## ATTAINABLE ARTIFICIAL GRAVITY & SPACE RADIATION PROTECTION SOLUTIONS FOR INTERPLANETARY SPACESHIPS

THESIS DEFENSE – 15 MAY 2020

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## TIMOTHY BISHOP

SICSA STUDENT

CONTRACT ENGINEER NASA JOHNSON SPACE CENTER – 4 YEARS ROBOTICS ANALYIST

US AIR FORCE – 14 YEARS (ACTIVE / RESERVE)
MECHANIC







## APPRECIATIONS

Loving Wife and Parents

SICSA Faculty – Larry Bell | Olga Bannova | Kriss Kennedy | Larry Toups

SICSA Students – 3 Years of Memories





## VISION

TO BUILD A FLEET OF VERSATILE SPACECRAFT, SENDING HUMANS ANYWHERE WITHIN THE SOLAR SYSTEM ... AND BEYOND





## Problem Definition

Deep Space Mission Architectures discard hardware, increasing costs that create barriers for improvements to crew safety; bred a risk-acceptance culture for human spaceflight

## Hypothesis

The construction and deployment of human-rated deep-space spacecraft is possible with current or near-term technologies; capable of integrating micro-gravity and space radiation countermeasures





## Mission

Provide sound and feasible construction methodologies for a spacecraft that provides realistic solutions to mitigate two prominent technology gaps:

Artificial Gravity and Space Radiation Protection

## Goals

- 1. Develop spacecraft habitat architecture capable of supporting human missions to various celestial bodies in the solar system
  - 2. Develop an artificial gravity system
  - 3. Develop space radiation countermeasures





#### Venus 30-Day Stay Mission\*

**1** Earth Departure: 2 June 2031

2 Venus Arrival: 25 September 2031

Venus Departure: 25 October 2031

Earth Arrival: 20 August 2032

## SPACECRAFT MISSION'S

Spacecraft Concept of Operations: Venus-Earth-Mars Proposed Trajectories

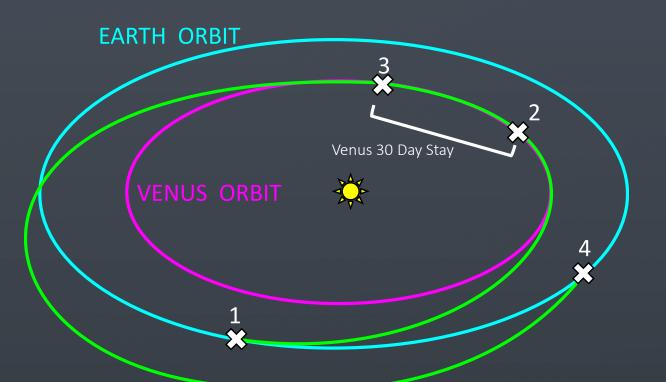
#### Mars 30-Day Stay Mission\*

5 Earth Departure: 12 April 2033

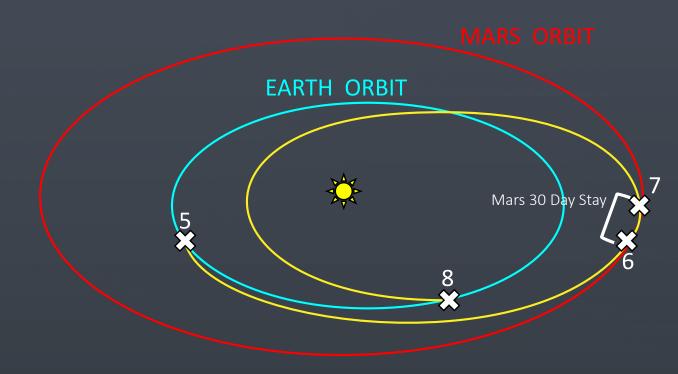
6 Mars Arrival: 9 October 2033

**7** Mars Departure: 8 November 2033

8 Earth Arrival: 16 July 2034



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\* NASA Ames Research Center Trajectory Brower



## Human Risks

#### SPACE RADIATION

Galactic Cosmic Rays Exposure - Steady stream of radiation

Long term effects (decades) – not well understood

Cancers in various parts of body

Cancer in bone high risk

Offspring defects increased

Solar Particle Events Exposure – Extreme bursts of radiation

Short term effects (hours to days)

Possible fatal dosage delivered

Symptoms of acute radiation poisoning

Nausea, vomiting, disorientation, etc.

#### MICRO GRAVITY

Lack of gravity promotes bone and muscle loss

Bone loss – hips affected the most

Muscle atrophy

Vision impairment

Lack of smell and taste

#### ROTATING SPACECRAFT

Vestibular effects caused by rotating reference frames

Disorientation

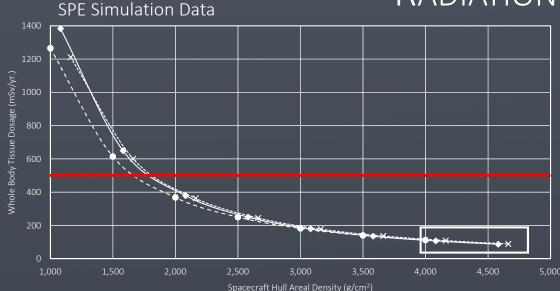
Vertigo

Inner ear fluid shifts





## RADIATION PROTECTION RESEARCH

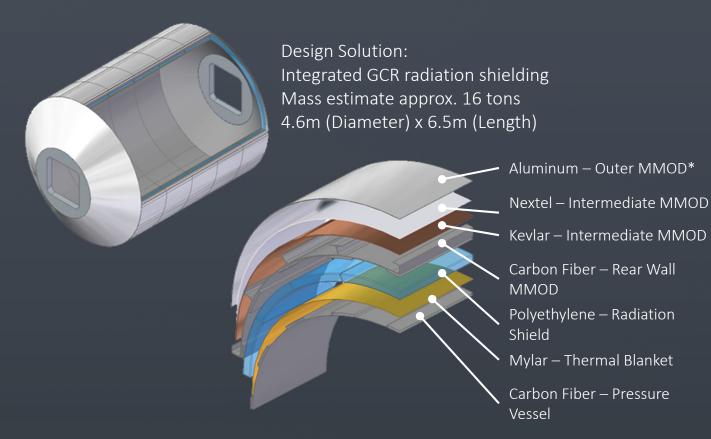




Radiation Protection Simulation Results:

Minimum Required Hull: 10 cm Polyethylene Equivalent Shielding

Minimum Required Solar Storm Shelter: 35 cm Polyethylene Equivalent Shielding



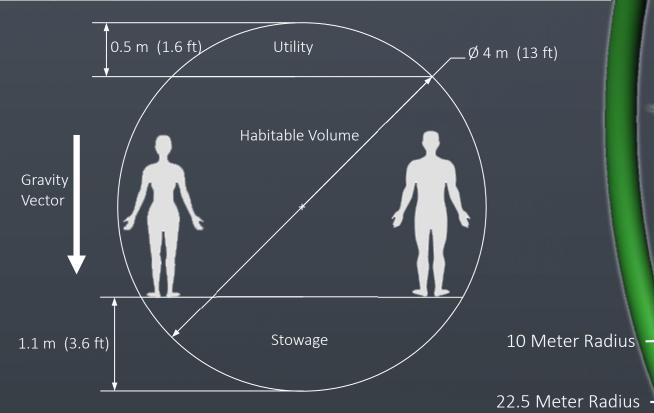




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#### Torus Habitat Considerations

Radius m (ft)	Ang Vel (rpm)	Centripetal Acc (g)	Surface Area m² (ft²)	Habitable Volume m³ (ft³)	Crew Size*
10 (33)	6	0.4	224 (2,411)	492 (17,375)	20
22.5 (74)	6	0.9	505 (5 <i>,</i> 436)	1,187 (41,919)	48
67 (220)	3.5	0.9	1,506 (16,210)	3,667 (129,499)	147



\* Derived from NASA/TM-2015-218564



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ARTIFICIAL GRAVITY



10

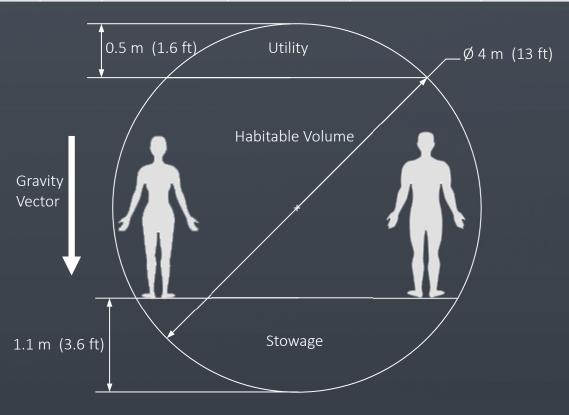
67 Meter Radius

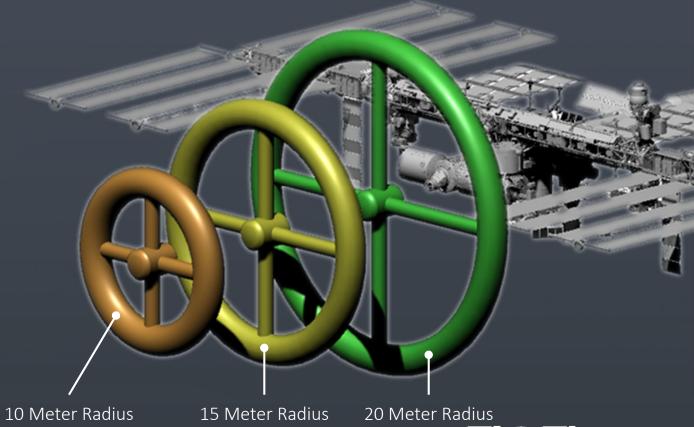
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## ARTIFICIAL GRAVITY

#### Revised Torus Habitat Considerations

Radius m (ft)	Ang Vel (rpm)	Centripetal Acc (g)	Surface Area m² (ft²)	Habitable Volume m³ (ft³)	Crew Size
10 (33)	6	0.4	224 (2,411)	492 (17,375)	20
15 (49)	6	0.6	337 (3,627)	769 (27,157)	23
20 (66)	6	0.8	449 (4,833)	1,048 (37,010)	34







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11



## ROTATING SPACECRAFT EFFECTS

Coriolis Force Diagrams



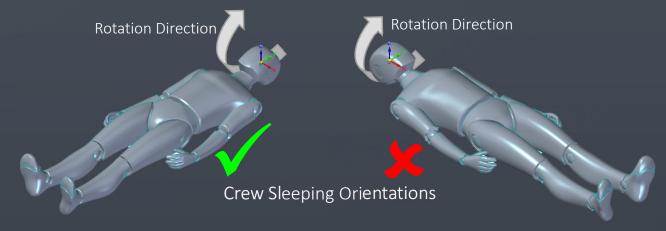
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Walking with rotation increases the feeling of "weight"

Walking against rotation decreases the feeling of "weight"

Ladder climbing "pushes" or "pulls" depending on orientation

Sleeping orientation head tilt on axis of rotation reduce Coriolis Force effects

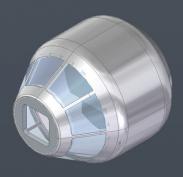


Perceived "Weight" While Walking for 70kg (154 lb.) individual

	Torus Radius		
Movement Scenario	10 m (33 ft)	15 m (49 ft)	20 m (66 ft)
Walk with rotation, kg (lbs)	41.7 (91.9)	55.8 (122.9)	69.9 (154.1)
Walk against rotation, kg (lbs)	14.7 (32.4)	28.8 (6.4)	42.9 (94.6)
Jog with rotation, kg (lbs)	50.7 (111.8)	64.7 (142.6)	78.9 (173.9)
Jog against rotation, kg (lbs)	5.7 (12.6)	19.8 (43.7)	33.9 (74.7)



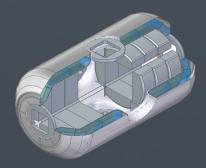
## SPACECRAFT HABITAT MODULES



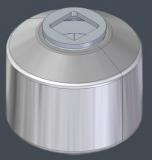
Command Module

Command & Data Handling Functions

Spaceship Telemetry



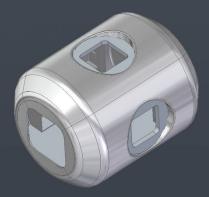
Center Module
Solar Storm Shelter
Main Systems Hub



Transit Module

Passage to Torus Section

Primary Storage



Junction Module

Cargo Vehicle Interface

Primary Utility Functions



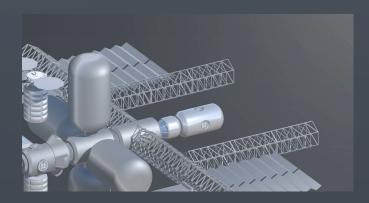
Primary Crew Functions
Curved Geometry For Artificial Gravity



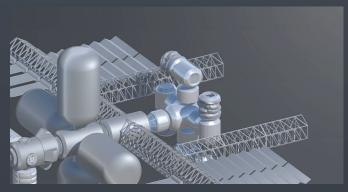
Provides science capabilities Large windows for planetary observation



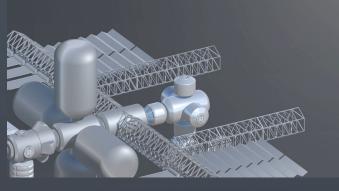
## Spaceship Habitat Assembly Time-lapse



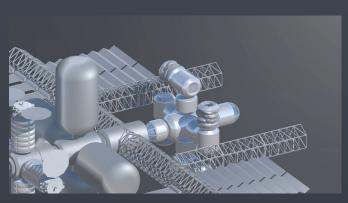
1) Command Module and Center Module are installed. Note the cargo vehicles on the left hand side which continuously supply the Assembly Station



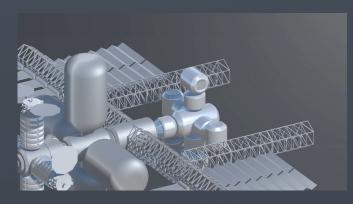
4) Inflatable modules are installed



2) Transit Modules are installed at all four locations on the Center Module



5) Science Module is installed at aft of the Center Module



3) Junction Modules are installed onto each Transit Module

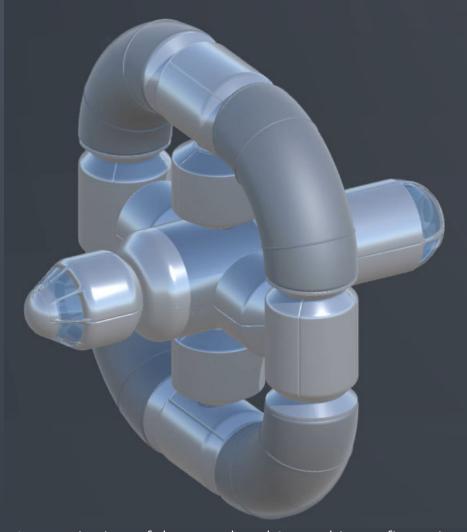


6) The Inflatable Modules are inflated



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## Spaceship Habitat Final Configuration



Isometric view of the completed Spaceship configuration

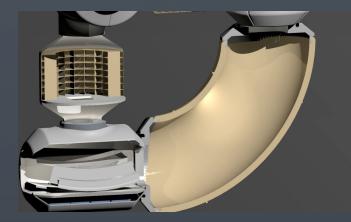




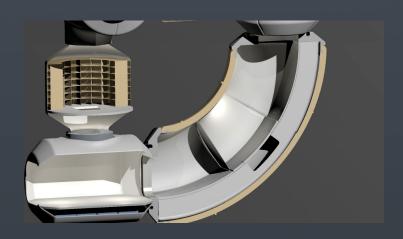
Aft isometric view of the Spaceship configuration, showing the Common Berthing Mechanisms and International Docking Adapters



## Interior Outfitting

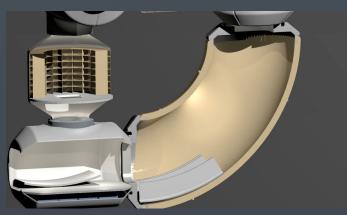


1) Components are packed in Junction Module, ready for assembly by crew

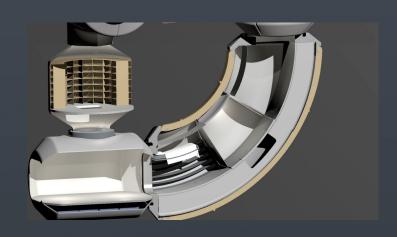


4) Internal walls are installed

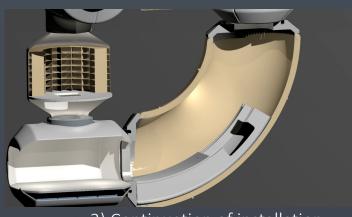




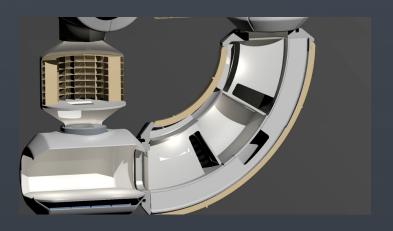
2) Subfloor stowage and utility structure is installed



5) Crew compartments are installed, such as storage and furniture



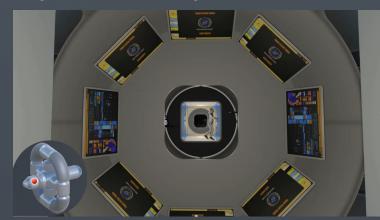
3) Continuation of installation



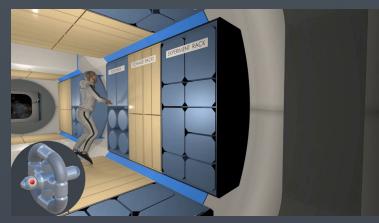
6) Completed interior assembly with hallway walls



## Spaceship Habitat Walkthrough



1) Command Module interior, fitted with 8 operations stations for spaceship keeping



2) Center Module interior with ECLSS, stowage and experiment racks



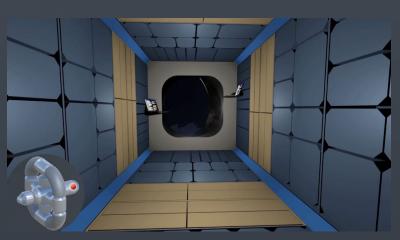
3) Crew ablutions module in the artificial gravity section, with washer/dryer unit, showers, basins and stowage



4) A multi-purpose section in the artificial gravity section fitted with desks and computers for work, as well as plants for the crew



5) Crew galley module in the artificial gravity section, with a kitchenette for cooking various types of food, refrigeration units, stowage and foldable table and chairs



6) Science module with a large number of experiment racks and computers



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