Gas Core Nuclear Rocket Engines Promise and Reality

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Gas Core Nuclear Rocket Engines
Background

- The gas core Nuclear Rocket has a long history as a promising concept
  - Eliminates solid core temperature limits
  - Promises 1.5 to 6 x improvement over solid core
  - Obvious potential for solar system exploration
  - Current study evaluates potential and problems for use on Icarus
    - By inspection not useful as primary
    - Evaluate for secondary applications

Gas Core Nuclear Rocket Engines
Concept

- Fissioning material (U235, UF_4, UF_6) gasified during operation
- Two types:
  - Open cycle - fissioning gaseous core stabilized by gas dynamic or electromagnetic means
    - Some leakage of fissioning material
  - Closed cycle – fissioning gas contained by transparent envelope (nuclear light bulb)

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Closed Cycle

- Pros
  - Minimal contamination of surroundings
  - No makeup of nuclear material required (except for burnup)
- Cons
  - Temperature limited by envelope
  - Life expectancy limited by darkening of envelope
- Possible use on Icarus as electric and thermal power source but lifetime an issue
- Is it better than a good solid core reactor?

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Open Cycle Concepts

- Hydrodynamic Stabilization
  - Vortex formed downstream of a center body by tangential injection of working fluid (H_2)
  - Nuclear material injected through center body into vortex core
  - Proper design minimizes loss of fissionable material
- Electromagnetic Stabilization
  - Similar configuration to hydrodynamic or:
  - Fissionable maintained in torus while H_2 flows down center

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Open Cycle Issues (1)

- Heat transfer
  - How to effectively transfer heat from fissionable to working fluid
  - Cooling of engine structure, especially nozzle
- Buoyancy Effect
  - When significant acceleration applied, density difference overwhelms vortex

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Open Cycle Issues (2)

- Dynamic stability of plasma
  - Analogous to high-frequency instability in chemical rockets
- Electromagnetic containment requires extremely high fields

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Open Cycle Issues (3)

- How is it started?
- How do you shut it down?
  - Single use can let fissionable escape – contamination issues
  - Desire for reuse greatly complicates shutdown
    - Dumping core requires new load of fissionable
    - Recapturing core has performance / handling / storage issues

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Some Thoughts

- Investigate combining hydrodynamic and electromagnetic containment
- Throat heat transfer
  - Conventional cooling probably limits I_{sp} to order of 1500 sec
  - Run at temperature high enough for magnetic nozzle
    - Could allow I_{sp} of 5000 to 6000 sec
    - May exclude operation at middle levels
    - May allow high I_{sp} with fluids other than H_2

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Some More Thoughts

- Heat transfer to working fluid (H_2 or?) is critical
  - H_2 tends to be transparent at wavelengths of interest
  - Seeding has been suggested but compromises performance

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Applications to Icarus

- Most obvious is independent probe
- Probe retargeting capability
  - Icarus cruises at 0.15 C (45,000 km/sec)
  - Probe with Isp = 6000 sec and mass ratio of 4.4
    - Velocity change 87.2 km/sec
    - Probe deployment @ E- 20 days yields about 1 AU deflection
    - Capability essentially linear with I_{sp}
- Midcourse correction Icarus vehicle possible – details design dependent

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Conclusion

- Gas Core Nuclear Rocket potentially useful to Icarus as auxiliary propulsion
- Huge potential for less difficult missions
- Technical problems significant but no worse than those for Icarus main propulsion
- Worthy of more study