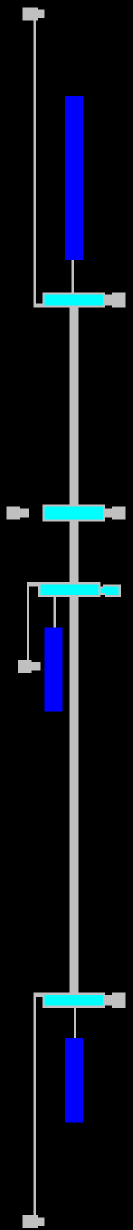
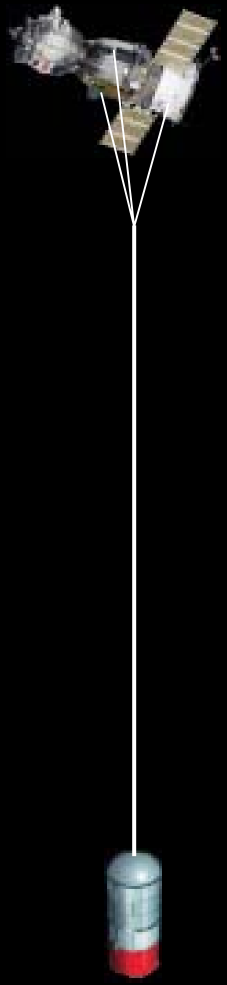


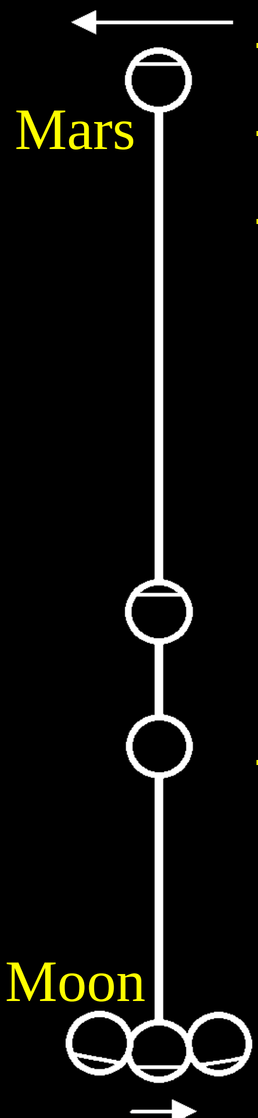
Design Concepts for a Manned Artificial Gravity Research Facility



2010 IAF Congress, Prague
September 27, 2010

Joe Carroll
Tether Applications, Inc.
619-421-2100; tether@cox.net

Possible Goals for Artificial Gravity Facility



- Focus on the overall effects of long-term hypogravity
- Allow realistic planning for Moon & Mars settlements
- Facility can address questions like:

  1. Can people stay healthy for years—and years later?

  2. Can mice and monkeys reproduce normally?

  3. Can monkeys raised in low gravity adapt to earth?

  4. What plants may be useful for food production?

  5. Does hypogravity allow advances in basic biology?

- Facility can also resolve nearer-term issues like:

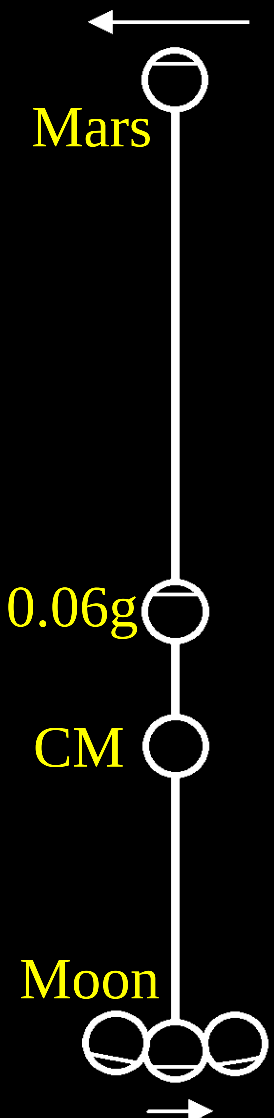
  6. How much gravity to use in cruise to and from Mars

  7. How much gravity to use on-station near NEOs

  8. What spin rates and designs are desired for cruise

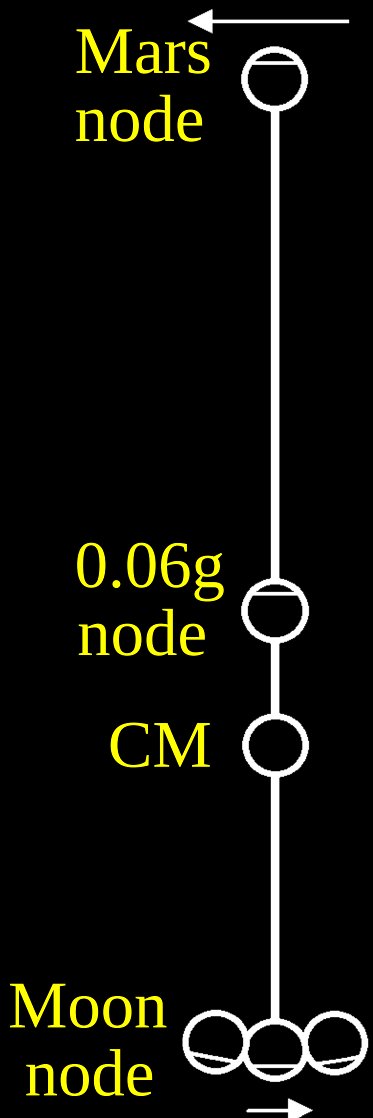
  9. What gravity countermeasures may still be needed

Why 0.06 Gee, and not Just Moon and Mars?



1. It’s the next ~1/e step, after Earth—Mars—Moon
   - This makes it a useful step for fundamental bio studies
   - Nobody knows what levels trigger gravity responses
2. It may be the lowest level allowing intuitive behavior
   - Sitting, using a desk, hygiene, even rolling over in bed
   - It may not require days of accommodation—or may aid it
   - It may be popular with tourists, or for unique exercises
3. It’s also good if you want some gravity, but not much
   - Plant growth tests; satellite assembly, etc.
4. Finally, it’s very easy to add: same hardware, etc.

Basic Moon/Mars Dumbbell Concept



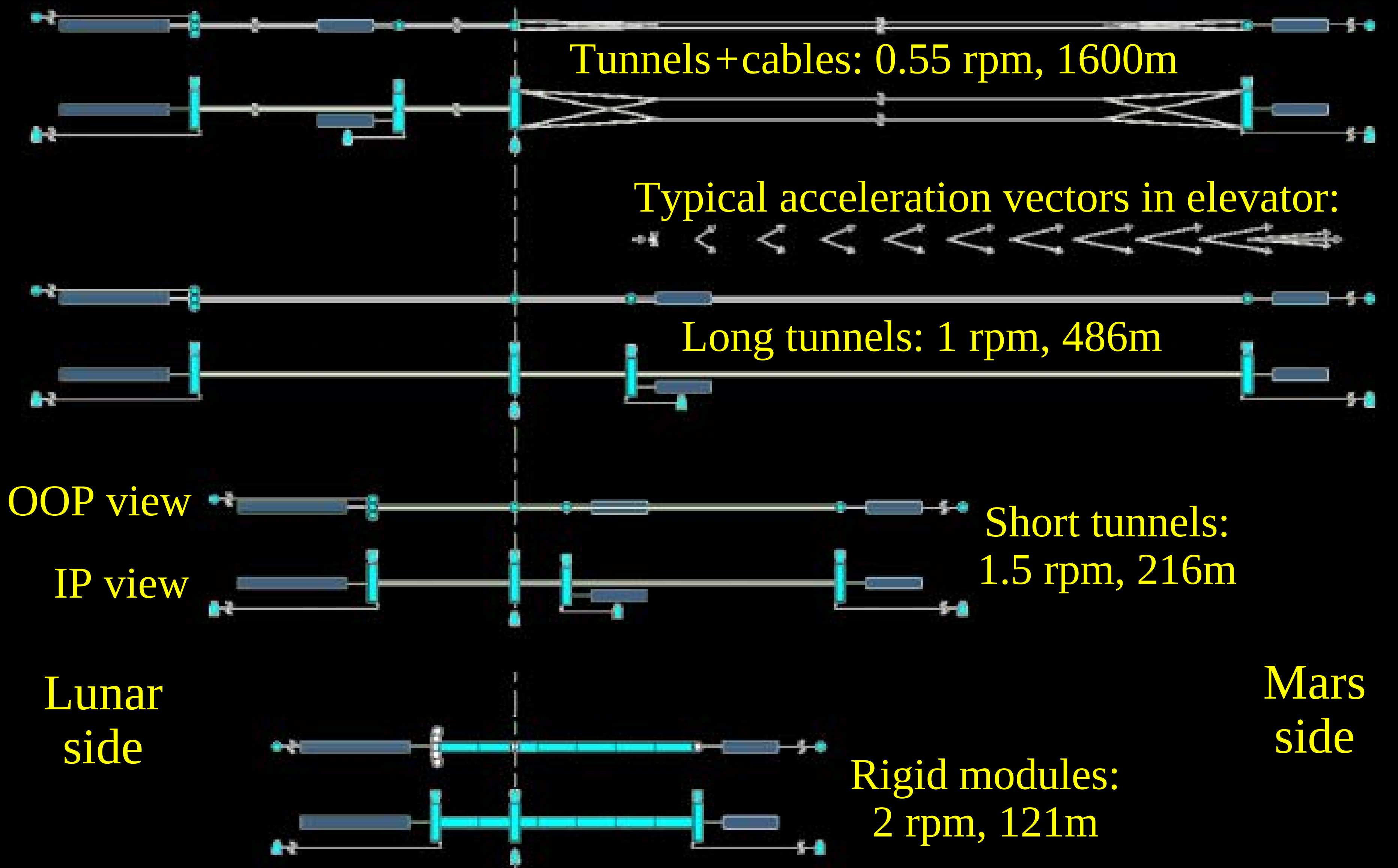
A Key Challenge:

We really don’t know what rotation rates are reasonable, since ground-based rotating rooms have ***very*** different effects. We need better tests of rotation & Coriolis susceptibility for these facilities. Until then, we should consider a variety of lengths ***and designs***:

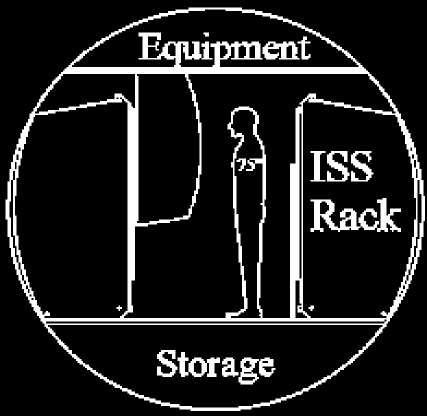
4 Options for Radial Structure:

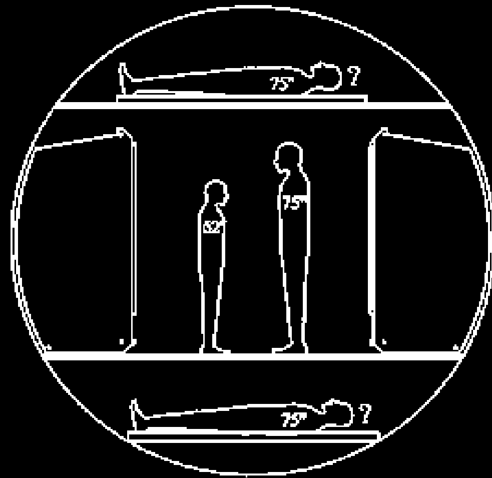
Spin rate	Length	Radial structure	Key length-limiters:
>2.0 rpm	<120m	Rigid modules	Mass of radial modules
>0.8 rpm	<760m	Airbeam tunnels	Tunnel area, impact risk
>0.55 rpm	<1.6km	Tunnels + cables	Area; post-cut perigees
>0.25 rpm	<8 km	Cables	Cable mass; node “

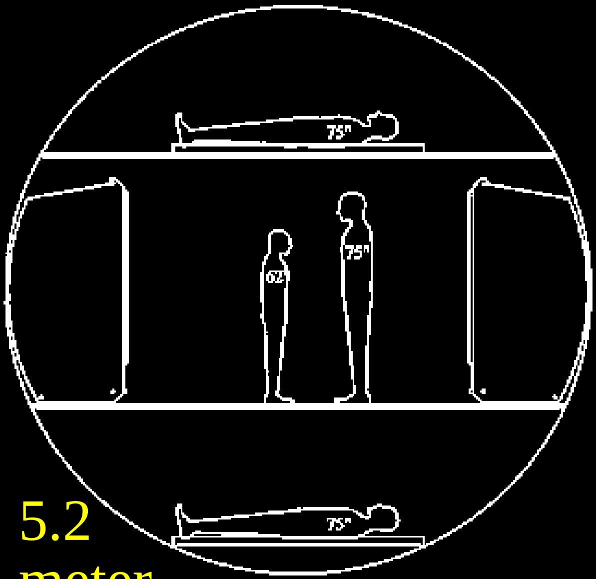
Radial Structure Options vs Length



Some Cabin Layout Options



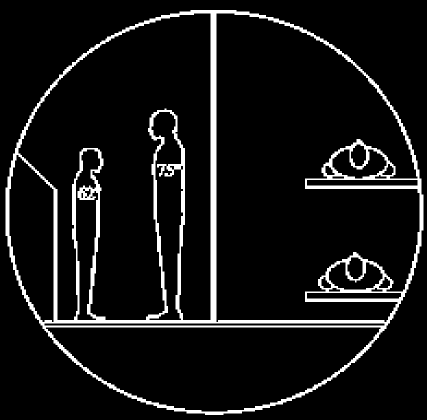


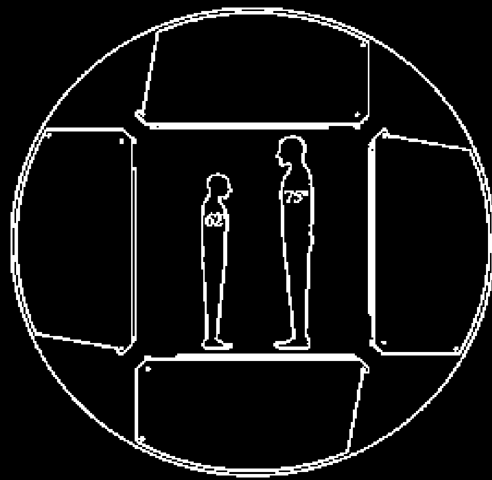


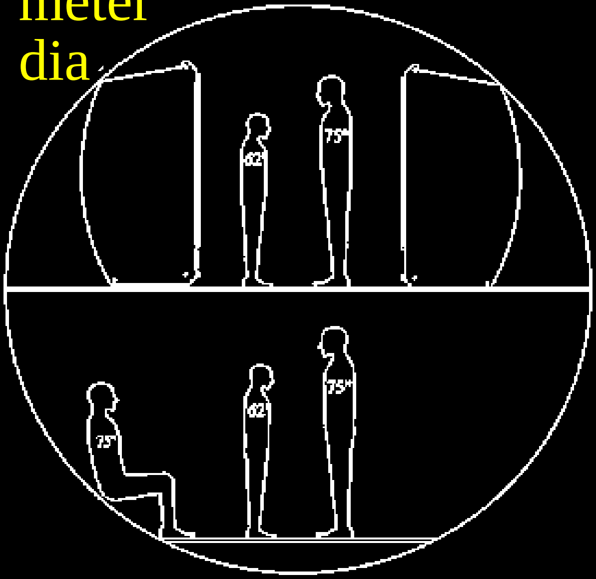
3.6 meter dia

4.2 meter dia

5.2 meter dia

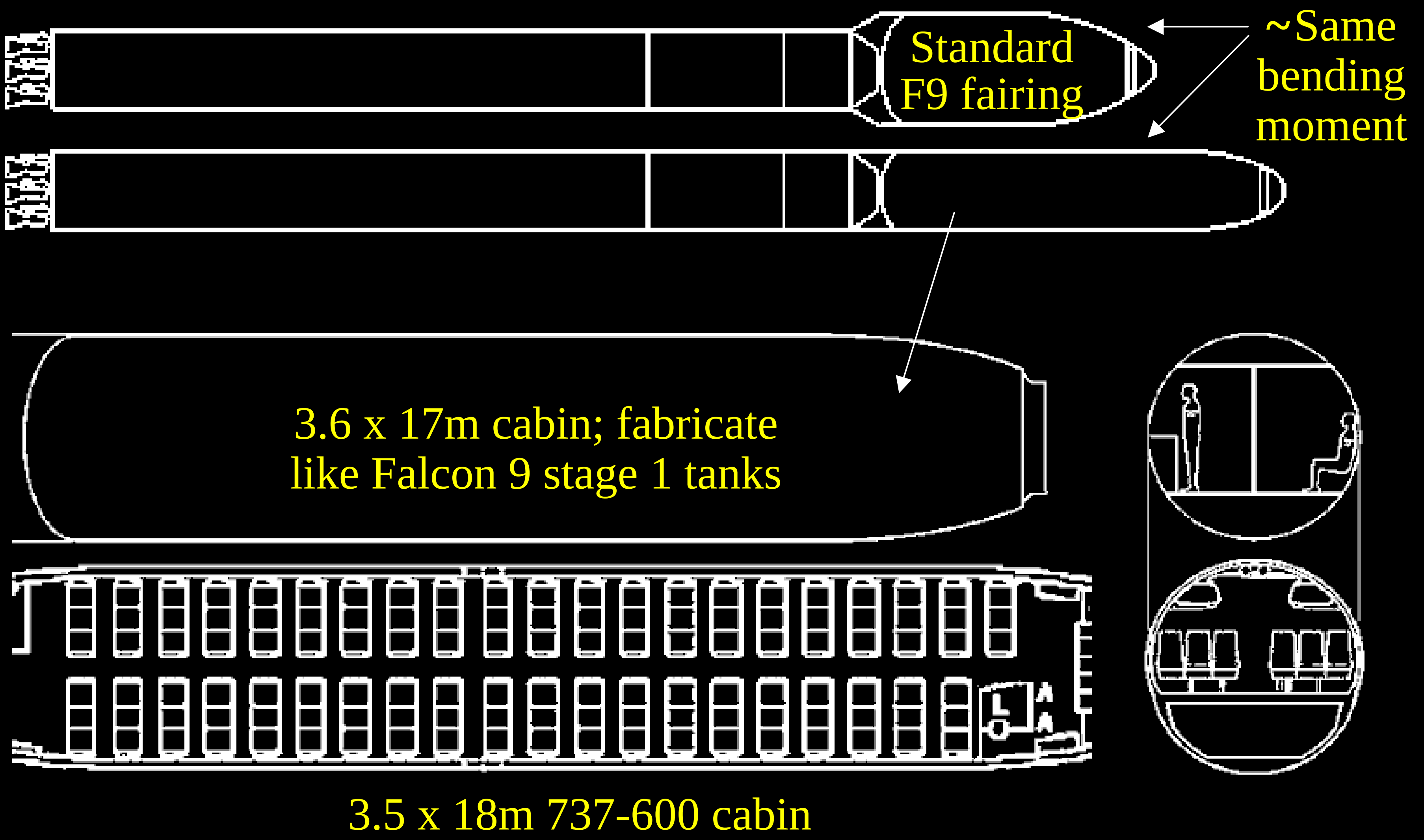






ISS lab layout

Falcon 9 Cabin Compared to 737-600



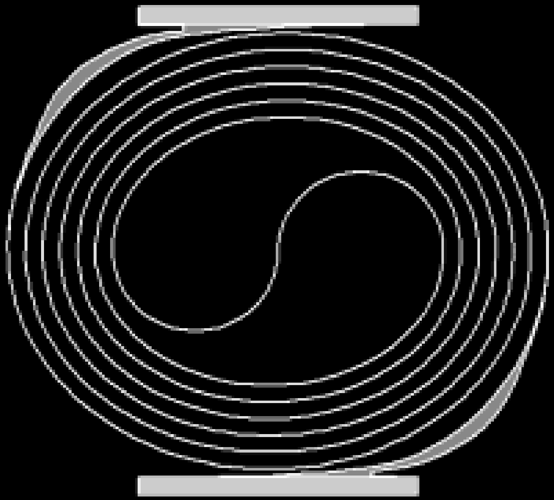
Airbeam Tunnels for Radial Structure

Inflatable airbeams

- Vectran fiber in flexible matrix
- Damage tolerant; easy to customize
- Two people can carry beam at left

Tunnel stowage

- Fold deflated beam in half & roll up
- Keeps rigid end fixtures on outside:



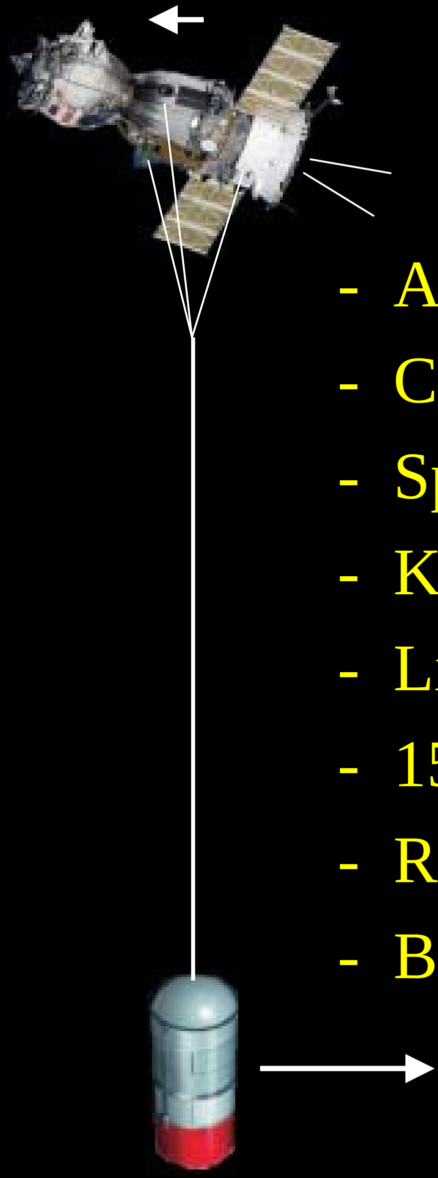
Five Stages of Facility Development

<u># cabins and key new operations</u>

0	Tether manned capsules to spent boosters for tests
1	Launch 1 cabin, berth capsule, spin up with booster
3	Launch 2 more cabins; join; use any counterweight
6	Launch 3 more cabins + tunnels; join to lunar node
14	Launch 8 more cabins, despin; attach; & spin up

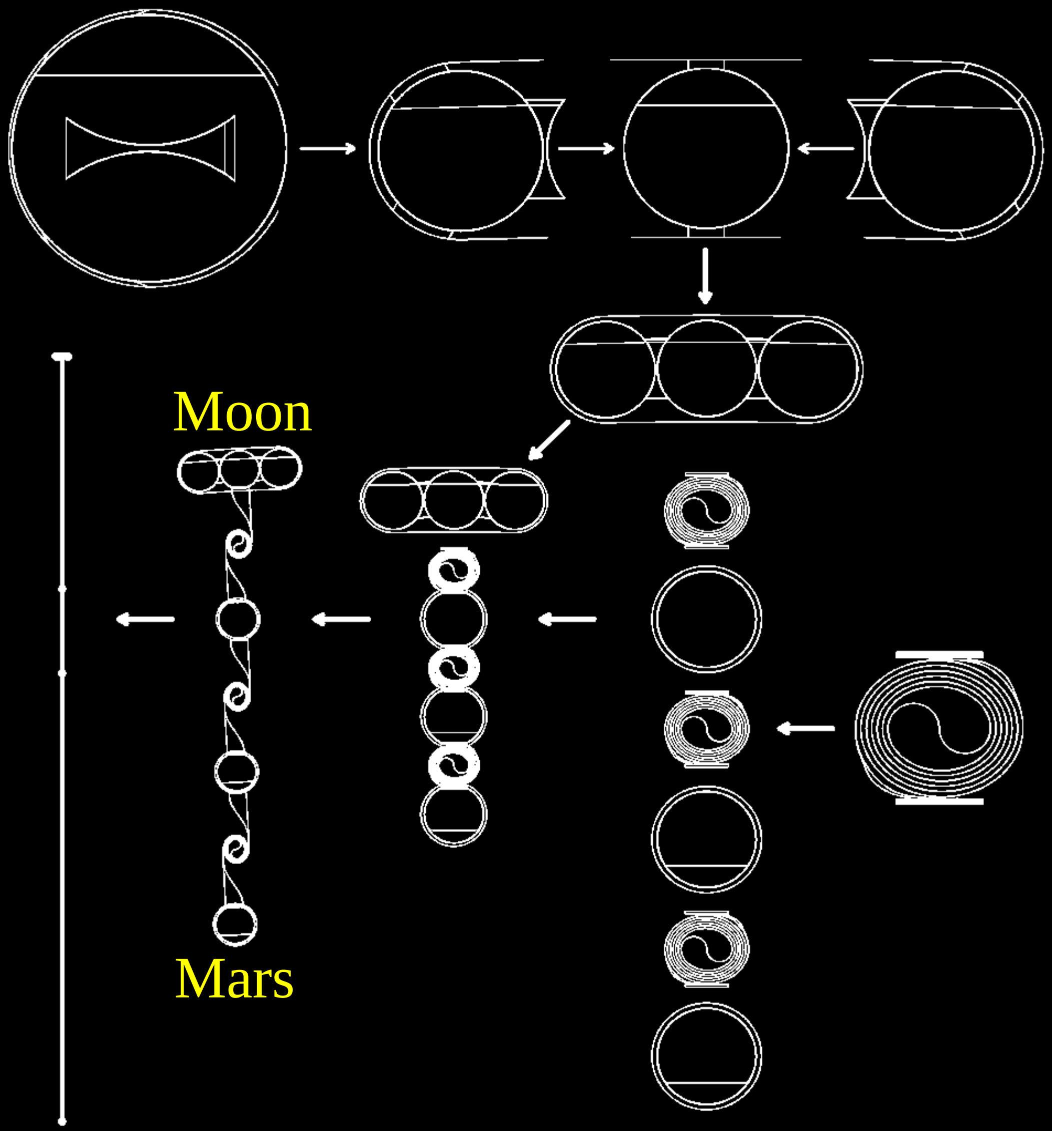
- The first 3 stages are developmental precursors
- A final decision on radial structure is needed by stage 4
- Stage 5 requires 8 more cabins; do only when needed

Stage 1: Gemini-like Tether Tests



- After MECO, pay out tether from booster to Soyuz
- Can be done during phasing, on any flight(s) to ISS
- Spin up w/pulsed posigrade burns during phasing
- Kite bridle on manned end can stabilize its attitude
- Like Gemini XI test, but longer tether & faster spin
- 150m from CM, 0.6-1 rpm gives 0.06-0.16 gee
- Release spent booster when it is moving backward
- Boost in south & release in north, to deorbit booster

Stages 2-4: Evolution



Stage 2: 1 cabin

- 1 cabin + spent booster
- Can test trapeze capture

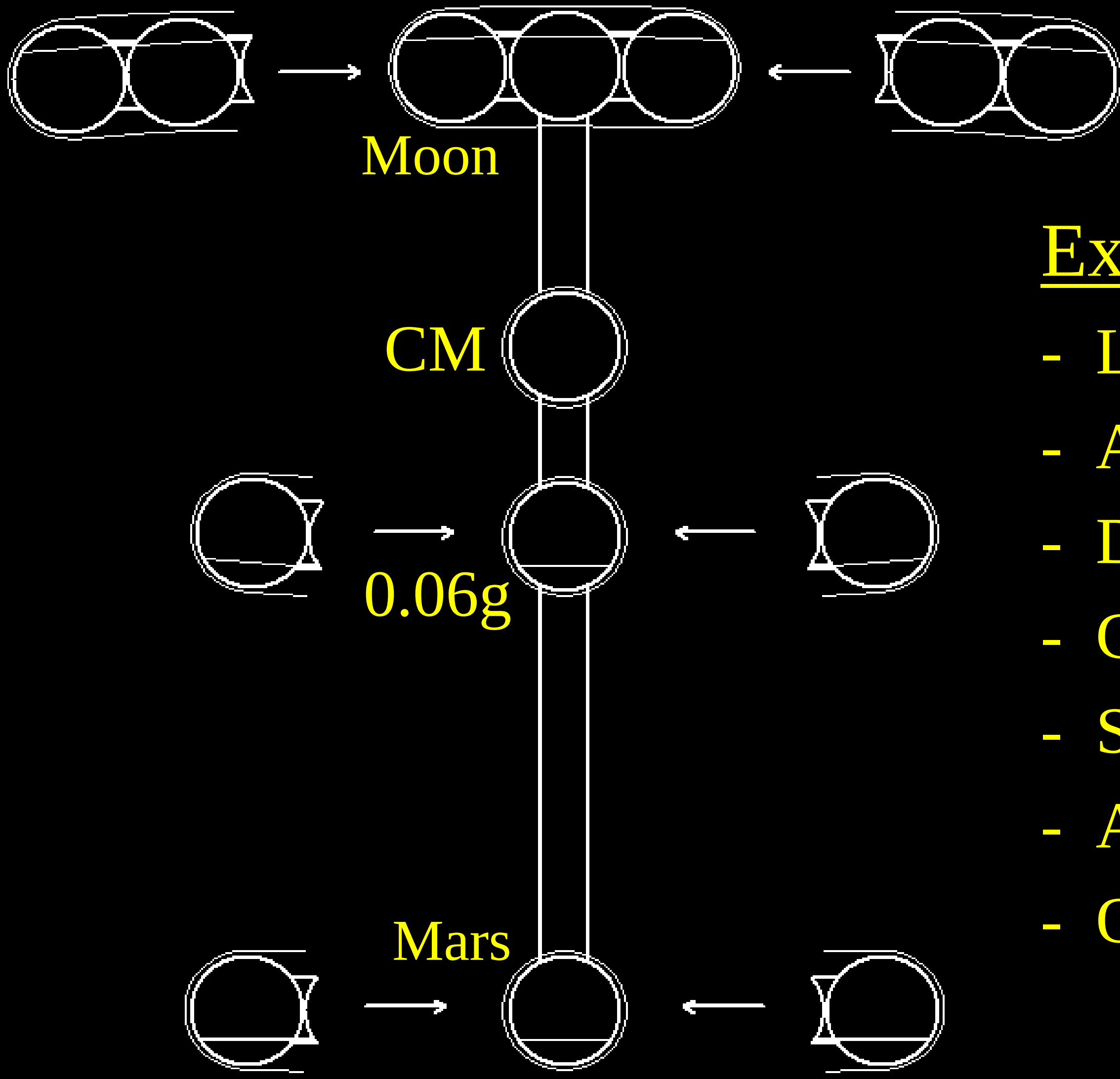
Stage 3: 3 cabins

- Attach 2 more cabins

Stage 4: full assembly

- Launch 3 cabins + tunnels
- Join 6 cabins w/tunnels
- Deploy tunnels 1 by 1
- Inflate slightly to deploy
- Spin up from Mars end

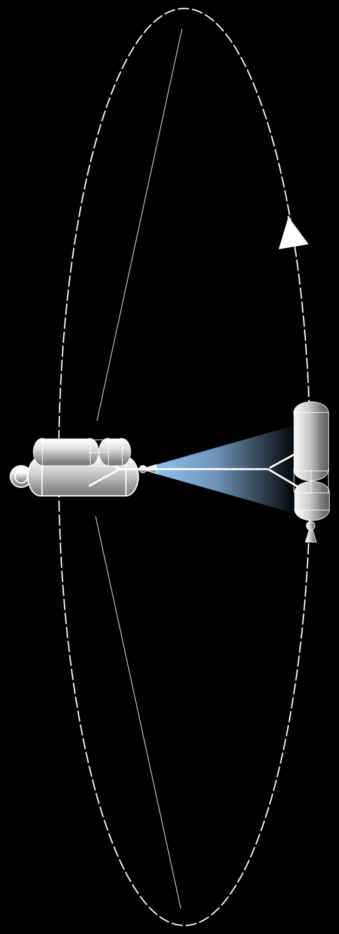
Stage 5: Facility Expansion



Expansion sequence:

- Launch **8** new cabins
- Assemble lunar pairs
- Despin (or slow down?)
- Capture & berth cabins
- Spin facility up again
- Adjust ballast, to balance
- Outfit new cabins later

Two Operational Derivatives

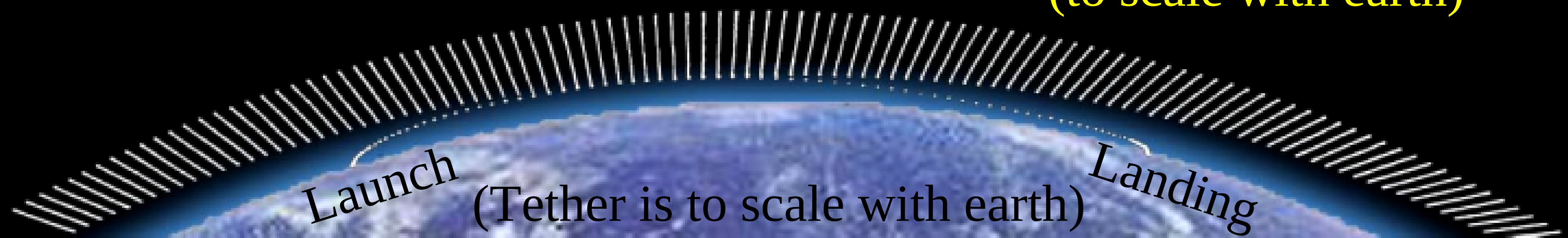


Spinning exploration cruise stage:

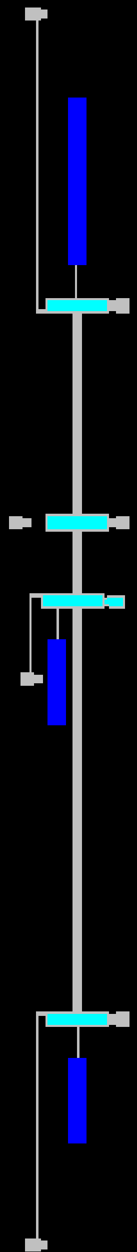
- Uses spent departure stage as ballast
- Can retain stage through maneuvers
- Tether cut: lose gravity, not mission

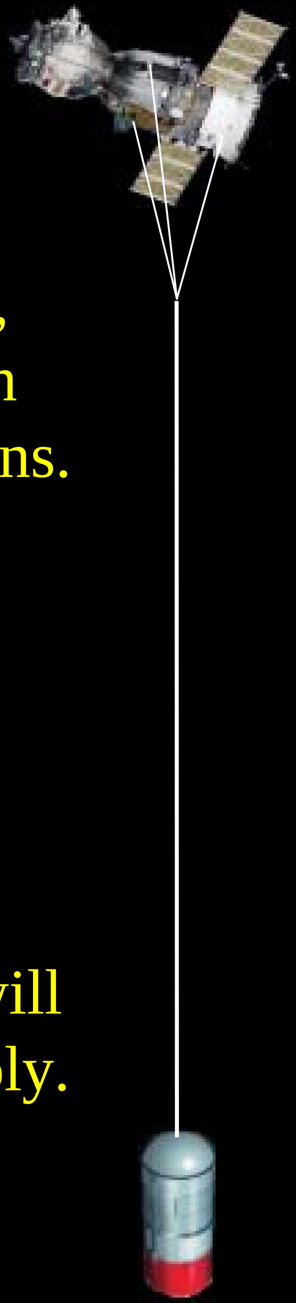
High-deltaV spinning LEO sling:

- 2-3.4 km/sec above ***and*** below V_{LEO}
- Similar trapeze accelerations (0.5-1g)
- Low capture altitude, for soft reentry
- Shown: 1.2 km/s ΔV; 290 km tether (to scale with earth)



Conclusions





1. Man has been going into orbit for almost 50 years, but we seem stuck. Maybe it's time to take human physiology seriously, ***before*** planning long missions.

2. A manned artificial gravity facility in LEO lets us learn more about our future and any limits on that future, ***and*** lets us test ways around those limits.

3. We can start with spinning tether tests as done on Gemini XI, to assess spin-related artifacts. This will let us settle on a facility design, quickly and cheaply.