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Technology Applications Assessment Team

NAUTILUS - X

Multi-Mission Space Exploration Vehicle

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FISO Telecon 1/26/2011



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MMSEV (Multi-Mission Space Exploration Vehicle)

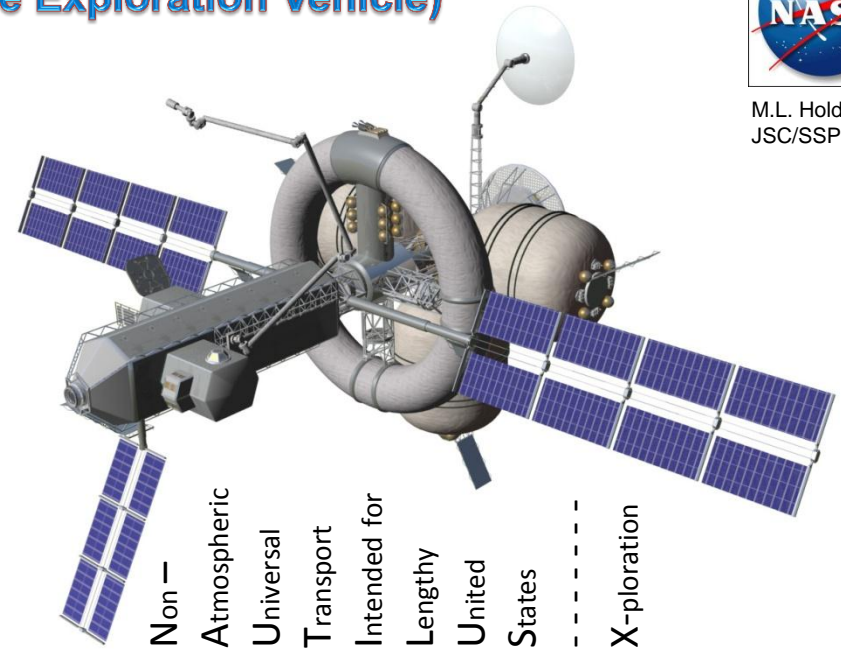


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Description and Objectives:

- Long-duration space journey vehicle for crew of 6 for periods of 1 -24 months
 - CIS-lunar would be initial Ops Zone [shakedown phase]
- Exo-atmospheric, Space-only vehicle
- Integrated Centrifuge for Crew Health
- ECLSS in deployed Large Volume w/ shirt-sleeve servicing
- Truss & Stringer thrust-load distribution concept (non-orthogird)
- Capable of utilizing variety of Mission-Specific Propulsion Units [integrated in LEO, semi-autonomously]
- Utilizes Inflatable & Deployed structures
- Incorporates Industrial Airlock for construction/maintenance
 - Integrated RMS
- Supports Crewed Celestial-body Descent/Return Exploration vehicle(s)
- Utilizes Orion/Commercial vehicles for crew rotation & Earth return from LEO



Approach:

- Multiple HLV (2-3) & Commercial ELV launches
- On-orbit LEO Integration/Construction
- First HLV payload provides Operational, self-supporting Core
- Centrifuge utilizes both inflatable & deployed structures
- Aero Braking deployed from Propulsion Integration Platform

Collaborators/Roles:

- JPL: Deployment Integ., Communications/Data Transmission
- AMES: ECLSS, Bio-Hab
- GSFC: GN&C, Independent System Integrator
- GRC: PowerPumps, PMD, External Ring-flywheel
- LaRC: Hoberman deployed structures & Trusses
- MSFC: Propulsion Unit(s) & Integration platform, Fluids Transfer & Mngt.
- JSC: Proj. Mngt – SE&I, ECLSS, Centrifuge, Structures, Avionics, GN&C, Software, Logistics Modules
- NASA HQTRS: Legislative & International Lead

Justification:

- Provides Order-of-Magnitude increase in long duration journey capability for sizeable Human Crews
 - Exploration & Discovery
 - Science Packages
- Supports HEDS 2.2.4.2 Habitat Evolution technology development
- Meets the requirement of Sec. 303 MULTIPURPOSE CREW VEHICLE Title III Expansion of Human Space Flight Beyond the International Space Station and Low-Earth Orbit, of the “National Aeronautics and Space Administration Authorization Act of 2010”

COST: \$ 3.7 B DCT & Implementation 64 months



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System Goals

- Fully exo-atmospheric/Space-only
 - No entry capability through Earth's Atmosphere
- Accommodate & Support Crew of 6
- Self-sustaining for months (1-24) of Operation
- Ability to Dock, Berth and/or Interface with ISS & Orion
- Self-reliant Space-Journey capability
- On-orbit semi-autonomous integration of a variety of Mission-specific Propulsion-Units



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Attributes

- Large volume for logistical stores
 - FOOD
 - Medical
 - Parts
 - Other
- Provide Artificial Gravity/ Partial(g) for Crew Health & GN&C
- Provide real-time “true” visual Command & Observe capability for Crew
- Capability to mitigate Space Radiation environment
- Ability to semi-autonomously integrate Mission Specific Propulsion-Pods
- Docking capability with CEV/Orion/EAT(European Auto Transfer)/Other
- Robust ECLS System
 - IVA based for service/maintenance



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Attributes

- Robust Communications Suite
- Designed for wide array of Thrust/Isp input(s)
 - Ion-class
 - Low level, Long Duration chemical
- Self powered
 - PV array
 - Solar Dynamic
- Industrial sized Airlock supports MMU[Manned Maneuvering Unit]
 - Logistical Point-of-Entry
 - Intermediate staging point for EVA
- External scientific payloads
 - Pre-configured support points
 - Power, Temp, Data, Command & Control



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Technology Development

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- Autonomous Rendezvous & Integration of LARGE structures
- Artificial Gravity/Partial-(g)
 - Basic design
 - System Integration and GN&C Impacts & Assessments
 - Materials
 - Hub design
 - Seals
 - Carriage Design
 - Bearings
 - Power transfer mechanisms
 - Flywheel torque-offset
 - External dynamic Ring-flywheel
 - CMG cluster(s)
- Semi-autonomous Integration of MULTIPLE Propulsion Units
 - Mission **SPECIFIC**
- Next generation MMU [old free-flyer MMMSS]
- Inflatable and/or Deployable module/structure design(s)
 - Transhab & Hoberman



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Technology Development

- High-gain/High-power Communications
- Radiation mitigation
 - Structural Integrated
 - Magnetic Field strategy (MIT)
 - Individual application augmentation
 - Suits & Pods
 - Safe-Zone [H₂O/H₂-slush strategy]
- Thrust structure integration through-out vehicle and across orbital assembly interfaces
 - Deployable exo-truss
- O-(g) & Partial-(g) hydroponics/agriculture
- ECLSS { IVA Maintenance, R&R }
 - Active membranes
 - Revitalization methodologies
 - Atmosphere Circulation
 - Temperature control
 - Humidity control



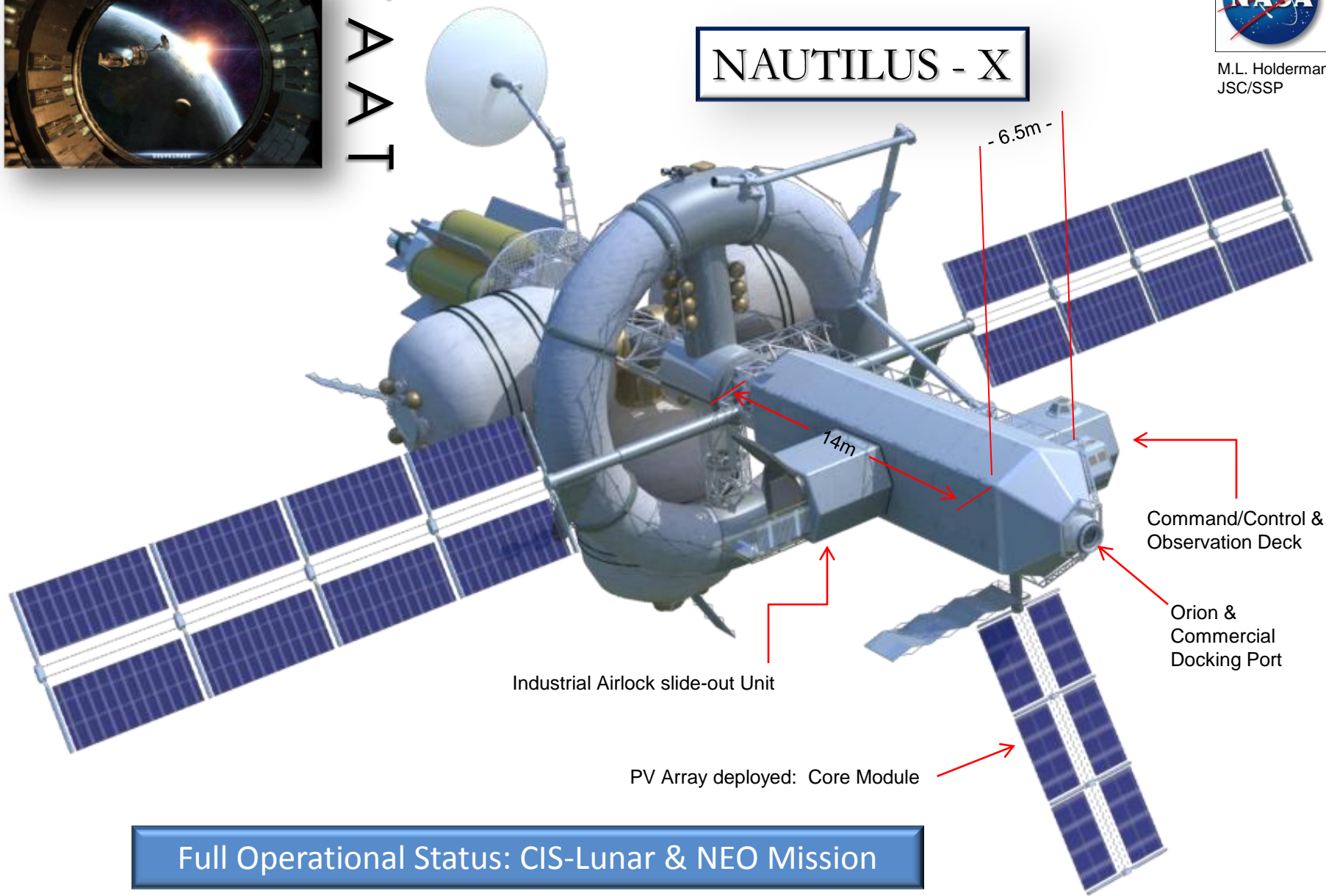
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Full Operational Status: CIS-Lunar & NEO Mission

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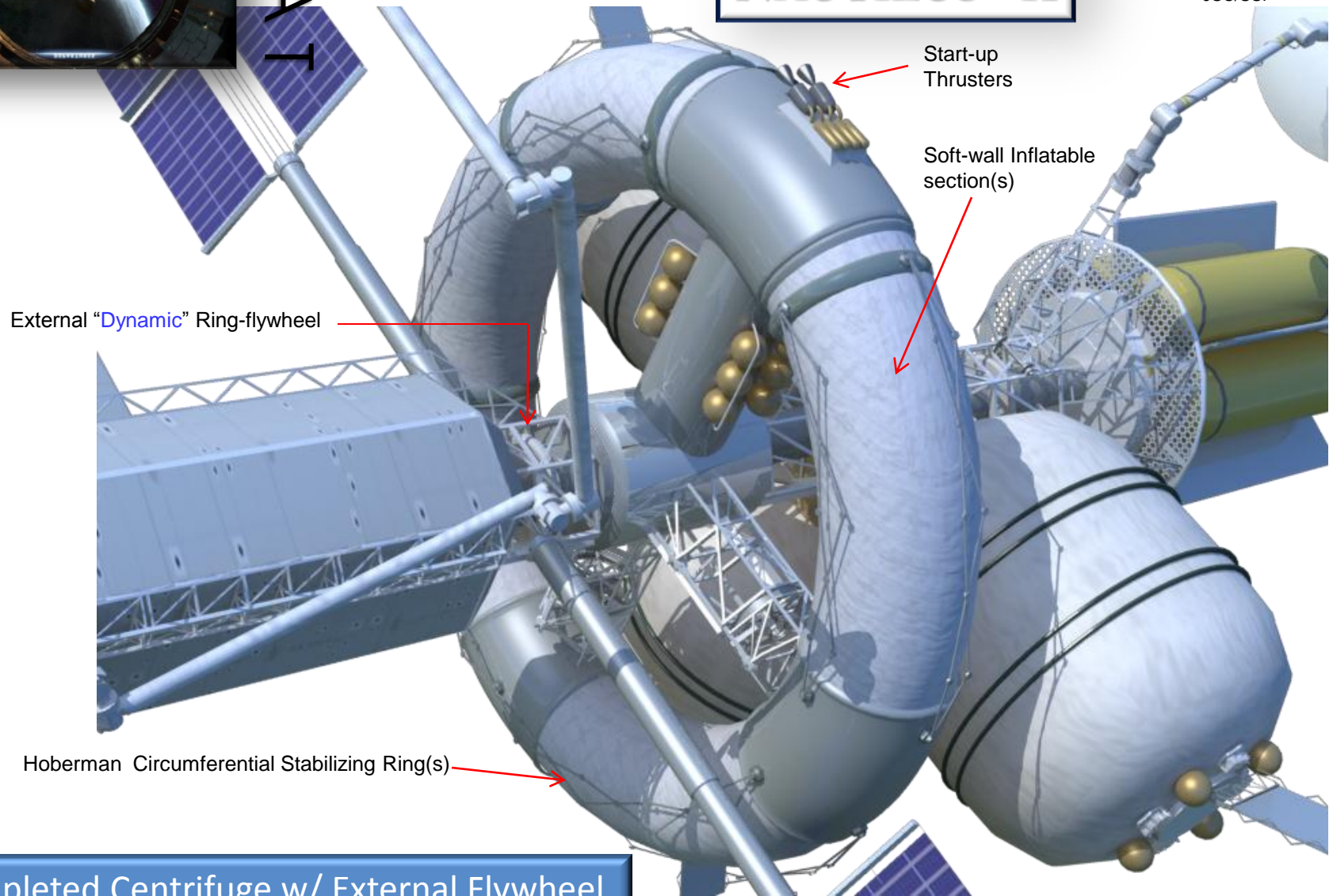


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Completed Centrifuge w/ External Flywheel



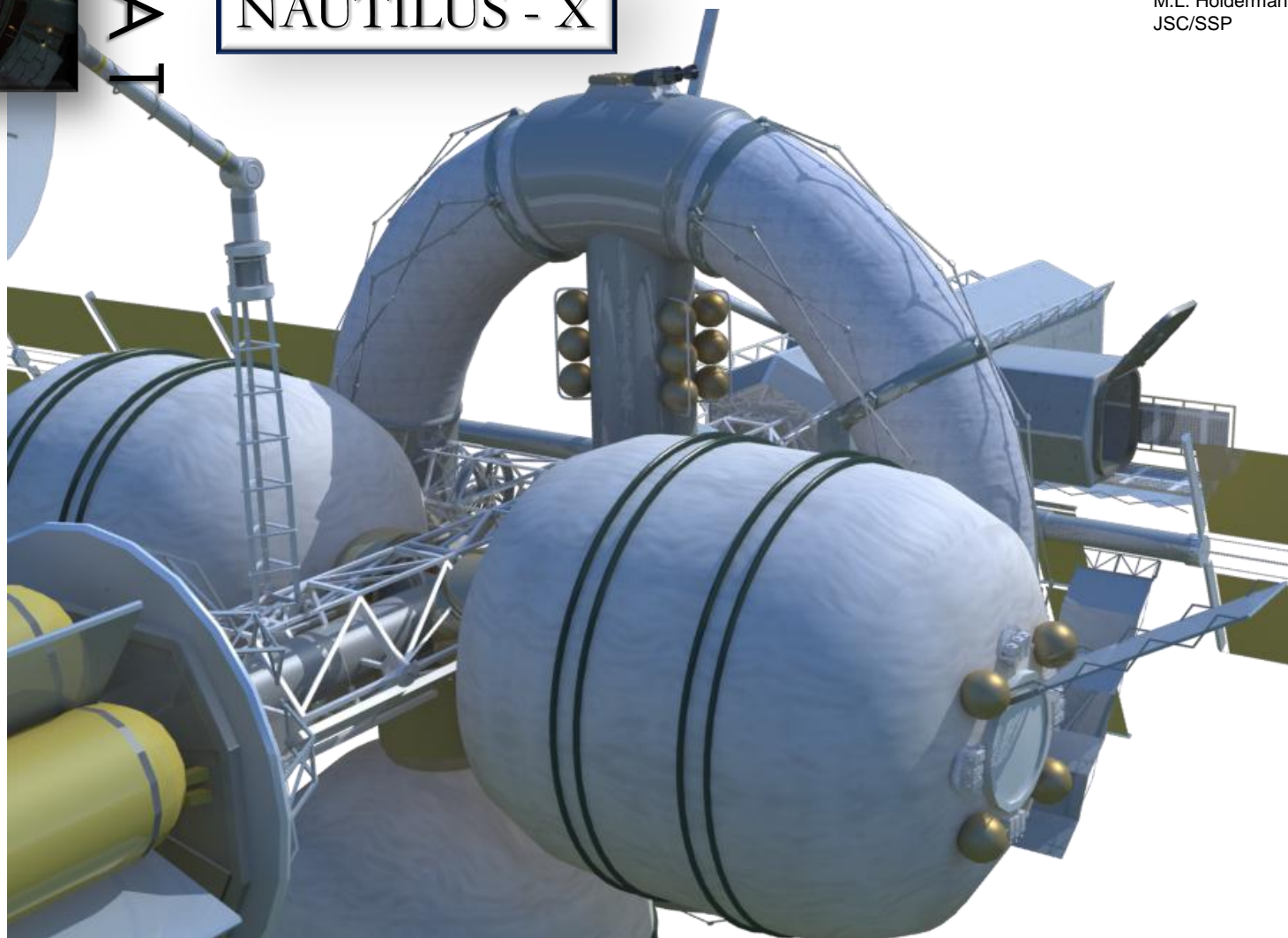
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View looking "Forward"

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ISS Centrifuge Demo*

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Description and Objectives:

- Utilize Hoberman-Sphere expandable structures with inflatable & expandable technology Soft-structures to erect a (low mass) structure that provides partial-(g) force for engineering evaluation
- First In-space demonstration of sufficient scale Centrifuge for testing and determination of artificial partial-(g) affects
- Impart Zero disturbance to ISS micro-gravity environment
- Potentially Off-load duty-cycle on ISS CMGs by introducing constant angular moment to augment GN&C
- (*) Ultimately provide partial-(g) sleep station for ISS Crew
 - Option for Food-prep station & small Dining area
 - Potential partial-(g) WC

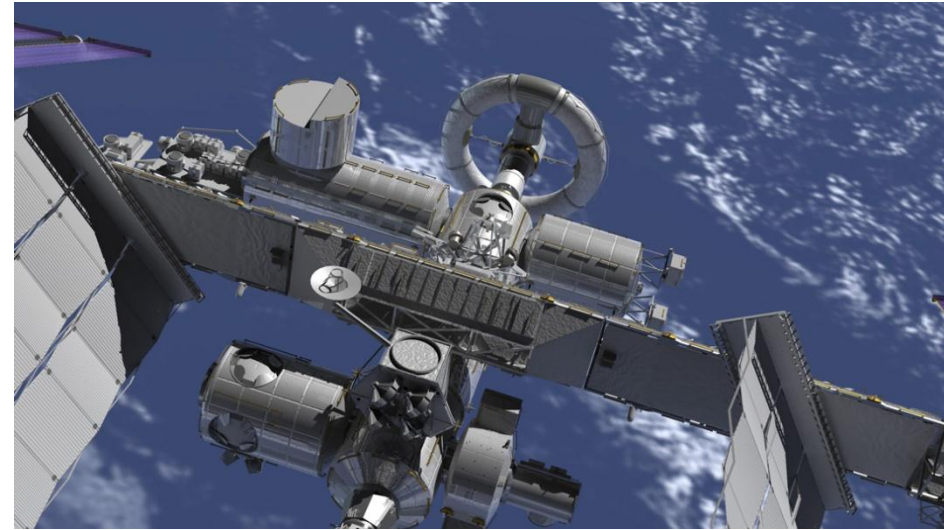
Approach:

- Existing Orbiter External Airlock used to attach Centrifuge to ISS
 - Also provides a contingency AirLock capability
- Hub design based on Hughes 376 Spin-Sat Tech.
 - Liquid metal & tensioned material seal design
 - Low noise/mass thrust and guide bearings
- Self deployment with IVA for final construction/verification
- Engineering pedigree with TransHab and EVA suits
 - Two individual ½ Circle deployments
- Hoberman based load & deployment ring
- Goal: single Delta-IV/Atlas-V launch

Collaborators/Roles:

JSC: Design Requirements/Project Mngt.,
Centrifuge Design/Test, Instrumentation,
Control Avionics/SW, Deployment scheme,
Structural Design & Materials selection,
Crew Training, On-Orbit Test OPS

JSC/Ames: Hub Seal & Bearings,
Payload Integration
Draper Labs: ISS GN&C impacts
GRC: Flywheel Design/Integr.
LaRC: Hoberman alignment
& load Circlce



Justification:

- Partial Gravity in space may be critical for enabling Long Term Human exploration within the Solar System
- A Centrifuge must be integrated into the baseline design of any transit or Journey-class spacecraft in order to take advantage of GN&C influences and specific design considerations
 - Rotating hub/ transition tunnel
 - Rotating mass with & w/o Crew present
- Early experience on ISS is critical to assessing and characterizing influences and affects of a Centrifuge relative to
 - Dynamic response & Influences
 - Human reaction(s) data-base
- DDT&E/DCT&I **<39 months \$84-143M**



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Development Challenges

Multi-Mission Space Exploration Vehicle



- Potential parallel development with HLV
 - Resource allocation
- HLV Payload integration
 - Ascent Vibro-Acoustic P/L environment(s)
 - Mass growth
 - Battery performance
- Centrifuge Hub
 - Torque off-set S/W & external ring flywheel
 - GN&C impacts [modeling]
 - Slip-rings
 - Drive Mechanism
 - Seals
 - Carrier design
- Centrifuge Design
 - Materials
 - Deployment mechanism(s): Inflatable Section(s)
 - Stiffening/Load Structure: Hoberman
- Propulsion Pod Integration Platform
 - Capture & Latch mechanisms
 - Data/Telemetry/Command & Control strings
- Exo-Thrust-structure
- Structural On-orbit Assembly Interface(s)



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Partnering & Collaboration

- JPL: Deployment Integ., Communications/Data Transmission
- AMES: ECLSS, Bio-Hab
- GSFC: GN&C, Independent System Integrator
- GRC: Power, Fluid Pumps, PMD, External Ring-flywheel
- LaRC: Hoberman : Deployed structures & Trusses
- NESG: "Shadow" Systems Integrator
- MSFC: Propulsion Unit(s) & Integration platform , Fluids-Transfer & Mngt.
- JSC: Proj. Mngt – SE&I , ECLSS, Centrifuge, Core-Structures, Avionics, GN&C, Software, Logistics Modules
- NASA HQTRS: Legislative & International Relations
- Academia: MIT, Cal-TECH/JPL, Stanford
- CIA/NRO/DoD: National Security
- National Institute of Health
- Large-Project, Traditionally NON-Aerospace, Program Developers
 - Power
 - Shipping
 - Infrastructure



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Technology Development

First TAAT Demonstration

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- CENTRIFUGE [HABITABLE] ARTIFICIAL GRAVITY/PARTIAL-(g)
 - Basic design
 - System Integration Impacts & Assessments
 - Materials & Deployment strategy
 - UV, Radiation-mitigation, Self-sealing, Micro-meteoroid defense
 - Inflatable and Expandable Structure integrated design
 - Hub design
 - Seals
 - Bearings
 - Materials
 - Power transfer mechanisms
 - Centrifuge torque-offset
 - External dynamic Ring-flywheel
 - CMG cluster(s) integration
 - Control Avionics & Software
 - Full-Test & Assay of HUMAN response to Partial-(g)



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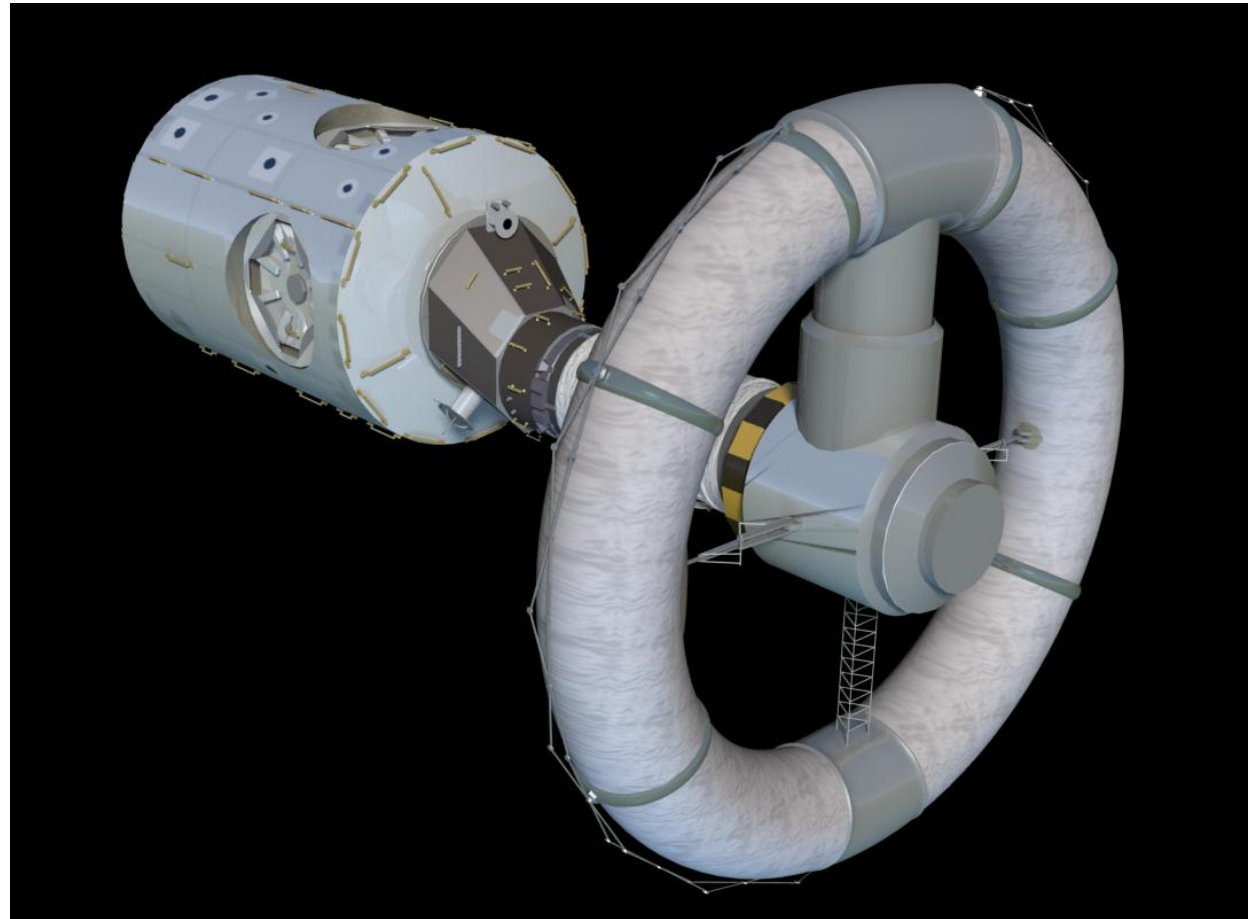


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ISS Centrifuge Demo

2011-2013 DEMO
COST: \$84M - \$143M

- Inflatable Based (TransHab)
- Hoberman Ring Stabilized
- External Ring-flywheel
- ISS micro-(g) experiment compatible





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ISS Centrifuge Demo (Inflatable-based)



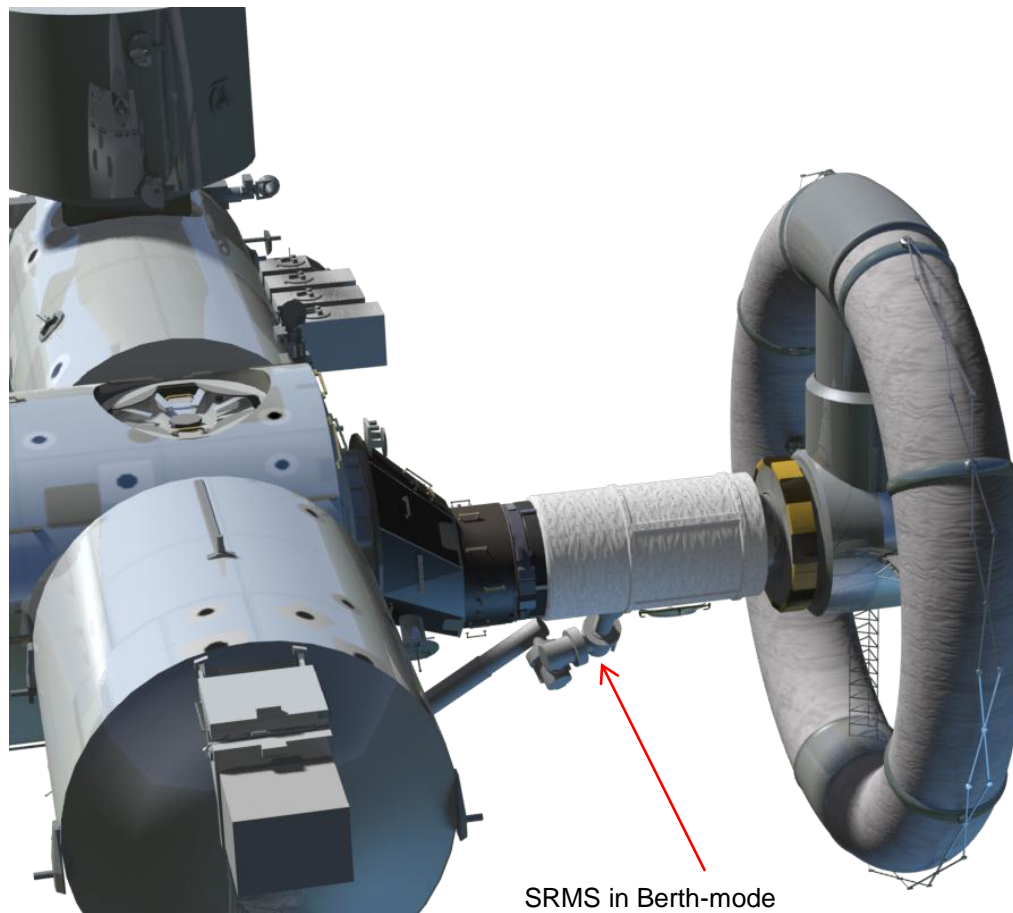
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DEMO Aspects:

- 30ft OD with 50in. cross-section ID
 - All internal dimensions and layout will accommodate EVA suite Astronaut
- Max RPM for Centrifuge may require longer acclimation period for crew between partial and zero-(g)

RPM	Partial - (g)	
	30ft dia.	40ft dia.
4	.08	.11
5	.13	.17
6	.18	.25
7	.25	.33
8	.33	.44
9	.41	.55
10	.51	.69

- Well-modeled & Assessed /Analyzed “net” influence on ISS CMGs and GN&C
 - Loads not to exceed Dock-port limits
- Smaller diameter Centrifuge incorporates shaped inflatable elements that are deployed from fixed hard nodes
- Hub design utilizes Liquid-metal seals with low-rumble/wobble thrust bearings
- Bearing rotational hardware derived from Hughes 376 spin-stabilized ComSats



SRMS in Berth-mode while Orbiter Air-lock is placed in Soft-Dock during micro-(g) activities on ISS



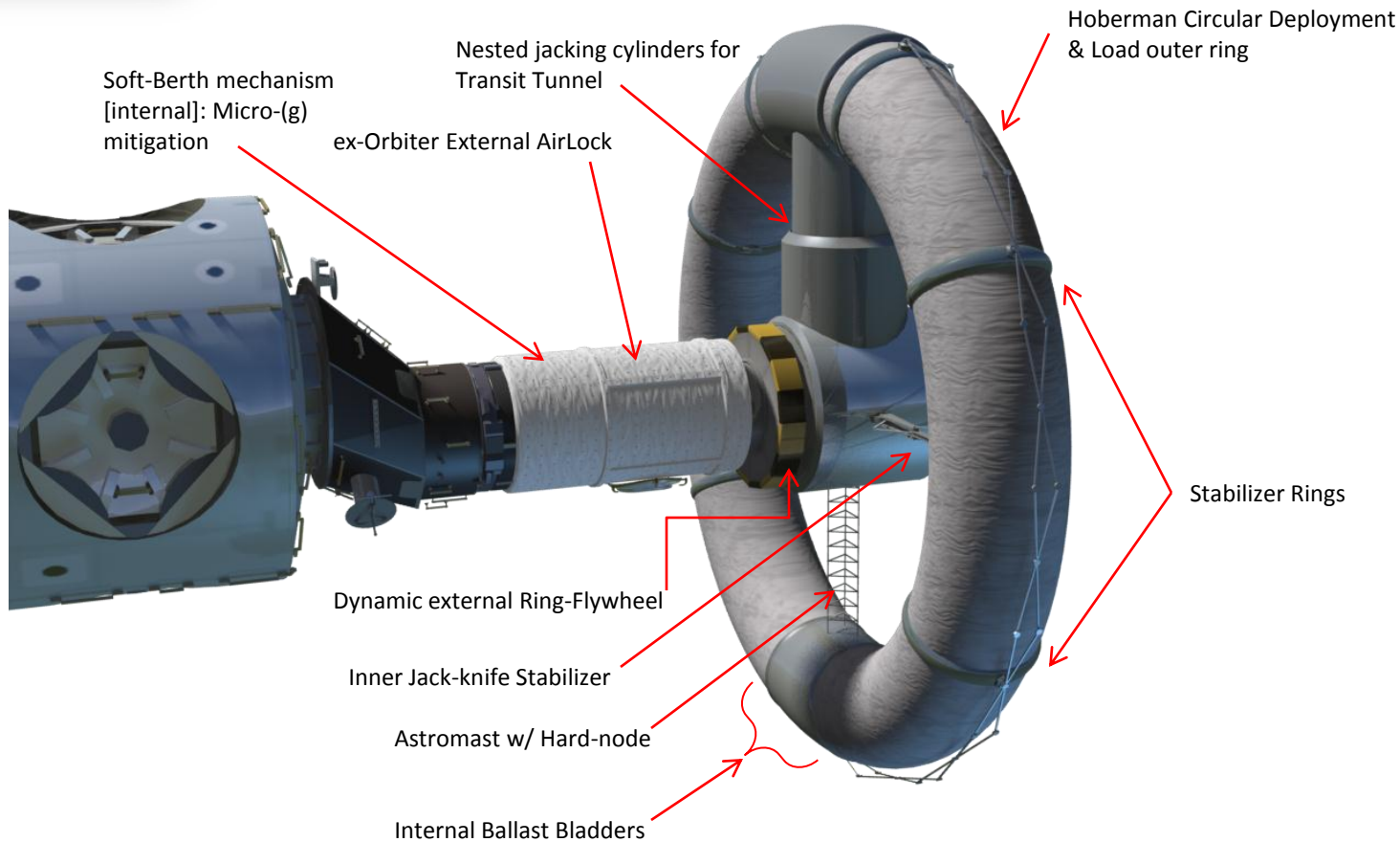
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ISS Centrifuge Demo* (Inflatable-based)



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* Test & Evaluation Centrifuge designed with capability to become Sleep Module for Crew



COST: \$84-143M DCT & Implement <39 months

<http://www.hoberman.com/portfolio/hobermansphere-lsc.php?myNum=10&mytext=Hoberman+Sphere+%28New+Jersey%29&myrollovertext=%3Cu%3EHoberman+Sphere+%28New+Jersey%29%3C%2Fu%3E&category=&projectname=Hoberman+Sphere+%28New+Jersey%29>

Design, Construct, Test & Implement: DCT&I



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ISS Centrifuge Demo*

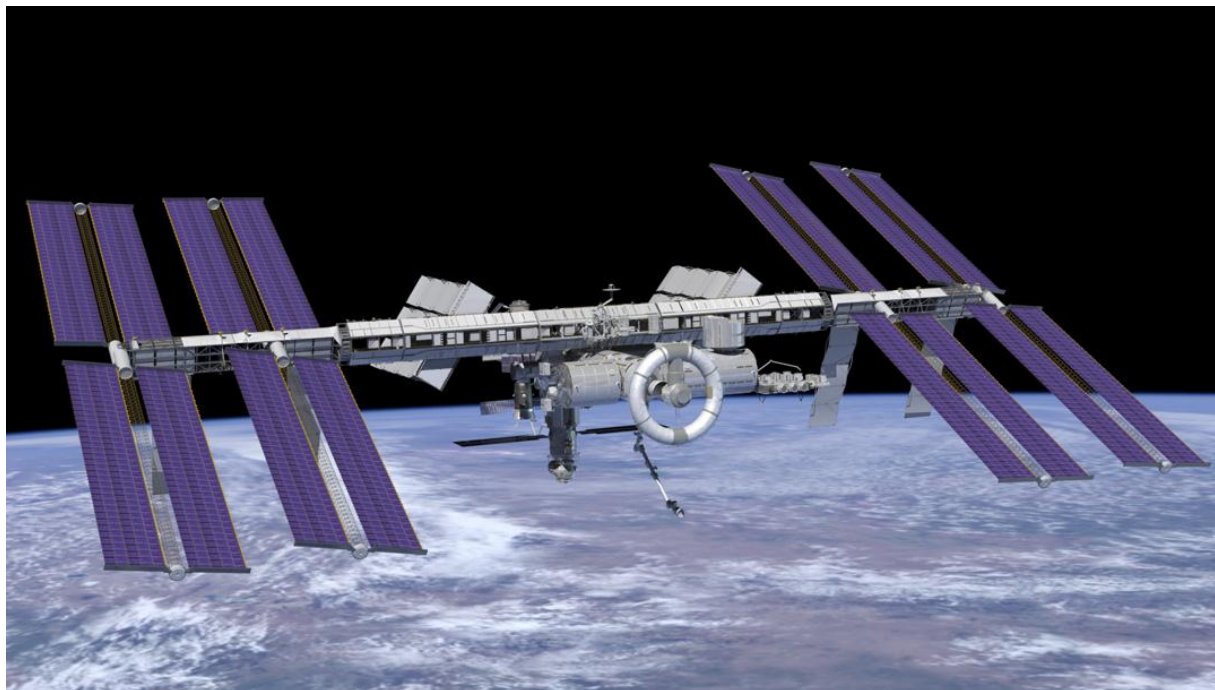
(Inflatable-based)



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DEMO Aspects:

- Kick motor utilized as both primary start-up and spin maintenance mechanism
- Drive motor(s) will be in ISS/Orbiter External Airlock
- Centrifuge can also serve as independent Emergency Shelter node
 - Independent internal separation capability from ISS for major contingency situation
- Engineering pedigree with TransHab and EVA suit material(s) & design principles
 - Two individual ½ Circle deployments
- Nested cylinder & deployable drawer approach for Transit Tunnel
- Ring Flywheel can be either driven from ex-Orbiter External Airlock or be self-contained on Hub [requires Hub battery-bank]
- CG offset of Centrifuge centerline mitigated with internal ballast bladders [urine/waste fluids]



* Test & Evaluation Centrifuge designed with capability to become Sleep Module for Crew

ISS Centrifuge Demo

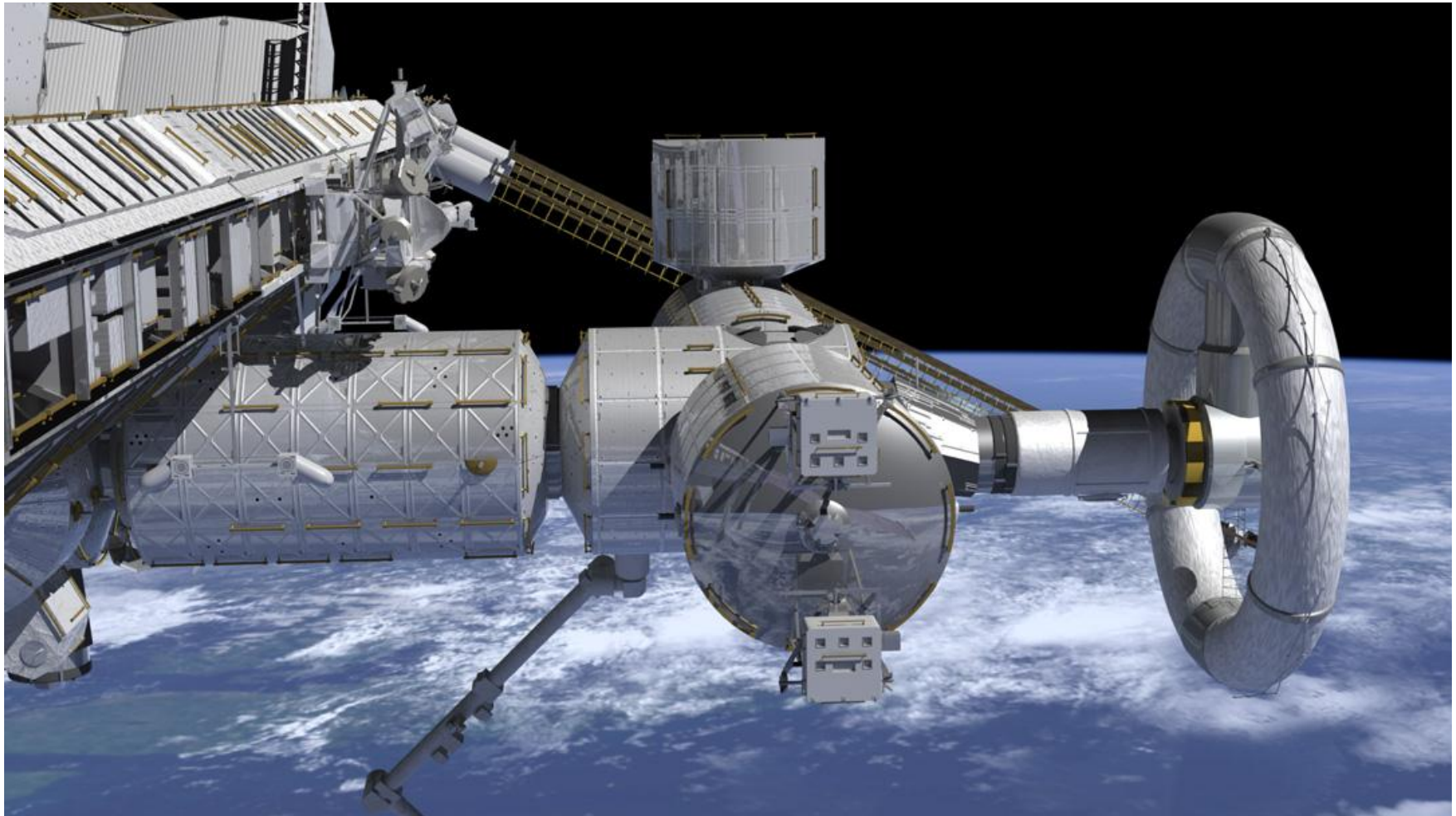


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- Inflatable Based (TransHab)
- Hoberman Ring Stabilized
- External Ring-flywheel
- ISS micro-(g) experiment compatible





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ISS Centrifuge Demo Activities: Representative Involvement - JSC



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- Thermal-Vac chamber would be fully utilized testing proto-type configurations and large-scale operating models of the Centrifuge [CF]
 - Bearing and hub design
 - Seal design
 - Inflatable/Hoberman deployment testing with mag-lev plates for 0-g simulation
- Bldg.9 would be converted to Full-scale CF lay-out with multiple mock-ups
 - Air-table for deployment/assembly checkout of CF assembly sequence
 - Human factor assessment
 - ECLSS integration
 - GN&C affects on thrust & control axis'
- Mission Operations Directorate
 - Emphasis focuses on start-up sequence of CF
 - Nominal operational influences of CF
- Space & Life-Sci [Dedicated Project]
 - Partial-(g) / Fractional-(g) effects on the human body
 - Repetitious exposure to partial-g and zero-g
 - Psyche/mood effects
 - Vascular
 - Digestive [tendency to vomit during transition]
 - Excretory
 - Ocular
 - Skeletal/Muscular
 - Sleep
 - Sleep chamber coupled to Radiation mitigation
 - Design of Partial-g toilet and body-wash-station
 - ECLSS design for IVA [Internal Vehicular Activity]maintenance & repair



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ISS Centrifuge Demo & JSC Involvement

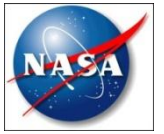


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- Engineering Directorate undertakes Exo(skeleton)-Truss design
 - Load distribution
 - Deployment scheme(s)
 - Thermal management techniques
 - Load transmitting Orbital structural interface design
- Engineering Directorate undertakes Flat-Panel Spacecraft design
 - Partial ortho-grid/iso-grid utilization
 - Integration of external/internal Exo-Truss
 - Engineering Directorate undertakes pre-configured Drawer-extension deployment strategy
 - Track design for Slide-out deployment
 - Seal & autonomous latch design [internal & external]
 - Load accommodation
 - Thermal management
 - Electrical/Comm/Data/ECLSS integration
- Engineering Directorate undertakes material development for Inflatable Elements of CF
- Engineering Directorate undertakes CF rotating hub design
- Engineering Directorate begins second-generation closed-loop ECLSS design
- Engineering Directorate undertakes Guidance & Control design of Nautilus-X
 - Accommodation of Multiple Propulsion Pods
 - Thrust models with operating CF
 - Software development
 - Star map generation for multiple MMSEV Missions
- Engineering Directorate undertakes Long-Distance Communications/Data suite design
 - Radar and Communications range re-activated/expanded
 - Vibro-Acoustic Lab addresses Propulsion Pod impacts on link stability & integrity



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Back-Up Charts



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Multi-Mission Space Exploration Vehicle

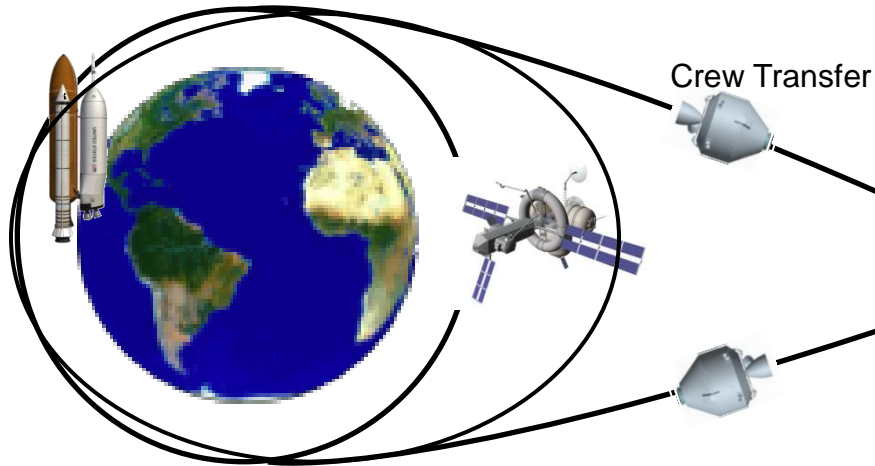
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Initial Operation(s) Concept



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Solar Electric Propulsion Spin out



L1 MMSEV

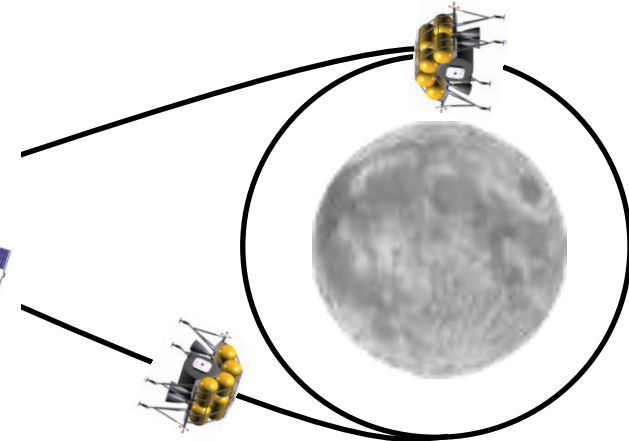
DEPOT

Life Boat/Living Quarters

Staging location/Hospital

Waiting for engines to go to MARS

INSITU (ICE, water)



Lunar Exploration



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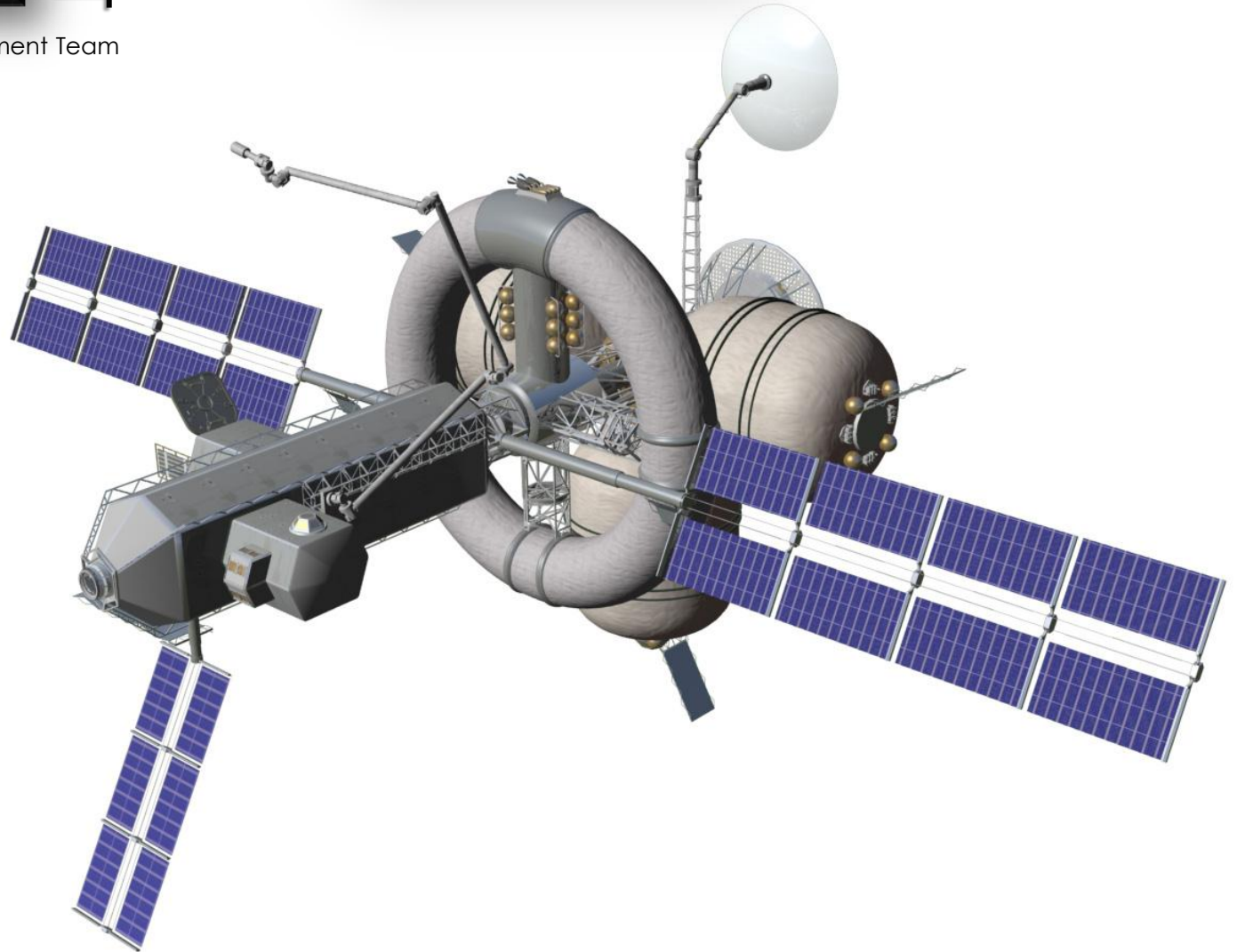
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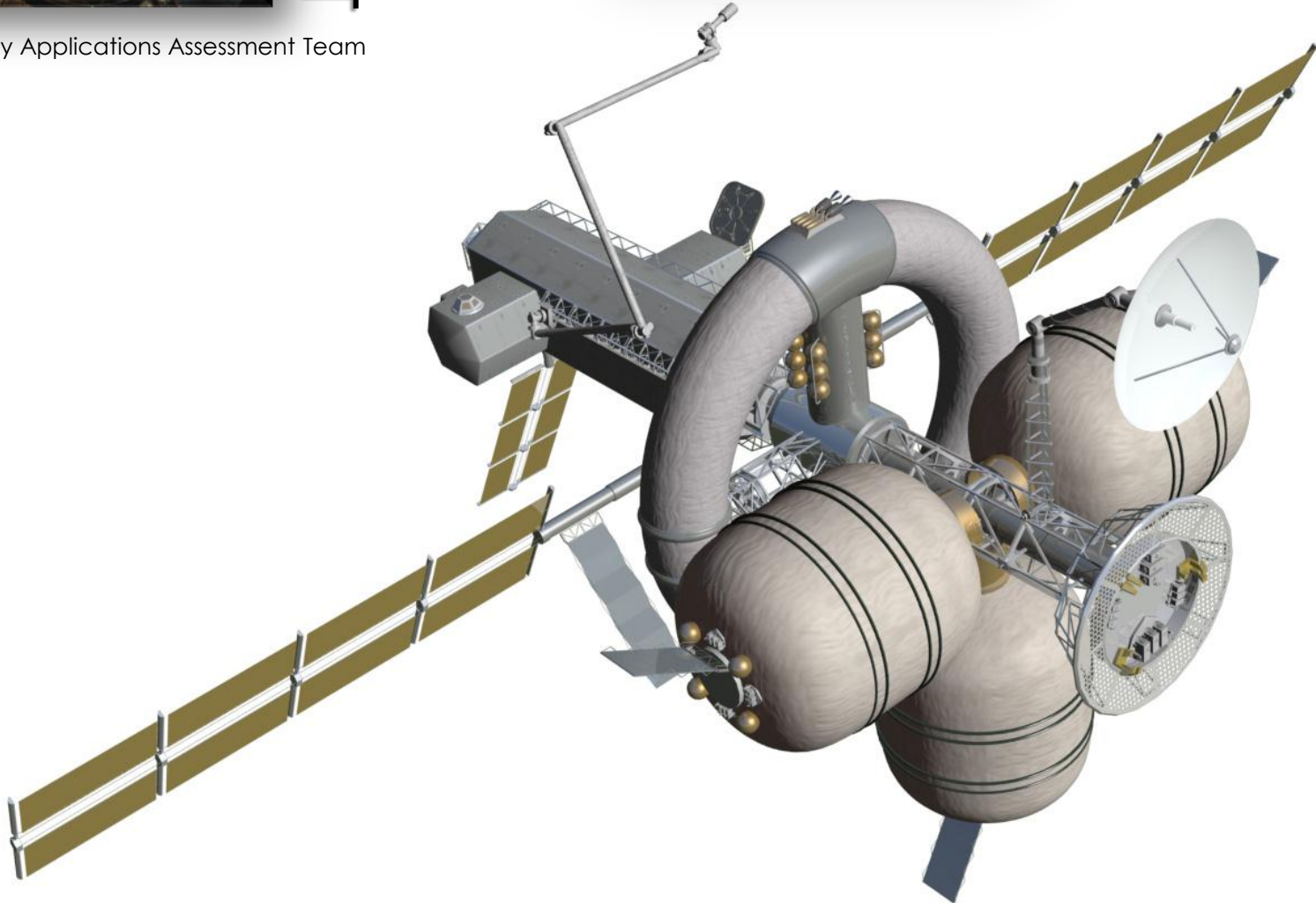
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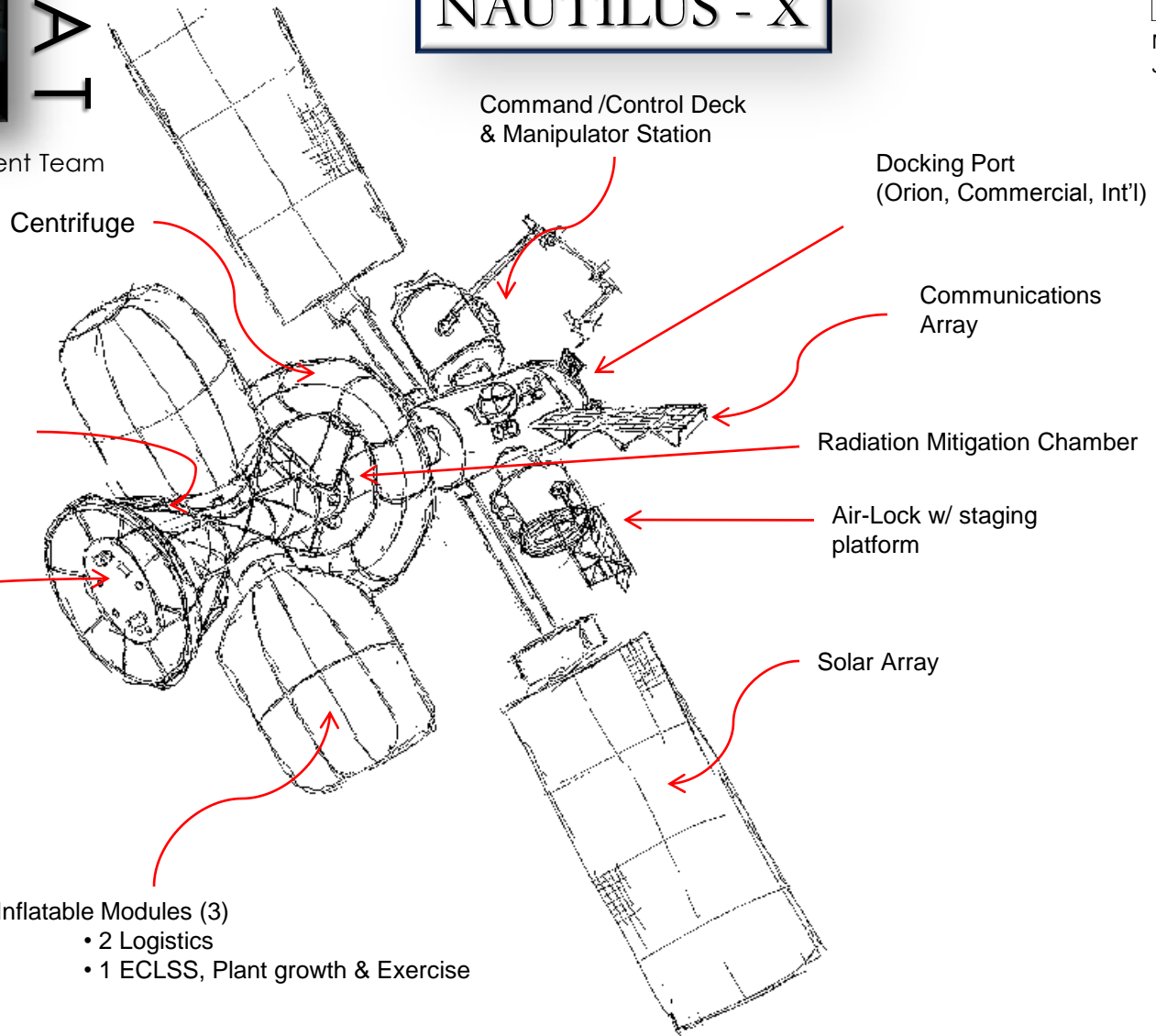
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Propulsion Integration Collar

- Mission Specific
- Electrical & C/C
- Thrust Structure

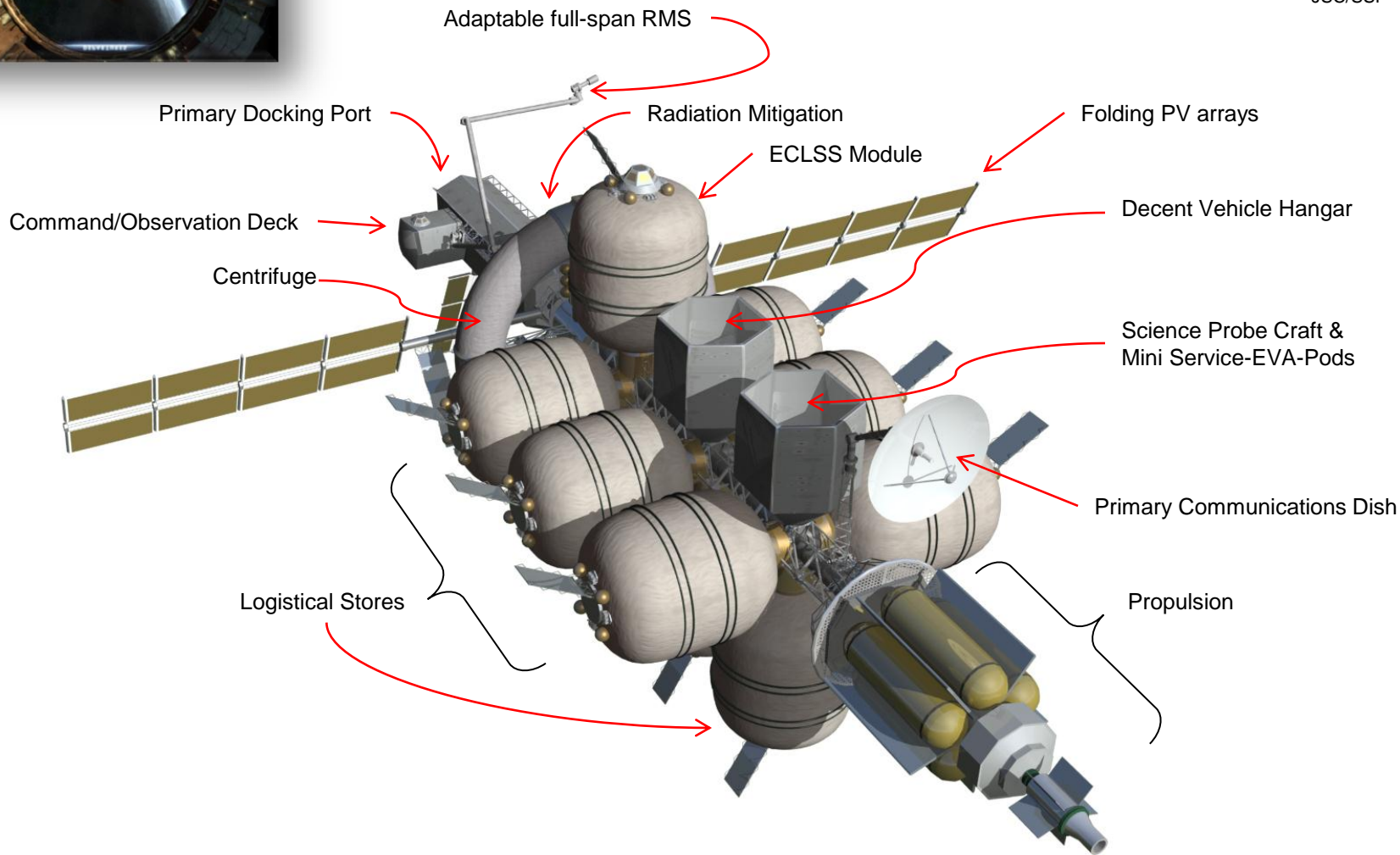
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Extended Duration Explorer



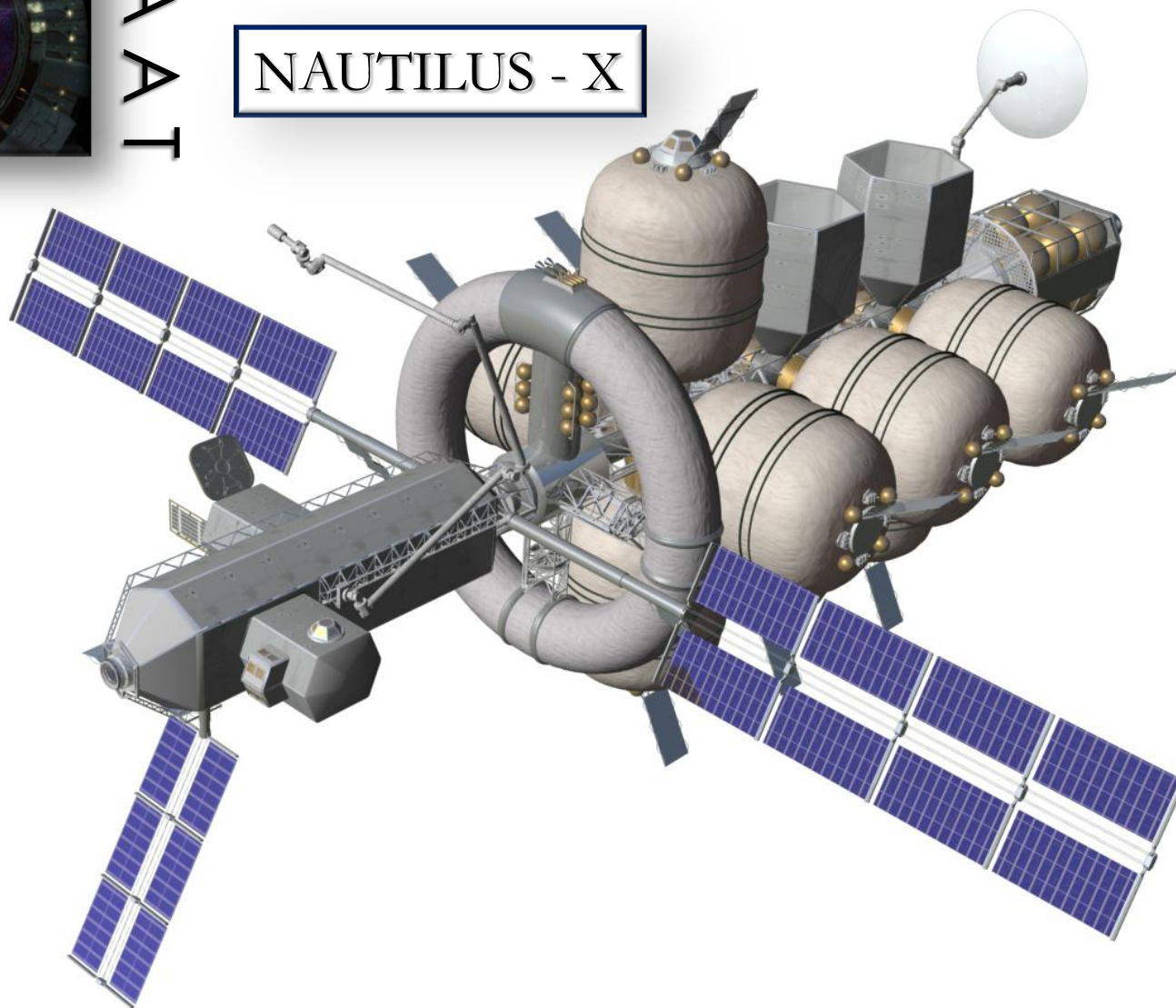
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Extended Duration Explorer