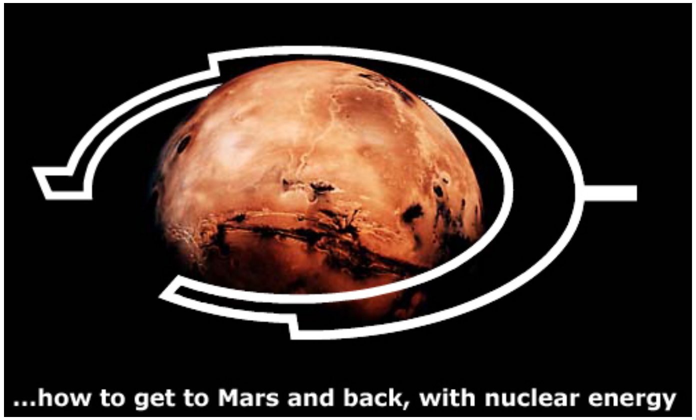
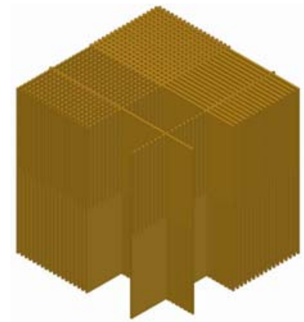




SELENE

MIT Nuclear Space Research

Andrew C. Kadak
Professor of the Practice
Nuclear Science & Engineering Department

September 2005

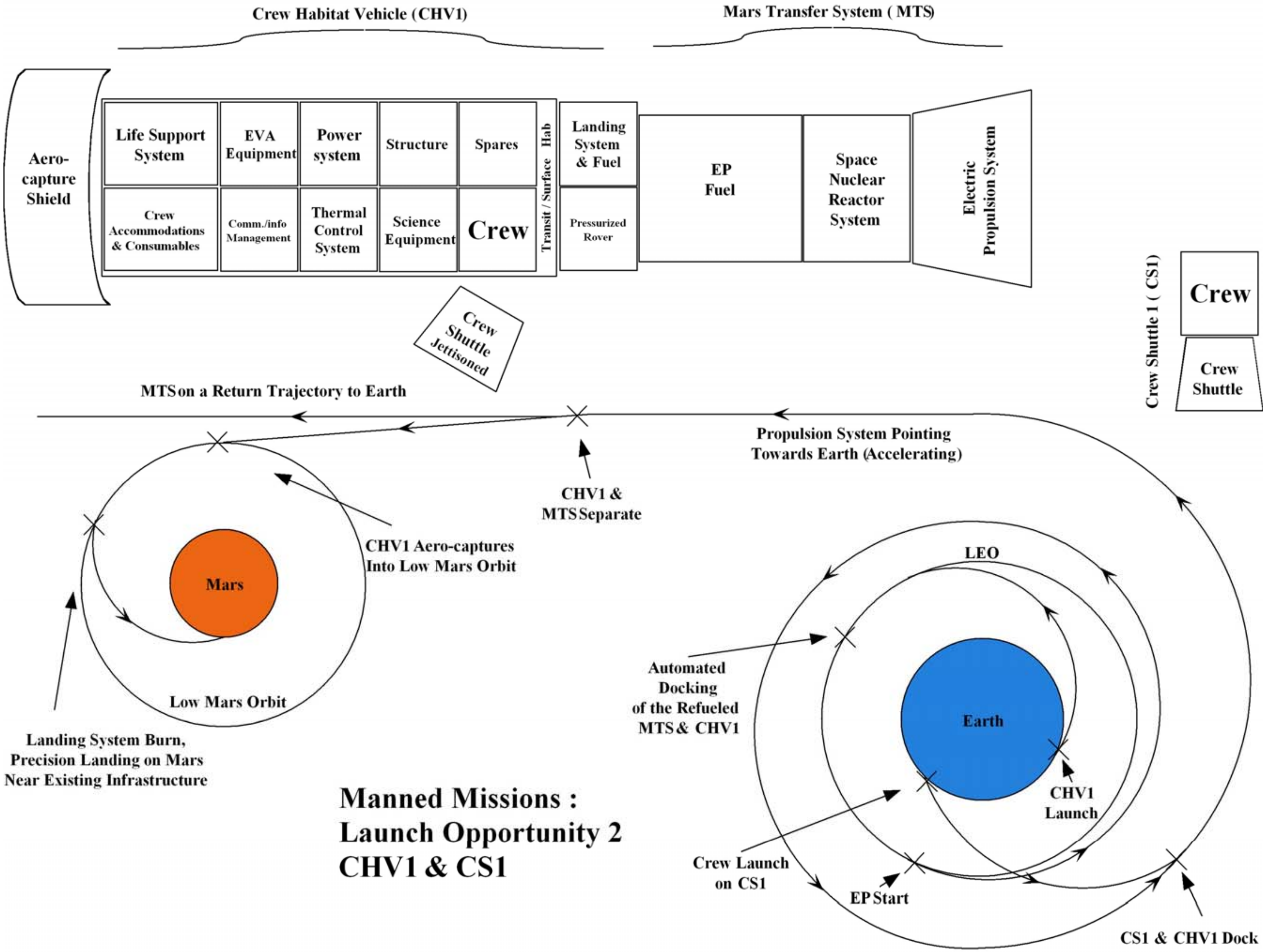
MIT's Space Initiative

- New to the Department – started in 2003

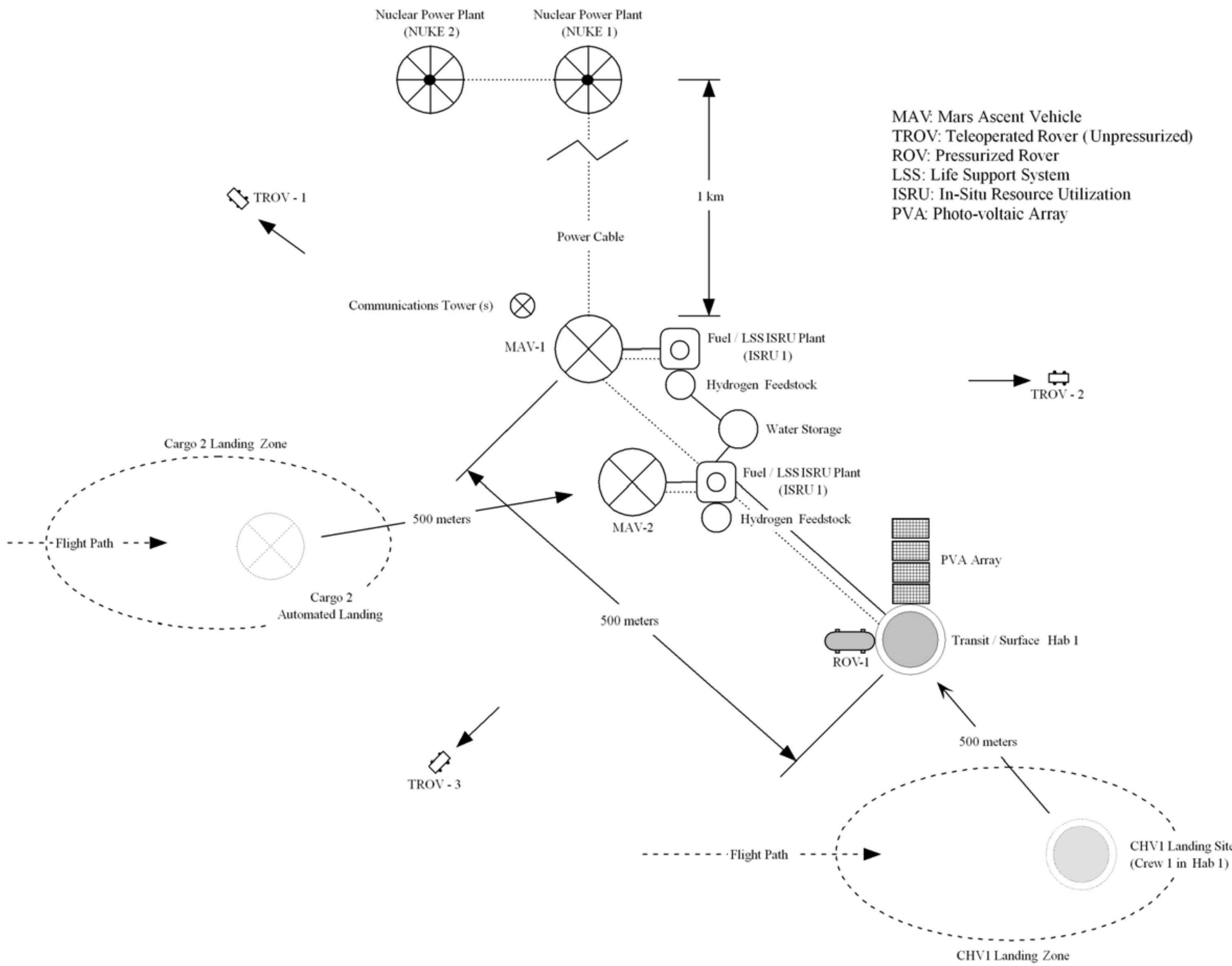
- Project undertaken as part of design course
  - Manned Mission to Mars – How to get people to Mars and back with Nuclear Energy
  - Selene - Sodium-Cooled Epithermal Long-term Exploration Nuclear Engine (MS thesis)
  - The Martian Surface Reactor: An Advanced Nuclear Power Station for Manned Extraterrestrial Exploration
  - Extraterrestrial Nuclear Power Stations: Transportation and Operation (MS Thesis)
  - Participated in MIT/Draper Lab NASA Concept Exploration and Refinement Study for future space missions (CERS)

Manned Mission to Mars

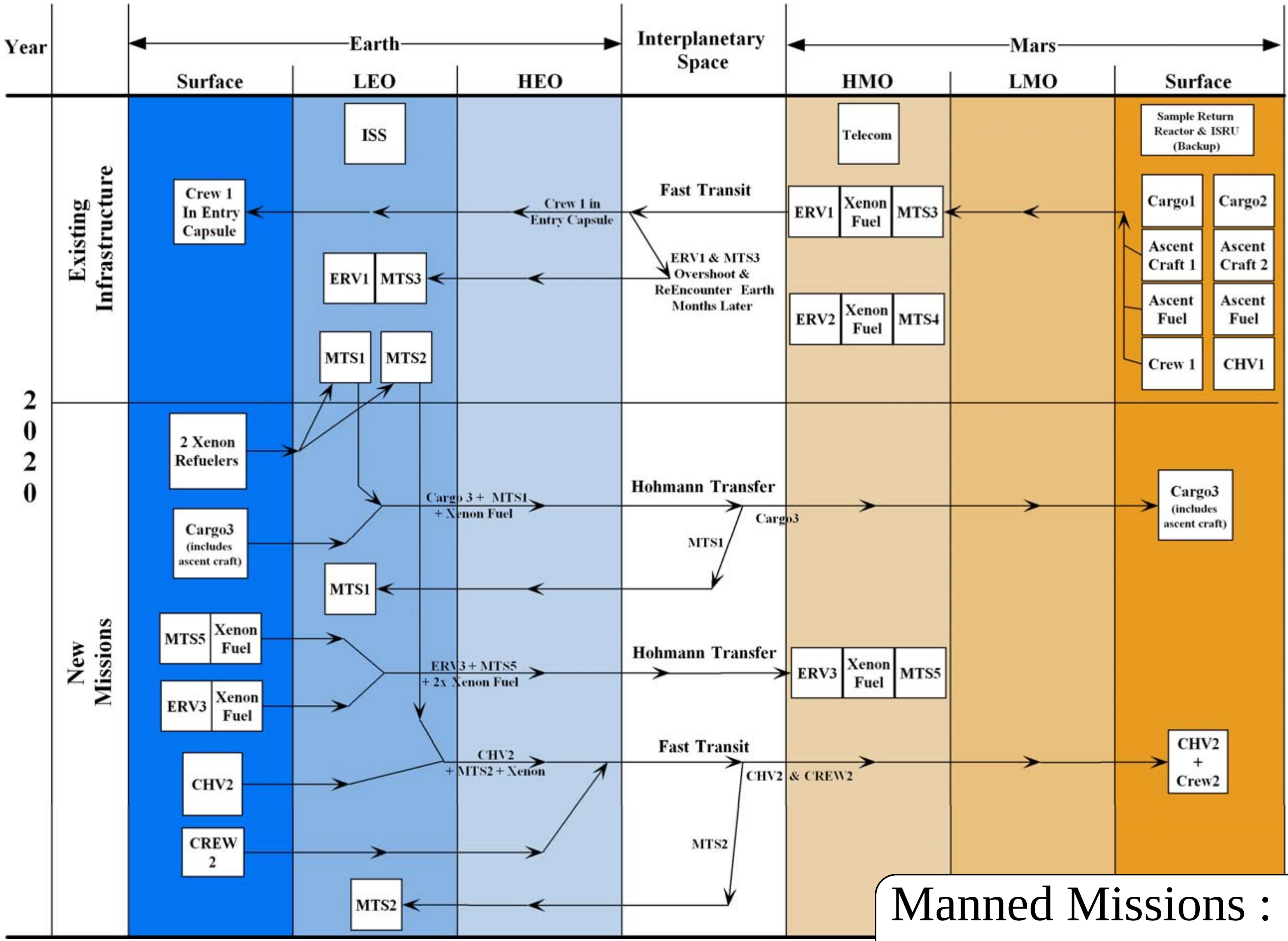
- Mission plan
- Decision methodology
- Space power system
- Surface power system
- Conclusions



Manned Missions : Launch Opportunity 2 CHV1 & CS1



Landing Site Layout for 1st Manned Mission

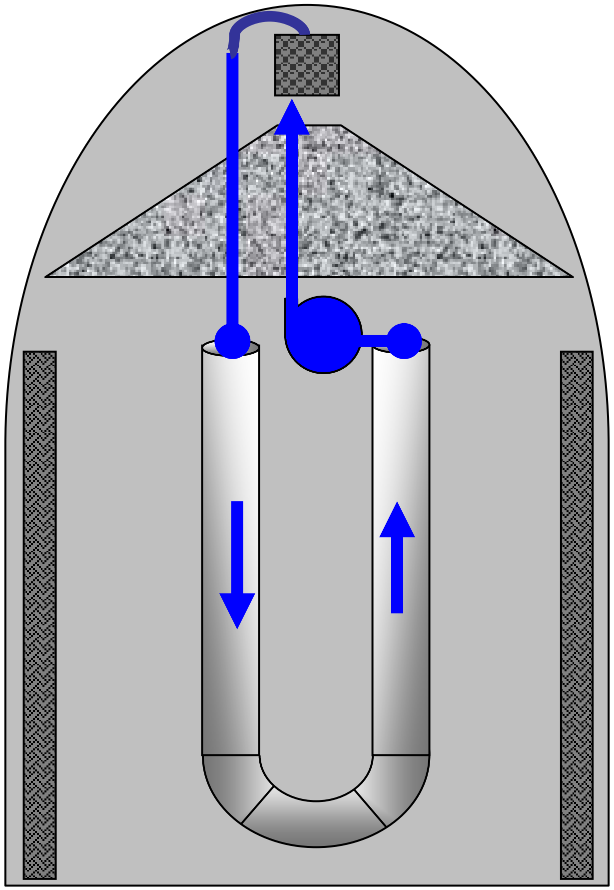


Manned Missions : Launch Opportunity 3

ANDIE

Advanced **N**uclear **D**esign for **I**nterplanetary **E**ngine

1. Molten salt transfers the heat from the core to the radiator
2. All power is radiated towards TPV collector
3. TEM self powered pumps circulate the molten salt coolant
4. TPV collectors generate DC from thermal radiation
5. Residual heat is dissipated into outer space



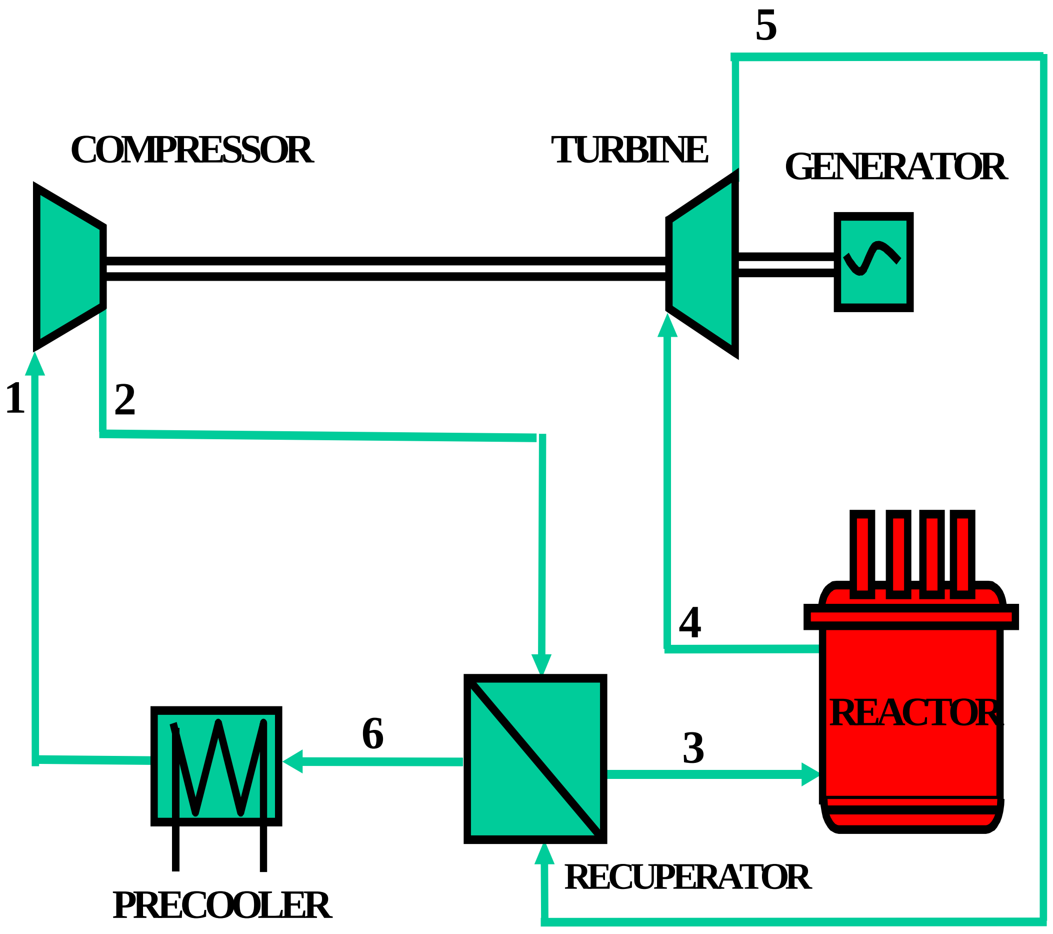
Surface Power System

- Cooled by Martian atmosphere (CO_2)
  - Insensitive to leaks
- Shielded by Martian soil and rocks
  - Low mass
- Hexagonal block type core
  - Slow thermal transient (large thermal inertia)
- Epithermal spectrum
  - Slow reactivity transient
  - Low reactivity swing

CADEC

CO_2 cooled Advanced Design for Epithermal Converter

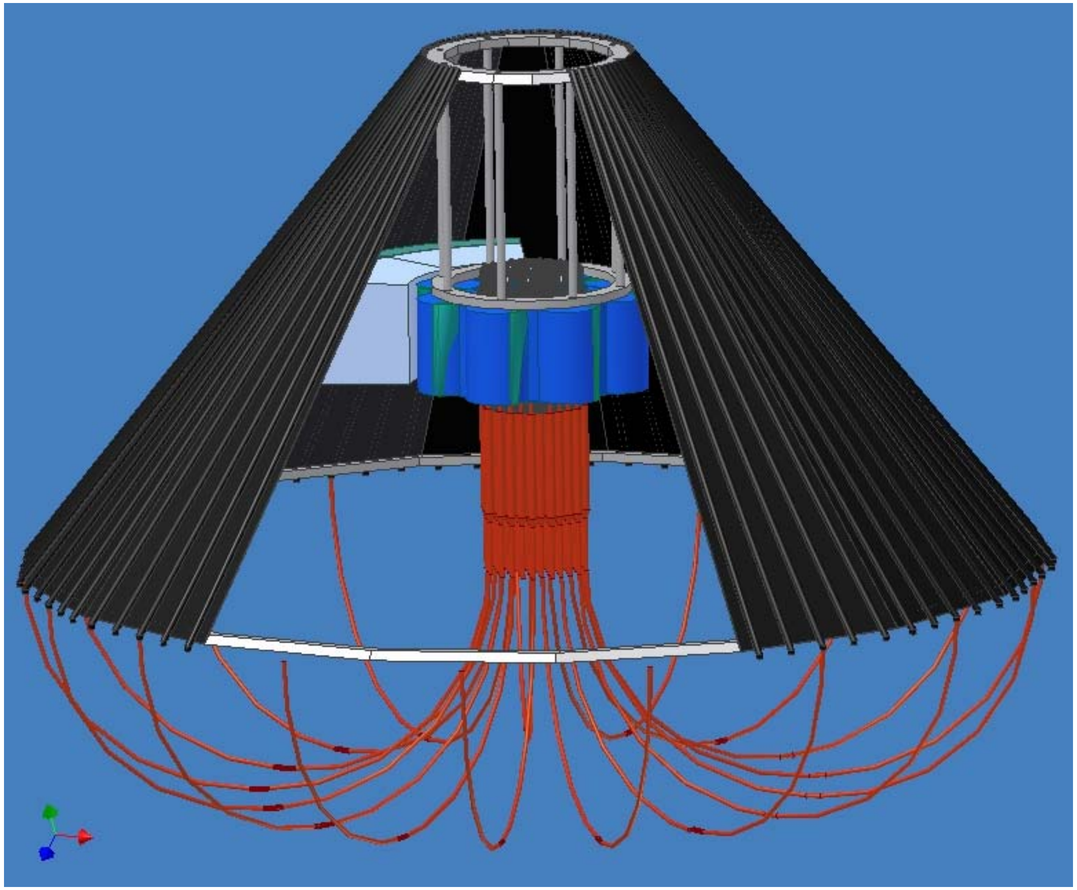
- Pressurized CO_2 from atmosphere cools the core
- Direct, closed, recuperated Brayton cycle for electricity production (η_{net}~20%)



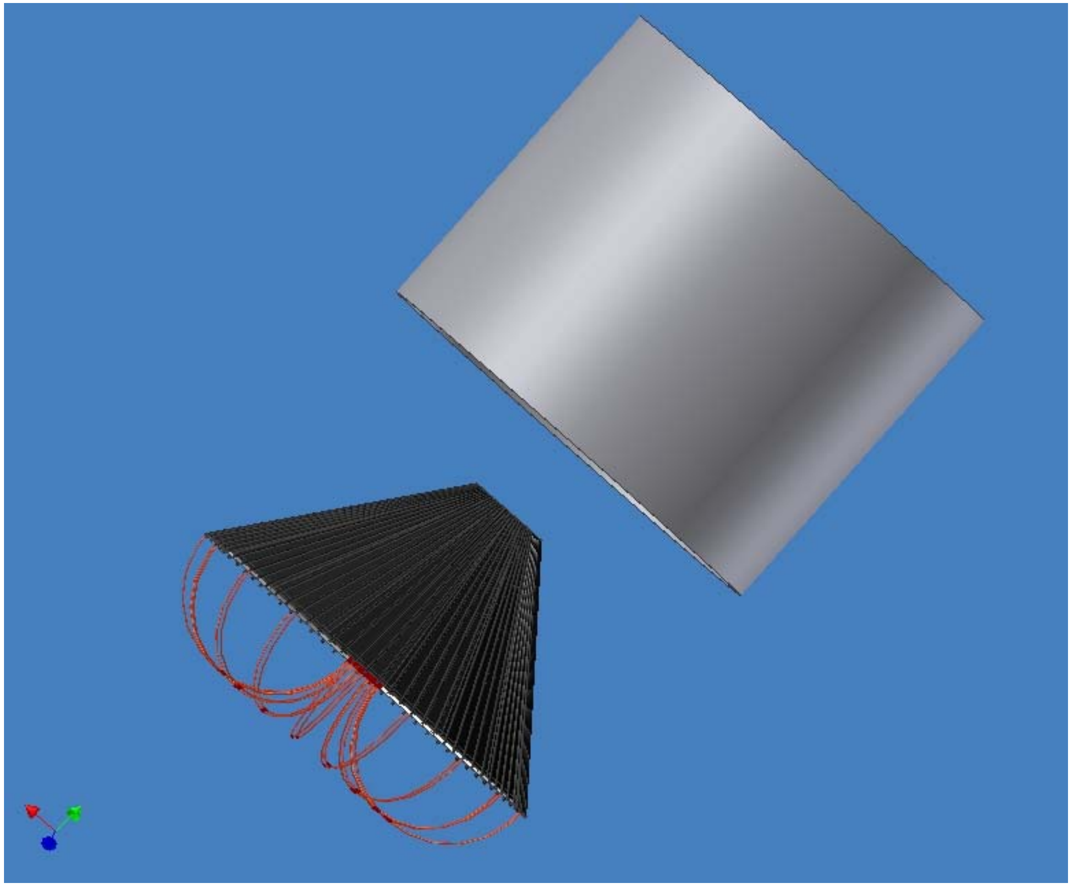
Martian Surface Reactor Group

December 3, 2004

MSR Assembly Sketches

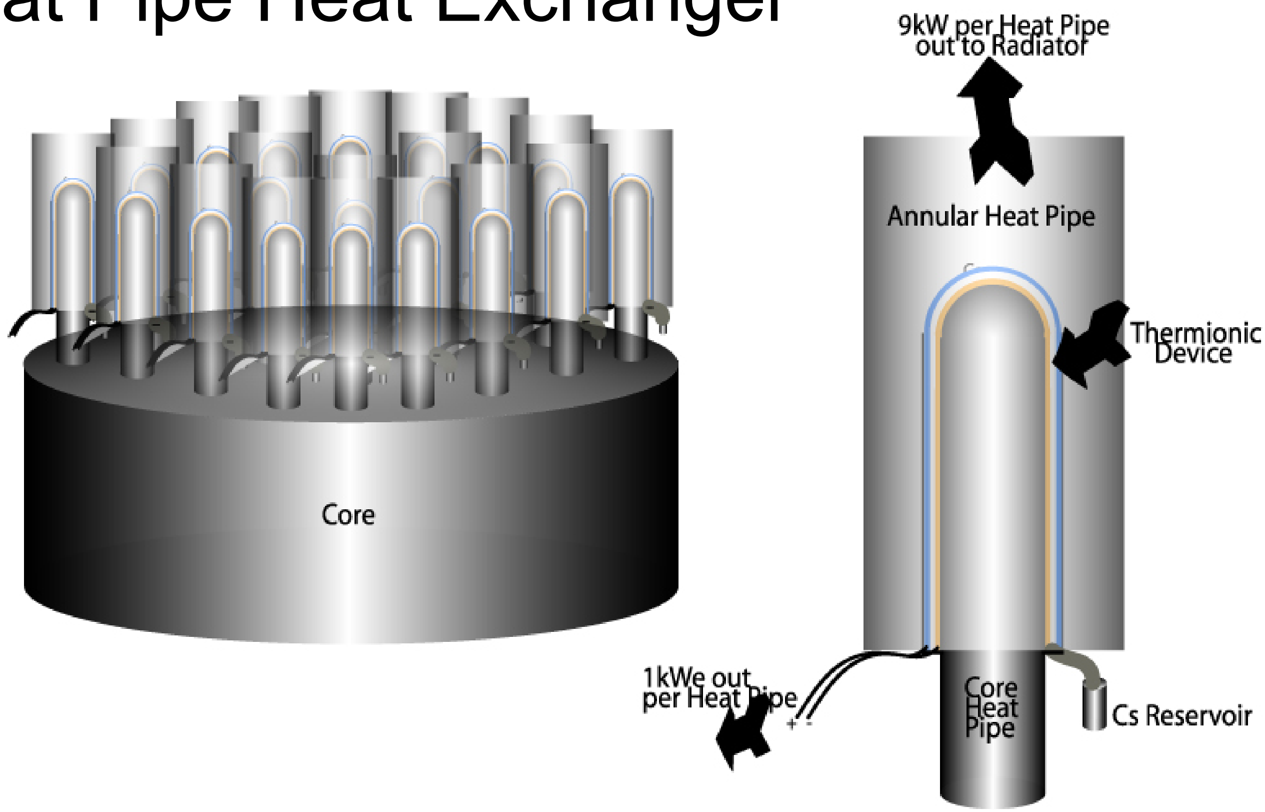


MSR Assembly Sketches (2)

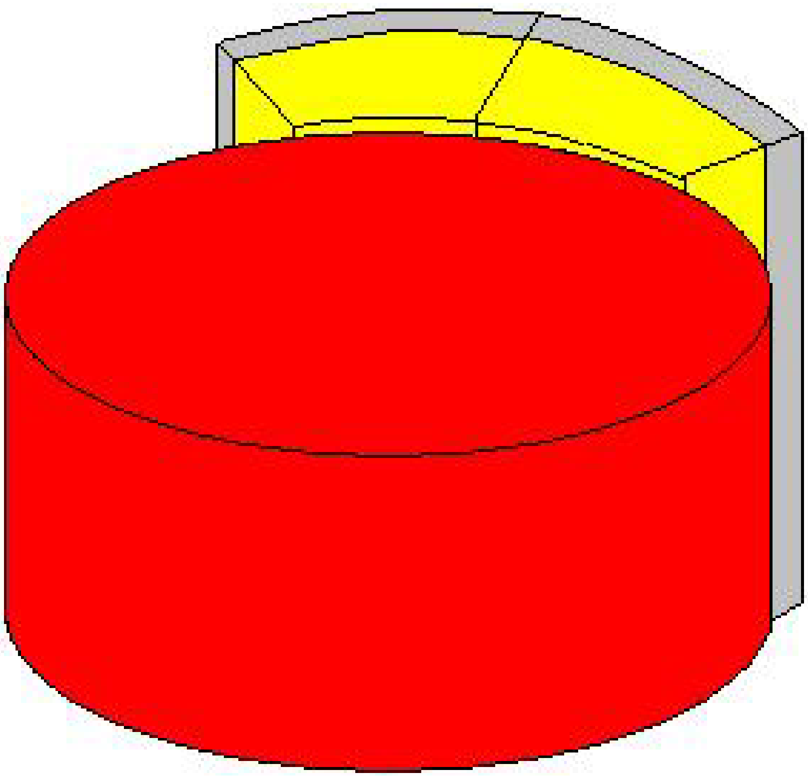


PCU – Heat Exchanger to Radiator

- Heat Pipe Heat Exchanger



Shielding - Design

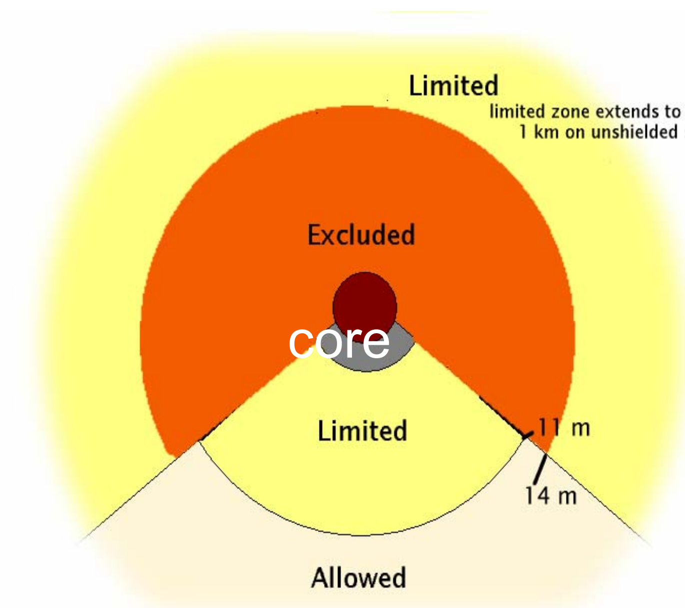


- Two pieces, each covering 40º of reactor radial surface
- Two layers: 40 cm B_4C (yellow) on inside, 12 cm W (gray) outside
- Scalable
  - at 200 kW(e) mass is 2.19 metric tons
  - at 50 kW(e), mass is 1.78 metric tons

Shielding - Design (3)

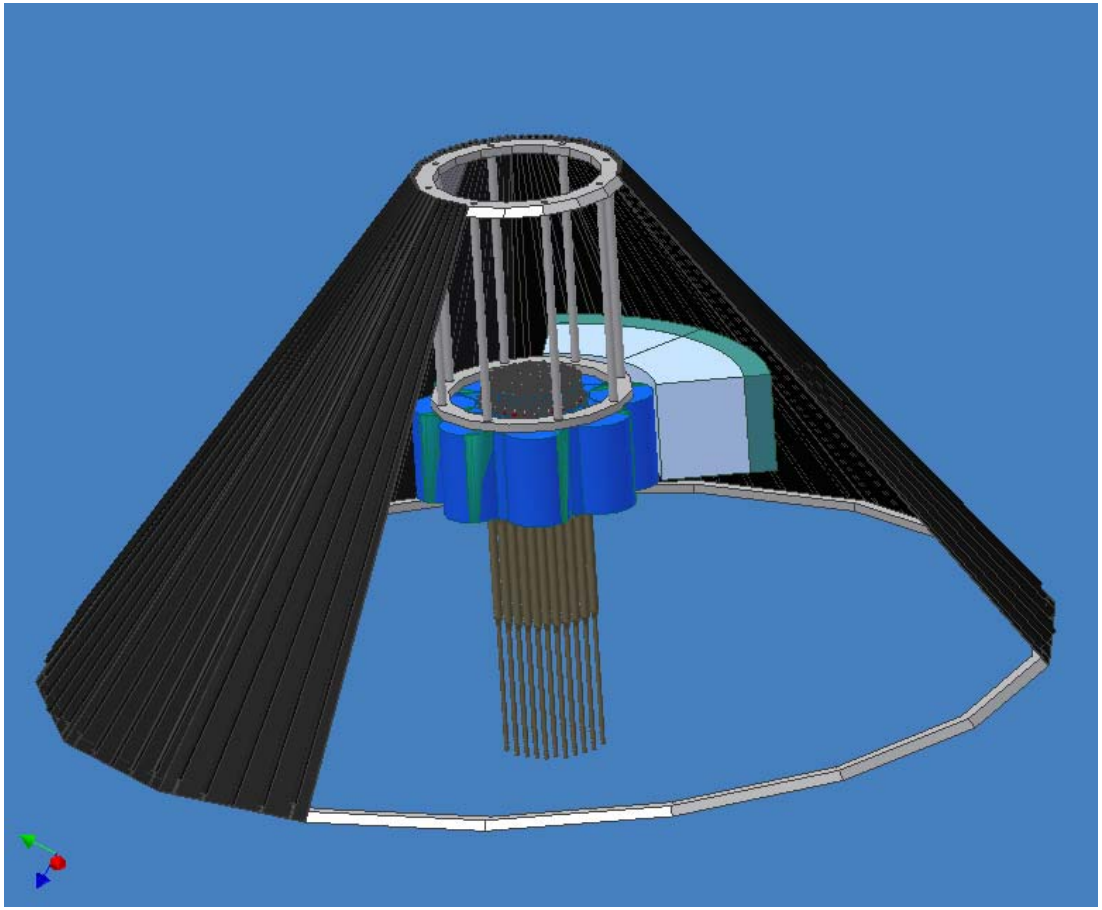
- Using a shadow shield requires implementation
  of exclusion zones:

- Unshielded Side:
  - 32 rem/hr - 14 m
  - 2.0 mrem/hr - 1008 m
  - 0.6 mrem/hr - 1841 m



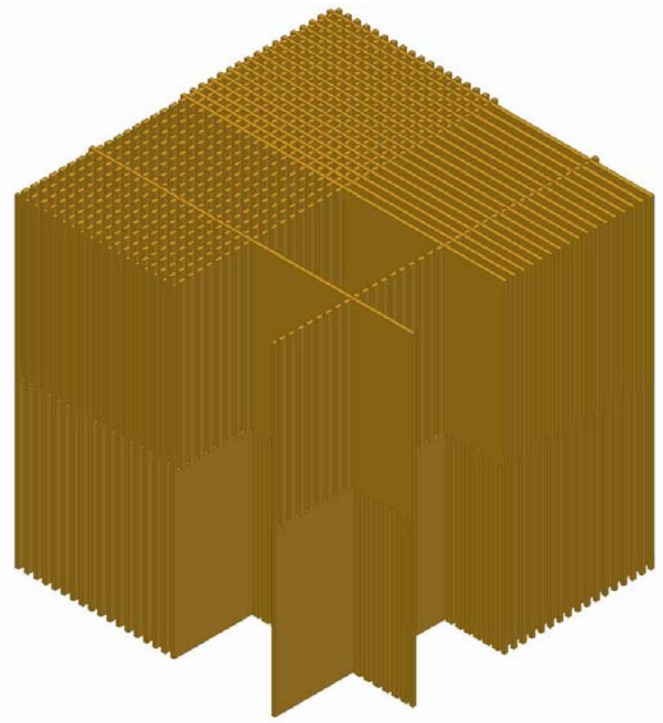
- Shielded Side:
  - 32 rem/hr - inside shield
  - 400 mrem/hr – at shield
    boundary
  - 2.0 mrem/hr - 11 m
  - 0.6 mrem/hr - 20 m

MSR Assembly Sketch



Design of Sodium-cooled Epithermal Long-term Exploration Nuclear Engine

- Response to NASA comment that PU fueled reactors are politically incorrect.



Selene

97% Enriched U235

Extraterrestrial Nuclear Power Stations: Transportation and Operation

- Reviewed Launch Requirements
- Cassini Safety Analysis
- Approval Process
- Landing options for the moon
- Startup of MSR
- Operational Needs - Shielding
- Electric Connections

NASA Exploration and Refinement Study

- MIT and Draper Labs - contract with NASA to review future space architecture options for deep space travel - “Mars Back”
- Development of specifications for Crew Exploration Vehicle (CEV)
- Also types of systems needed for manned exploration and mission options.
- Nuclear Engineering Students part of several teams - surface operations and power for propulsion.

Future Directions

- Focus on power systems
- Nuclear Thermal Rocket
- Development of power conversion systems including thermionic systems
- Optimization of shielding and radiator designs
- Consideration of real problems for operating reactors in space - maintenance, radiation exposure, power supplies.