Philips ‘BoLo’, ‘YoYo’, and ‘PoGo’ Space Habitats

A cost-effective system to create 1 g environments for long duration space occupation

Experience has shown that the human body suffers from long exposure to a zero g environment.

Proposed solutions include the von Braun torus and O’Neill cylinder, which have been subjected to extensive engineering study.

JAPL has over fifty years of experience in engineering design and construction management, from nuclear reactors, missile and launch systems, and submarine building and deployment. JAPL suggests that although the poetry of these rotating behemoths is obvious, the real cost of logistical supply and support make them infeasible with current human capability.

An alternate cost-effective solution is being proposed: the BoLo habitat and its derivatives. The following describes generally the concepts.

This proposal relies upon the significant work done by many recent aerospace teams to develop the software and equipment allowing automated docking and soft landings of spaceships. This precise control allows coordinated placement of multiple craft and the ability to easily change the shape of and relative motion of the elements of a joined habitat.

The requirements for the creation and sustenance of a 1 g environment and habitat could be as little as the cost of three orbiters.

The solution is to spin two orbiters on a tether about a common center, which is now feasible due to the automation, allowing the spacecraft to work with precise synchronization.

Safe interplanetary flight can be accomplished by yoking the orbiters together in LEO, initiating powered flight as a unit until velocity vectors to be gained are achieved for the desired trajectory, separating the spacecraft to the ends of the tether, and in concert, slowly begin orbit about the common center to generate simulated gravity on each ship.

When required, prior to arrival on station, the ships can actively reduce their relative motion until they once again spool in the tether and attach to one another.

This design can also be used not just for travel, but for any long duration or permanent structure in a location capable of accommodating an activity of this size (not in orbit lanes, LEO).

This design can be expanded to any multiples of spacecraft.

Additional engineering and material can be applied to the BoLo system to provide storage, and also mass transfer between habitats, potentially less than the cost of a third orbiter.

Cover Page
Project Summary

BoLo, YoYo, and PoGo Space Habitats
Cost Effective - Functional 1 g Space Structures

132601-2-092-2005

15 August 2019

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Drawn by: Allen Philips

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The advantage of the BoLO-YoYo-PoGo design is its low cost, engineering and logistic feasibility, and substantial capacity for scaling.

Each system can be scaled to the mission need, and

Each mission configuration can be changed and swapped as necessary, and systems can be reused and reconfigured for multiple missions.

Want to send a Chinese vessel and an American? Change the vessel harness and change the tether length to balance the forces, voila!

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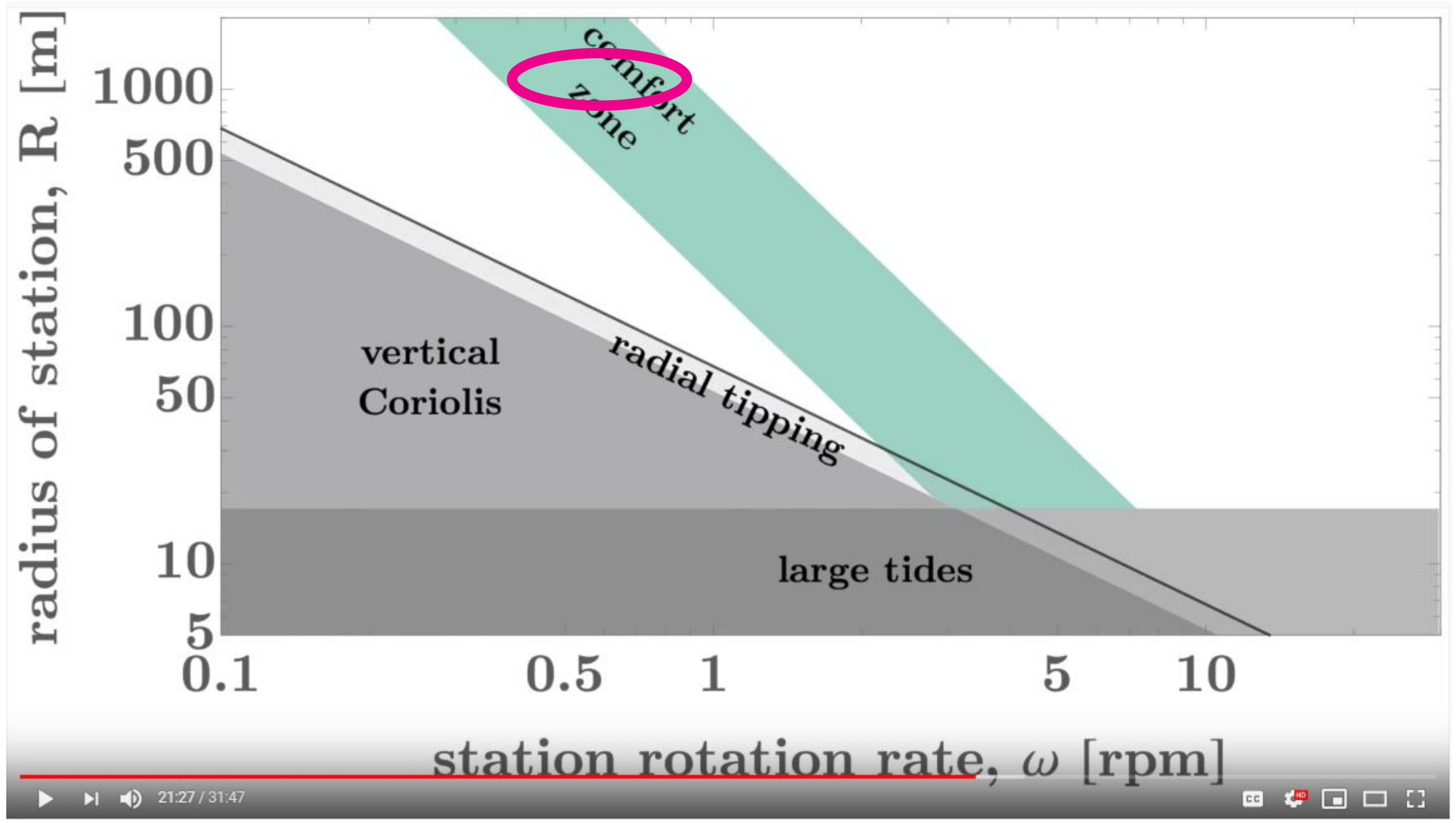
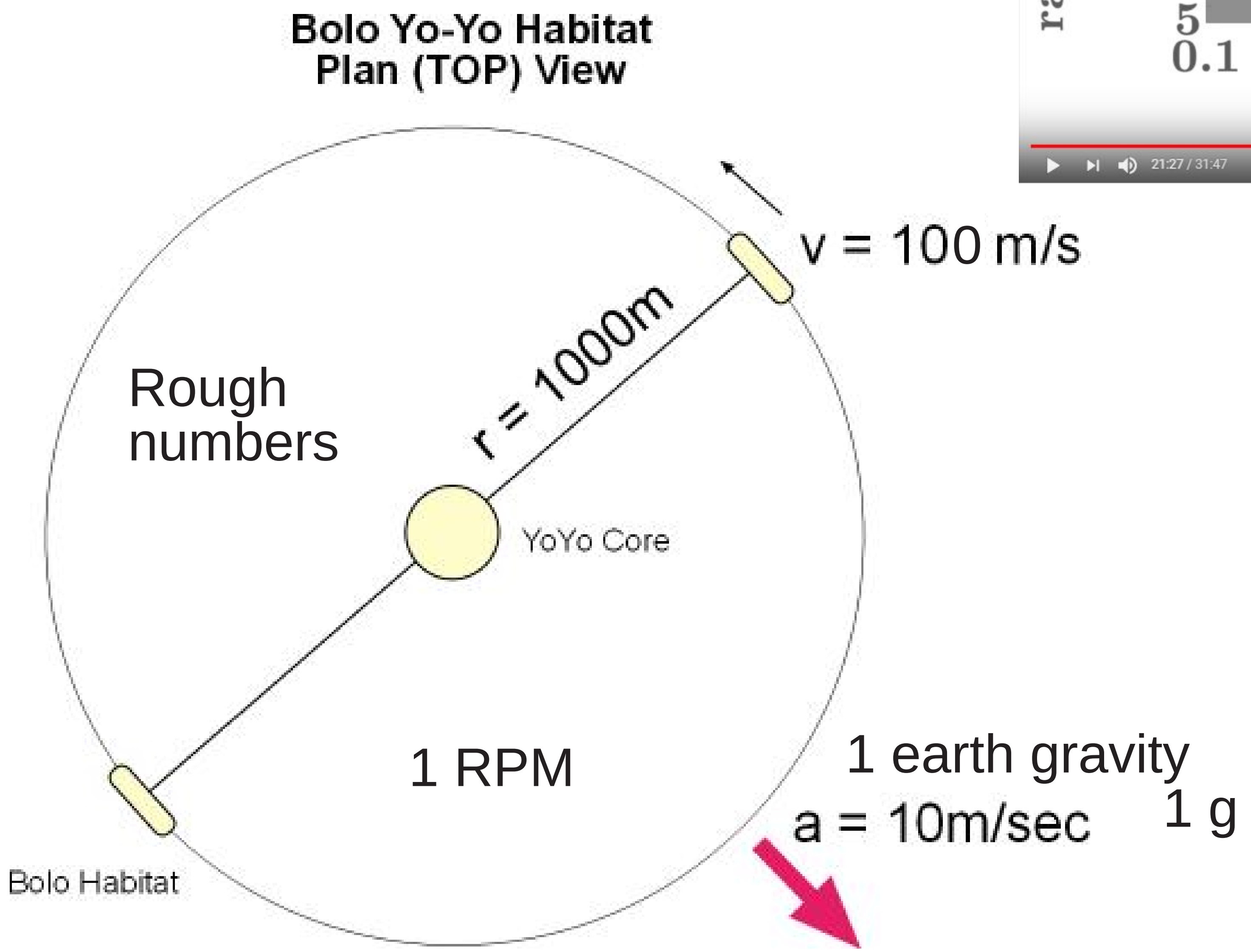
BoLo Habitat Overview

When two BoLo Habitats are rotaing around a common center at radius 1000 m and a rate of 0.5 to 1 rpm, the occupants will experience a force similar to earth's gravity.



Station comfort zone calculation plot courtesy Columbai Univeristy Cool Worlds



BoLo Habitat Overview

This overcomes the inability of the human body to remain healthy in 1g environments and allows long duration planetary travel and interplanetary activities.

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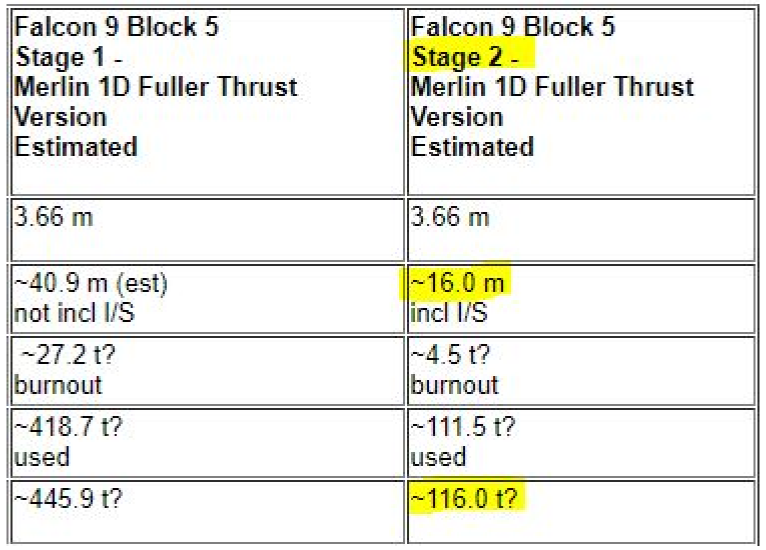
BoLo Habitat Overview

The BoLo Habitats can be constructed at significantly reduced infrastructure cost and logistical effort as follows:

- Two spacecraft in low earth orbit
- Two stainless steel aircraft cable tether systems
- King Pin

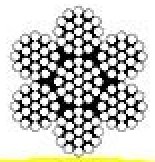


Falcon 9 Block 5 **Stage 1 -** **Merlin 1D Fuller Thrust** **Version** **Estimated**	Falcon 9 Block 5 **Stage 2 -** **Merlin 1D Fuller Thrust** **Version** **Estimated**
3.66 m	3.66 m
~40.9 m (est) not incl I/S	~16.0 m incl I/S
~27.2 t? burnout	~4.5 t? burnout
~418.7 t? used	~111.5 t? used
~445.9 t?	~116.0 t?

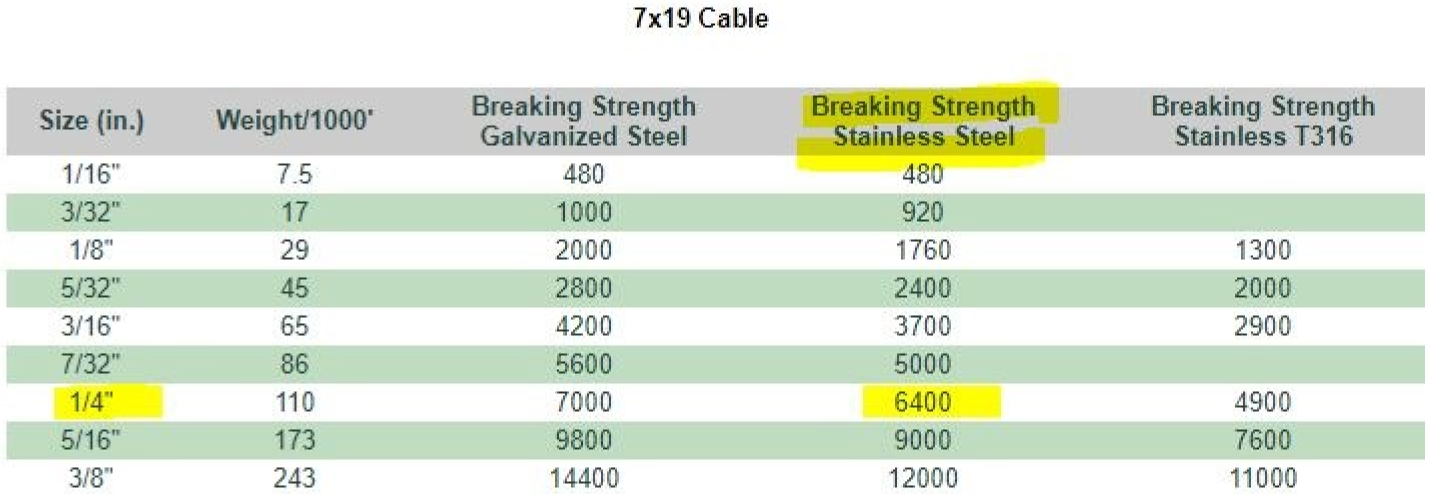
Basic Structural Information

A Falcon 9 2nd stage fully loaded:

Dia: 12ft   Length 60ft   mass 100 tons



7x19 Aircraft Cable



7x19 Cable

Size (in.)	Weight/1000'	Breaking Strength Galvanized Steel	Breaking Strength Stainless Steel	Breaking Strength Stainless T316
1/16"	7.5	480	480	
3/32"	17	1000	920	
1/8"	29	2000	1760	1300
5/32"	45	2800	2400	2000
3/16"	65	4200	3700	2900
7/32"	86	5600	5000	
1/4"	110	7000	6400	4900
5/16"	173	9800	9000	7600
3/8"	243	14400	12000	11000

sixteen 1/4 cables in 1 sq inch

16 x 6400 = 102,400#

= one 50'long 12' diameter 2nd stage, fully loaded

three 1 inch cable for one habitat for stability

Initial Parameters

A BoLo could be supported by three 1 inch aircraft cables and generate 1g in a habitable space the size of a tour bus.

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BoLo Habitat Minimum Requirements

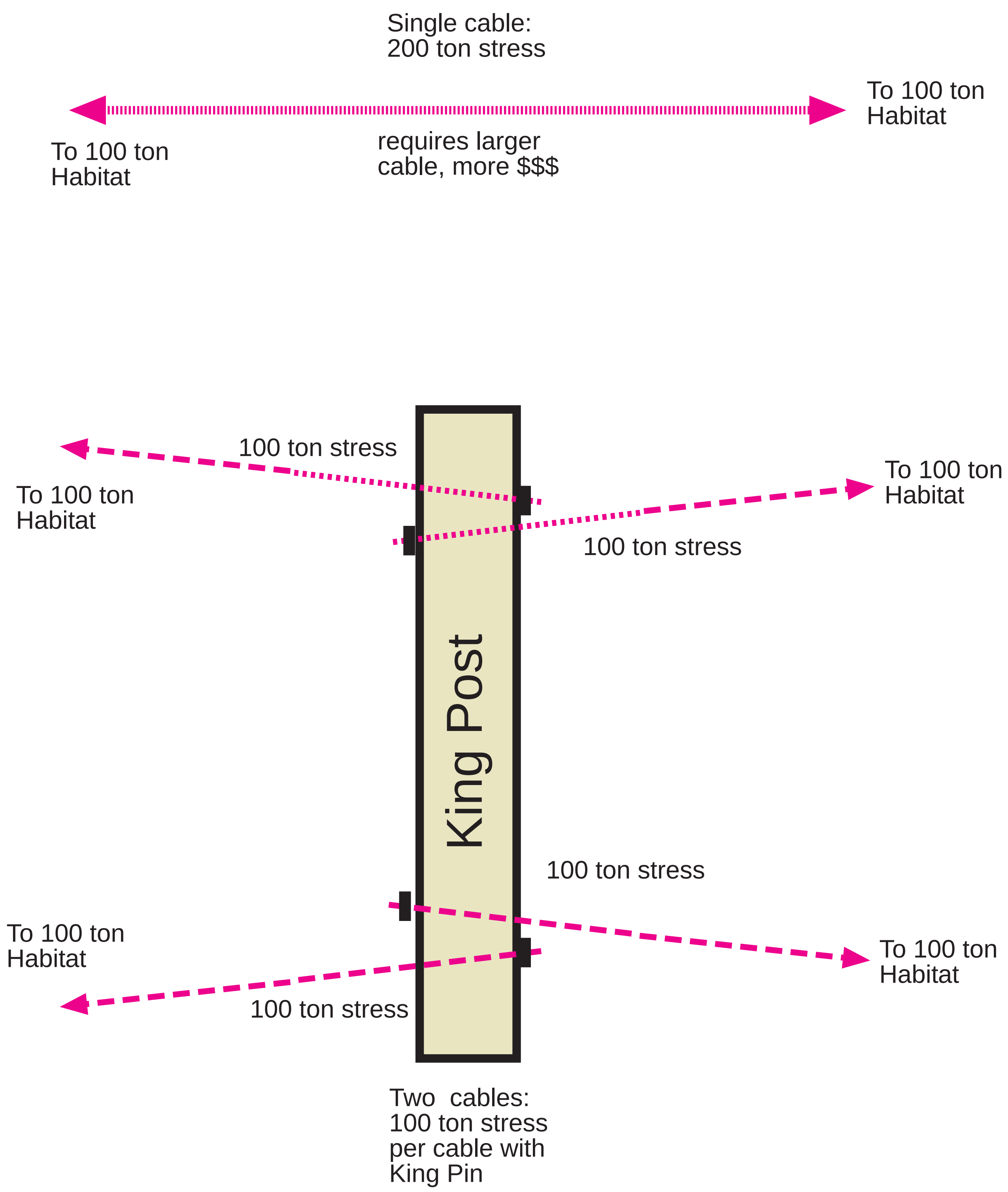
The BoLo Habitats must be able to accept force on at least two axis. The vertical axis for boost, and a horizontal axis for 1 g living quarters. An example of this would be the space shuttle which can lie on its belly, or stand on its tail, on earth.

The Habitats must have life support and energy capability.

The habitats are assumed to have size, boost and thrust capability similar to the Falcon 9 first stage. (Other sizes work too)

A central king pin at the locus of rotation is essential to reduce the strain on the tether by 50%, and thereby reduce mass and cost of the tether.

The tether system must include a harness to hang the Habitats.



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BoLo-YoYo Habitat

The BoLo-YoYo Habitat is functionally and significantly more capable than the BoLo on a tether, without a significant cost upgrade or logistic demand.

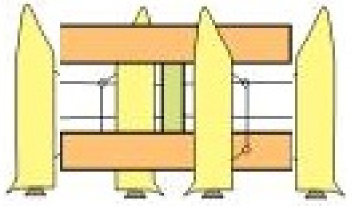
Added to the basic BoLo configuration, a scaffolding of trusses (YoYo) can be erected at the center of rotation and the spacecraft affixed during acceleration to the necessary trajectory. When in ballistic flight, the craft can at that time spool out to rotation distance as in the BoLo flight.

What makes this configuration significant is the storage capability of the YoYo scaffolding, carrying everything from food to oxygen, available during arrival or emergency.

This relieves the Habitats from having to use up living space for those supplies. Additionally, solar arrays can be placed at the YoYo, relieving the arrays from of the stress of acceleration.

BoLo-YoYo

The YoYo can be unpressurized and unheated (to save cost and logistics) as well as have less secure pressurized compartments without having to be as robust as life safety design would be.



BoLo-YoYo
in collapsed configuration

BoLo-YoYo in expanded configuration

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YoYo

The YoYo can be unpressurized and unheated (to save cost and logistics), as well as have less secure pressurized compartments without having to be as robust as would be a compartmentalized life support system.

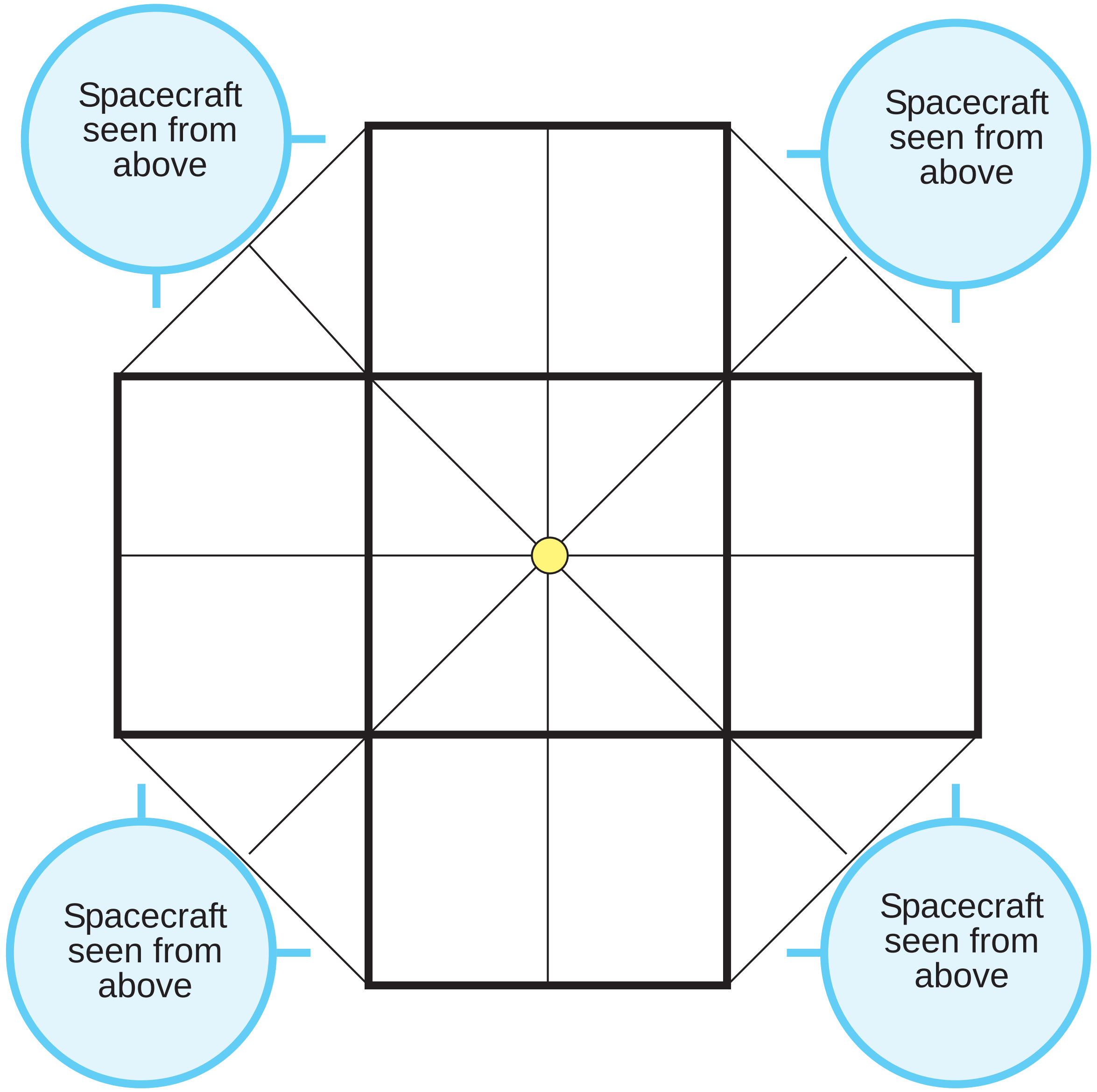
The YoYo can be constructed with piping, creating a truss system. Maximum delivery size could be as small as 20’x 2” pipe and connectors allowing the YoYo to be as large as desired yet fit within a launch vehicle and assembled on site. Size would depend on mission requirements.

The YoYo would require an active system to allow it to independently use thrusters rotate at the same rate as the surrounding ships. It also could have a main engine to allow thrust to accompany the pressurized habitats and eliminate additional fuel requirements for the independent craft.

The truss can be loaded up with supplies, such as fuel, life support materials, and repair parts, reducing the requirements obligated to be carried within the habitats.

The number of docked ships is only limited by the mission requirements, not by the basic YoYo concept. Odd number of ships can be accommodated with a suitably sized King Pin.

Solar panels can be deployed from the YoYo reducing the stress that would occur if attached to the habitats. Power and comm capability could be passed to the habitat by structured conductors spooled at the same time as the strength members.



Plan View of YoYo: Center Truss Storage Area and King Pin: Suitable for 8 vessels.
(Four attached, collapsed configuration, seen from above)

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PoGo

The major drawback to the BoLo and Bolo-YoYo Habitat design is the inability to transfer equipment, supplies and personnel between stations while in rotation. The PoGo solves this.

After extension to the rotating position, and while a low rotation speed, lightweight struts can be assembled from the YoYo structure to the rotating vessels.

The struts can be piping, allowing fluids to transfer between locations. The struts can be robust enough that an external elevator can be suspended and attached to them.

Many issues are created by the addition of struts.

- As mass moves inward or outward, the moving mass will push or pull against the struts laterally and they must be able to withstand these forces. If mass movement is slow, the forcing functions are reduced.

- As mass moves inward or outward, the system rotational speed will be affected non-linearly due to the flexible cables vs rigid spokes of a torus.

These effects can be mitigated by pumping fluid mass in opposition to the “elevator” similar to a submarine ballast control system.

The strut/piping must be carefully selected that when the lateral stresses are experienced by mass changing radius, that the deflections are all elastic to prevent hysteresis loss and failure.

Additional factors

These stresses caused by “vertically” moving masses would create lateral deflections of the struts, which would have to controlled by a combination of material engineering and operational constraints.

The moving masses must be analyzed because they would potentially create harmonic force addition due to the lateral deflections somewhat similar to a guitar string oscillation. The nodes would not be linear because the forces change with the radius of the deflecting forces, requiring significant mathematical modeling and engineering experiment in orbit. Not impossible.

Engineering models can be tested in LEO. Initially a two body problem with a radius of 100 feet and habitat masses of 100 #, to habitat mass of 100kg and cable r = 100’.

(Ah, metric. Pops says his mind flips between metric and English, depending on if he is doing a math model or a practical experiment. He often notes that there are two kinds of countries in the world, those that use metric, and the one that went to the moon.)

The use of a ballast system adds the failure mode of explosive venting during rupture, and becomes more complicated in the outer trajectories due to fluids freezing up in the low temperatures. Ballast tanks and associated plumbing would become part of the YoYo configuration.

JAPL estimates that the additional cost of the BoLo-YoYo-PoGo configuration would be the optimum choice for a Mars mission considering the increased capacity and capability, while the basic BoLo would be adequate for investigating NEAR asteroids.

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