Exploration of Jovian Atmosphere Using Nuclear Ramjet Flyer

by

George Maise

Plus Ultra Technologies, Inc.

Stony Brook, New York

Presented at NIAC 3rd Annual Meeting,

NASA Ames, June 5-6, 2001

Presentation Contents

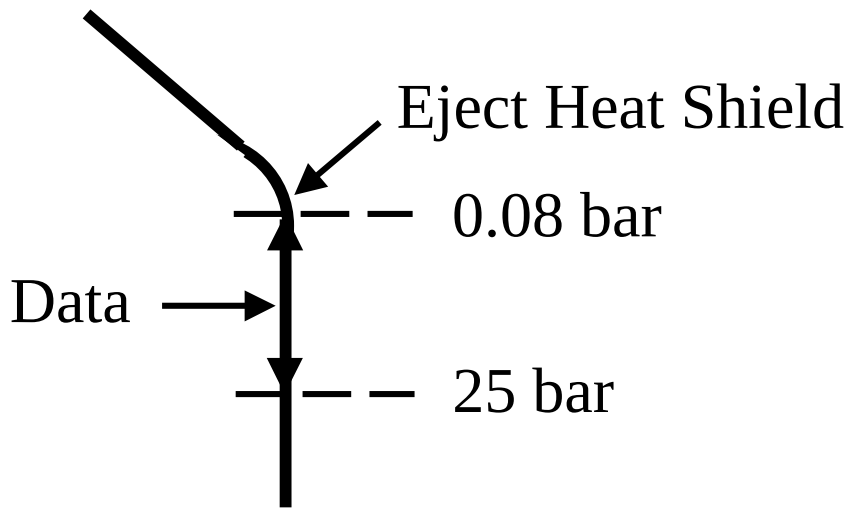
- Results of Phase I Study (May - October 2000)
- Outline of Phase II Tasks and preliminary findings

Galileo Probe

- To date, only direct measurement of Jovian atmospheric properties.

- Launched: 1989
- Entered Jovian atmosphere: December 7, 1995

- V = 47.4 km/s
- T_o = 15,000 deg C
- Decel. = 230 g



Characteristics of Nuclear Ramjet Flyer:

- Jovian atmosphere is an unlimited source of propellant.
- MITEE compact nuclear reactor is (nearly) unlimited source of heat.
- With few moving parts mechanical wear should be minimal.

Nuclear Ramjet Flyer

MITEE Nuclear Engine

- MITEE (**MI**niature Reac**T**or **E**engin**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.)

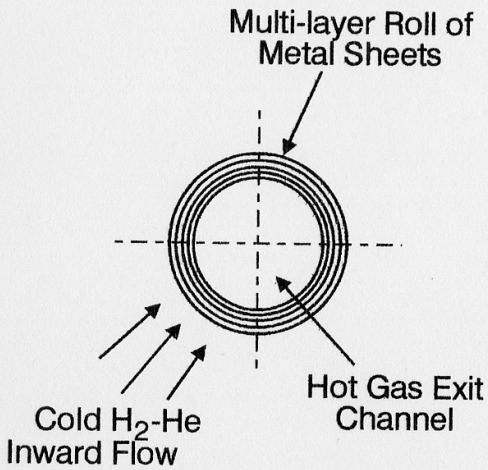
- Have Proposed MITEE-Based Rocket Engine for Solar System Exploration Missions:
  - Jupiter Orbiter: 2 Years
  - Europa Lander/Sample Return: 5 Years
  - Pluto Fly-By: 7 Years
  - Gavitational Lens at 550 AU: 30 Years

MITEE Nuclear Engine (Contd.)

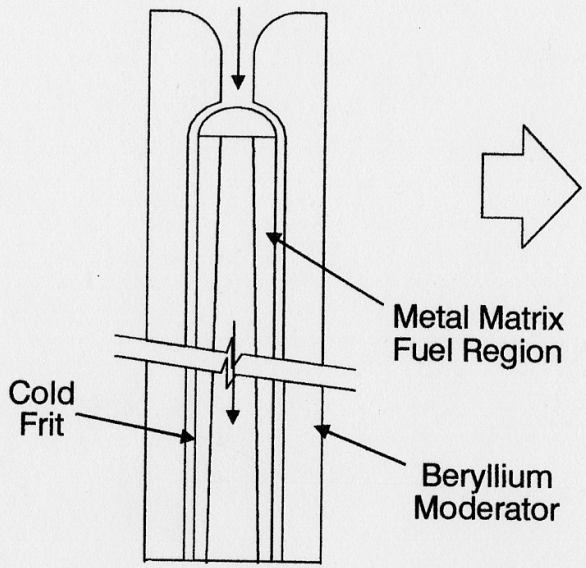
- MITEE can be adapted for ramjet application:
  - Replace H_2 propellant supply system by inlet and diffuser.
  - Reduce power density form 10 MW/liter to 2 Mw/liter
  - Reduce outlet temperature from 3000 K to 1500 K
  - Increase operating life from ~1 hr to months.

THE MITEE REACTOR ASSEMBLY

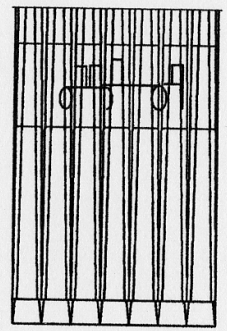
MITEE FUEL REGION



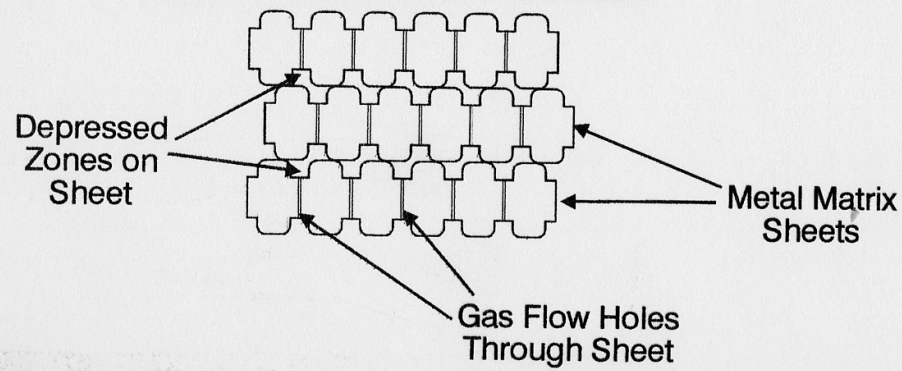
FUEL ELEMENT



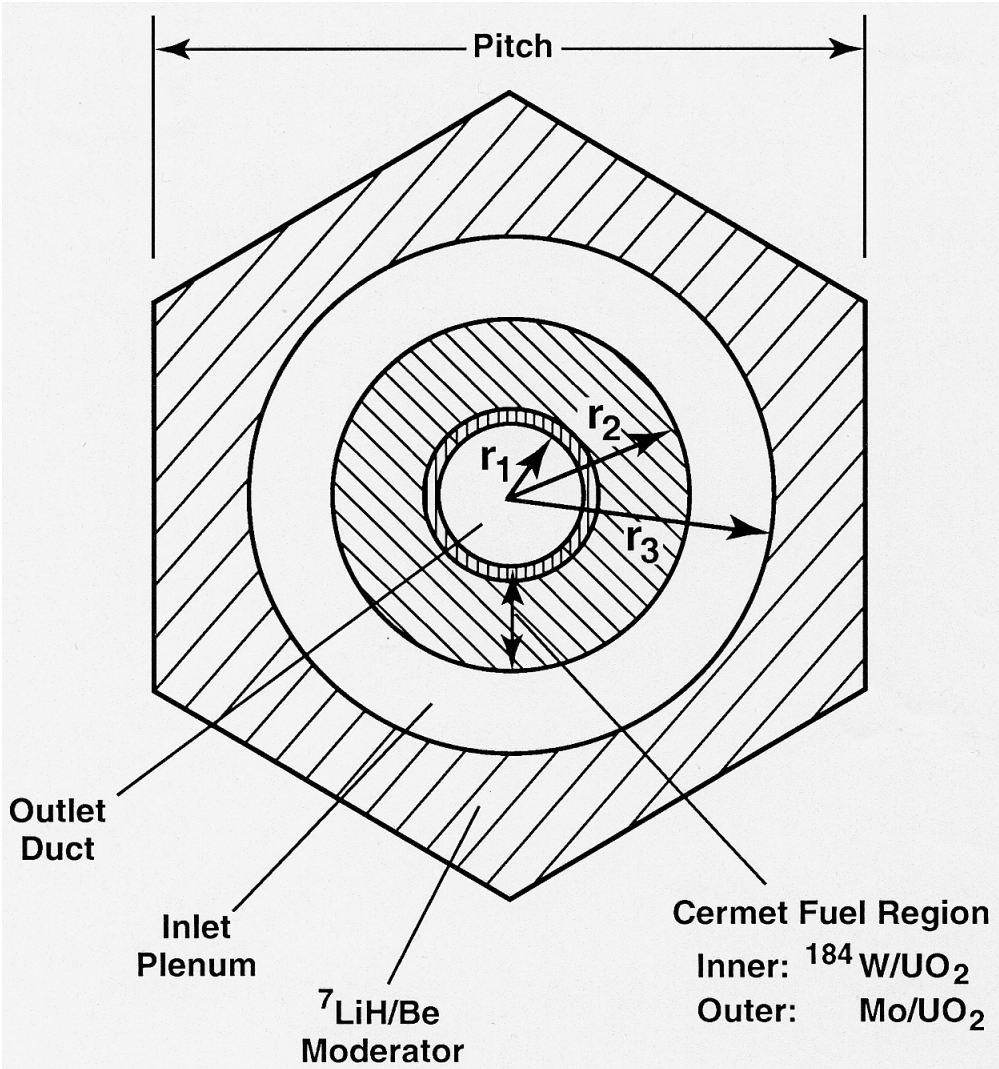
REACTOR



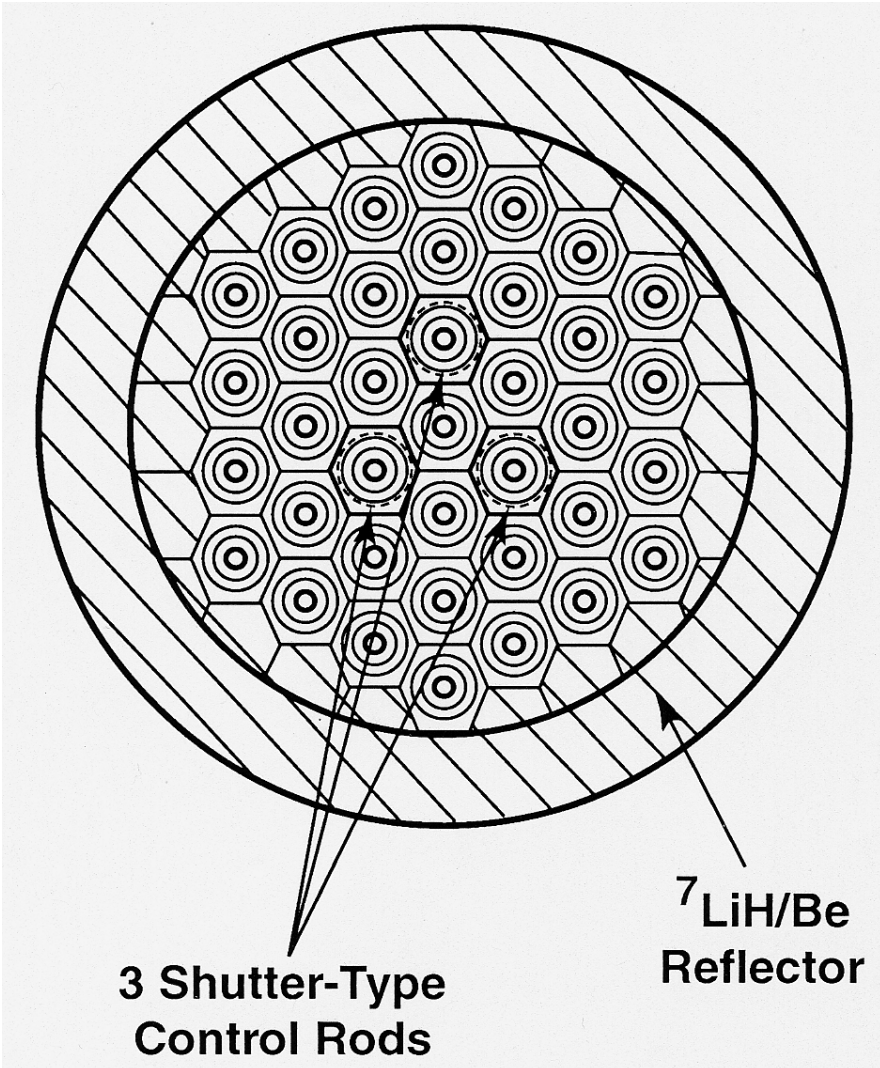
MULTIPLE SHEET LAYERS



Cross Section of Single Fuel Element



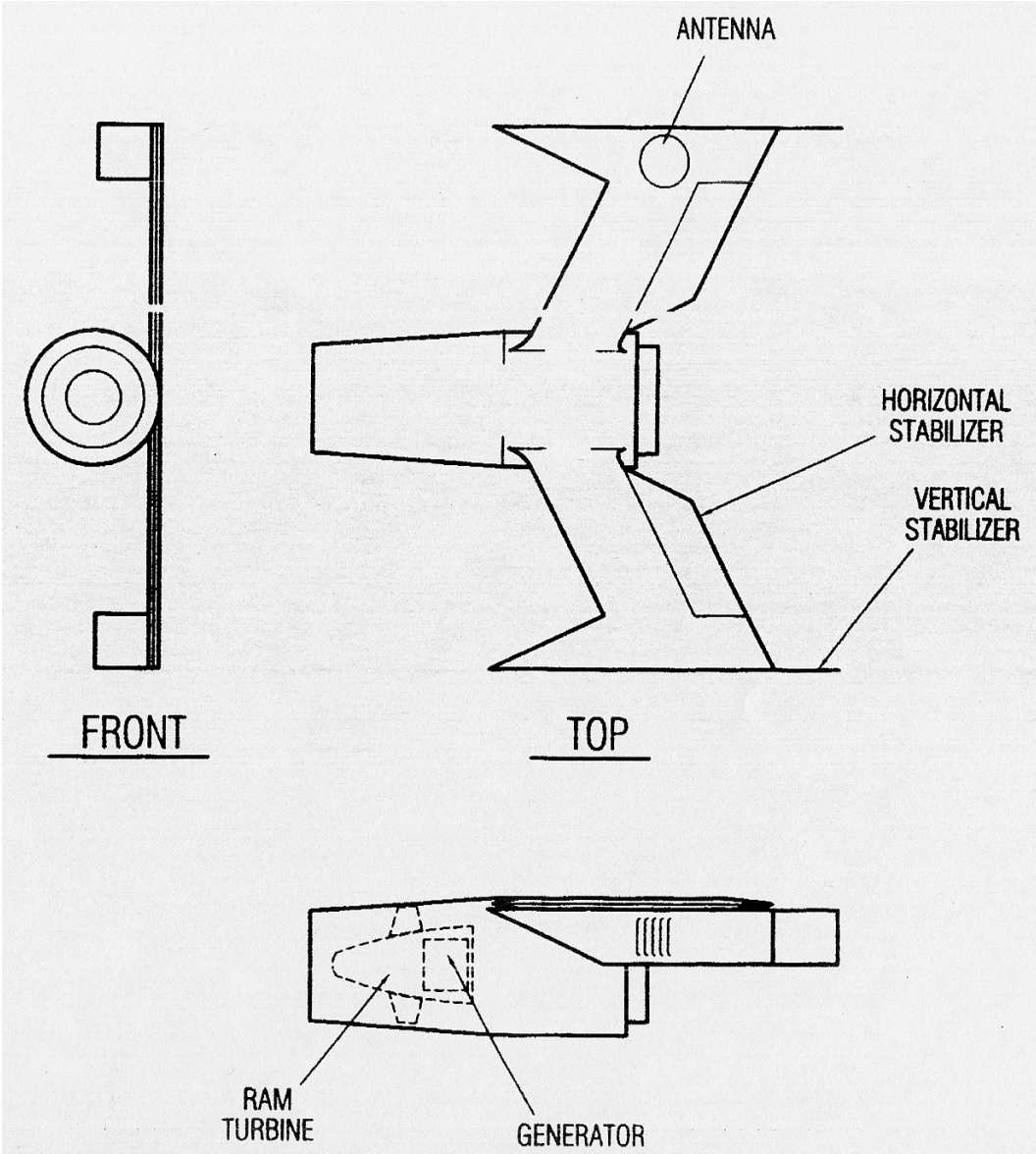
Cross Section of Core



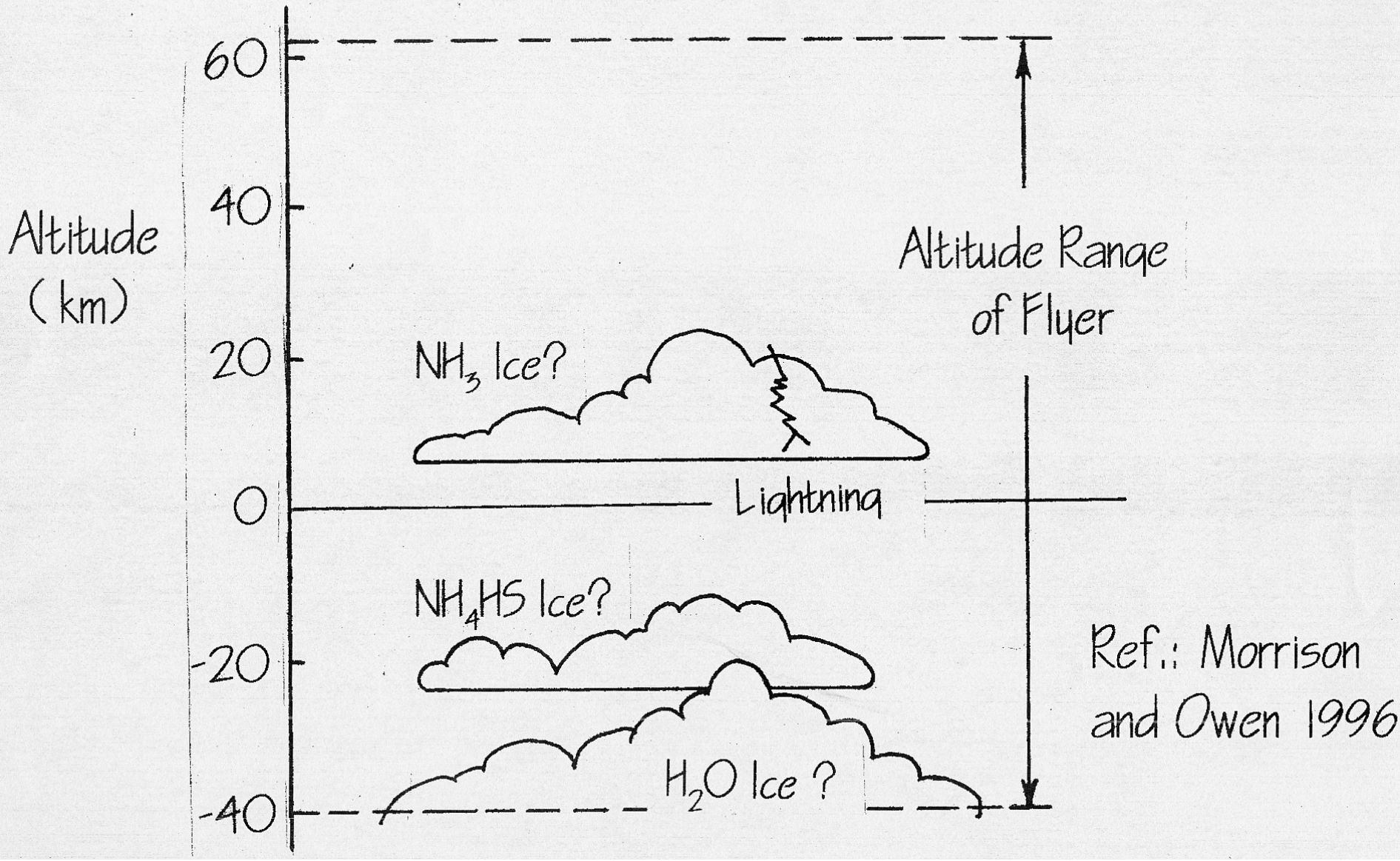
Radiation Safety

- 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 Flyer



Ramjet Flight Envelope



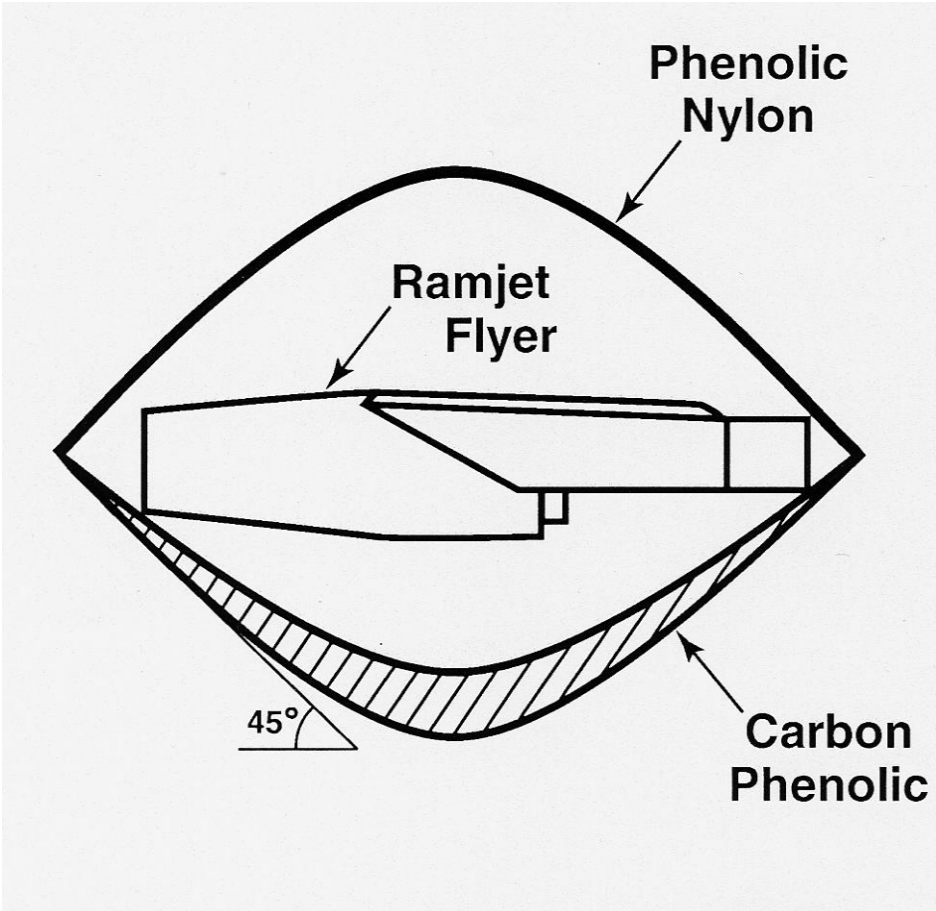
Mission Characteristics

- Payload of 640 kg, comprised of
  - Ramjet Flyer 220 kg
  - Thermal Shield 220 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

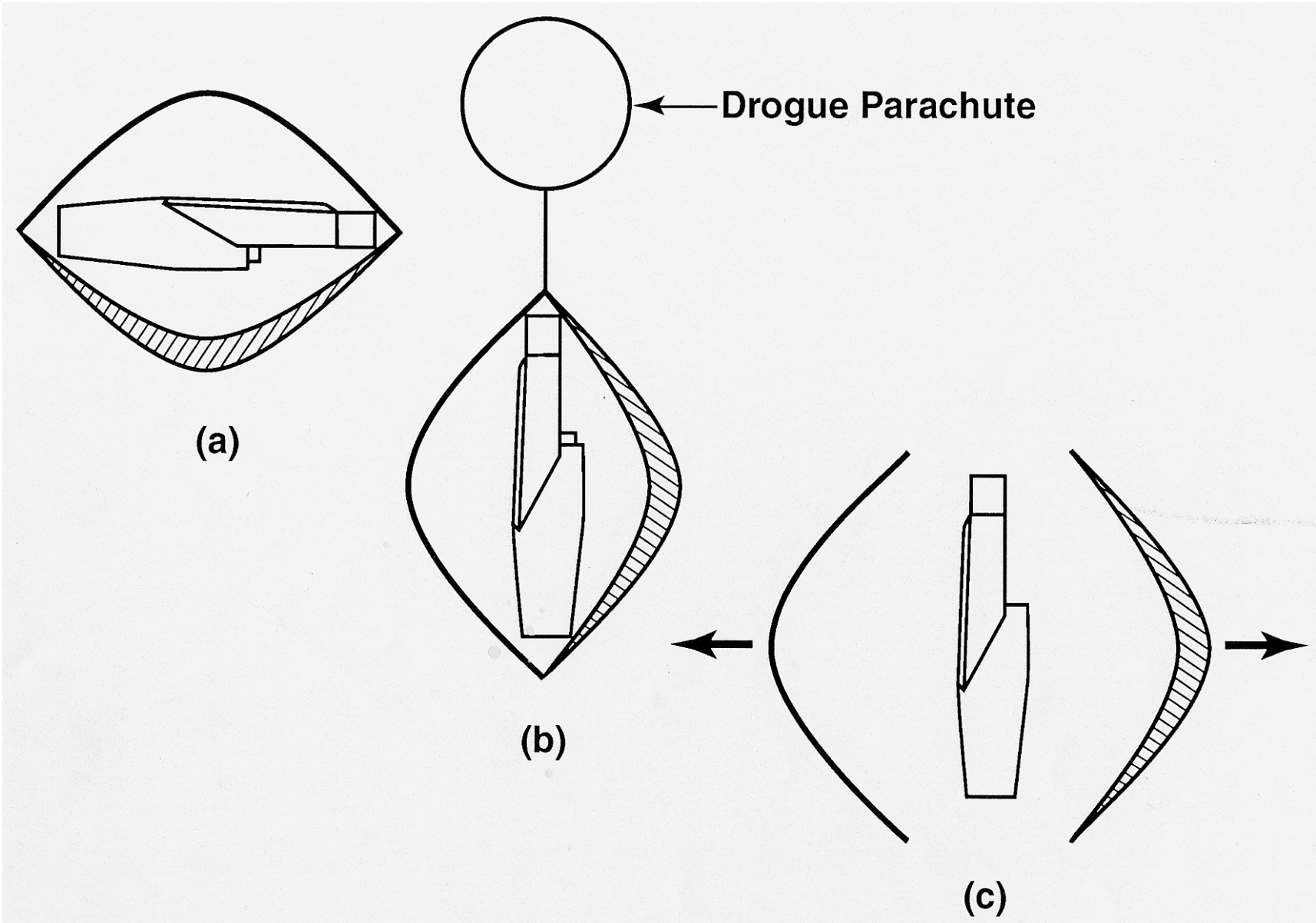
Mission Characteristics (Contd.)

- 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.

Packaging of Ramjet Flyer in Entry Capsule



Separation of Flyer from Entry Capsule



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

Phase I 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.

Phase II Tasks

1. Integration of Reactor/Ramjet/Airframe
2. Platform Stability
3. Radiation Shielding
4. Data Transmission and Vehicle Control
5. Mission Analysis
6. Development Plan and Cost
7. Ramjet Flyer Workshop

Task 1
Integration of Reactor/Ramjet/Airframe

- Subcontract with GASL (General Applied Sciences Laboratory) for CFD analyses and for integration of ramjet/airframe.

- Neutronic and thermal/hydraulic analysis of MITEE nuclear engine proceeding in-house.

Task 2
Platform Stability

- Characterize turbulence and gusting in Jovian atmosphere, based on most recent findings.

- Apply the resulting loads on the Nuclear Ramjet Flyer and determine stability characteristics.

- Develop autonomous control system.

Task 3
Radiation Effects on Instruments

- Potential sources of radiation:

    1. Background radiation in Jovian atmosphere
    2. Radiation from exhaust plume
    3. Radiation from nuclear engine

  Radiation from unshielded nuclear engine is by far the overriding contributor.

- First approximation: Same instruments as Galileo

Instruments Carried on the Galileo Probe

Science Instrument	**Properties Measured**	**M** (kg)	**P** (W)
Atmospheric Structure Instrument	Temperature, pressure, density and mean molecular weight	4.1	6
Neutral Mass Spectrometer	Chemical composition of atmosphere	13.3	25
Nephelometer	Clouds, solid/liquid particles	4.7	11

Instruments on the Galileo Probe (Contd)

Lightning and Radio Emissions Detector/Energetic Particles Instrument	Lightning and energetic particles	2.9	3
Helium Abundance Detector	Accurate measurement of helium/hydrogen ratio	5	1
Net Flux Radiometer	Thermal (from interior) and solar energy	3.4	13
	Total:	33.4	59

Task 3
Preliminary Findings

- Radiation dose for instrument design: 10^6 RAD
- Galileo instruments built using 1970's electronics.
- Great strides in miniaturization and radiation hardening. (E.g., nephelometer volume ~1800 cm^3 ⧖ ~50 cm^3)
- Using Galileo instruments leads to unrealistically conservative design.
- Obtain design characteristics for state-of -the-art instruments with radiation-hardened electronics.

Current Status of Program

- Phase II effort ongoing.
- Use of Galileo instruments inappropriate even for flyer preliminary design. Need state-of-the-art information on current scientific instruments.