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Technology Applications Assessment Team

M.L. Holderman
JSC/SSP

NAUTILUS - X

Multi-Mission Space Exploration Vehicle

Non –
Atmospheric
Universal
Transport
Intended for
Lengthy
United
States
- - - - - - - - - - -
X-ploration

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FISO Telecon 1/26/2011

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MMSEV (Multi-Mission Space Exploration Vehicle)

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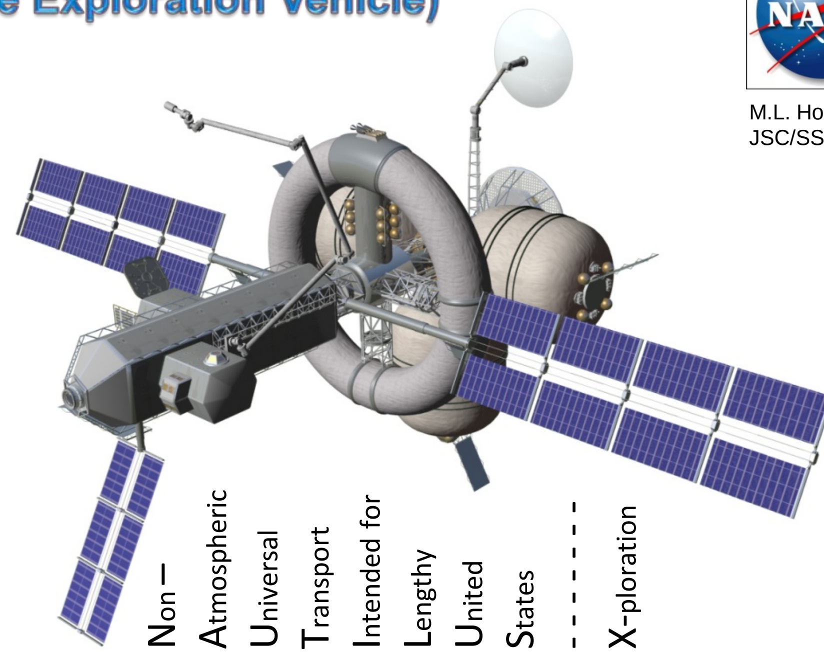
Description and Objectives:

- 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

Multi-Mission Space Exploration Vehicle

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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 [H20/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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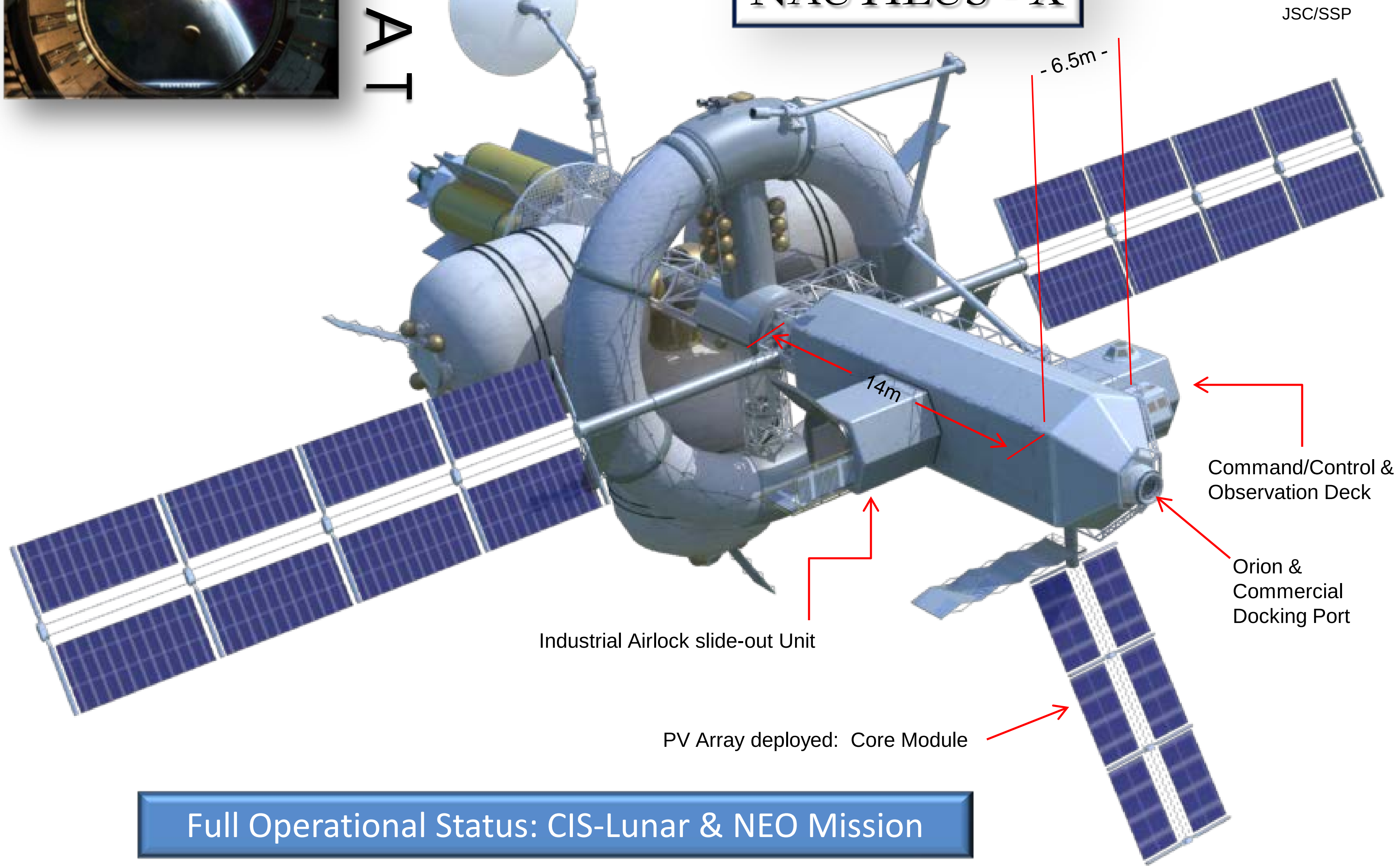

Full Operational Status: CIS-Lunar & NEO Mission

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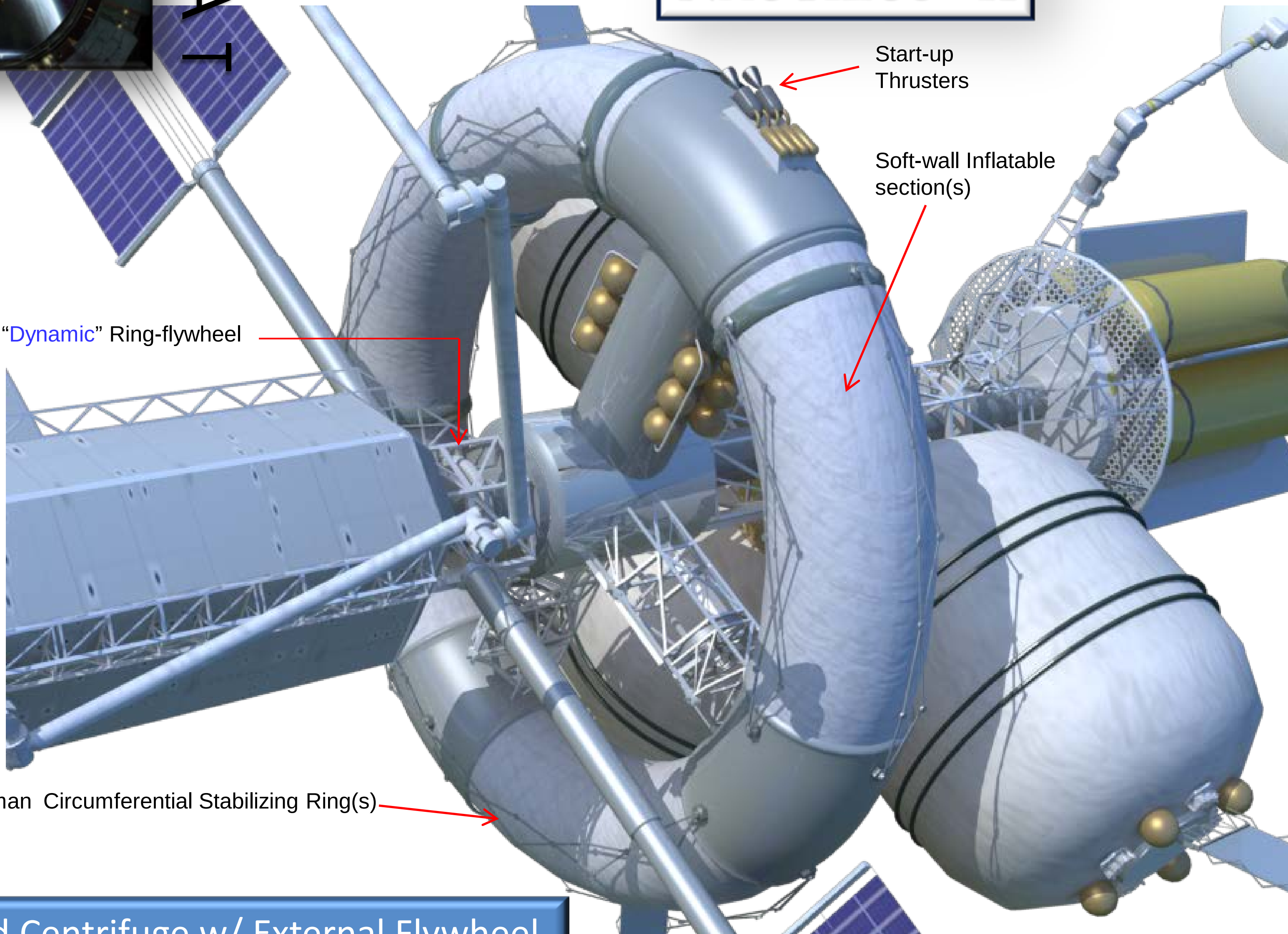

Completed Centrifuge w/ External Flywheel

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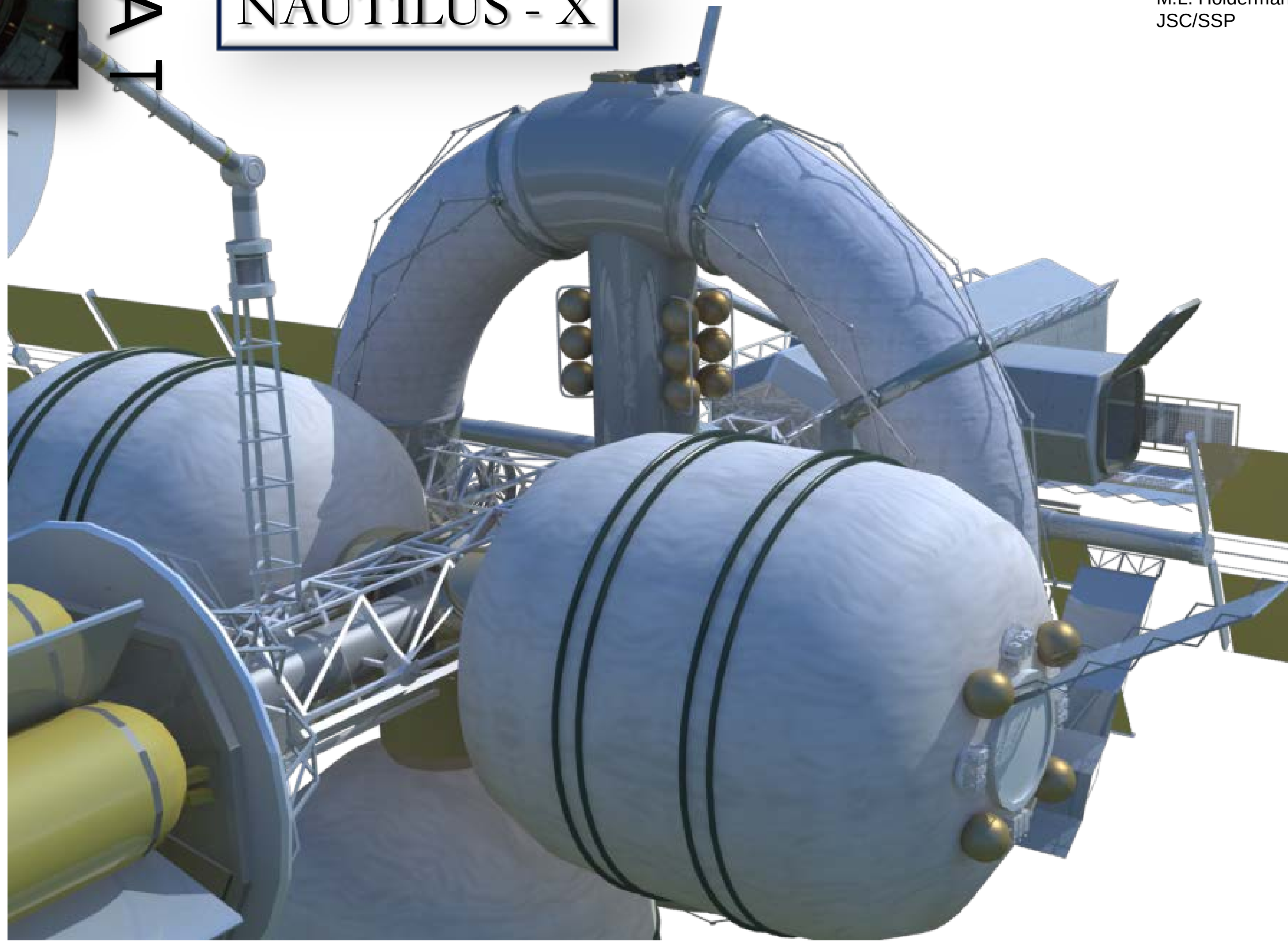

View looking “Forward”

ISS Centrifuge Demo*

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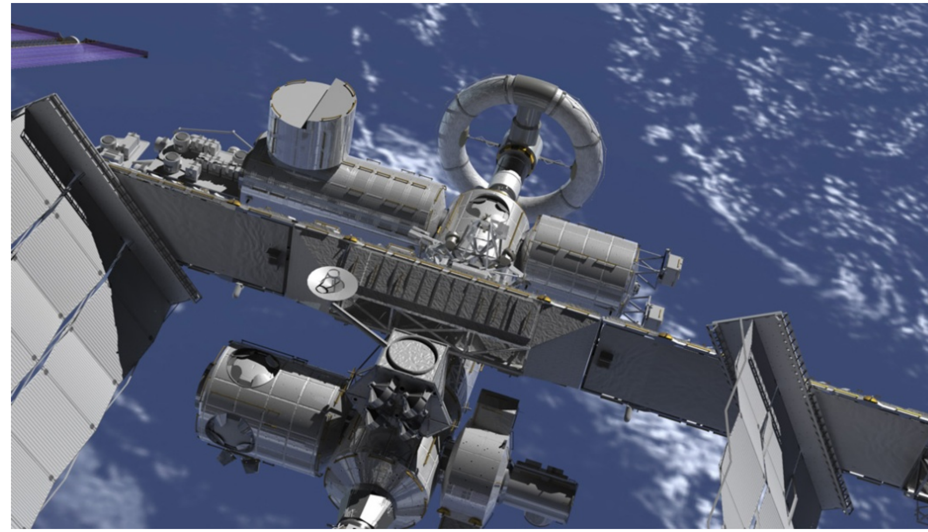

Description and Objectives:

- 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 Cirlce

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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Multi-Mission Space Exploration Vehicle

Development Challenges

- Potential parallel development with HLV
  - Resource allocation
- HLV Payload integration
  - Ascent Vibro-Accoustic 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
- NESC: “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

Multi-Mission Space Exploration Vehicle

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NAUTILUS - X

- <u>CENTRIFUGE [HABITABLE] ARTIFICIAL GRAVITY/PARTIAL-(g)</u>
  - 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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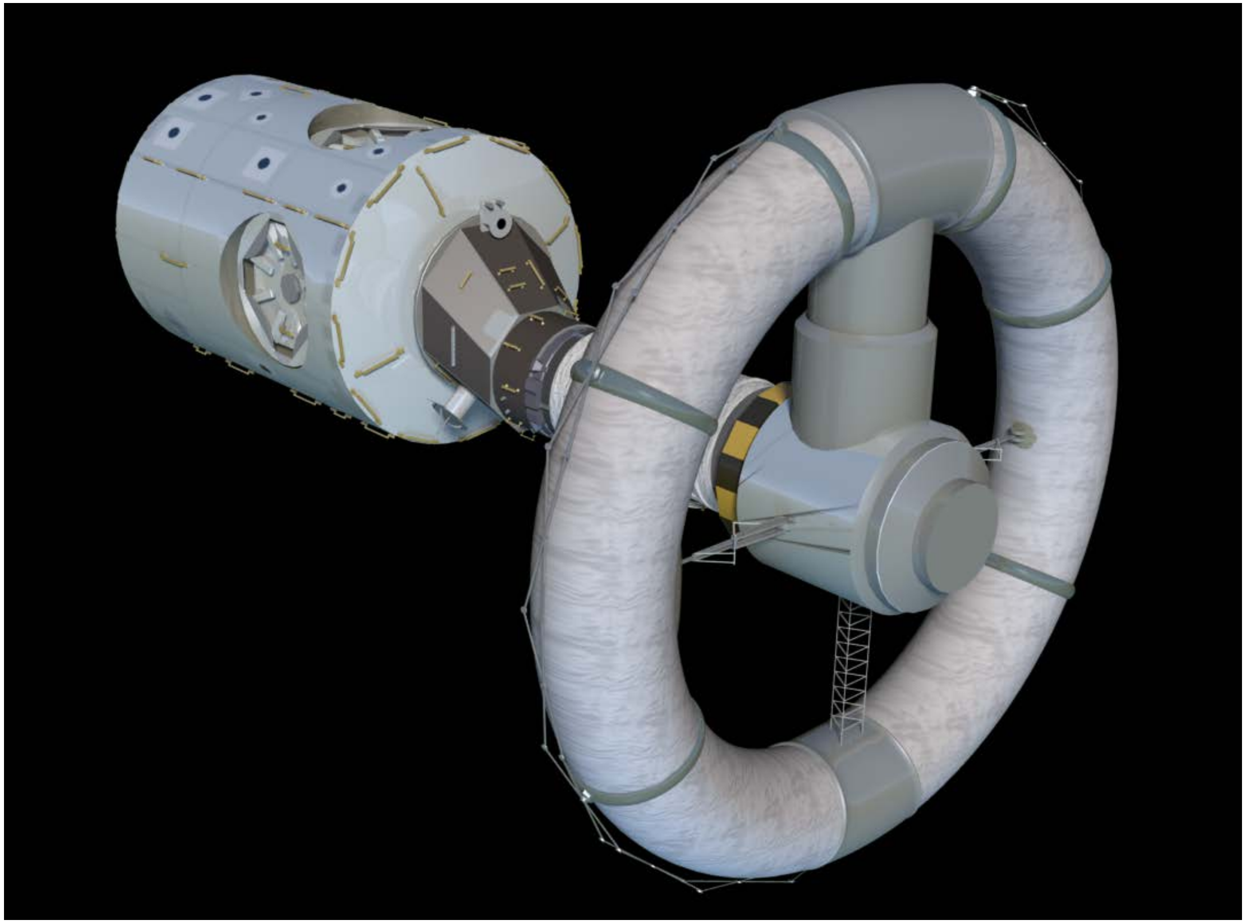
ISS Centrifuge Demo

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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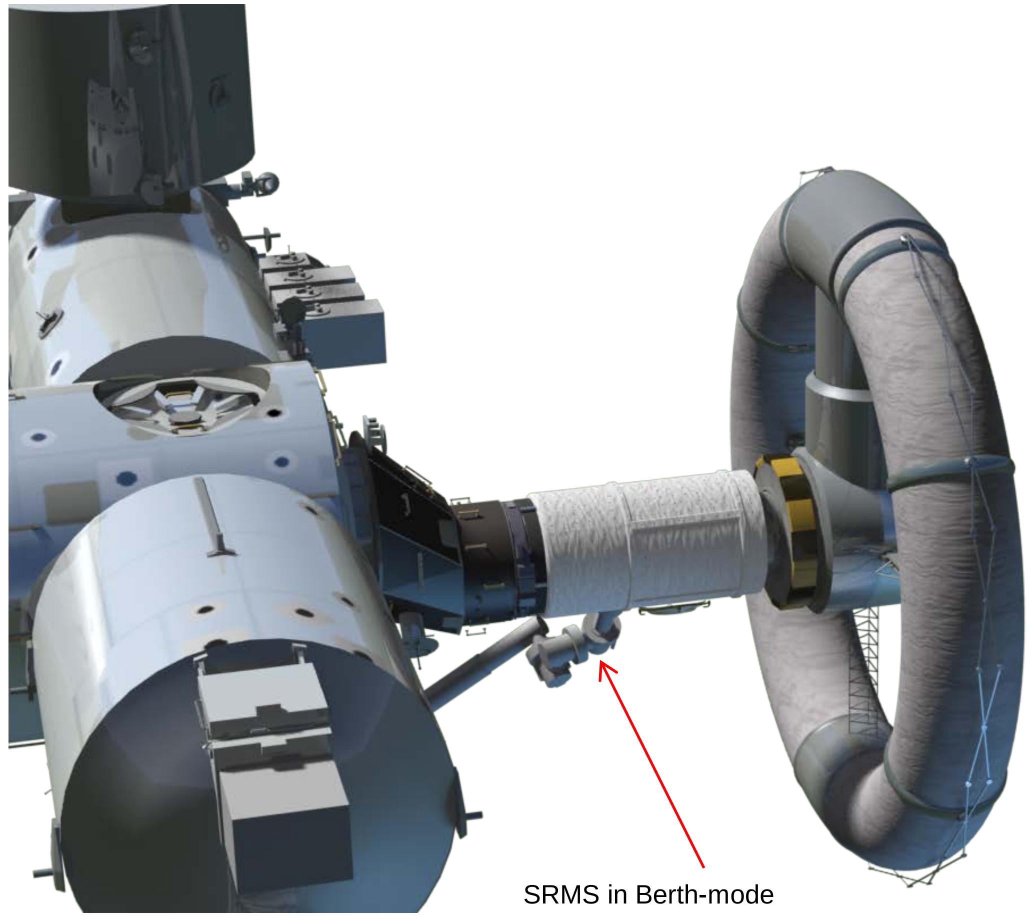
DEMO Aspects:

- 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)

Partial - (g)

RPM	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



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ISS Centrifuge Demo*
(Inflatable-based)

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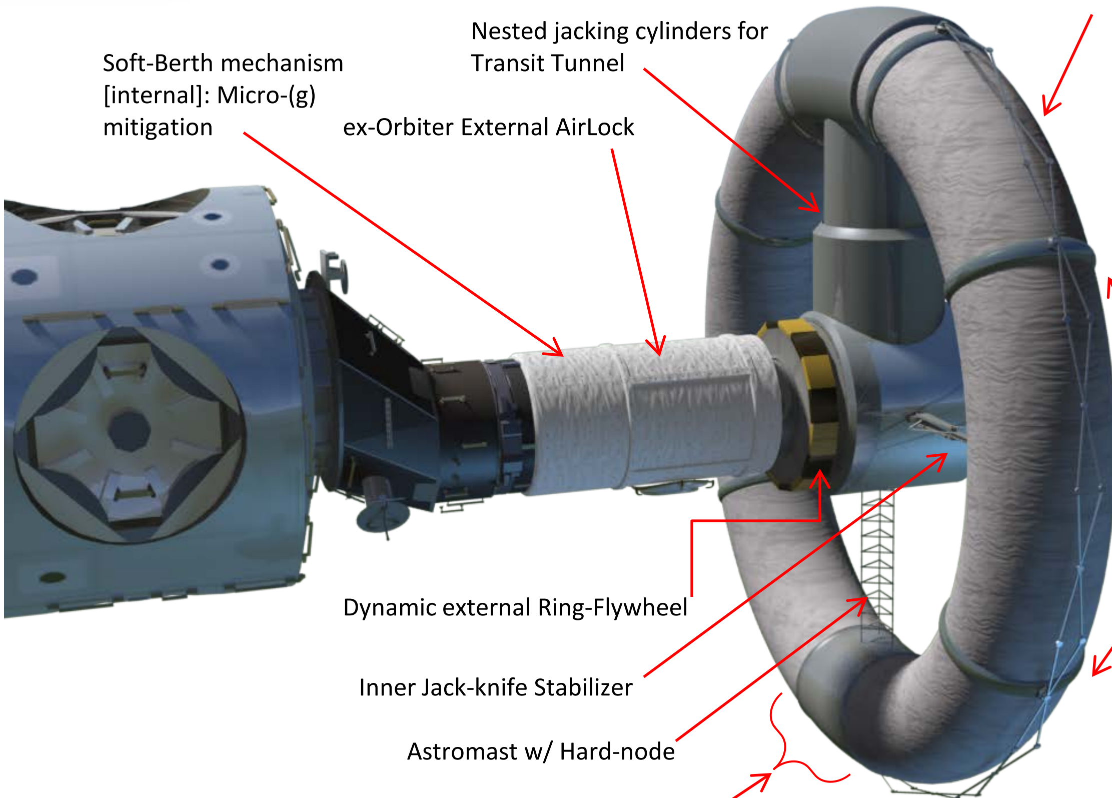

* Test & Evaluation Centrifuge designed with capability to become Sleep Module for Crew

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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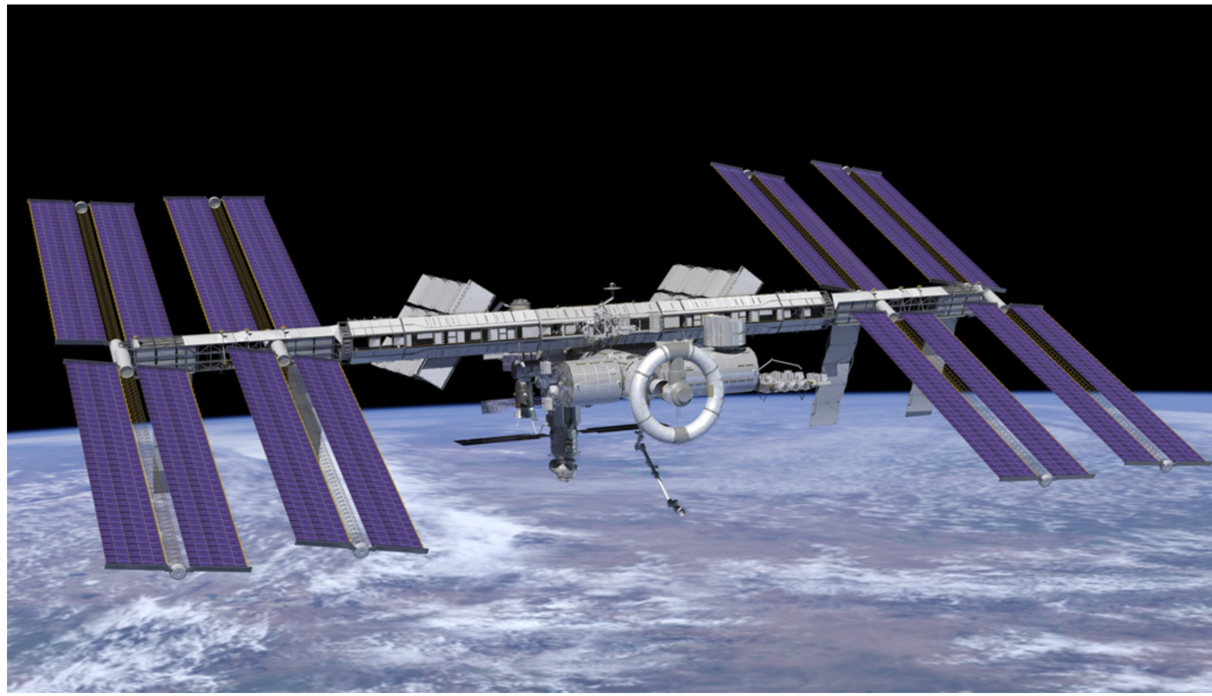
DEMO Aspects:

- 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

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ISS Centrifuge Demo

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

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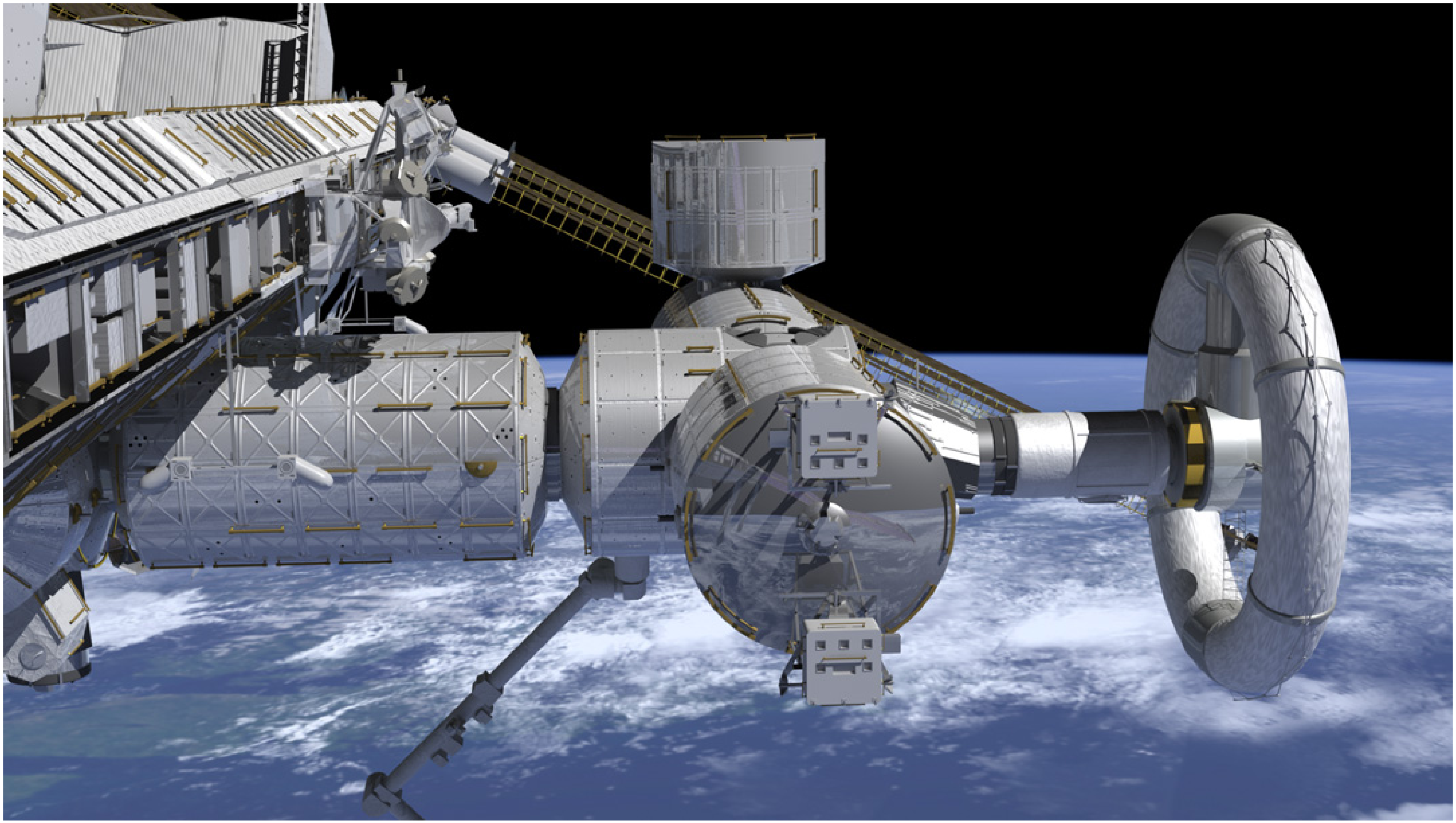

ISS Centrifuge Demo Activities:
Representative Involvement - JSC

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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'

- <u>Mission Operations Directorate</u>
  - Emphasis focuses on start-up sequence of CF
  - Nominal operational influences of CF

- <u>Space & Life-Sci [Dedicated Project]</u>
  - 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

ISS Centrifuge Demo & JSC Envolvement

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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-Accoustic Lab addresses Propulsion Pod impacts on link stability & integrity

Back-Up Charts

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Multi-Mission Space Exploration Vehicle

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Initial Operation(s) Concept

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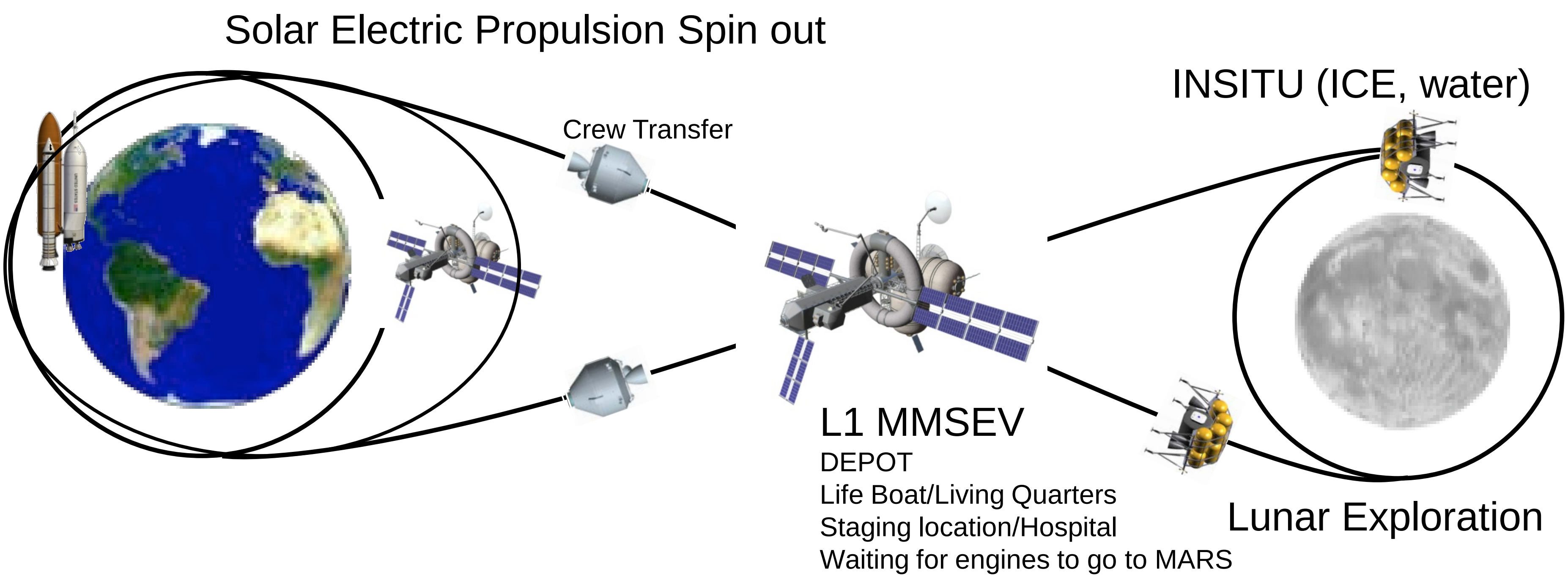

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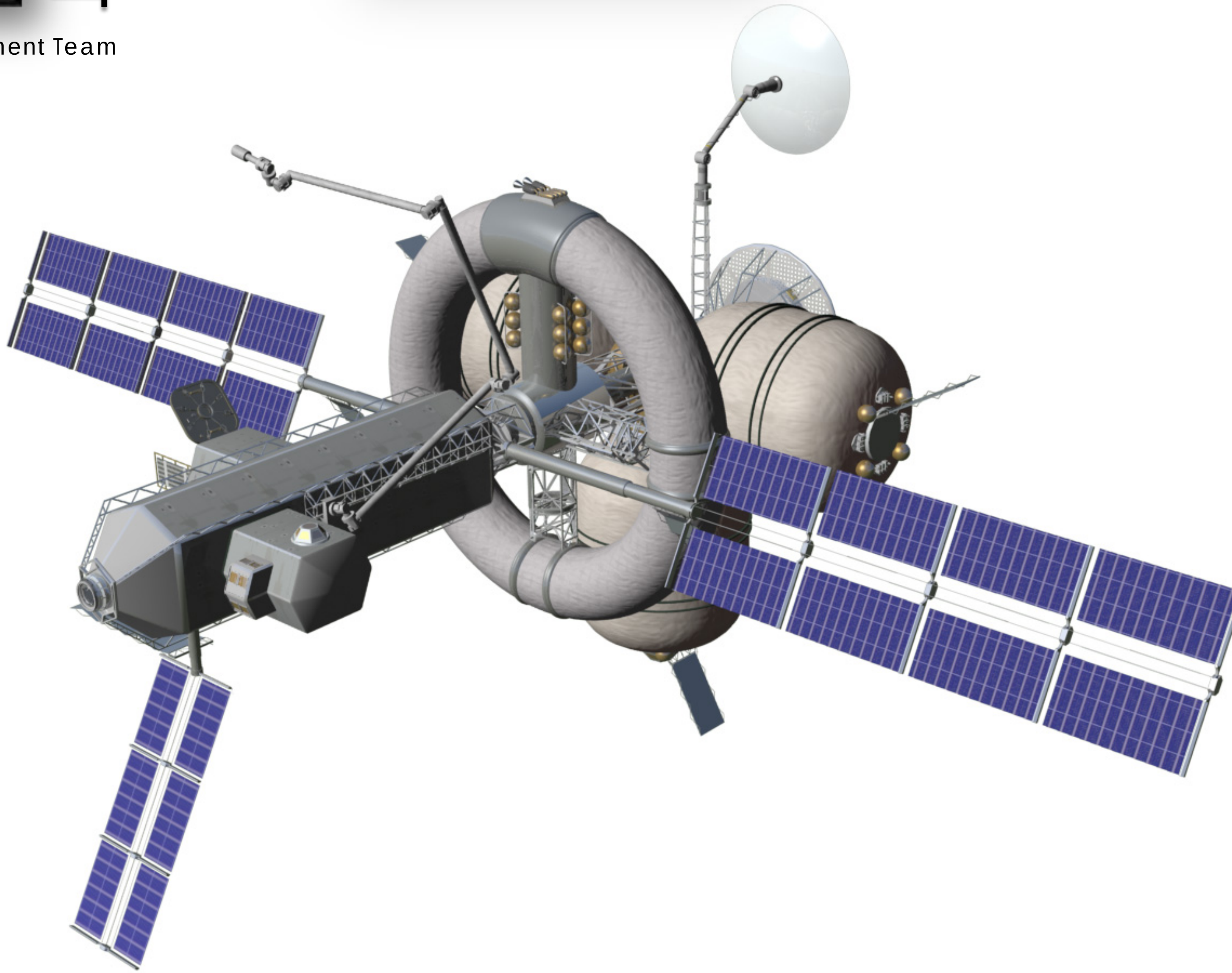

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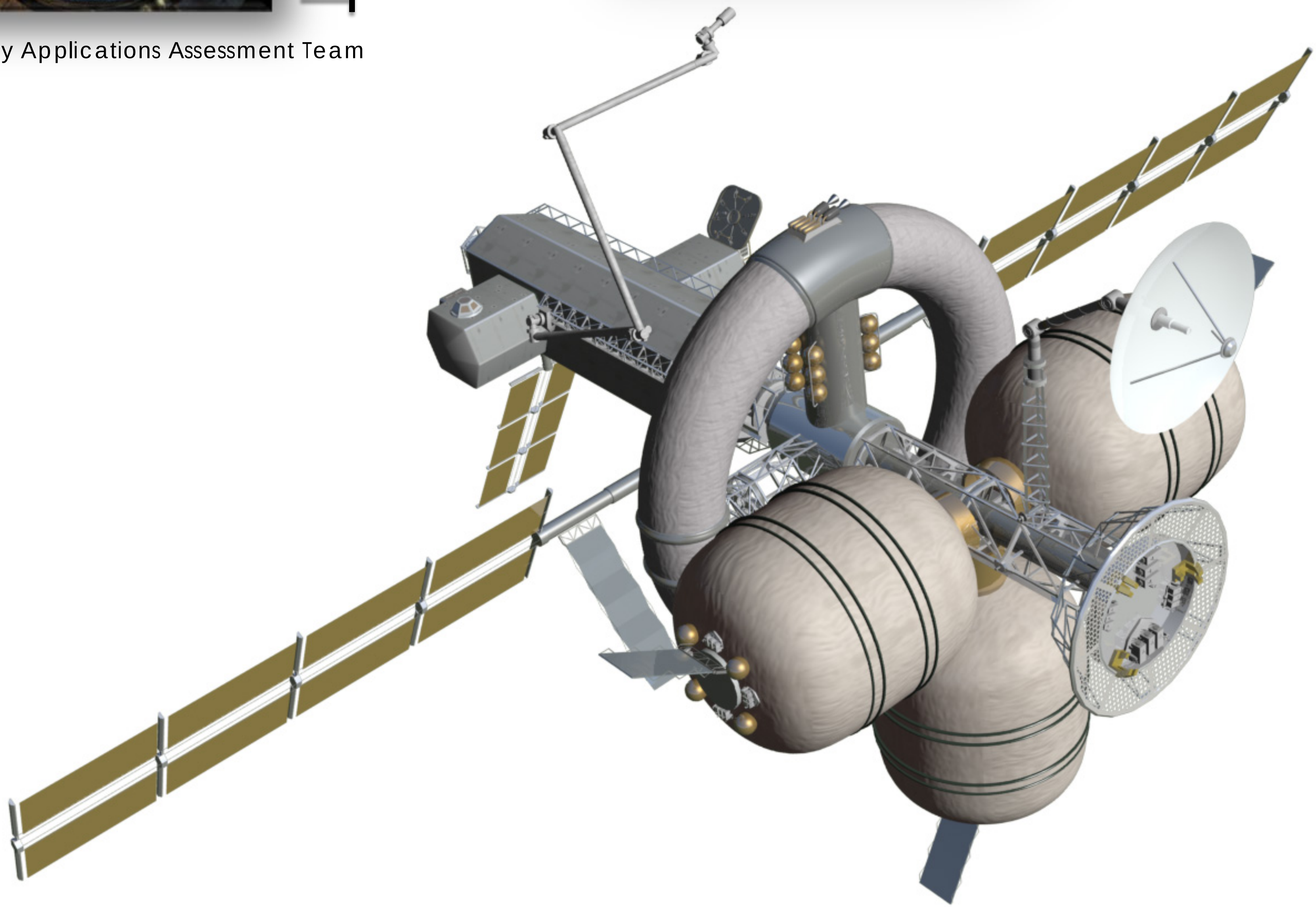

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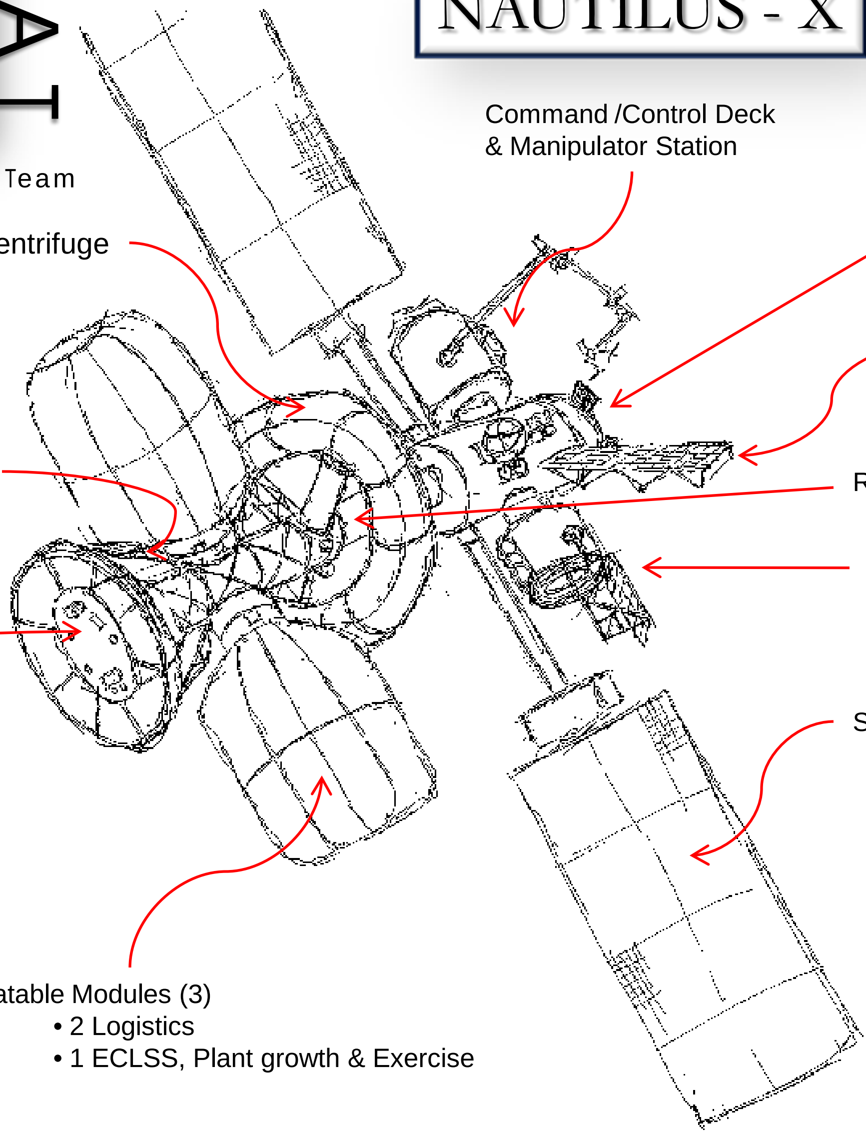

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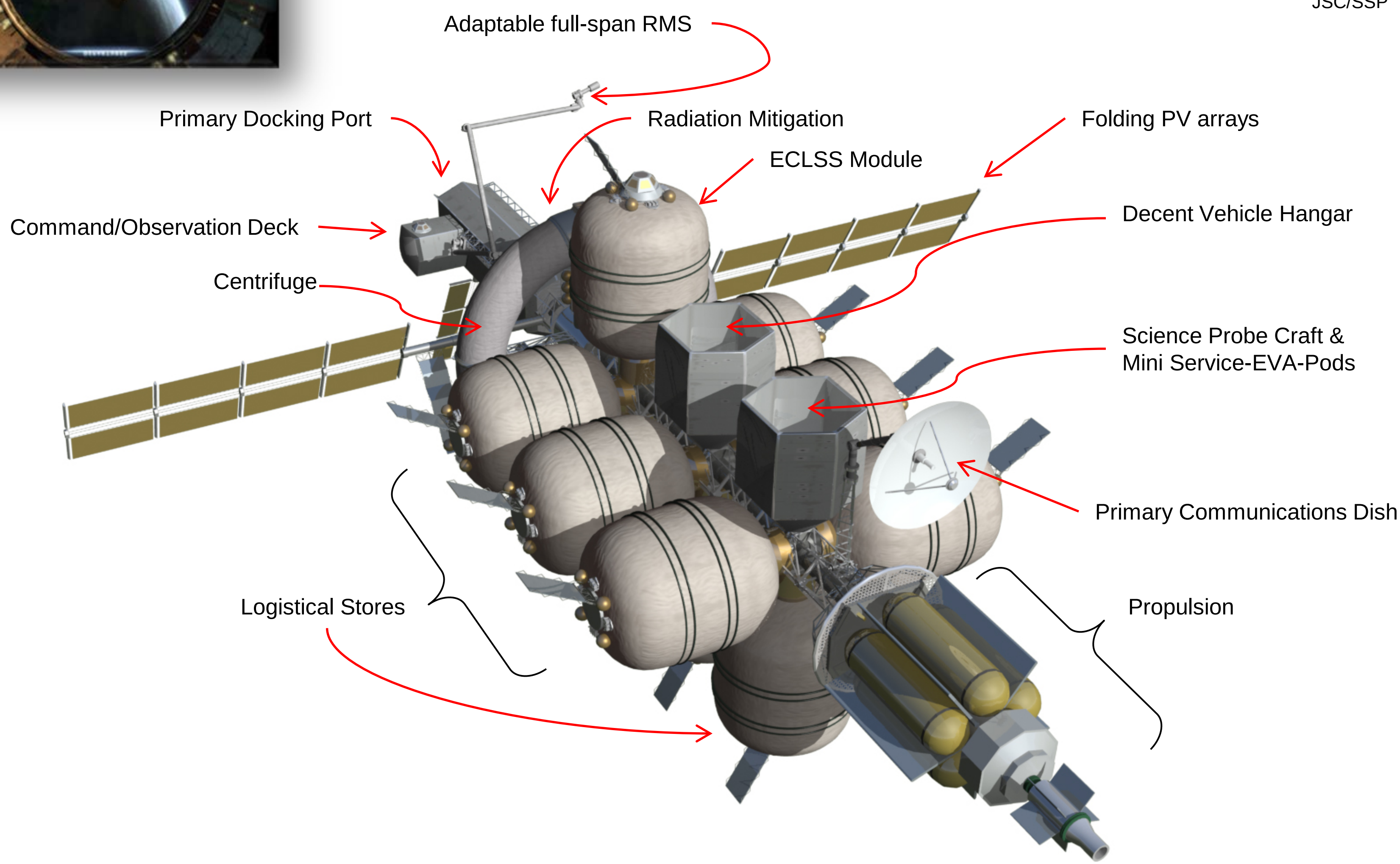

Extended Duration Explorer

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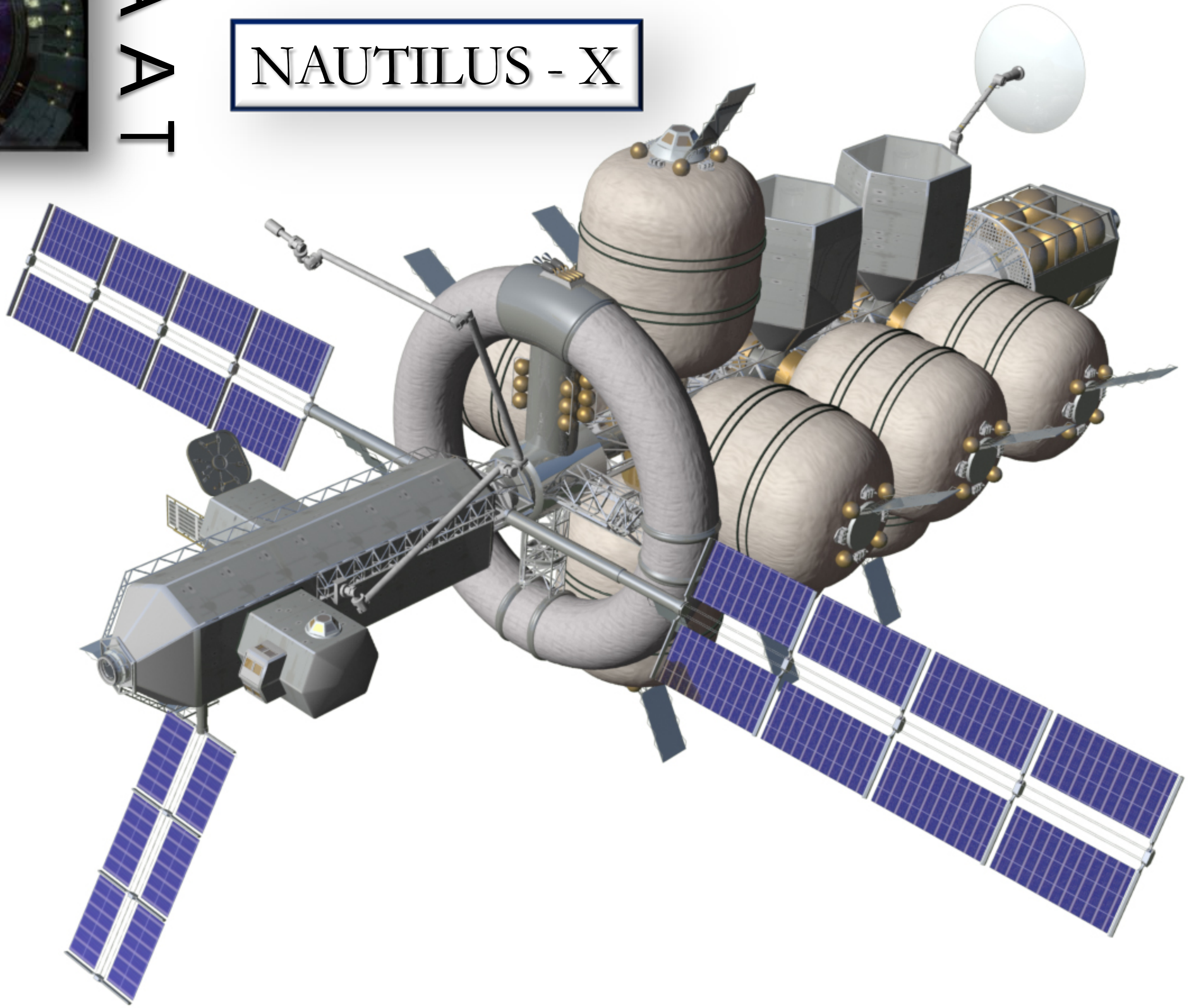

Extended Duration Explorer