
- Task 7: Nuclear Ramjet for Collection of He-3 on Uranus

# Preliminary Conclusions

- Ramjet flyer provides unique tool for mapping in detail Jovian atmosphere.
- Detailed data should help explain poorly understood features of Jovian atmosphere, e.g., the Great Red Spot.
- Concept applicable to other planetary atmospheres.