WhirliGig Transfer Vehicle for motor-driven, restartable A.G.

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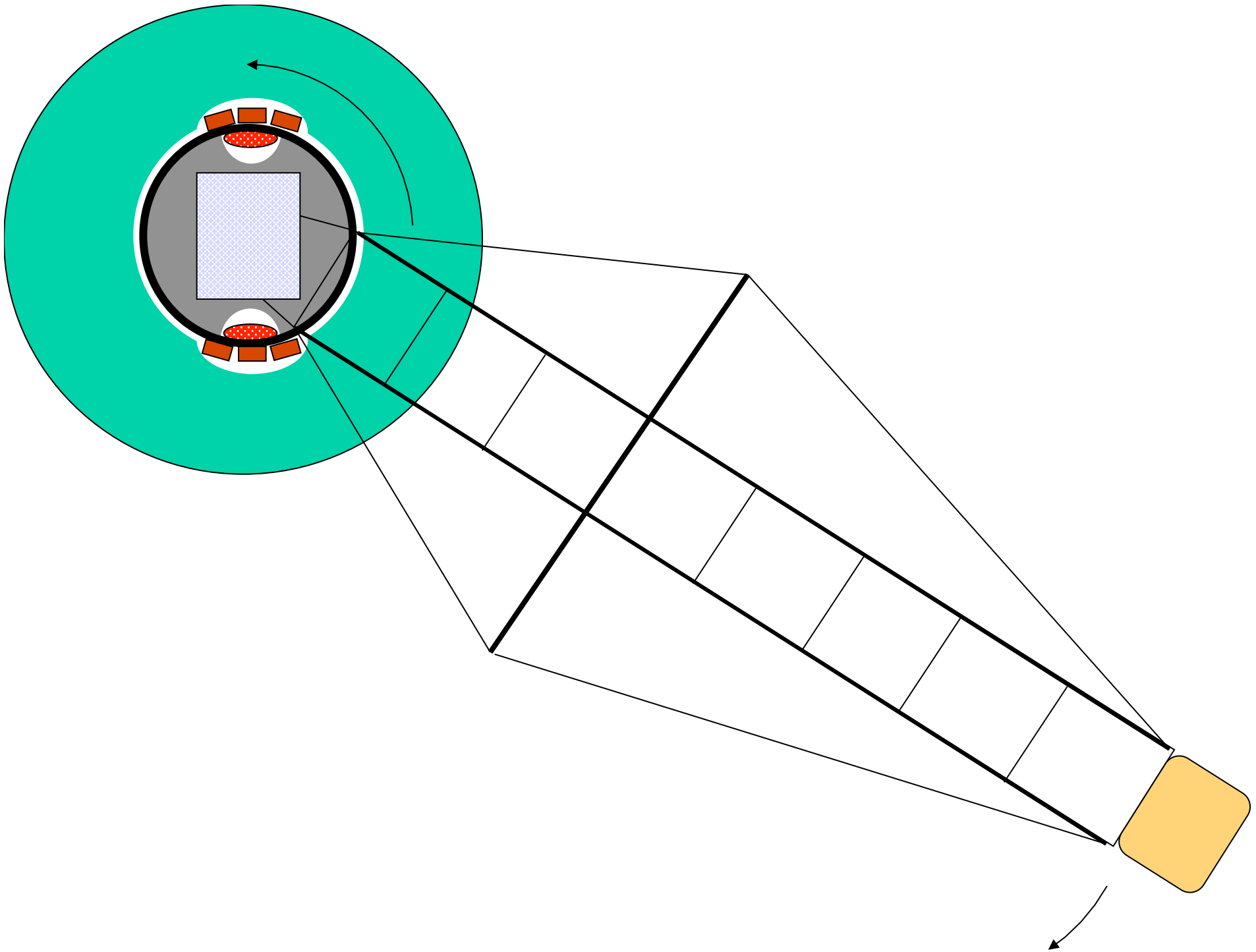
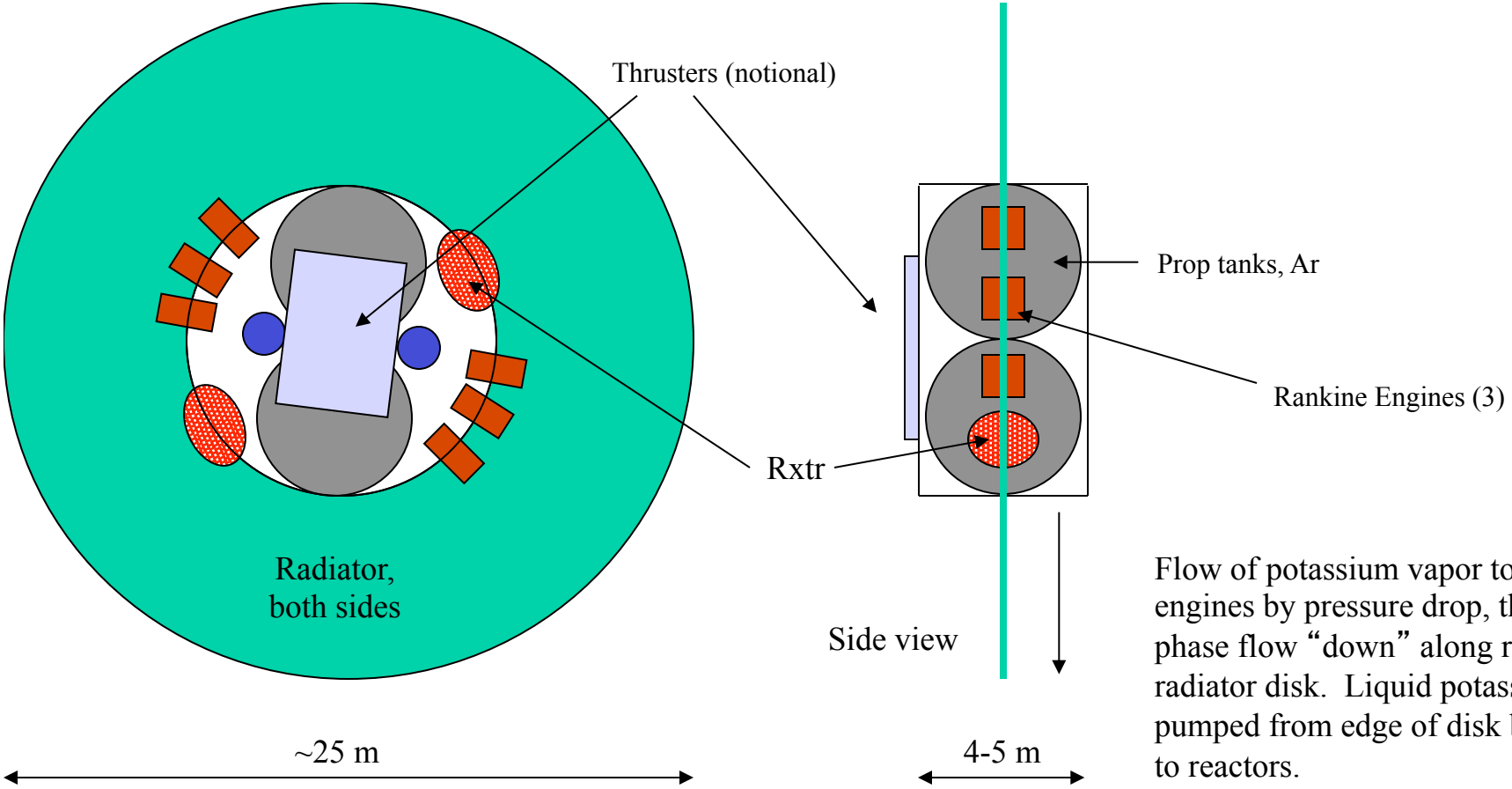
June, 2002





Flow of potassium vapor to Rankine engines by pressure drop, then 2-phase flow "down" along radius of radiator disk. Liquid potassium pumped from edge of disk back up to reactors.

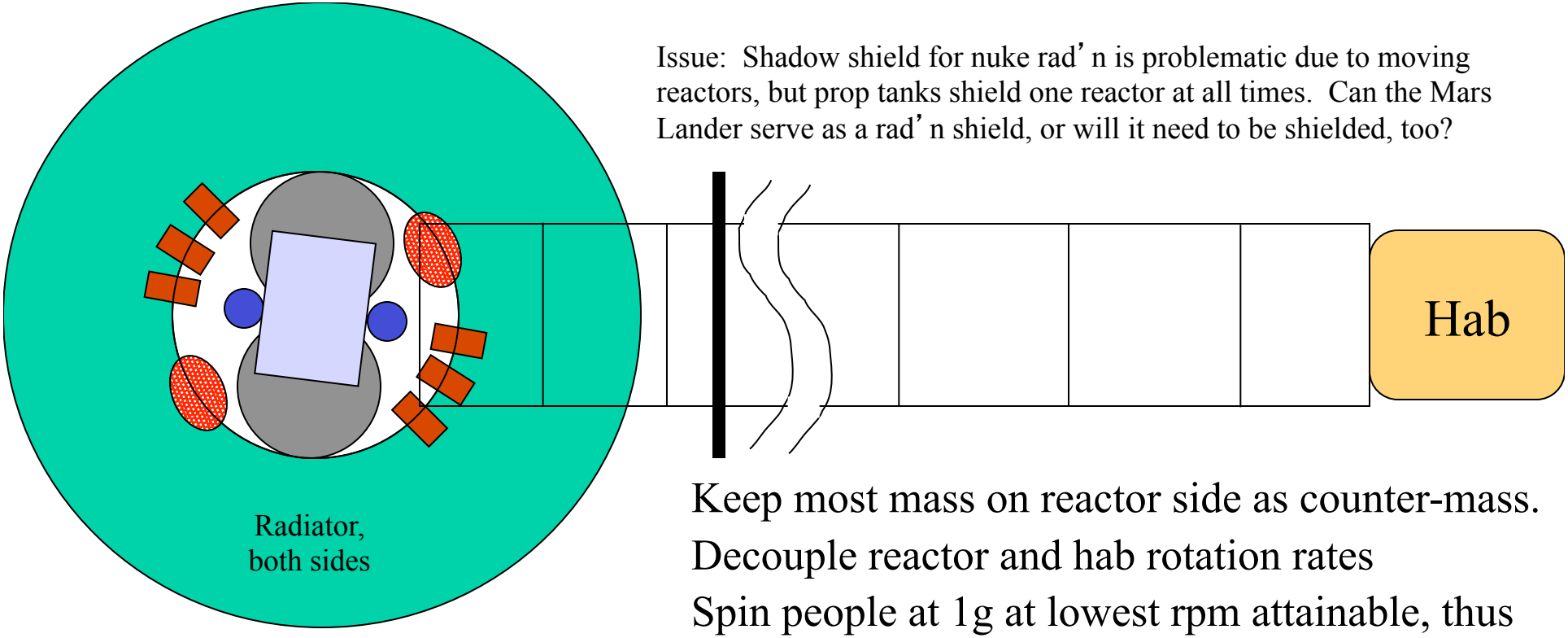
12 - 14 rpm

1 g at reactor radius,

~2 g at tip of radiator

Need to spin power system to 1g, but no constraint on rpm's.

Most or all of the power produced by the nukes will be consumed within the rotating cage, so power, prop, and thermal connections are minimal. A small amount of power may need to be routed to the hab via slip joints. Hab would have it's own thermal rejection. Hab could have it's own power source if desired, such as arrays on the long truss.



Issue: Shadow shield for nuke rad'n is problematic due to moving reactors, but prop tanks shield one reactor at all times. Can the Mars Lander serve as a rad'n shield, or will it need to be shielded, too?

Keep most mass on reactor side as counter-mass.

Decouple reactor and hab rotation rates

Spin people at 1g at lowest rpm attainable, thus longer radius.

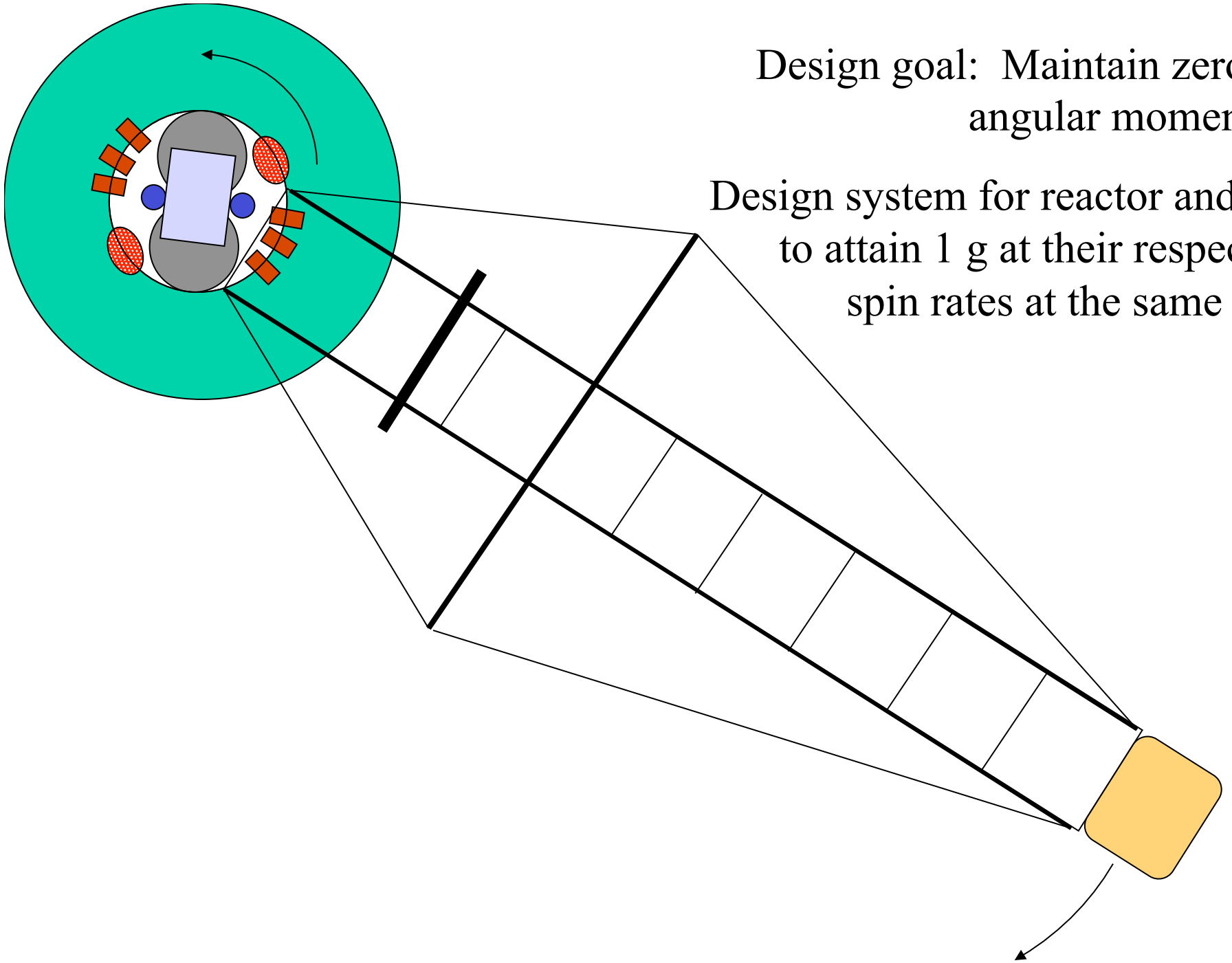
Can the system be designed so that spinning up the reactor cage to 1 g at ~12 rpm also spins up the hab to 3 to 4 rpm (or even lower?)? Electric motors can be used to spin-up, spin-down, etc., not propellant.

Vehicle center of rotation would be where taxis and landers dock.

Issue: As prop is consumed, c.g. will shift. To counter this, perhaps hab can be pulled in a bit to maintain 1g and keep c.g. where lander is located, slowly increasing rpm over the course of the mission. Thus, you may want to start at longer radius with lower rpm so that you can end at 4 rpm (open to trade.) Other mass could be moved to cancel loss of prop, including waste/trash, lander, radiation shielding water, etc.

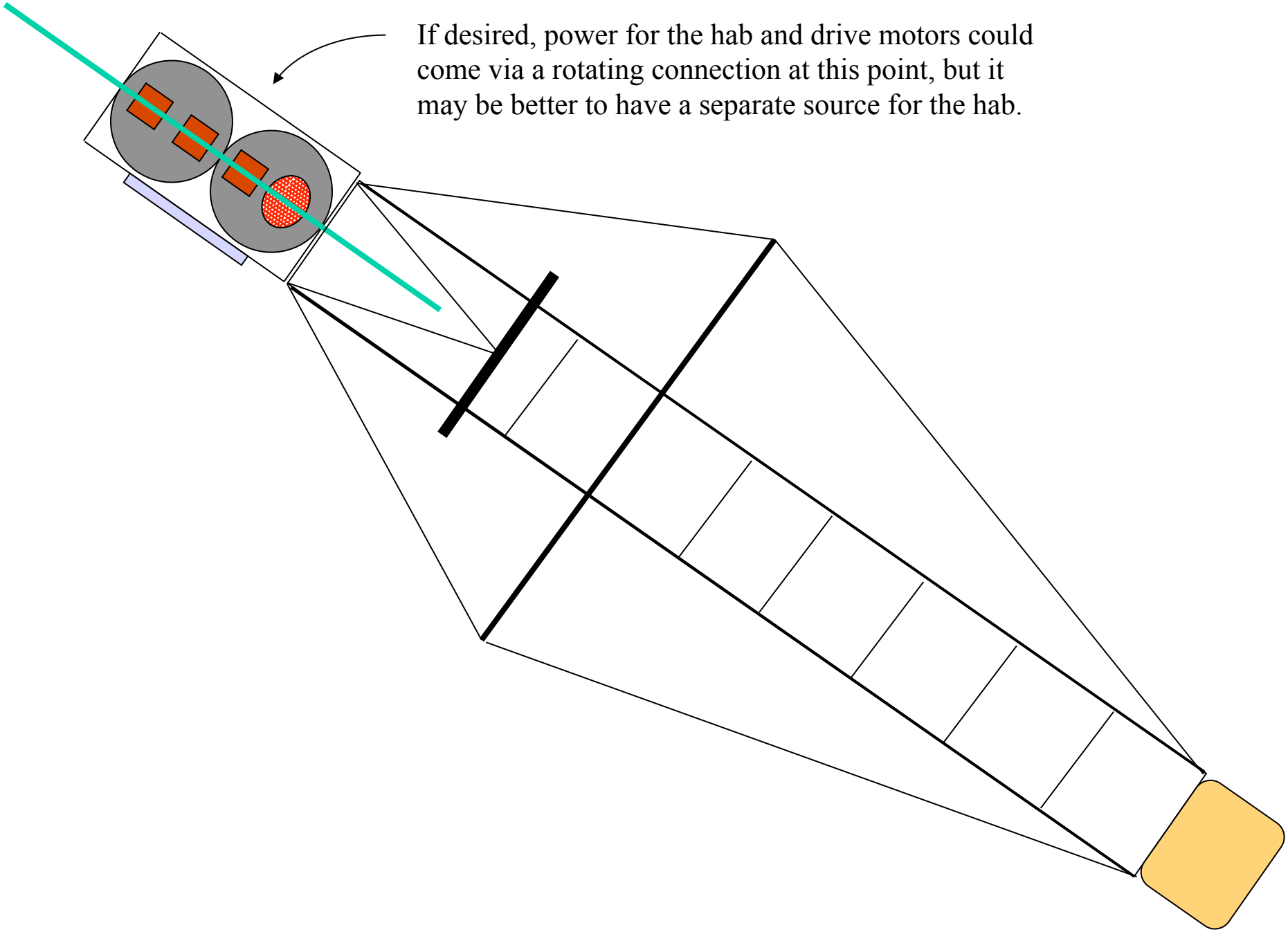
Issue: Actual g level at reactors will vary due to rotation around vehicle c.g. The shorter this is offset from the center of the cage, and the lower the vehicle rpm, the less it will vary.

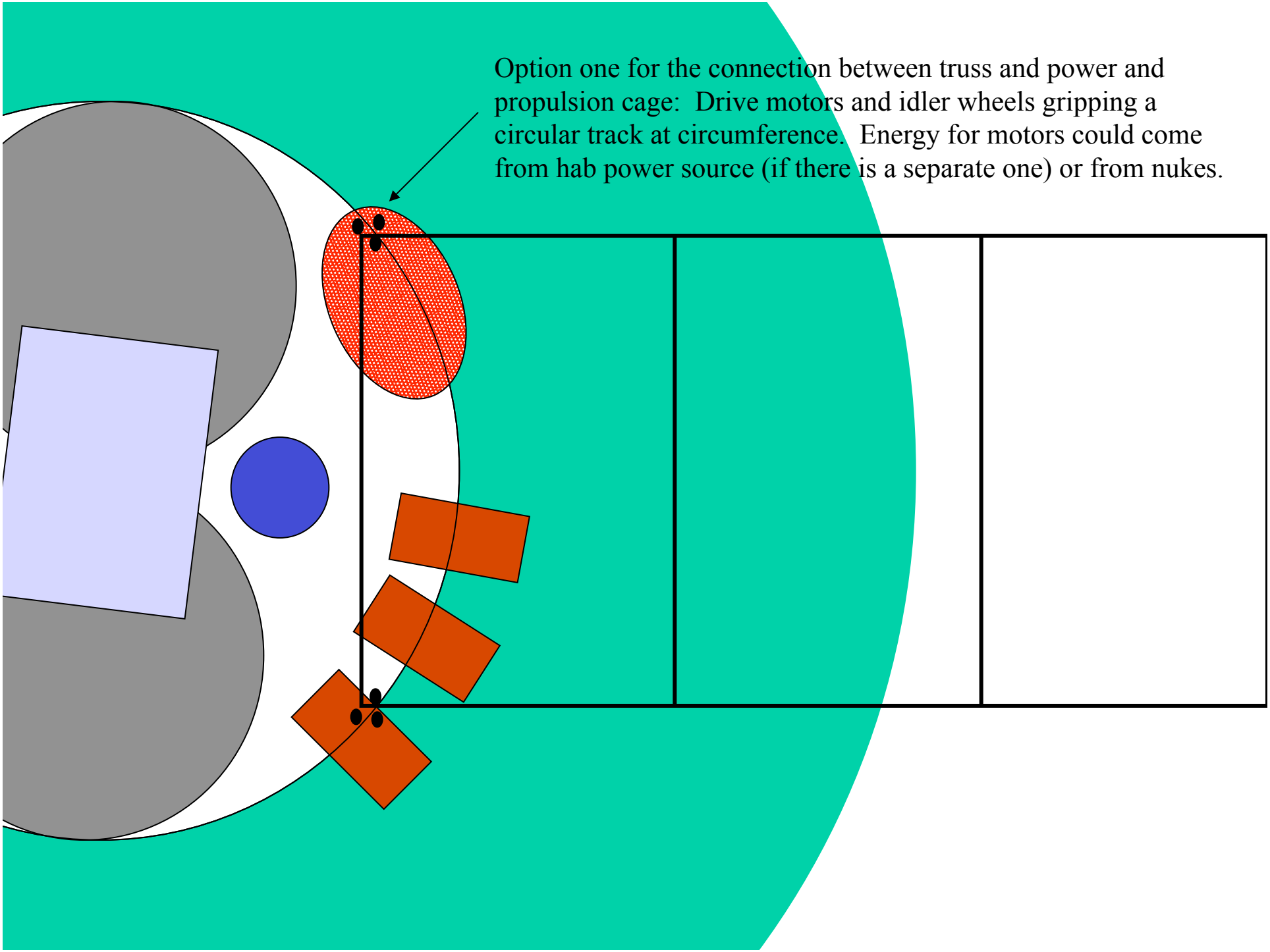
Power to start spin up could be lower power from nukes, not full power, or from another source.

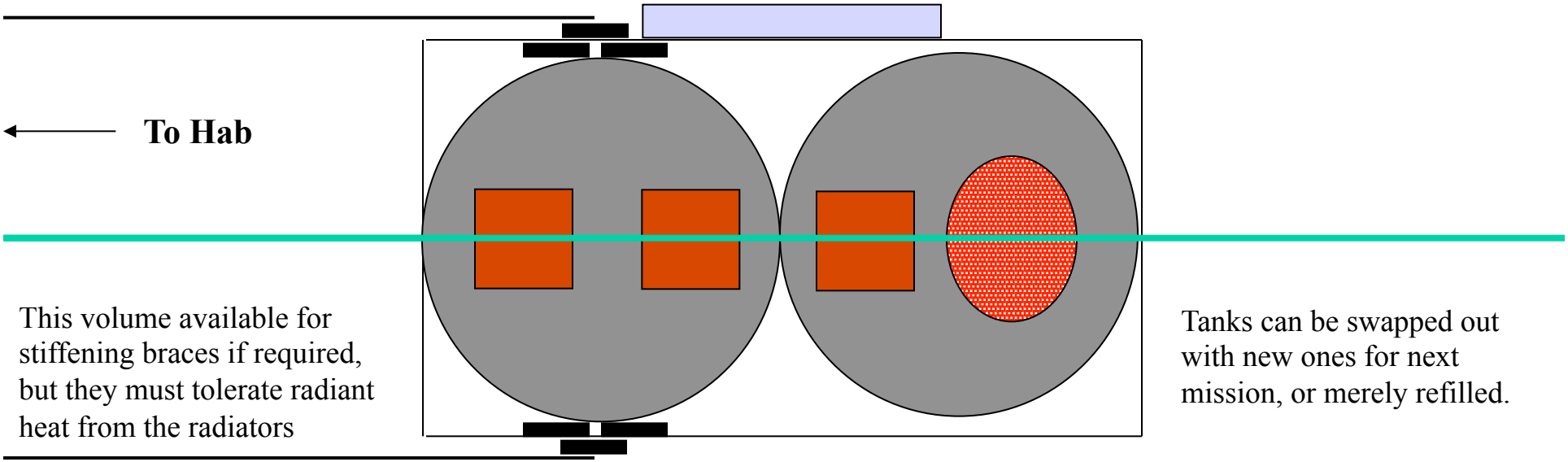


Design goal: Maintain zero net angular momentum

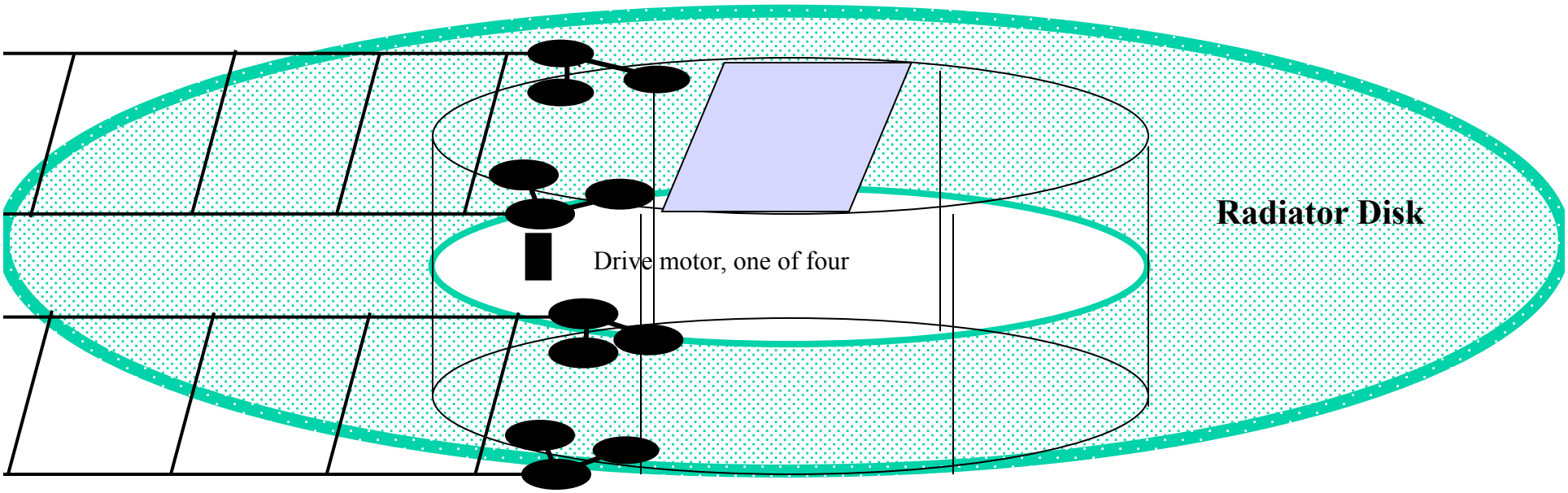
Design system for reactor and hab to attain 1 g at their respective spin rates at the same time

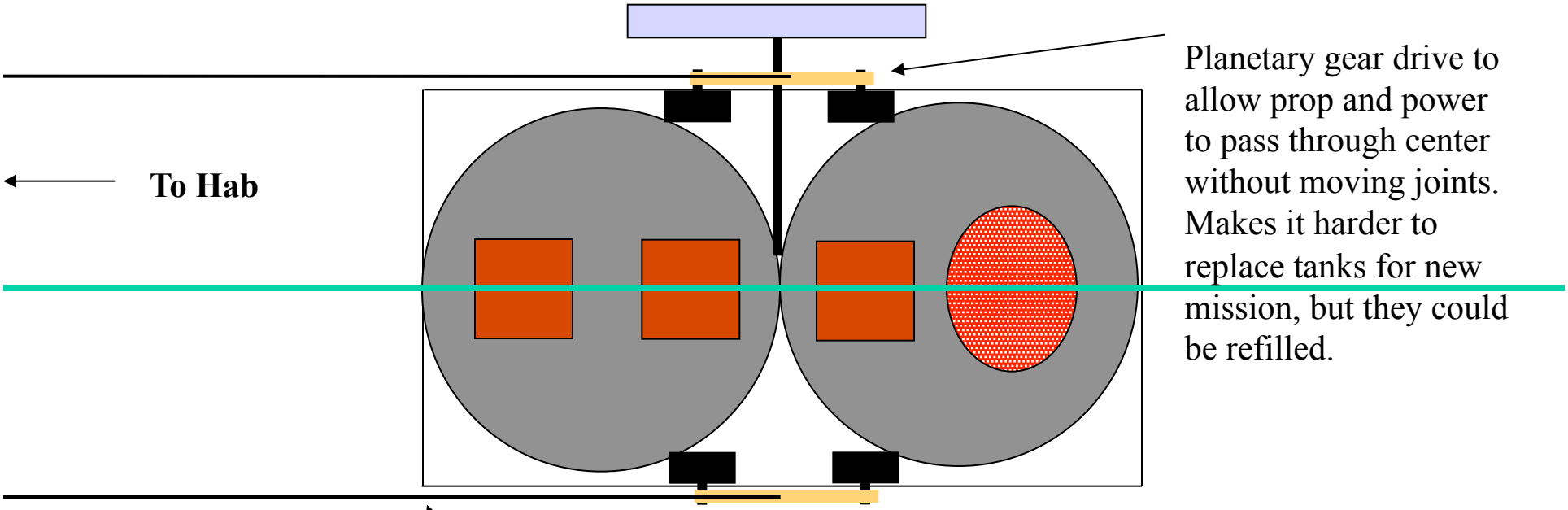

If desired, power for the hab and drive motors could come via a rotating connection at this point, but it may be better to have a separate source for the hab.


Option one for the connection between truss and power and propulsion cage: Drive motors and idler wheels gripping a circular track at circumference. Energy for motors could come from hab power source (if there is a separate one) or from nukes.



Power to drive rotation motors can come from truss

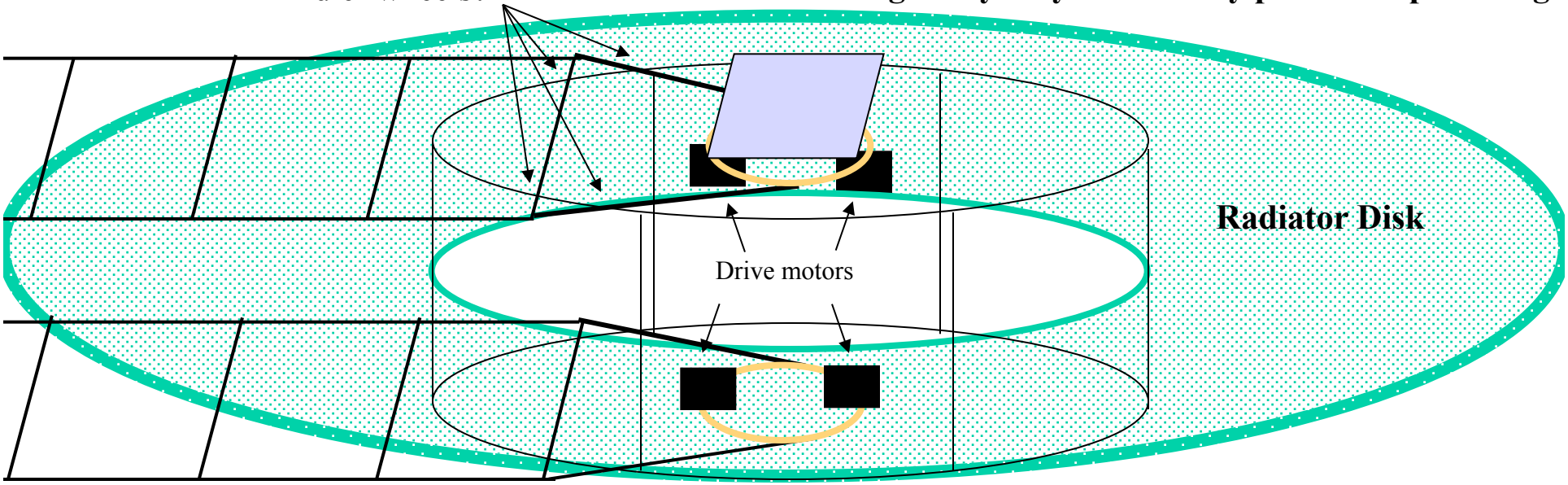


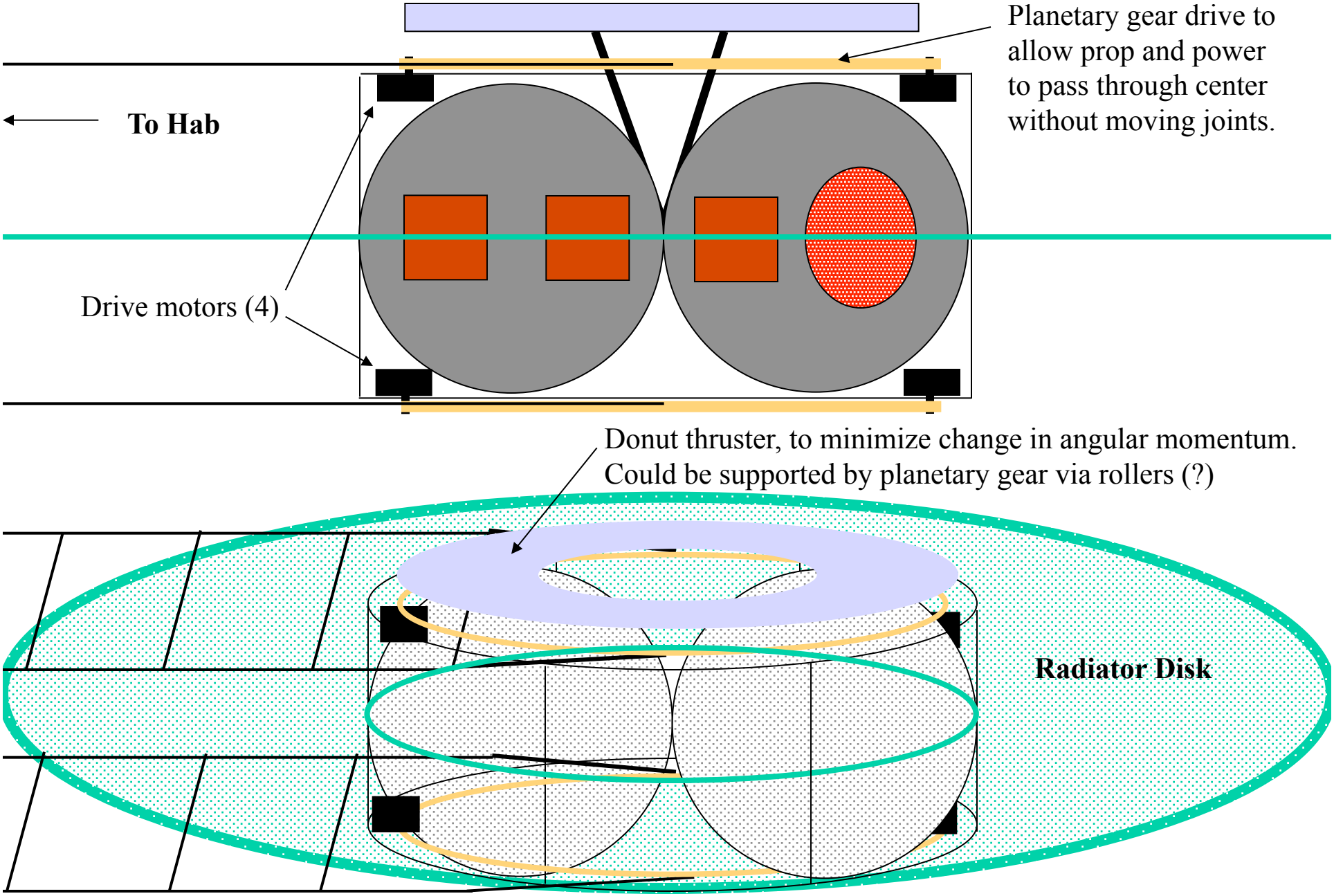


Planetary gear drive to allow prop and power to pass through center without moving joints. Makes it harder to replace tanks for new mission, but they could be refilled.

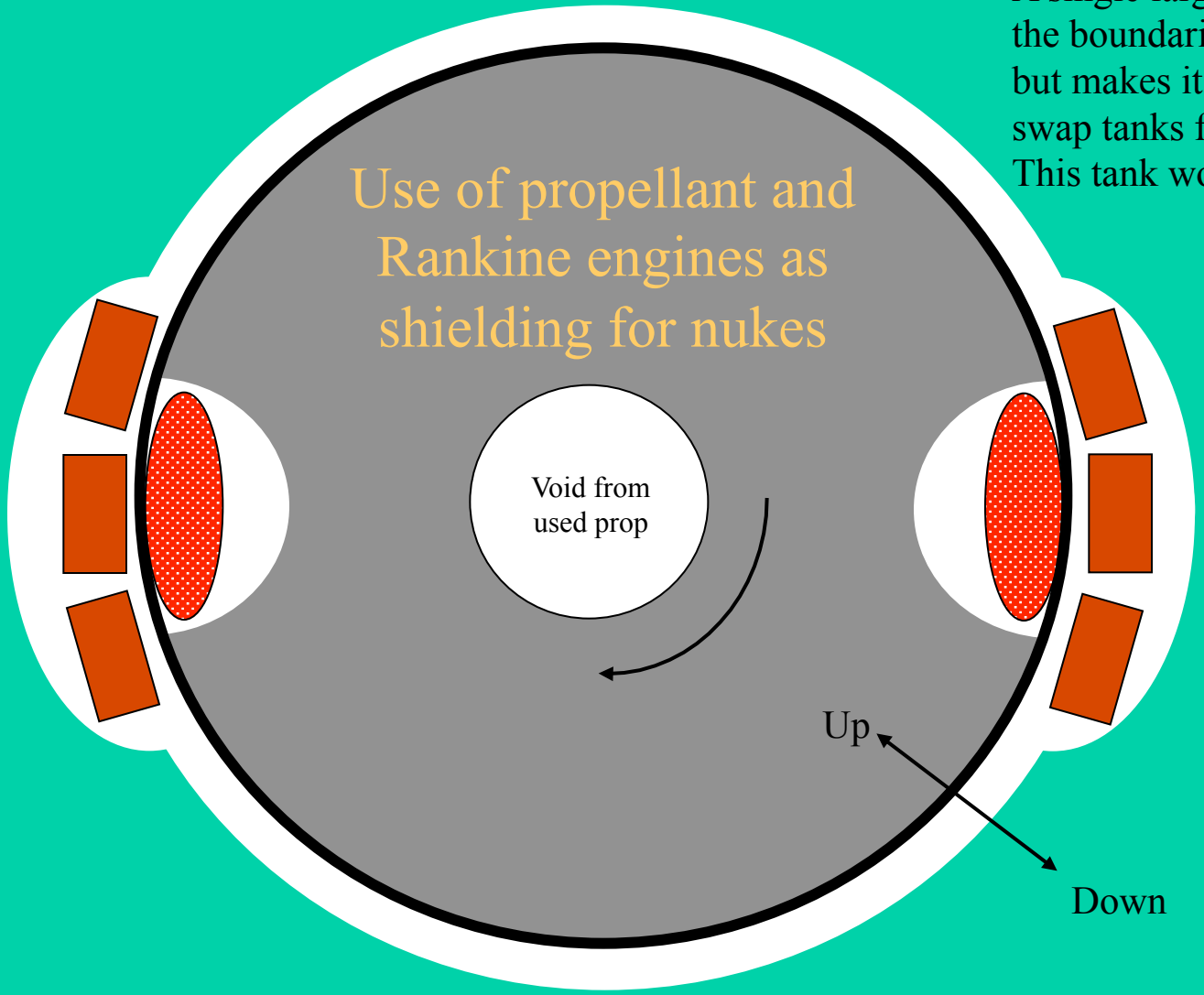
Idler wheels?

Alternate design - Power to drive motors can come from nukes, although they may not be fully powered up until 1g

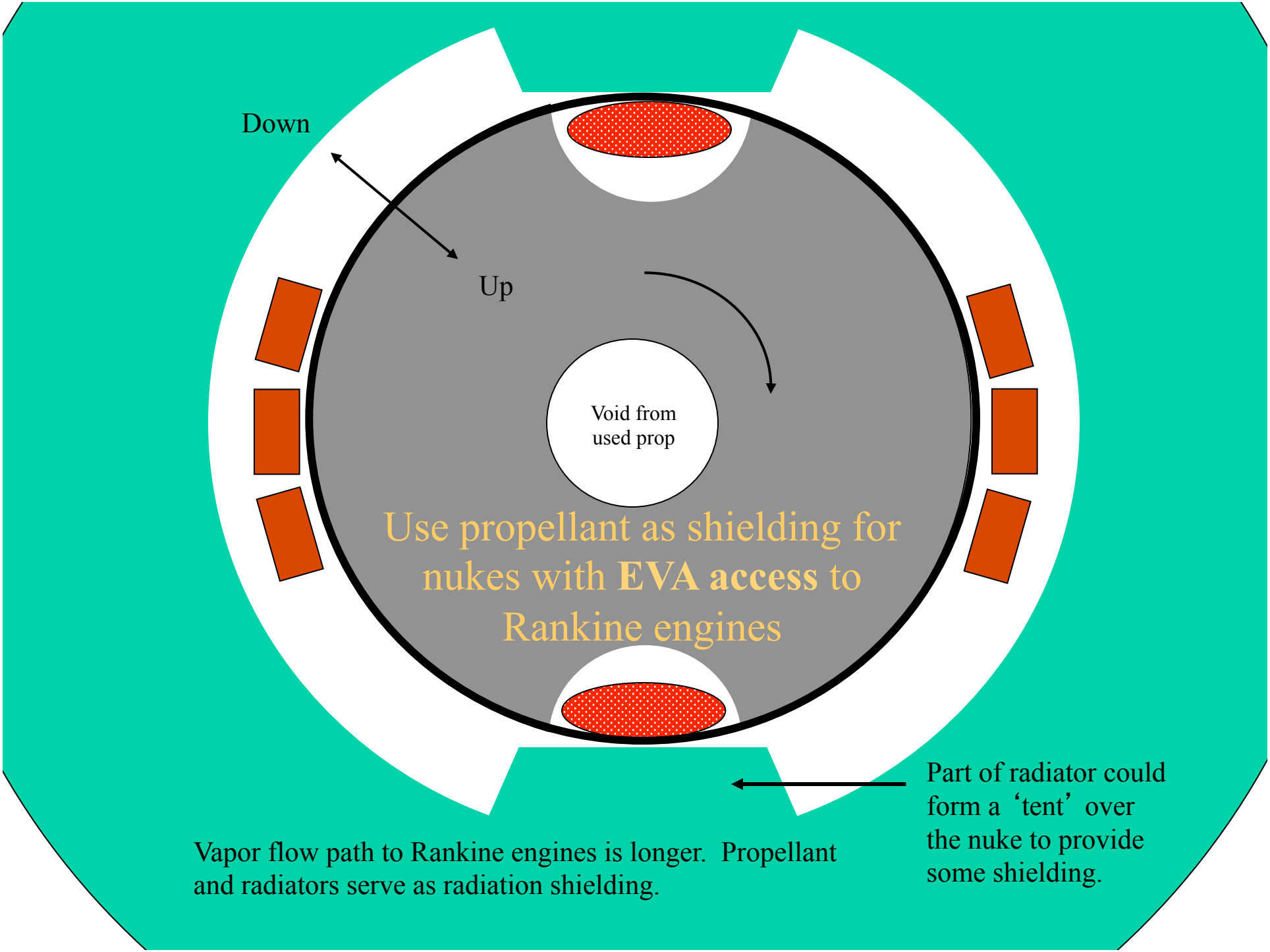


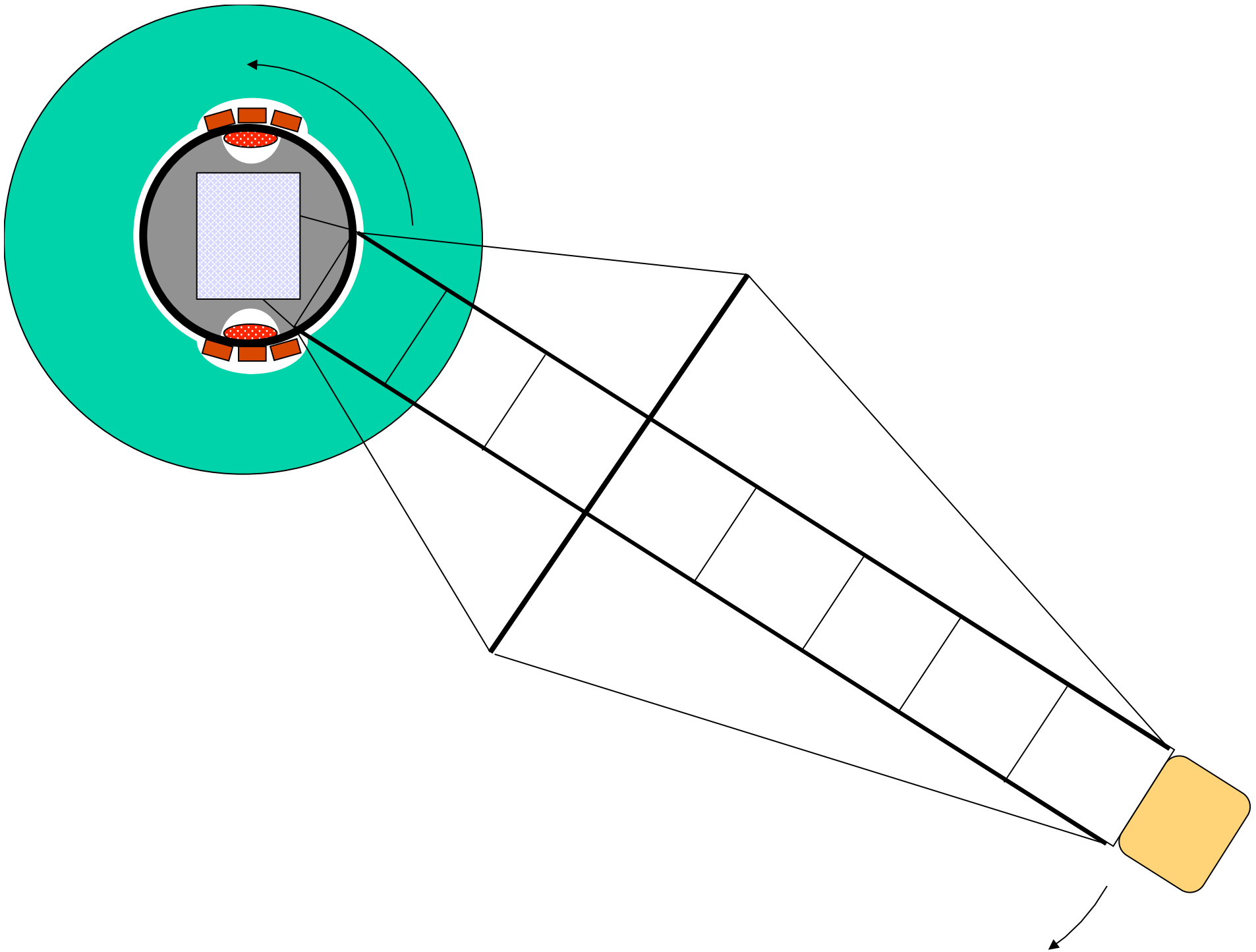

Planetary gear drive to allow prop and power to pass through center without moving joints.
To Hab
Drive motors (4)
Donut thruster, to minimize change in angular momentum. Could be supported by planetary gear via rollers (?)
Radiator Disk

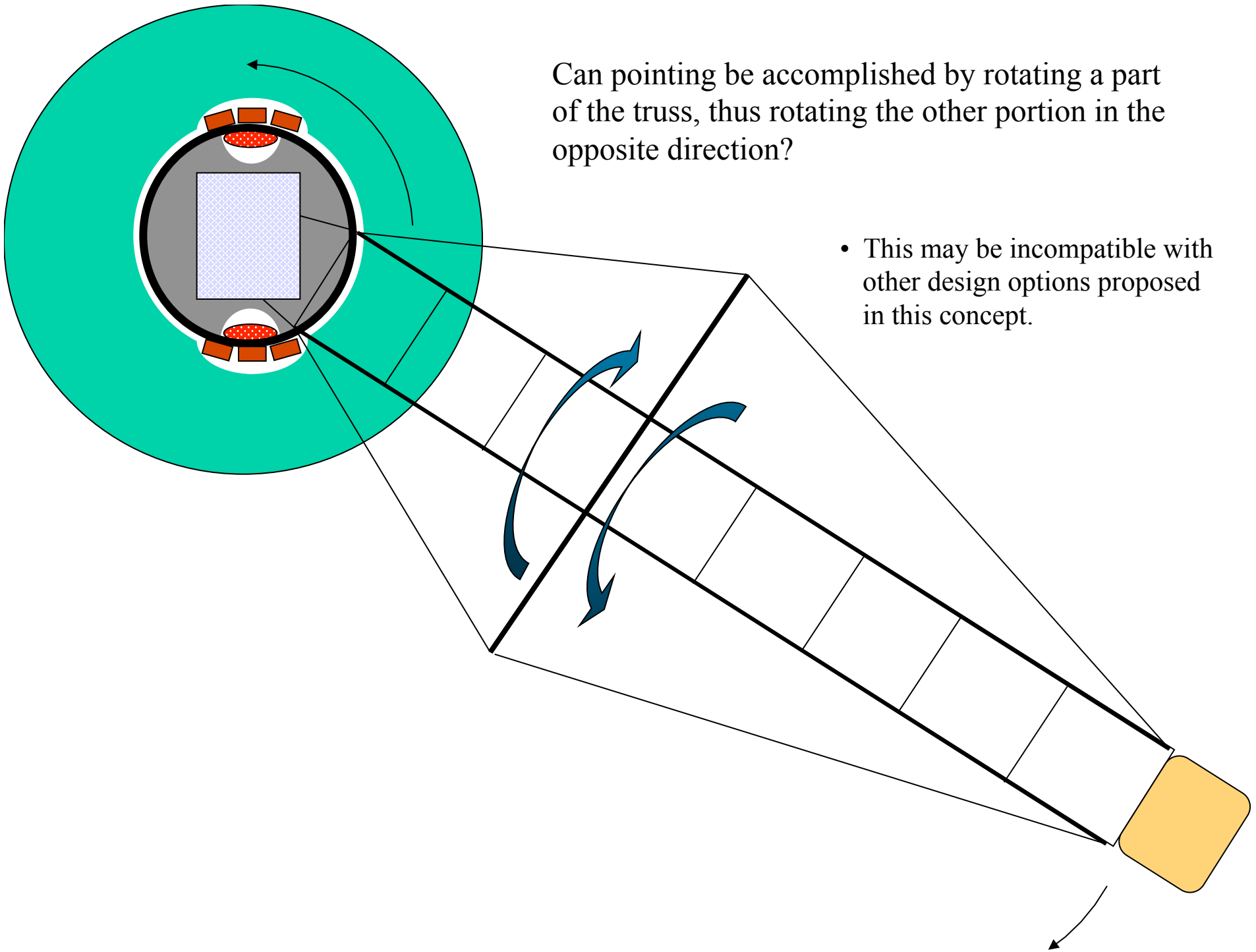
A single large tank defines the boundaries of the cage but makes it impossible to swap tanks for next flight. This tank would need to be refilled.



Single cylindrical propellant tank has squirrel cage track around its end caps. Recessed volumes carved out of tank for reactor. Rankine engines placed 'below' nuke, but vapor piped out of top of reactors to use natural boiling action to advantage. Pressure drop takes vapor to Rankine engines. Fluid then flows downhill to radiators. Propellant and engines serve as radiation shielding.

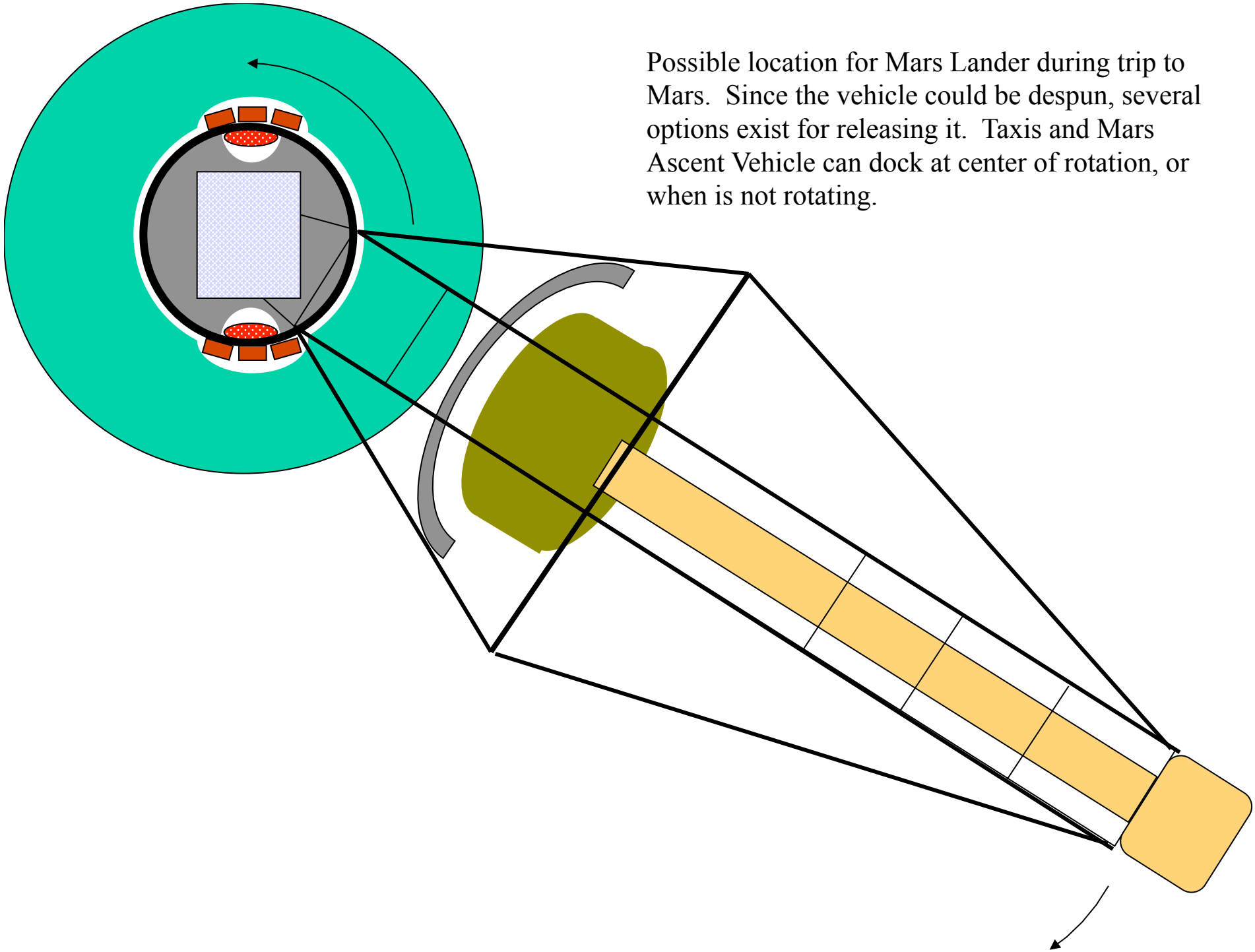

Down
Up
Void from
used prop
Use propellant as shielding for nukes with **EVA access** to Rankine engines
Part of radiator could form a 'tent' over the nuke to provide some shielding.
Vapor flow path to Rankine engines is longer. Propellant and radiators serve as radiation shielding.





Can pointing be accomplished by rotating a part of the truss, thus rotating the other portion in the opposite direction?

- This may be incompatible with other design options proposed in this concept.



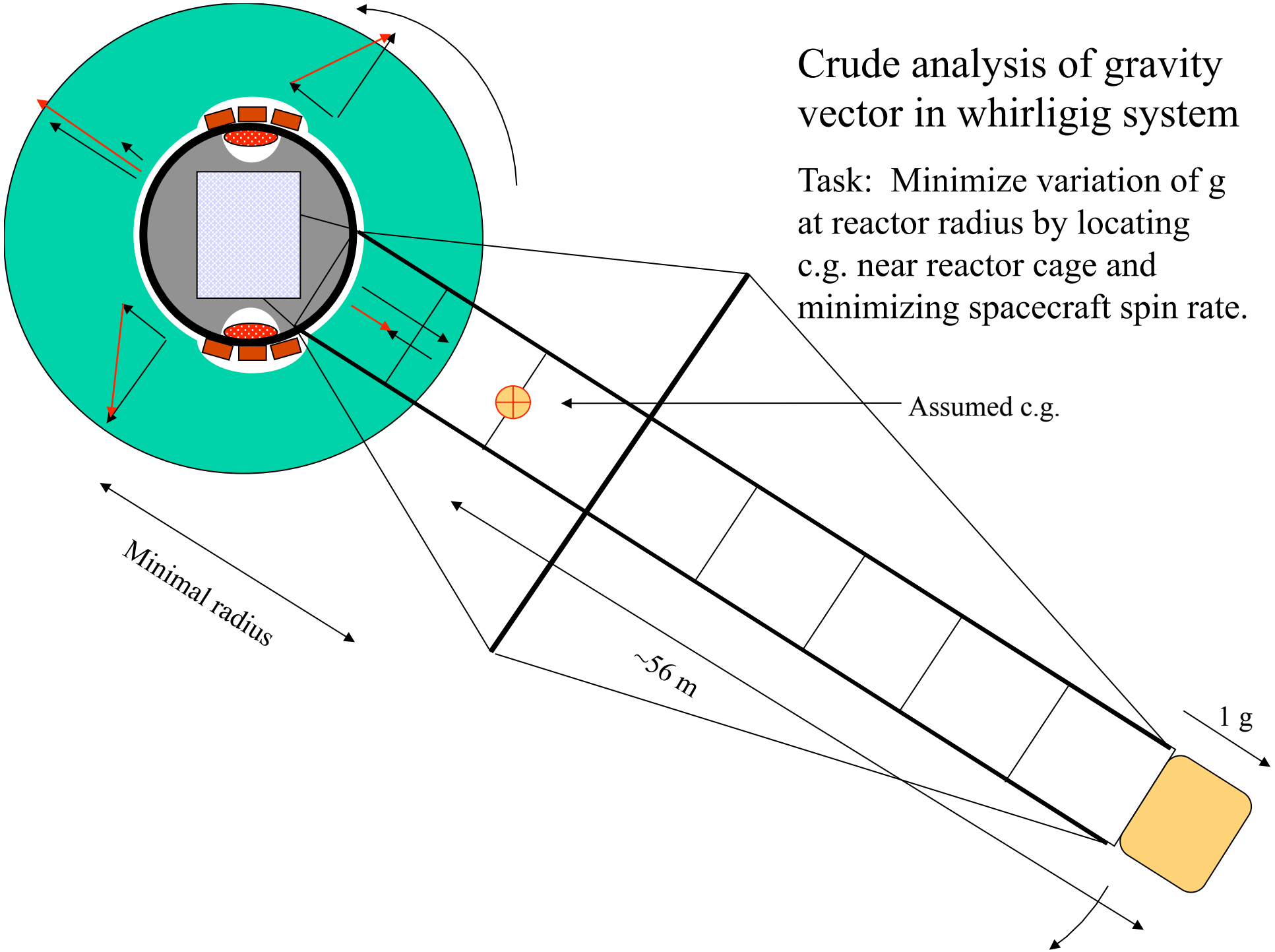
Possible location for Mars Lander during trip to Mars. Since the vehicle could be despun, several options exist for releasing it. Taxis and Mars Ascent Vehicle can dock at center of rotation, or when is not rotating.

Questions & Uncertainties

- What combination of spin rates, truss length, and mass distribution is correct for a 1 g hab and cage?
- How will sloshing affect spin rate, stability, etc.?
- Is EVA around Rankine engines required?
- What is the best shielding strategy for EVAs and the Hab (taking into account it is an interplanetary ship)?
- Can the truss be twisted to allow further control of thrust? (While the Lander is attached?)
- Does this ship still act like a gyroscope? Do its separate parts still act that way and fight each other?
- What variations in g will be experienced by equipment in the squirrel cage? Does counter-rotation keep g fairly constant despite the changing radius from the c.g.?

Crude analysis of gravity vector in whirligig system

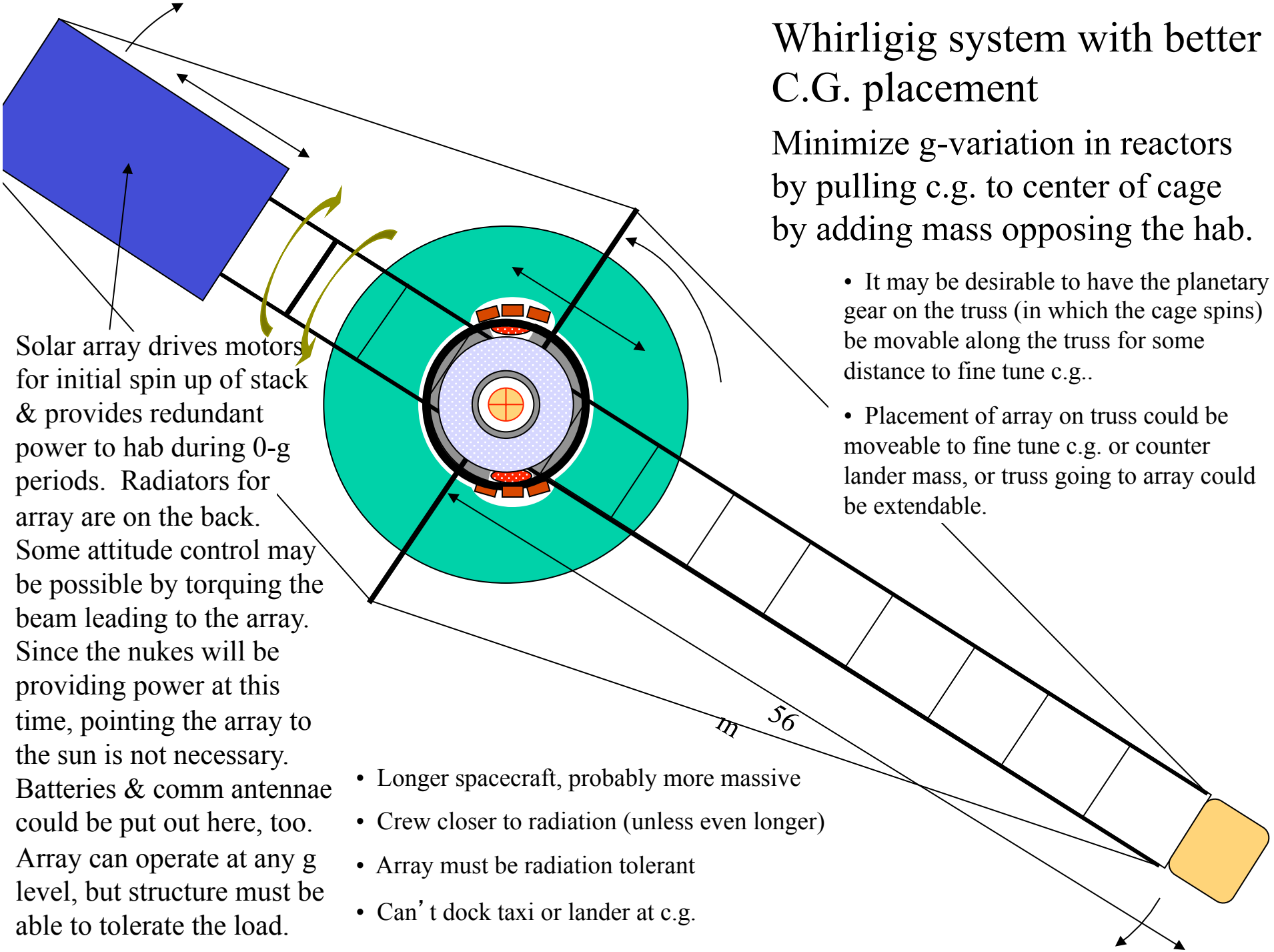
Task: Minimize variation of g at reactor radius by locating c.g. near reactor cage and minimizing spacecraft spin rate.



Whirligig system with better C.G. placement

Minimize g-variation in reactors by pulling c.g. to center of cage by adding mass opposing the hab.

- It may be desirable to have the planetary gear on the truss (in which the cage spins) be movable along the truss for some distance to fine tune c.g..
- Placement of array on truss could be moveable to fine tune c.g. or counter lander mass, or truss going to array could be extendable.



Solar array drives motors for initial spin up of stack & provides redundant power to hab during 0-g periods. Radiators for array are on the back. Some attitude control may be possible by torquing the beam leading to the array. Since the nukes will be providing power at this time, pointing the array to the sun is not necessary. Batteries & comm antennae could be put out here, too. Array can operate at any g level, but structure must be able to tolerate the load.

- Longer spacecraft, probably more massive
- Crew closer to radiation (unless even longer)
- Array must be radiation tolerant
- Can't dock taxi or lander at c.g.

Opportunities

- G-level of reactor can be varied separately from that of the hab. It is possible that eventually it might be operated more efficiently at > or < 1 g.
- Many other designs which maintain a net angular momentum of 0 are conceivable.

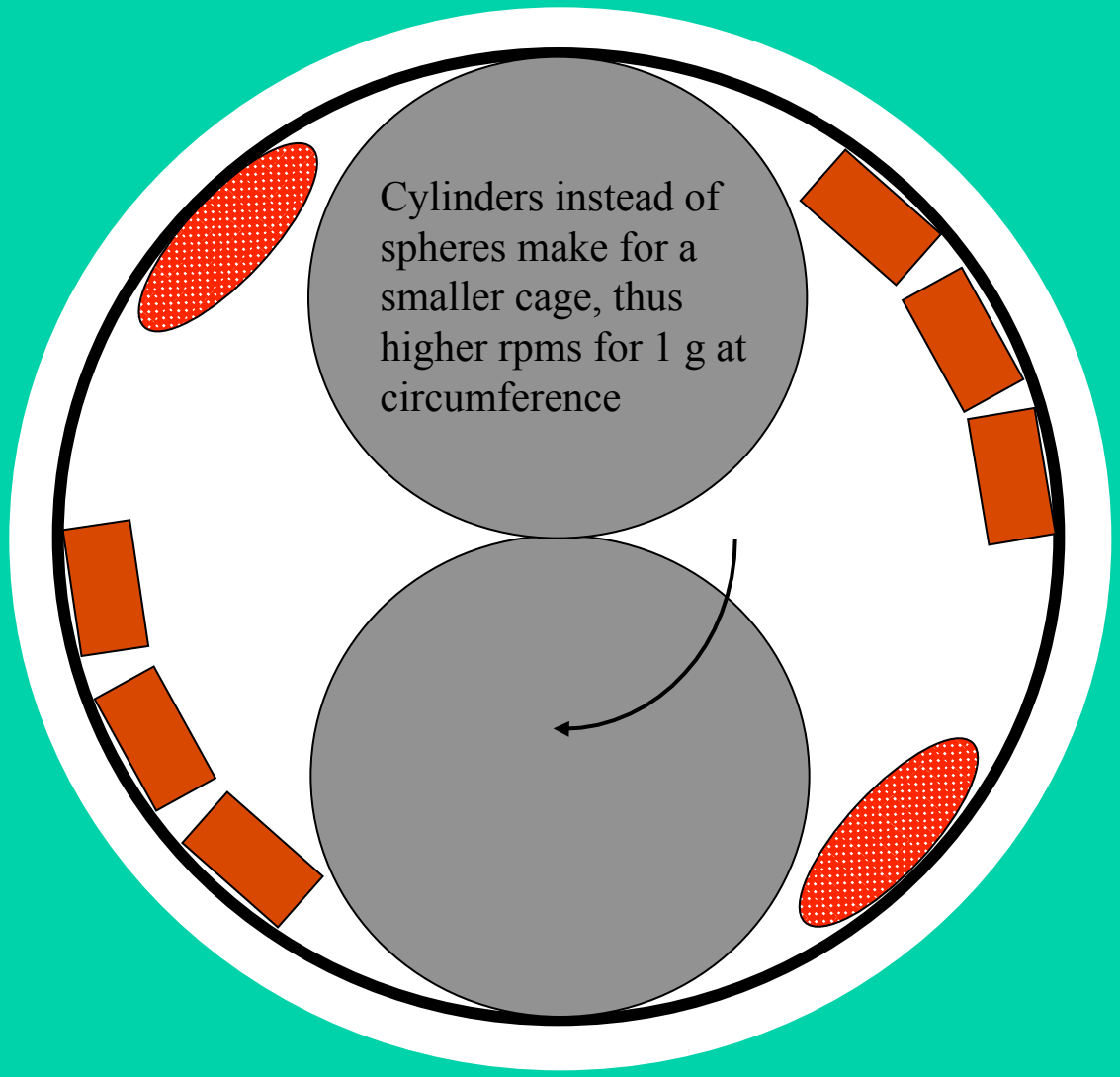
Summary

Plusses

- Spin up counter-rotating masses with electric motors, not prop
- Multiple spin down/up with no penalty
- No need to balance hab and nukes
- Decouples rpm requirements for humans and nukes
- Shield nuke with prop and Rankine engines, and perhaps Mars lander
- No rotating joints for power, prop, cooling
- Frees up c.g. for docking lander, taxi
- Net angular momentum stays 0 (goal)
- Flywheel emergency power possible
- Very similar vehicle could be designed for variable g research facility for LEO

Minuses

- As prop is consumed, c.g. may shift
- As prop is consumed, angular momentum may need to be adjusted (motors available to do so, but split between reactors and hab may cause rotation rate to increase for crew)
- A.G. level in squirrel cage may vary sinusoidally (1 +/- g) as it spins
- EVAs to repair anything on cage will require going to 0 g (no spin), which may take a long time to attain.
- Sloshing may be a control problem.
- Parts flung off cage could hit hab.



Propellant serves as radiation shielding for one reactor at a time, but EVA around Rankine engines would not be safe unless additional shielding is placed between reactor and engines. This design makes it easier to swap out prop tanks for subsequent flights.

LEO Variable G Research Facility Concept

Uses same principle of counter-rotation for spin-up and spin-down