SICSA
SASAKAWA INTERNATIONAL CENTER FOR SPACE ARCHITECTURE
UNIVERSITY of HOUSTON

Life and Biological Sciences Facility (LaBS)

An Evolution in Space Platform Design and Operation

May 2004

Project Statement

To design a low cost, quick and easy to assemble, commercially viable space station in support NASA's vision for space exploration as proposed by the University of Houston's Sasakawa International Center for Space Architecture (SICSA).

Acknowledgements

- **Project Director**
  - **Professor Larry Bell (Director, SICSA, College of Architecture, University of Houston)**
- **Project Originator/ Advisor**
  - **Dr. Bonnie Dunbar (Asst. Director for University Research Affairs, NASA JSC / Adjunct Professor, SICSA, College of Architecture, University of Houston)**
- **Project Advisor**
  - **Dr. Valery K. Aksamentov**

    Boeing

    Project Manager Shuttle Return to Flight NASA Systems
- **Research Assistant**
  - **Ms. Olga Bannova (Senior Research Architect, SICSA, College of Architecture, University of Houston)**

Acknowledgements

- **SICSA Team of Undergraduate & Graduate Students**

5th Year Students	M. Arch Students	MS Space Arch Students
Gilberto Arenas	Elena Howard	Donald Barker (USA)
Ted Borel	Cagri Kanver	Blake Merrifield (Oceaneering)
Robert Burell	Daniel Whalen	Shalin Mody (USA)
Tonya Mack		Carl Merry (USA)
Chad Murders		Shehnaz Soni (Boeing)
Roxana Vasquez		
Bryan Whitener		
Luis-Antonio Zavala		
Peter Ogbac		

SICSA 2003-2004 LaBS Facility Design Team

Acknowledgements

- **SICSA Presenters & References**
  - **Dr. Carlton Allen** (Manager of Astromaterials Acquisition and Curation Office, NASA JSC)
  - **Mr. Karl Baker** (Business Developer for Aerospace Corporation)
  - **Ms. Anita Gayle** (Senior Engineer Space Shuttle Payload & Cargo Integration, Boeing)
  - **Mr. William Gerstenmaier** (ISS Program Manager, NASA JSC)
  - **Dr. Don Henninger** (Chief Scientist for Crew & Thermal Systems Division, NASA JSC)
  - **Dr. Helen Lane** (Chief Nutritionist, Life Sciences Directorate, NASA JSC)
  - **Dr. Shanon Lucid** (NASA Astronaut)
  - **Dr. Kam Lulla** (Chief Scientist for Earth Observations, NASA JSC)
  - **Dr. Neal Pellis** (Associate Director of Biological Sciences & Applications Office, NASA JSC)
  - **Mr. John Muratore** (Manager of Space Shuttle Integration, NASA JSC)

Project Background

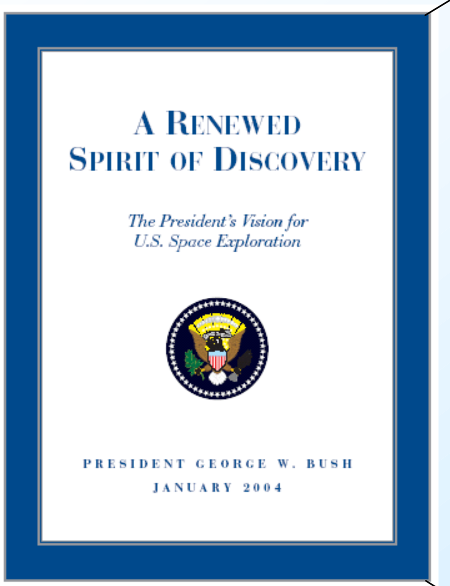
This project was undertaken during the 2003-2004 academic year in response to an RFP that was provided by Dr. Bonnie Dunbar.

The facility outlined in the RFP primarily serves as a LEO, life and biological sciences laboratory and technology test bed that supports future exploration initiatives, provides sustainable infrastructures, and employs a learned evolution in space station platforms.

Project Background

Vision for Space Exploration

THE FUNDAMENTAL GOAL OF THIS VISION IS TO ADVANCE U.S. SCIENTIFIC, SECURITY, AND ECONOMIC INTEREST THROUGH A ROBUST SPACE EXPLORATION PROGRAM



Implement a sustained and affordable human and robotic program to explore the solar system and beyond

Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations;

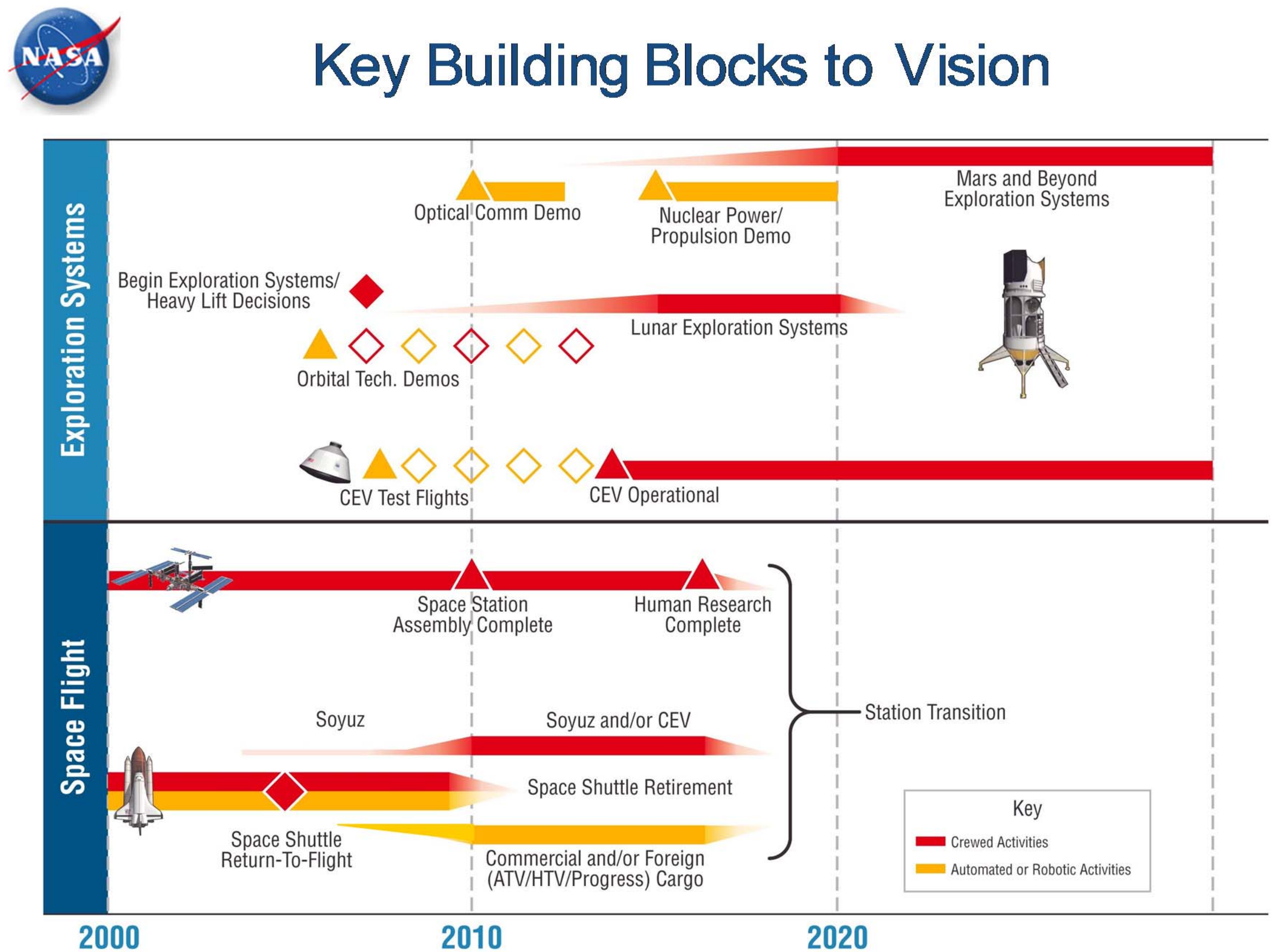
Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration; and

Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests.

LaBS

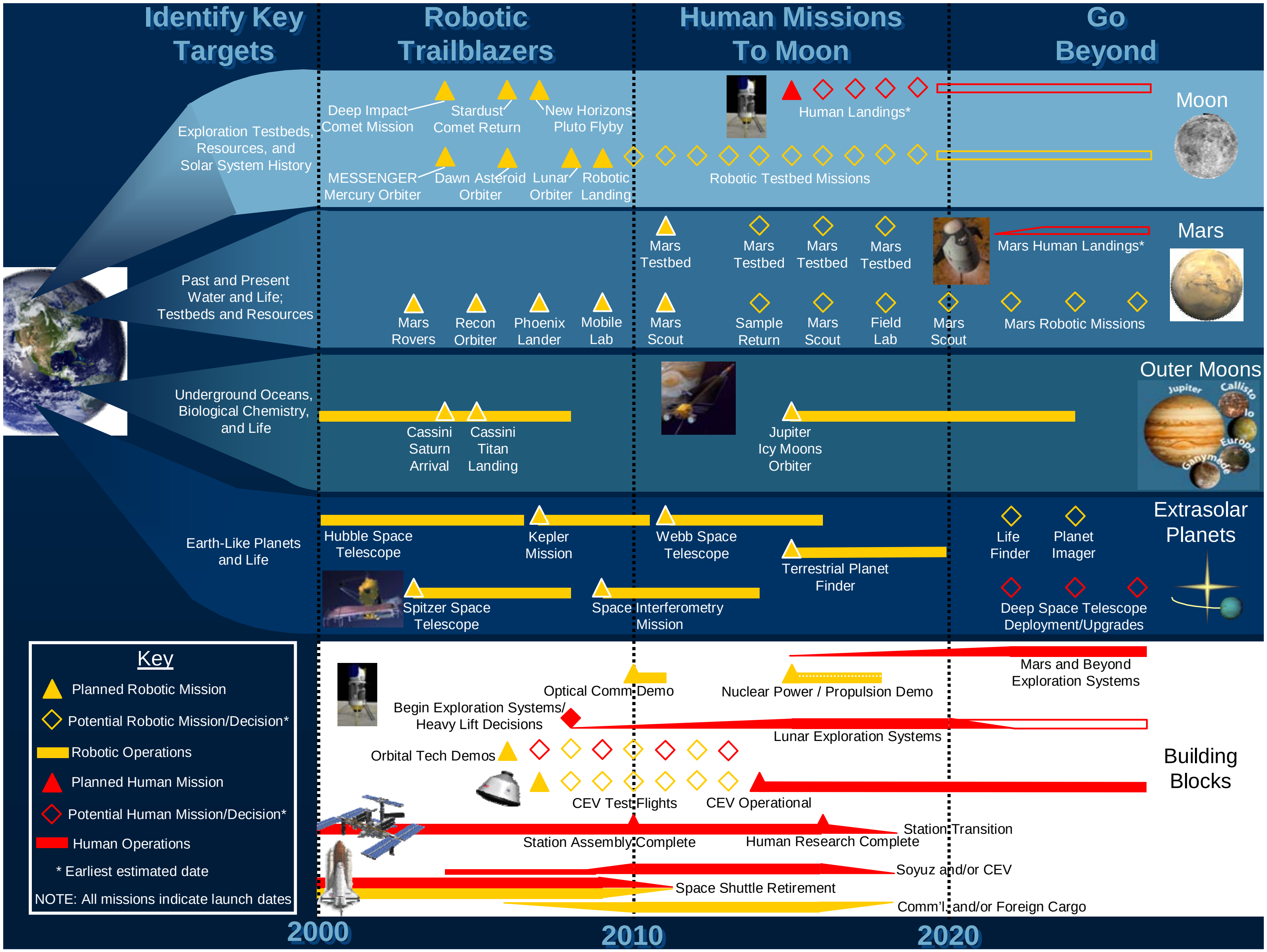
UNIVERSITY of HOUSTON

Project Background



LaBS

Project Background



RFP Driver Overview

Primary features and attributes:

- Enhanced safeguards, operational efficiency and redundancy while incorporating an optimized maintenance and repair strategy.
- Permanent habitation & operational capability to be achieved after only three assembly flights and one crew flight.
- Accommodations that support three crewmembers over extended periods of time up to six months.
- An optimized micro-gravity research environment for human biological, micro fluidics and botanical research.
- A test-bed capable of supporting a variety of advanced technologies and systems (e.g., advanced regenerative life support) applying “plug-n-play” features.
- Low-drag design with ion and limited chemical propulsion systems which provide for a reduction in propellant consumables and improved orbital maintenance efficiency.
- Double containment endcone airlock/gloveboxes that support Mars sample return and are rated to support Biohazard Level IV operations.

Design Driver Overview

The project was designed to support the continued evolution of human tended space stations as well as contributing to NASA's Life Sciences & Moon and Mars exploration goals:

1. Use/build upon existing manufacturing and operational assets where feasible in order to control costs and apply proven technologies and systems:
   - ✓ Atlas V or Delta IV and Space Shuttle as launch platforms.
   - ✓ Established manufacturing templates & tooling (including pressure vessels, experiment racks, hatches and berthing/docking interfaces).
   - ✓ Second generation systems and software (e.g., ECLSS hardware and FDR) that have incorporated lessons learned from previous programs.

Design Driver Overview

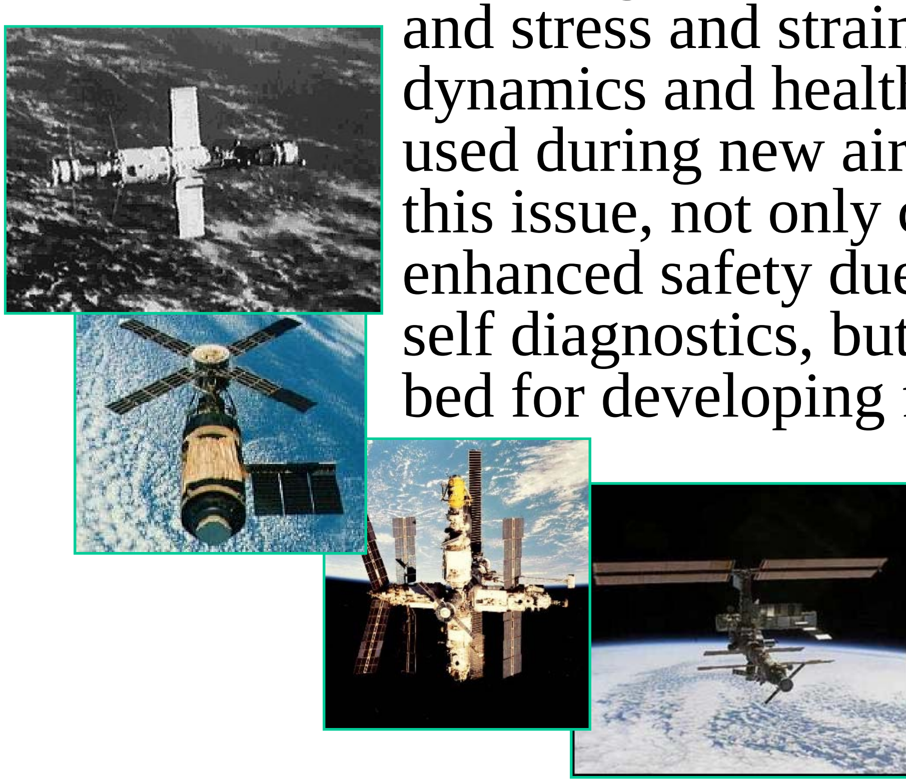
2. Develop and test new technologies which support continued space station evolution, human adaptation and response research, and the NASA's exploration goals:
   - ✓ Expandable telescoping or inflatable modules that maximize habitable pressurized volumes without increasing launch payload volume.
   - ✓ Advanced power production systems (i.e., 60 KW RTG) that minimize micro-gravity orbital perturbations and provides vehicle power.
   - ✓ Advanced ion propulsion for efficient & continuous orbit maintenance.
   - ✓ Test bed facilities incorporating "plug-n-play" features that enable future advanced systems testing and development.

station rotation

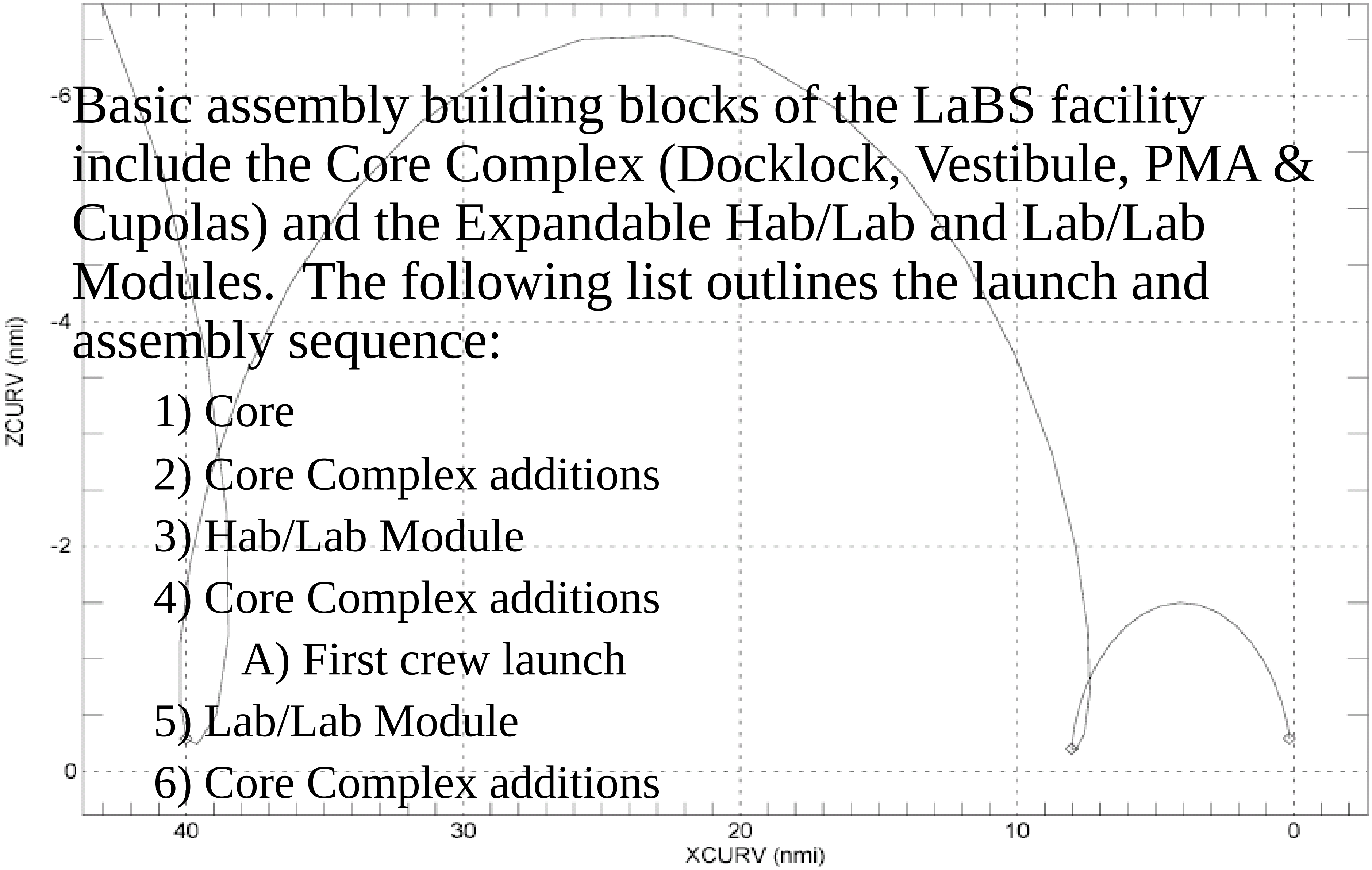
Historical Lessons

The proposed LaBS facility is an evolutionary step in space station design that utilizes lessons learned from current and previous programs.

A primary lesson learned is the need to outfit space vehicles with numerous and appropriate sensor arrays, including ultrasonic, thermal, radiation, atmospheric, and stress and strain, which monitor both vehicle dynamics and health – similar to initial instrumentation used during new aircraft flight testing. By addressing this issue, not only can this station take advantage of enhanced safety due to its being outfitted for complex self diagnostics, but is itself acting as a engineering test-bed for developing future space stations and vehicles.



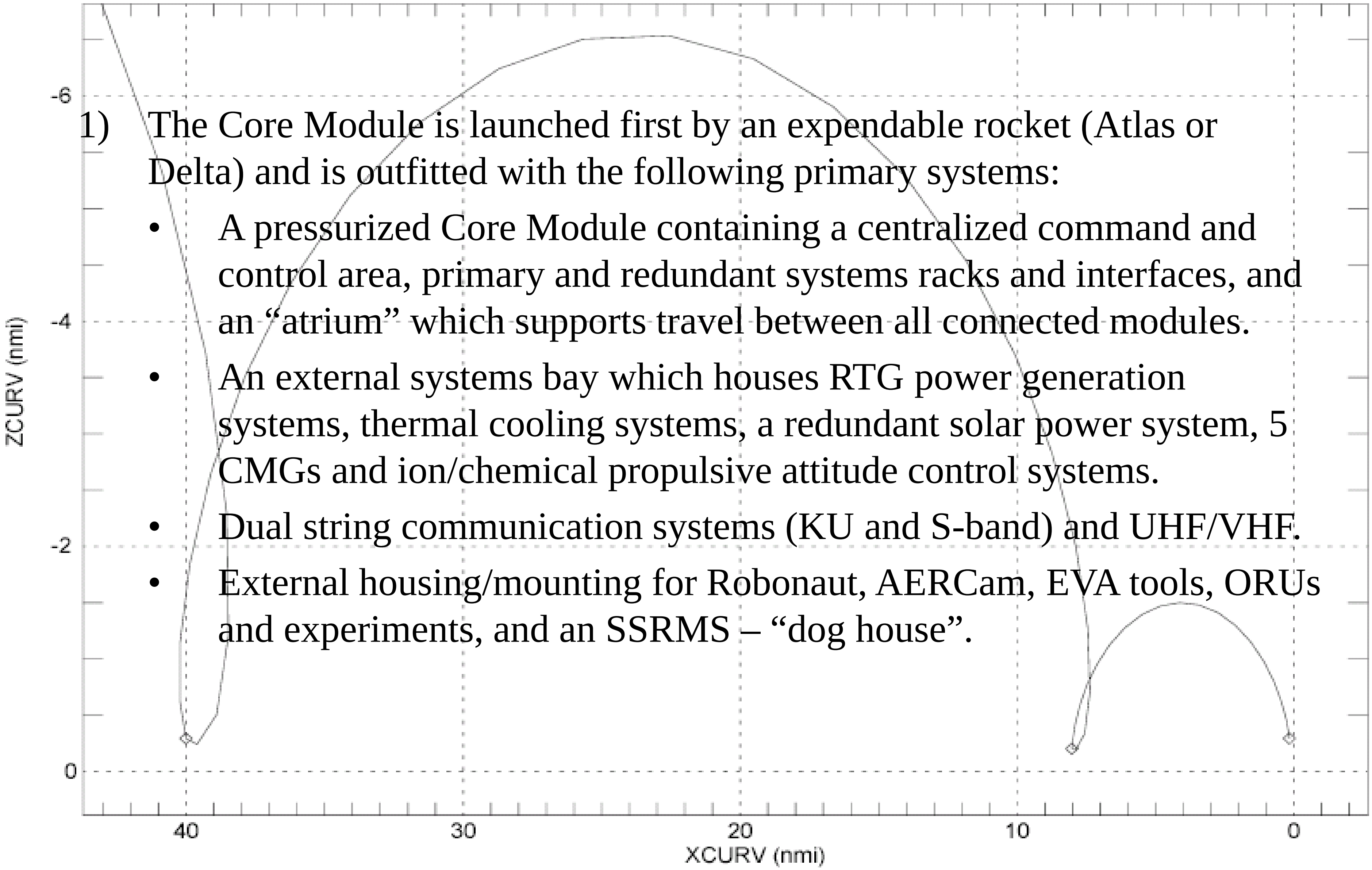
Elements and Assembly Sequence



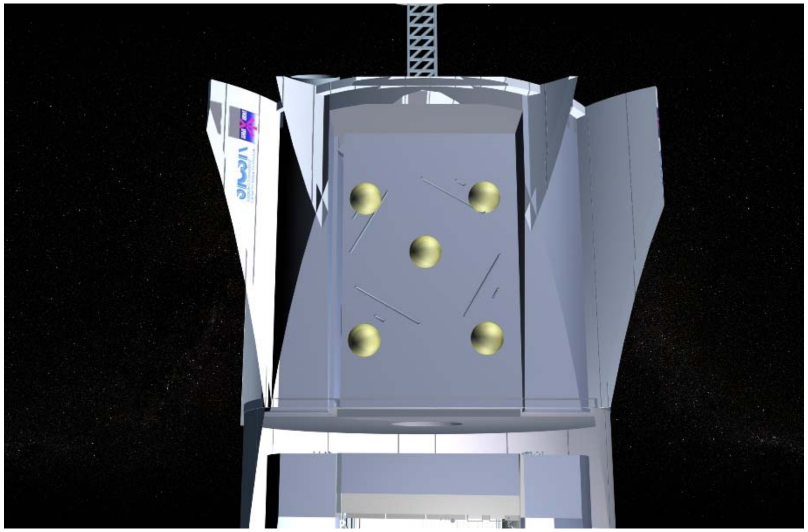
Basic assembly building blocks of the LaBS facility include the Core Complex (Docklock, Vestibule, PMA & Cupolas) and the Expandable Hab/Lab and Lab/Lab Modules. The following list outlines the launch and assembly sequence:

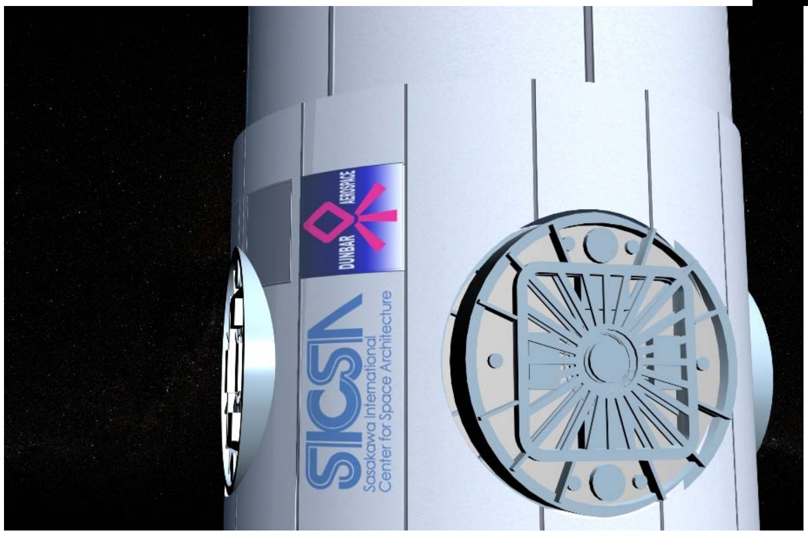
1) Core
2) Core Complex additions
3) Hab/Lab Module
4) Core Complex additions
    A) First crew launch
5) Lab/Lab Module
6) Core Complex additions

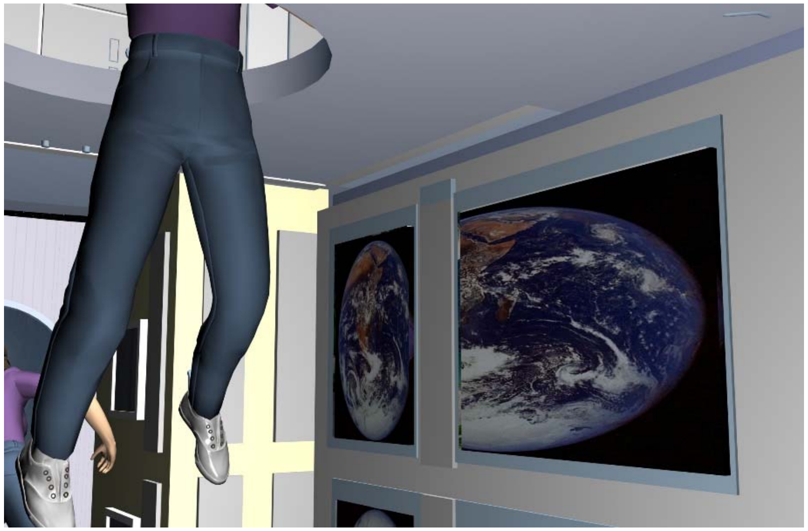
Elements and Assembly



1) The Core Module is launched first by an expendable rocket (Atlas or Delta) and is outfitted with the following primary systems:
   - A pressurized Core Module containing a centralized command and control area, primary and redundant systems racks and interfaces, and an “atrium” which supports travel between all connected modules.
   - An external systems bay which houses RTG power generation systems, thermal cooling systems, a redundant solar power system, 5 CMGs and ion/chemical propulsive attitude control systems.
   - Dual string communication systems (KU and S-band) and UHF/VHF.
   - External housing/mounting for Robonaut, AERCam, EVA tools, ORUs and experiments, and an SSRMS – “dog house”.

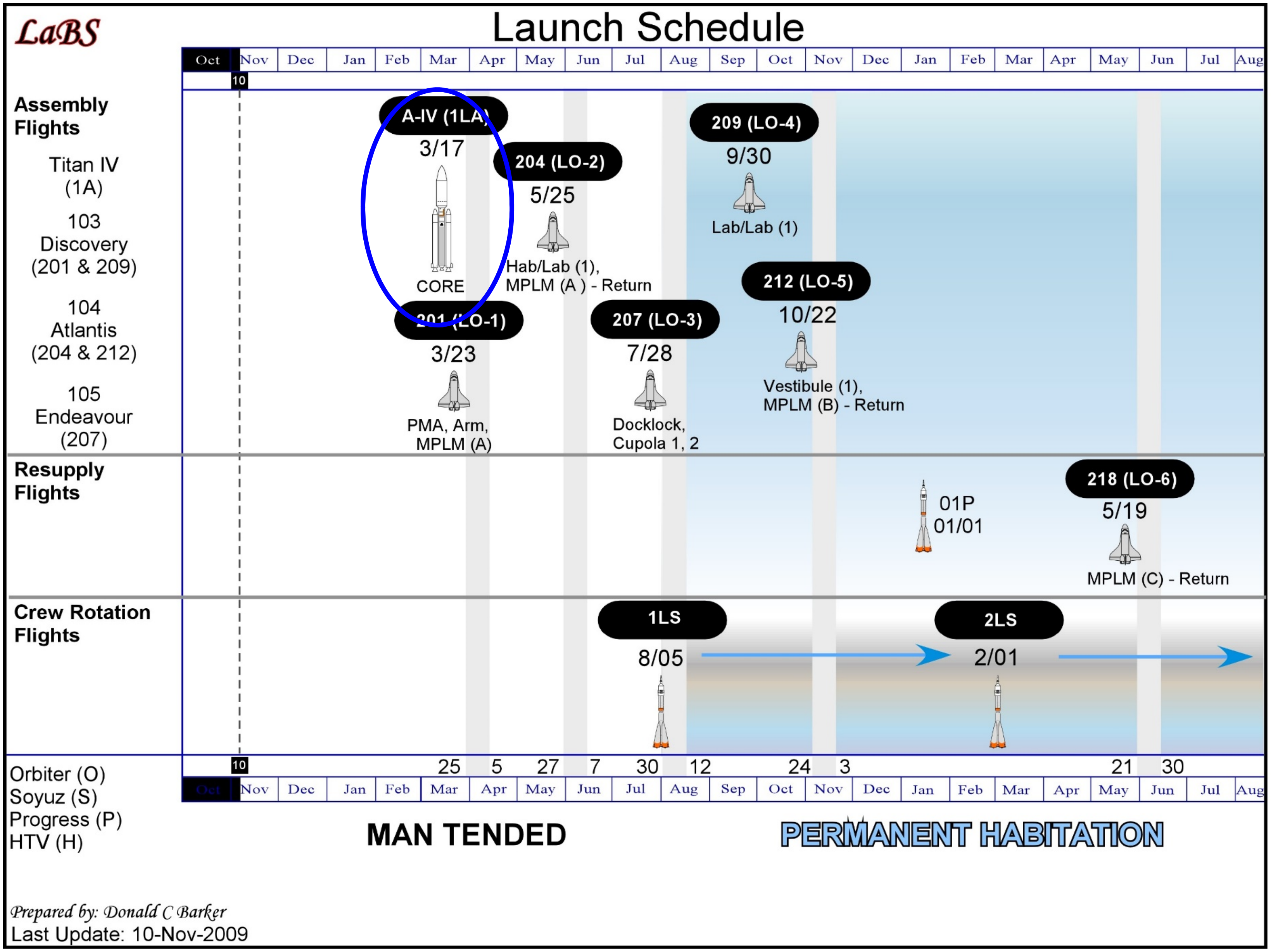



DUNBAR
SICSA
Sasakawa International
Center for Space Architecture



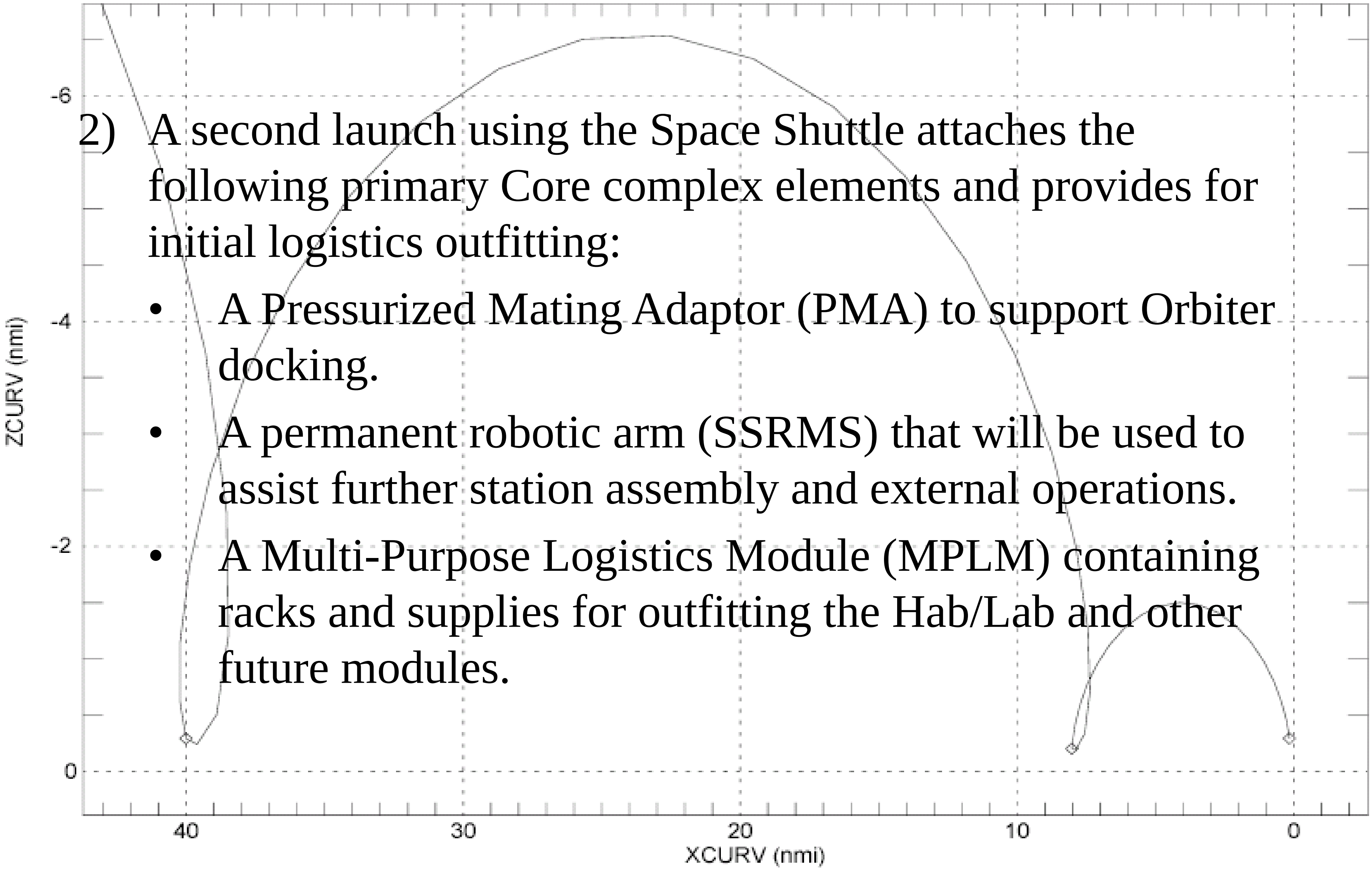
UNIVERSITY of HOUSTON

Assembly Overview



Elements and Assembly

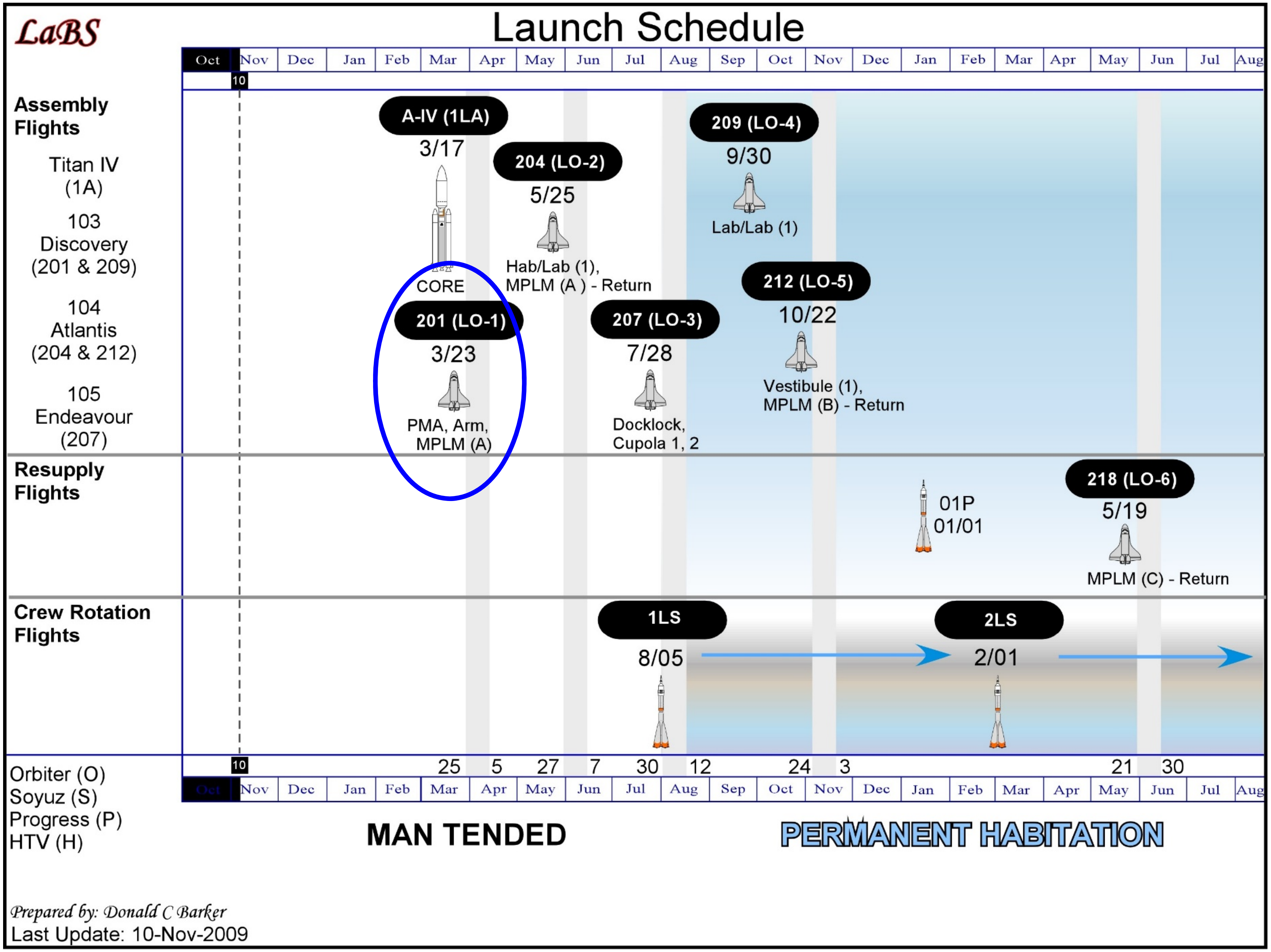
2) A second launch using the Space Shuttle attaches the following primary Core complex elements and provides for initial logistics outfitting:
   - A Pressurized Mating Adaptor (PMA) to support Orbiter docking.
   - A permanent robotic arm (SSRMS) that will be used to assist further station assembly and external operations.
   - A Multi-Purpose Logistics Module (MPLM) containing racks and supplies for outfitting the Hab/Lab and other future modules.



LaBS

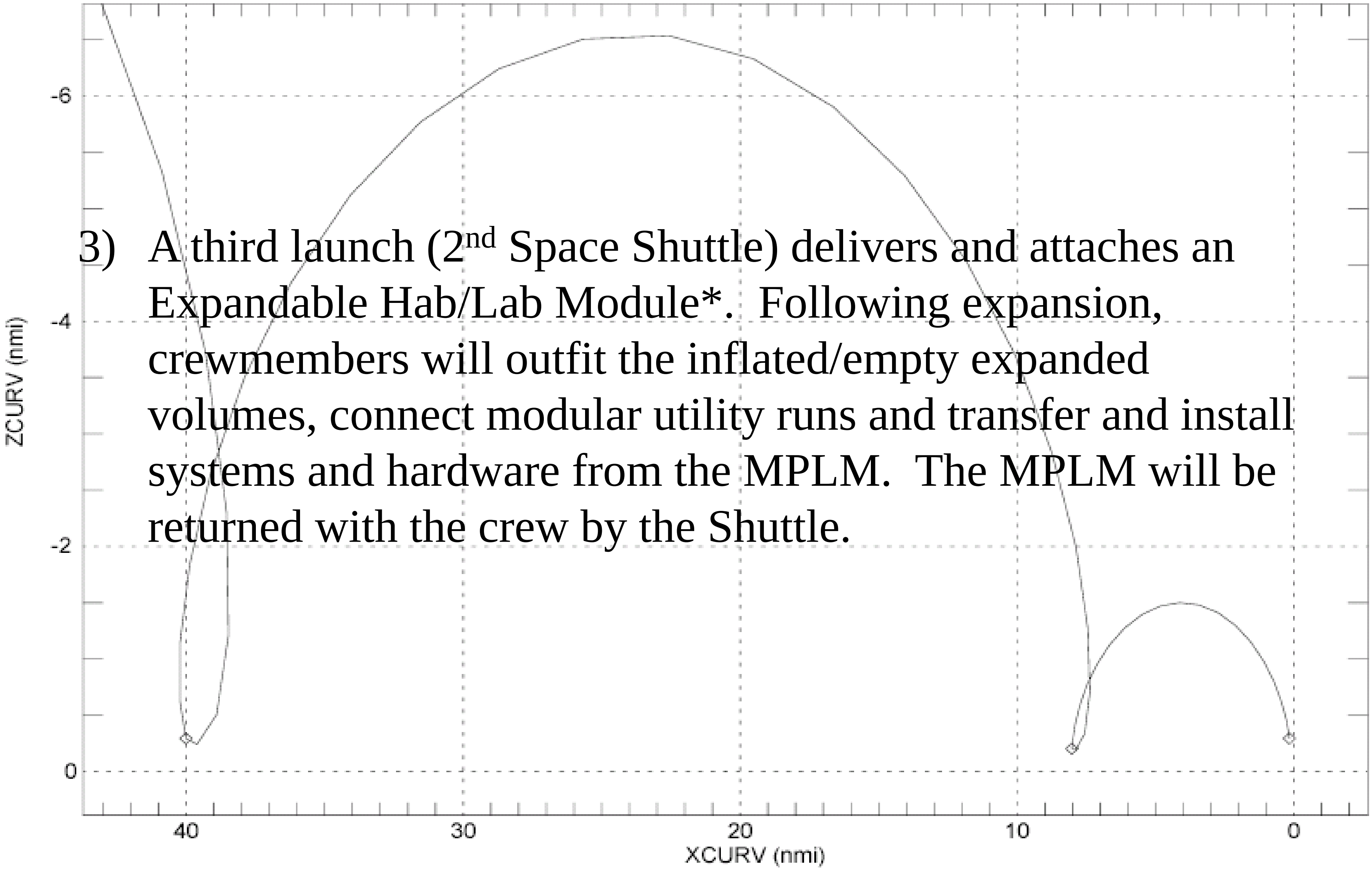
UNIVERSITY of HOUSTON

Assembly Overview



Elements and Assembly

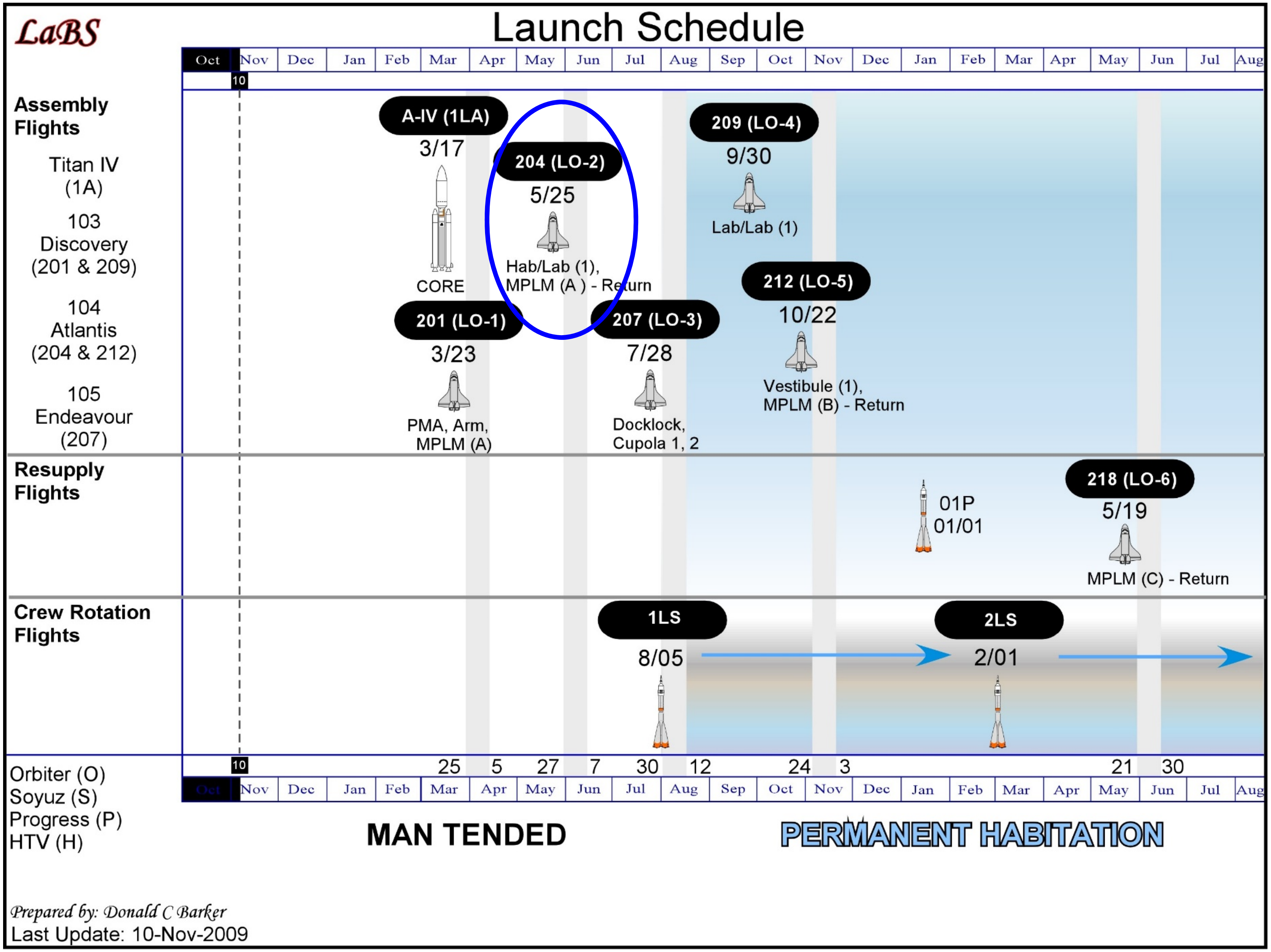
3) A third launch (2nd Space Shuttle) delivers and attaches an Expandable Hab/Lab Module*. Following expansion, crewmembers will outfit the inflated/empty expanded volumes, connect modular utility runs and transfer and install systems and hardware from the MPLM. The MPLM will be returned with the crew by the Shuttle.



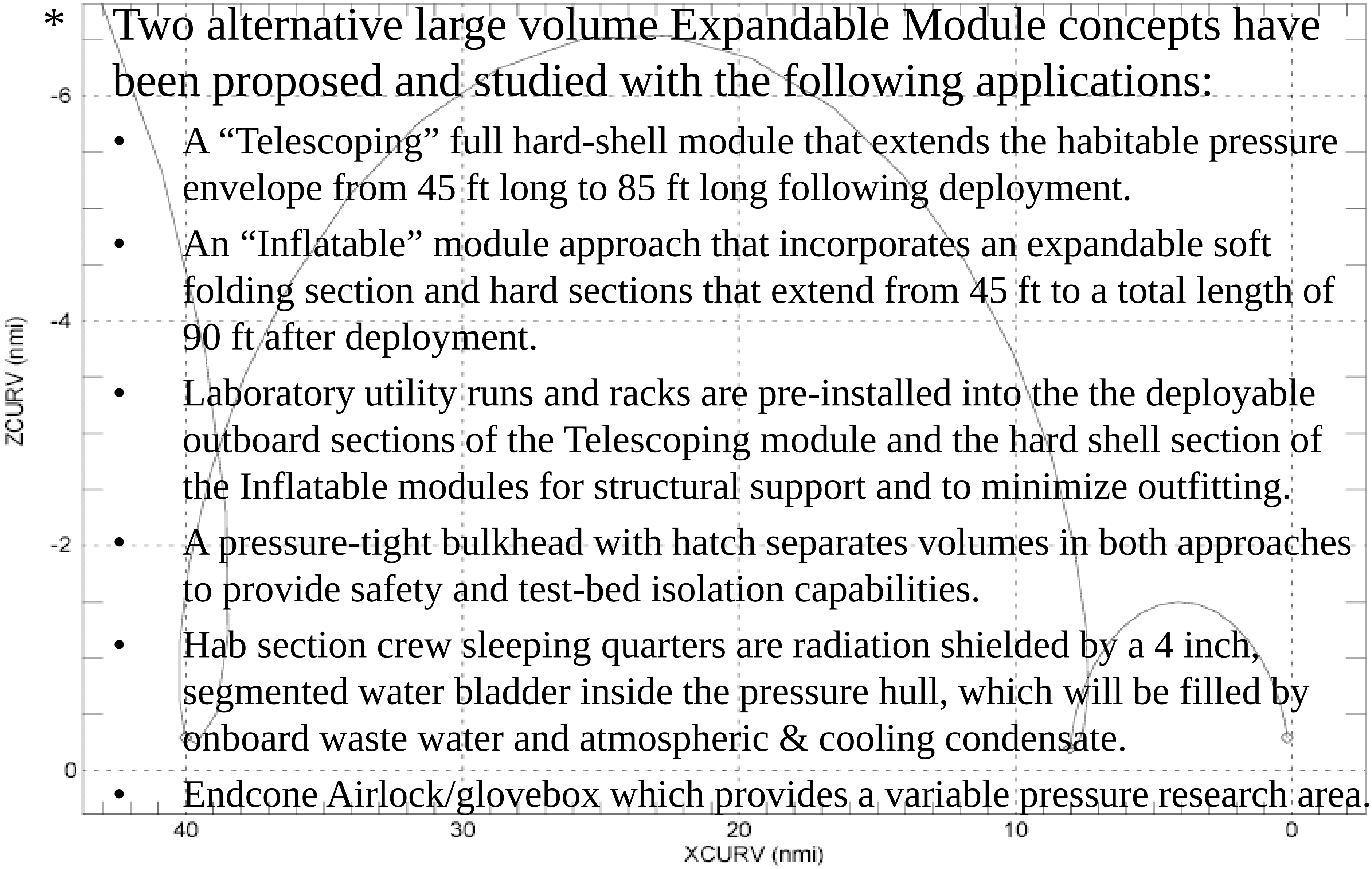
LaBS

UNIVERSITY of HOUSTON

Assembly Overview

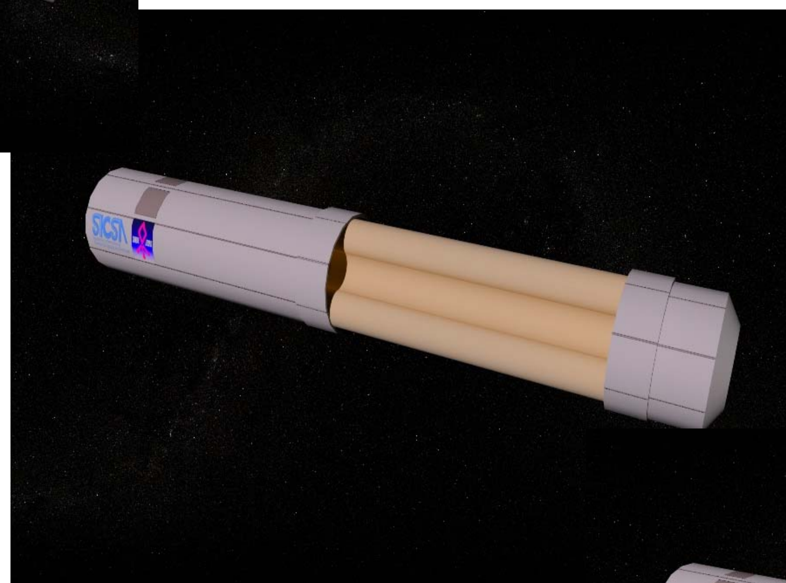


Elements and Assembly



* Two alternative large volume Expandable Module concepts have been proposed and studied with the following applications:
  - A “Telescoping” full hard-shell module that extends the habitable pressure envelope from 45 ft long to 85 ft long following deployment.
  - An “Inflatable” module approach that incorporates an expandable soft folding section and hard sections that extend from 45 ft to a total length of 90 ft after deployment.
  - Laboratory utility runs and racks are pre-installed into the the deployable outboard sections of the Telescoping module and the hard shell section of the Inflatable modules for structural support and to minimize outfitting.
  - A pressure-tight bulkhead with hatch separates volumes in both approaches to provide safety and test-bed isolation capabilities.
  - Hab section crew sleeping quarters are radiation shielded by a 4 inch, segmented water bladder inside the pressure hull, which will be filled by onboard waste water and atmospheric & cooling condensate.
  - Endcone Airlock/glovebox which provides a variable pressure research area.


SICSA

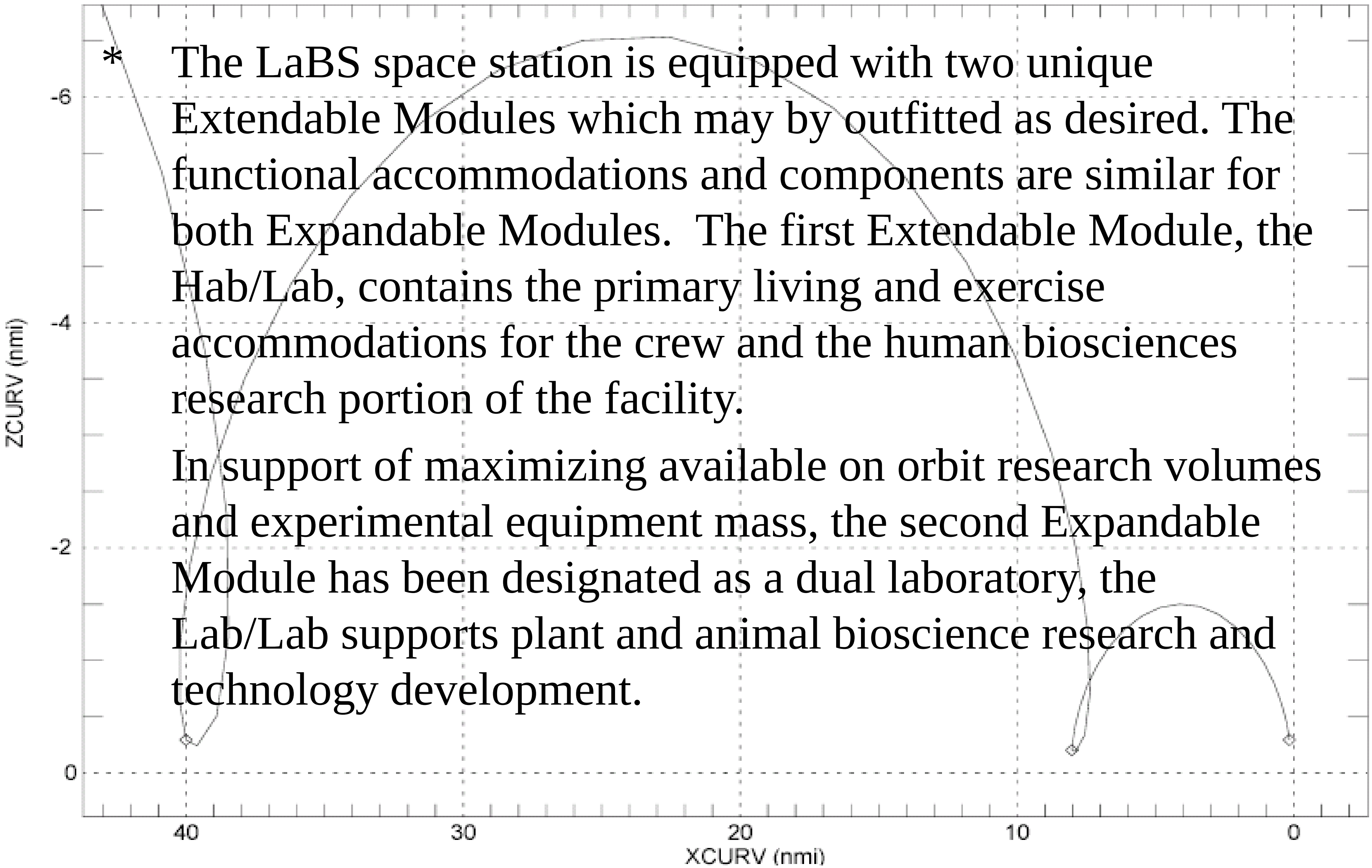

SICSA


SICSA

Elements and Assembly

* The LaBS space station is equipped with two unique Extendable Modules which may by outfitted as desired. The functional accommodations and components are similar for both Expandable Modules. The first Extendable Module, the Hab/Lab, contains the primary living and exercise accommodations for the crew and the human biosciences research portion of the facility.

  In support of maximizing available on orbit research volumes and experimental equipment mass, the second Expandable Module has been designated as a dual laboratory, the Lab/Lab supports plant and animal bioscience research and technology development.

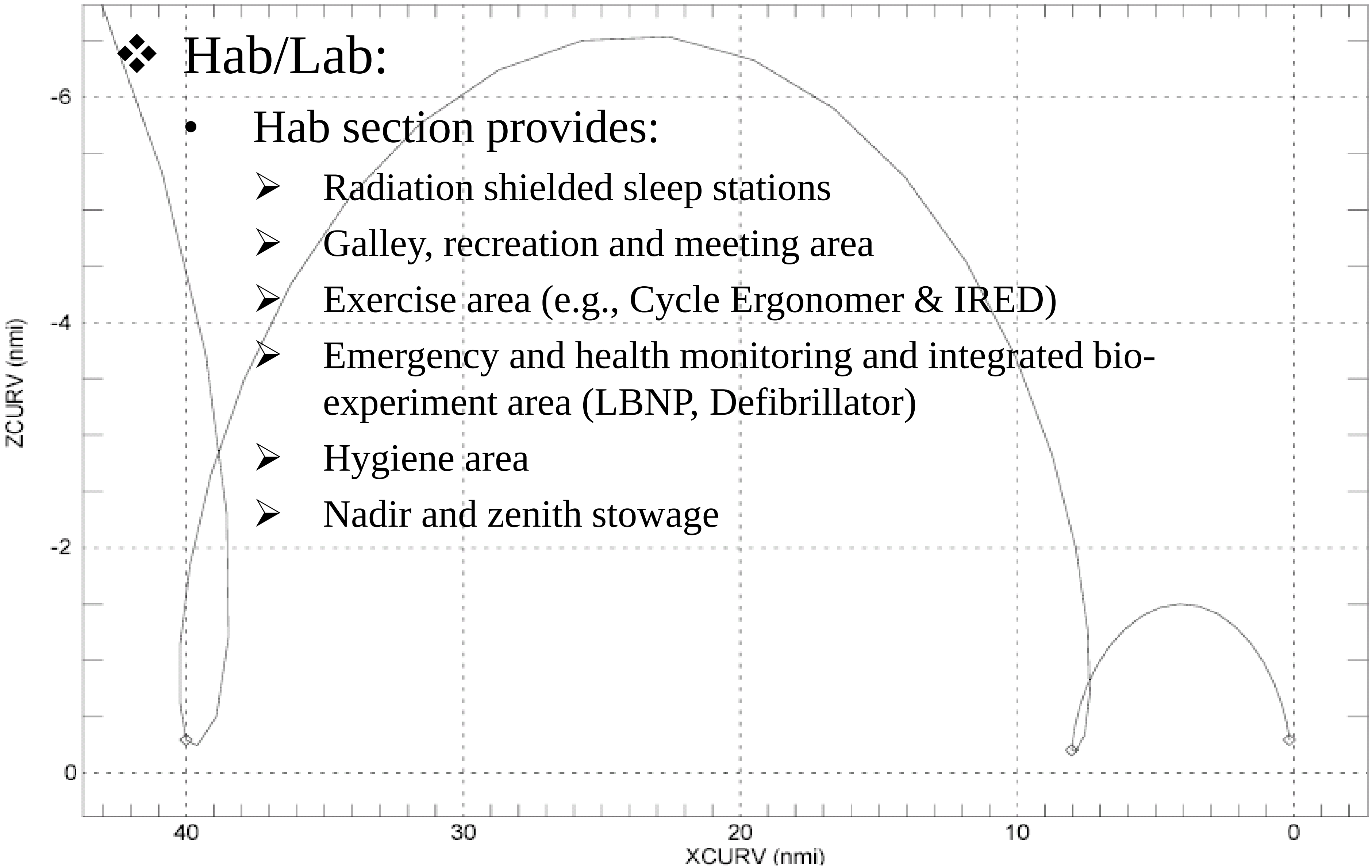


LaBS

UNIVERSITY *of* HOUSTON

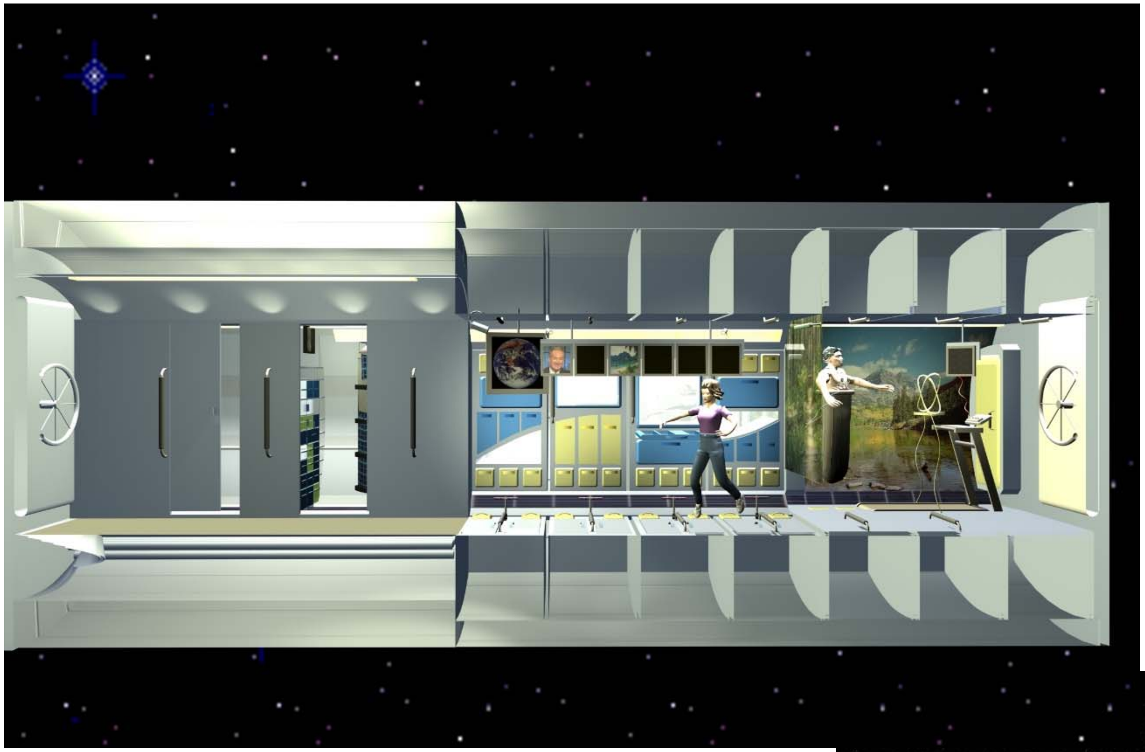
Elements and Assembly

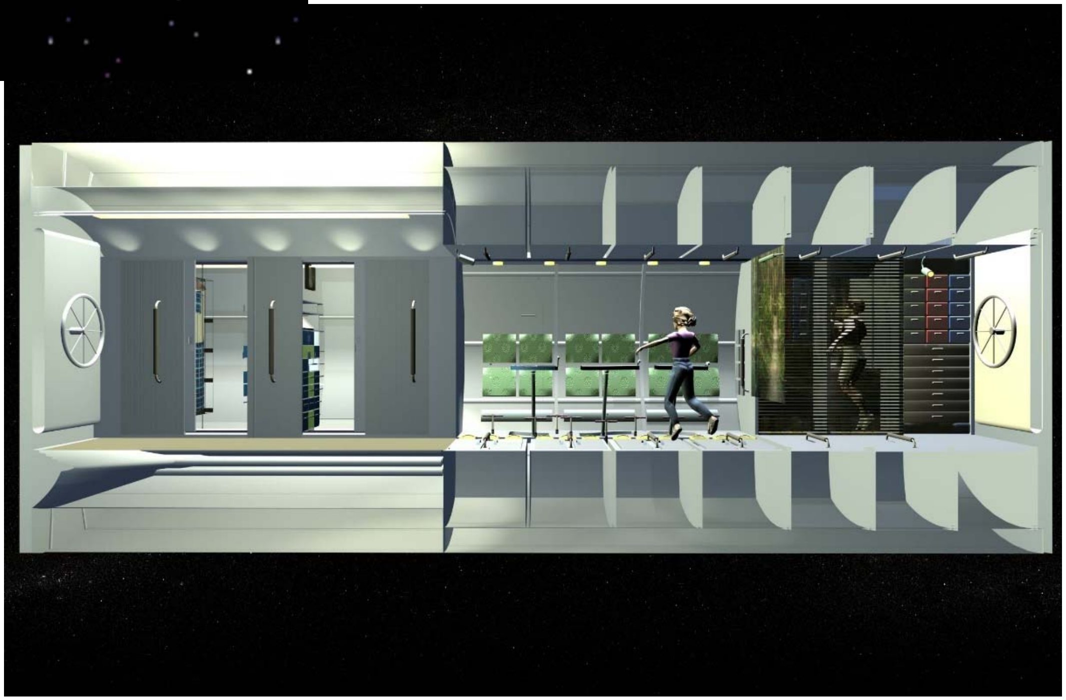
- Hab/Lab:
  - Hab section provides:
    - Radiation shielded sleep stations
    - Galley, recreation and meeting area
    - Exercise area (e.g., Cycle Ergonomer & IRED)
    - Emergency and health monitoring and integrated bio-experiment area (LBNP, Defibrillator)
    - Hygiene area
    - Nadir and zenith stowage

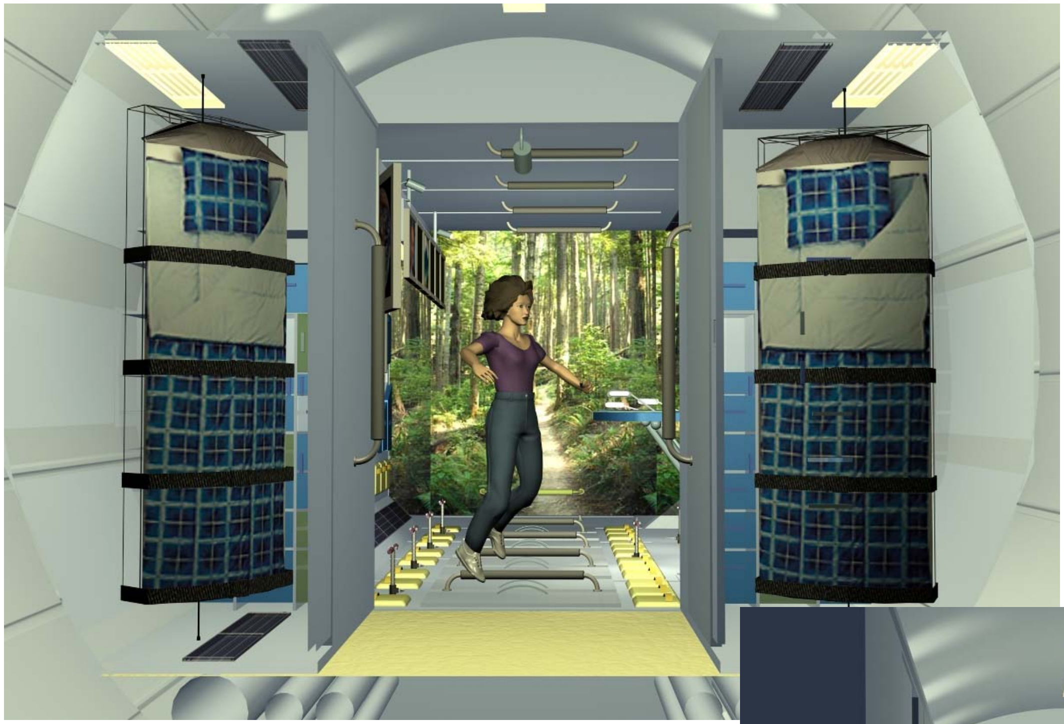


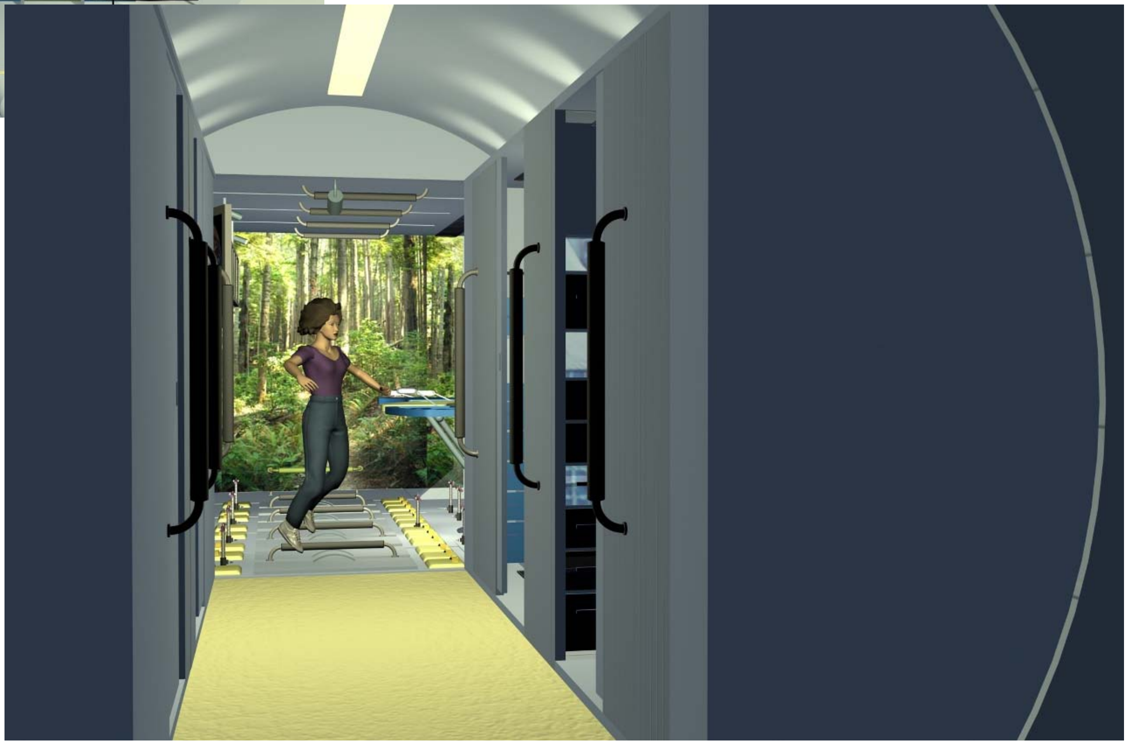
LaBS

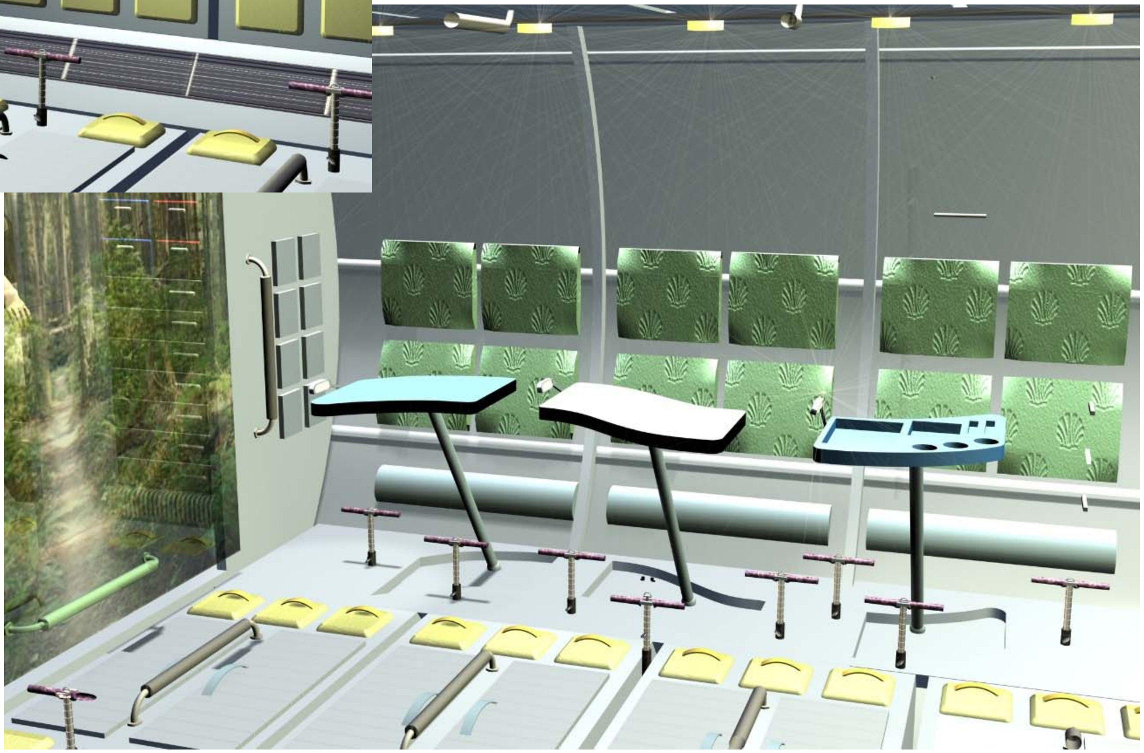
UNIVERSITY *of* HOUSTON





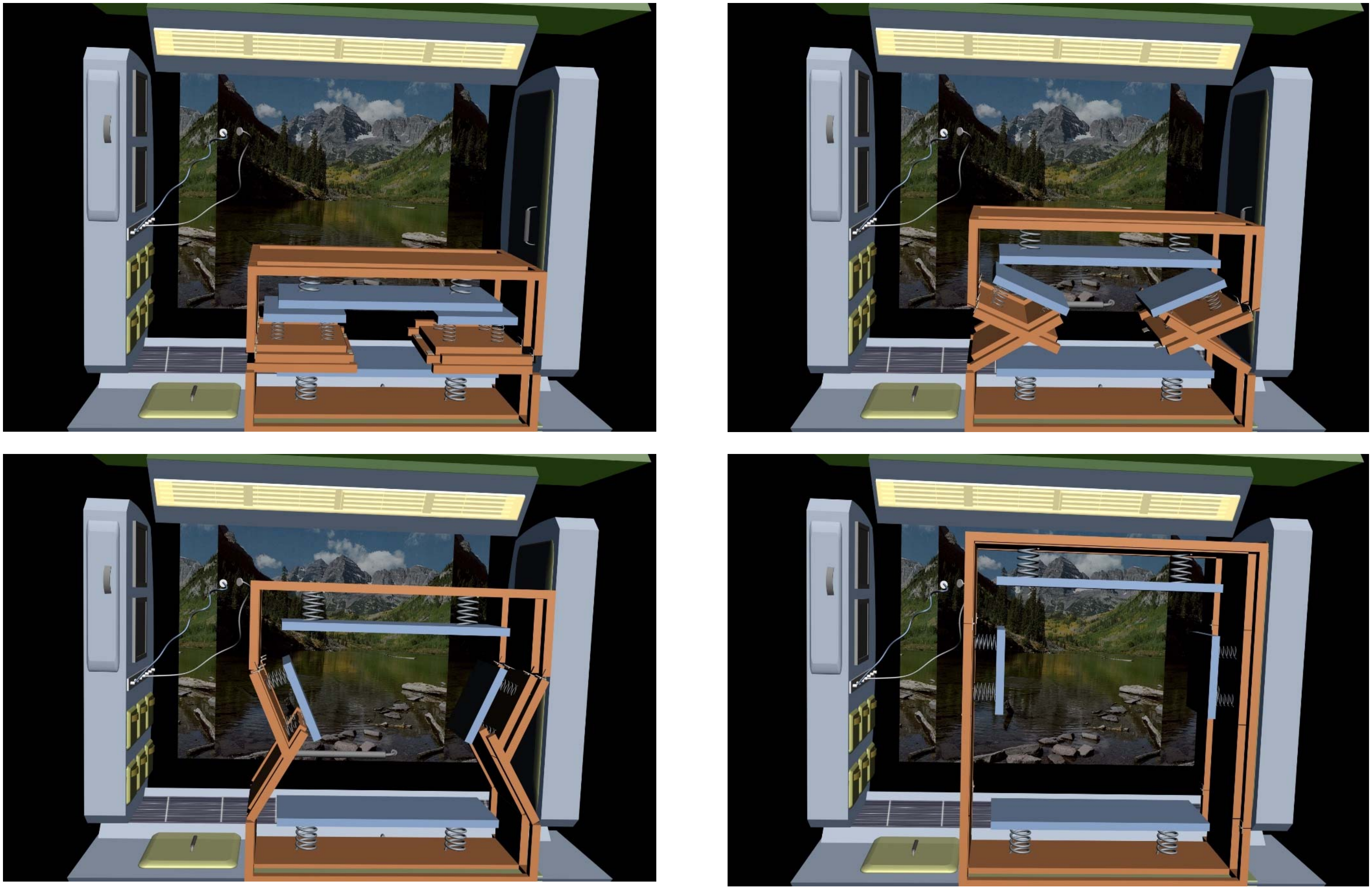


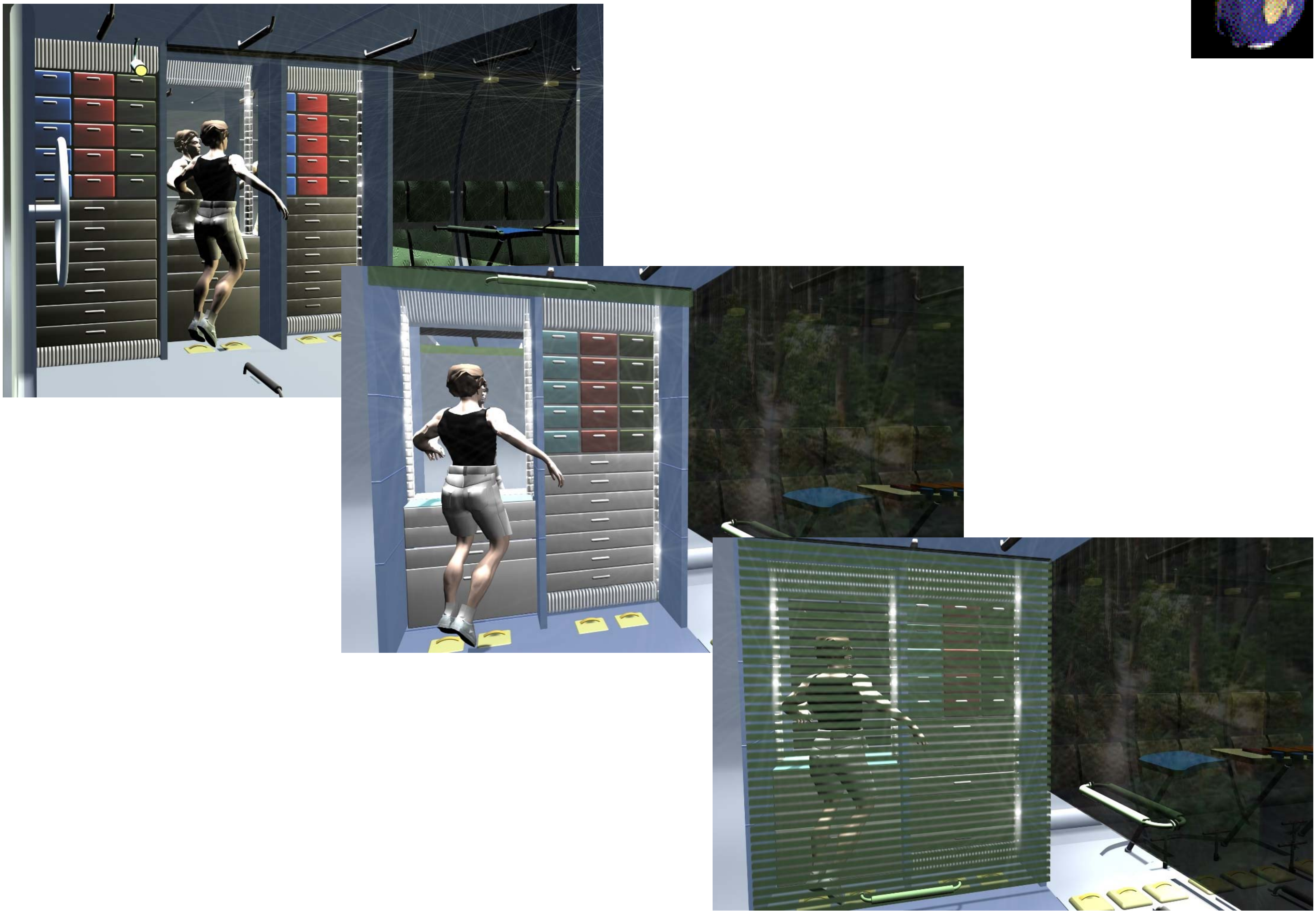


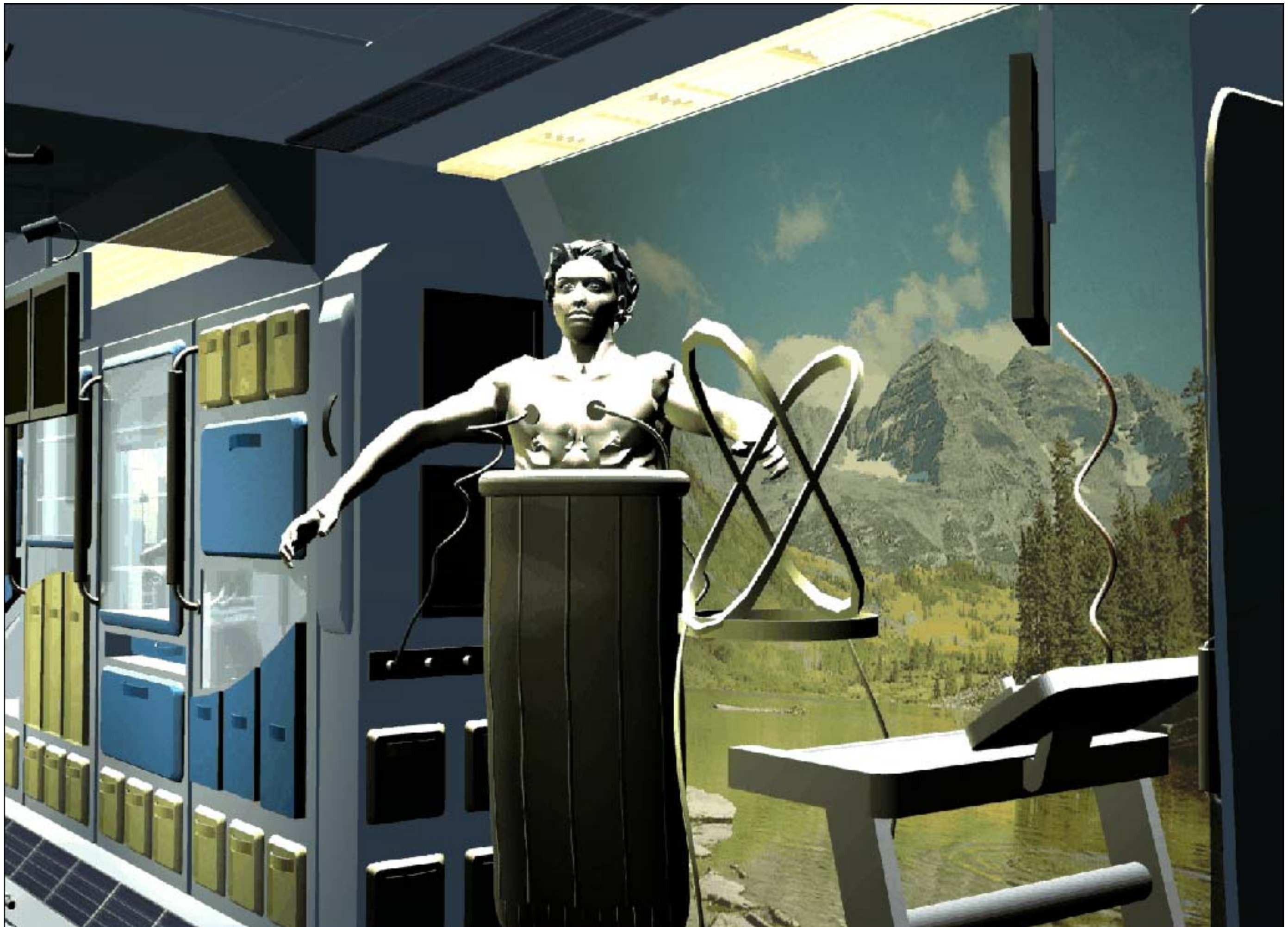


LaBS

UNIVERSITY of HOUSTON



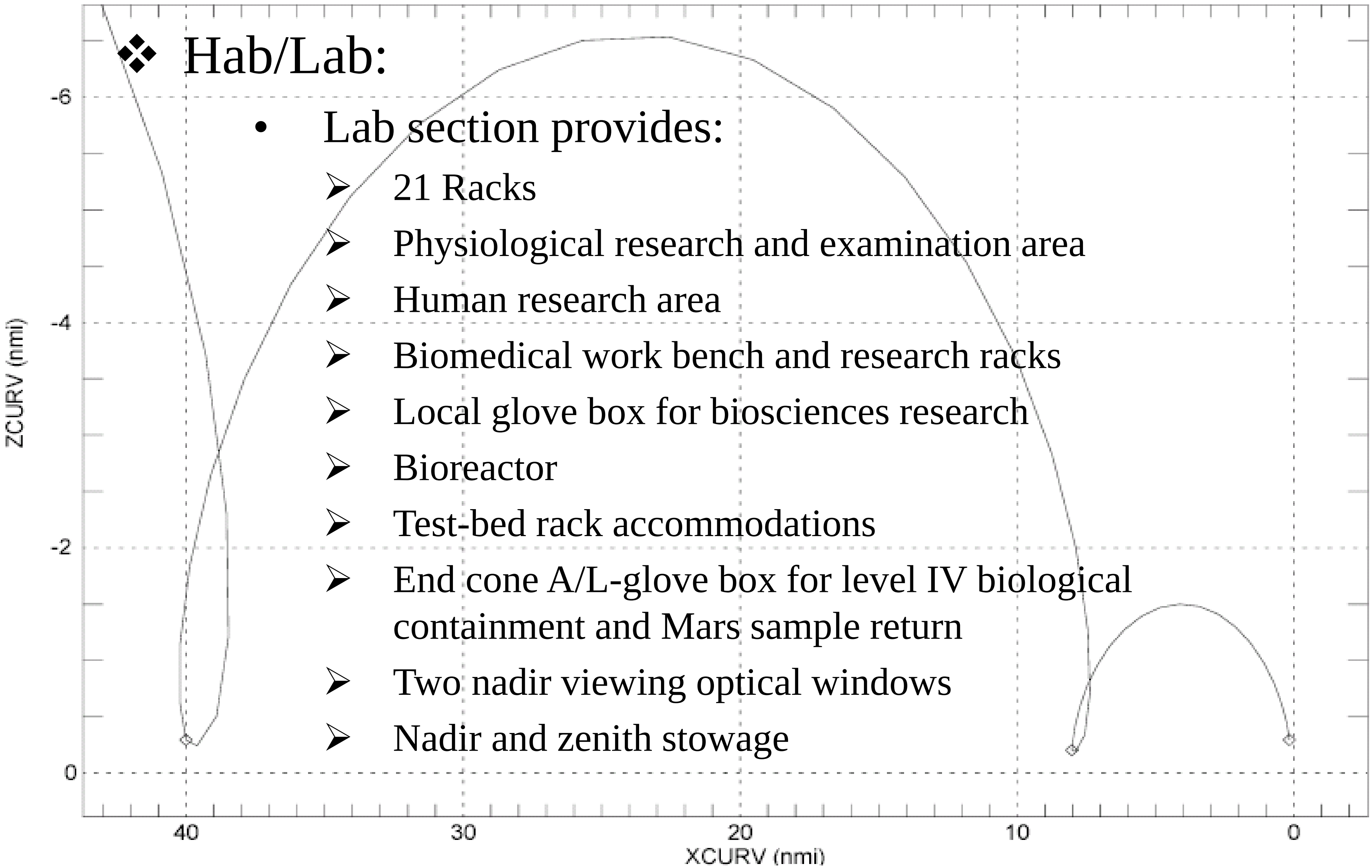




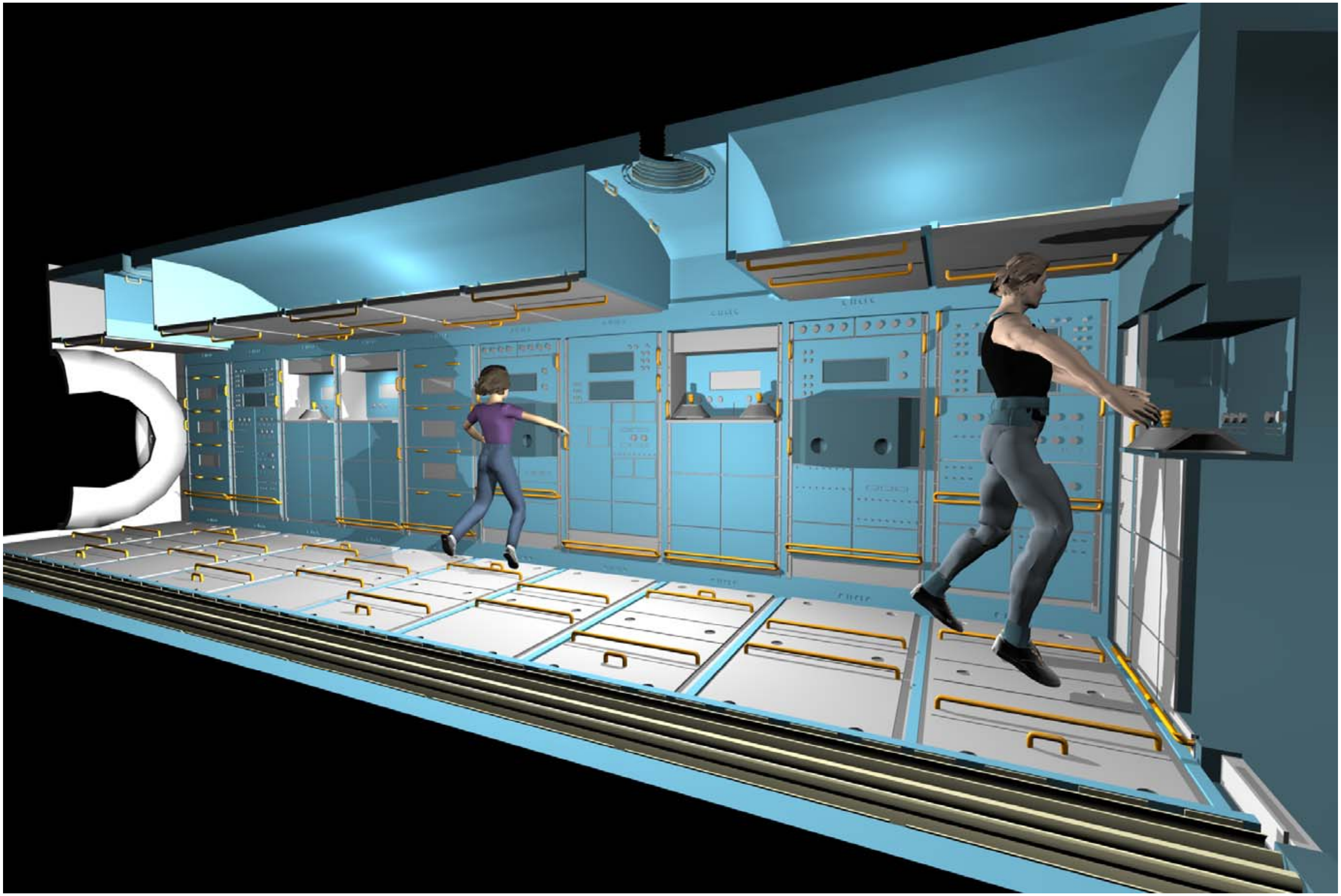
EXERCISE FLY THROUGH

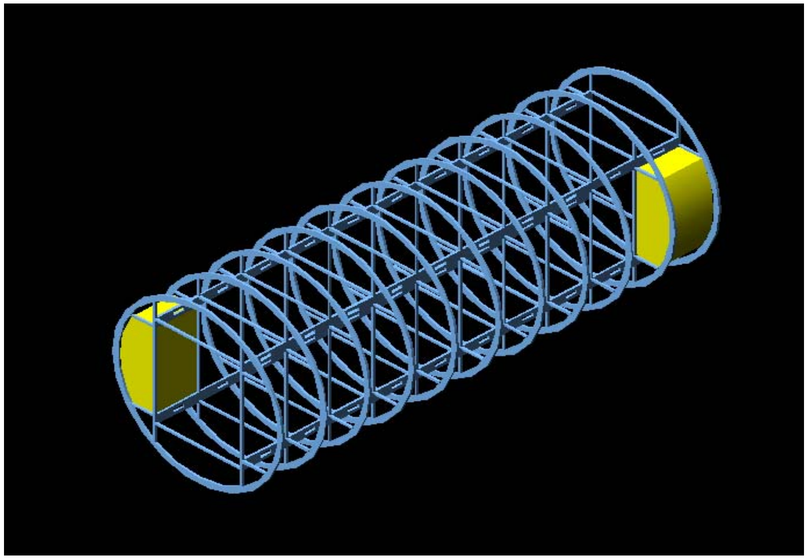
LaBS

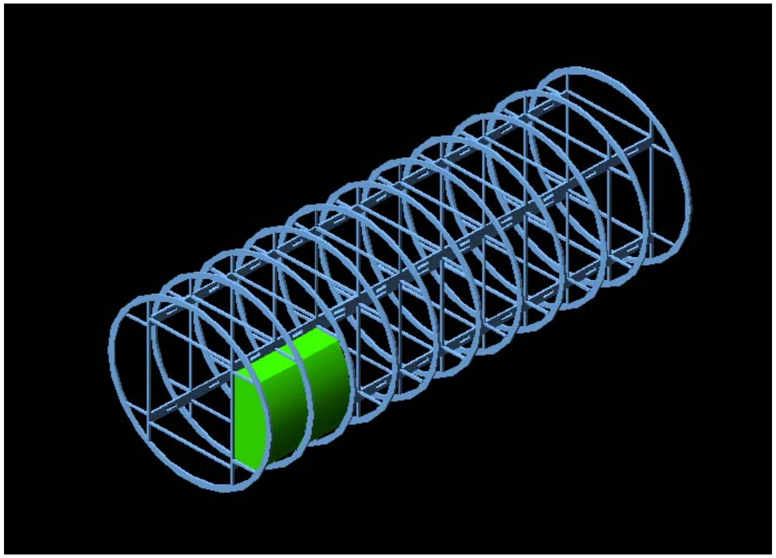
Elements and Assembly

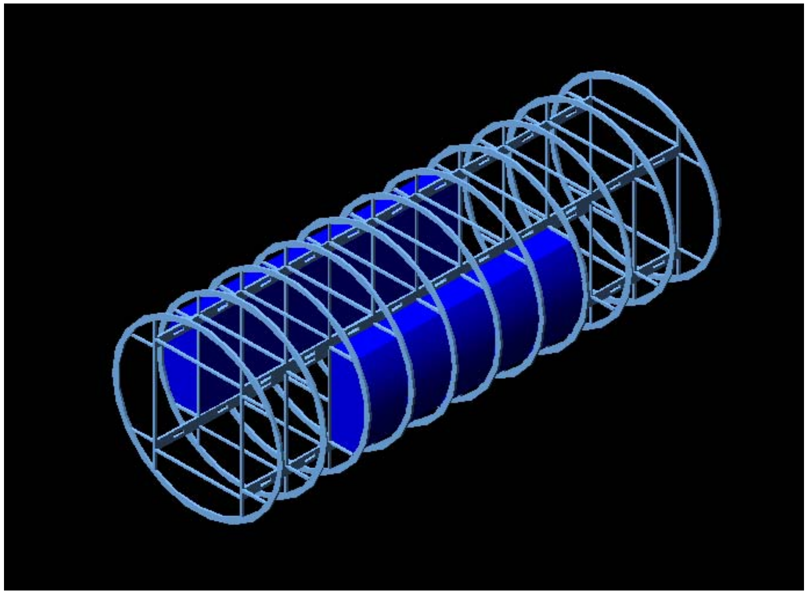


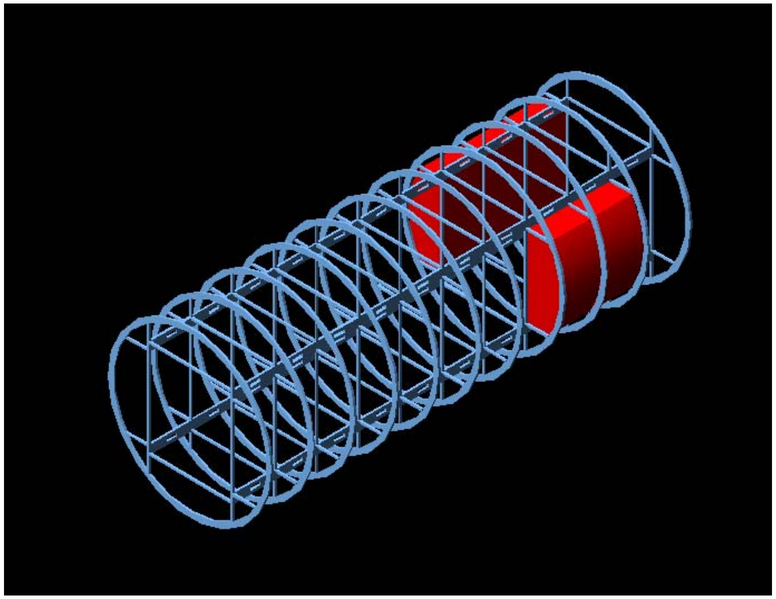
- ❖ Hab/Lab:
  - Lab section provides:
    - ➢ 21 Racks
    - ➢ Physiological research and examination area
    - ➢ Human research area
    - ➢ Biomedical work bench and research racks
    - ➢ Local glove box for biosciences research
    - ➢ Bioreactor
    - ➢ Test-bed rack accommodations
    - ➢ End cone A/L-glove box for level IV biological containment and Mars sample return
    - ➢ Two nadir viewing optical windows
    - ➢ Nadir and zenith stowage

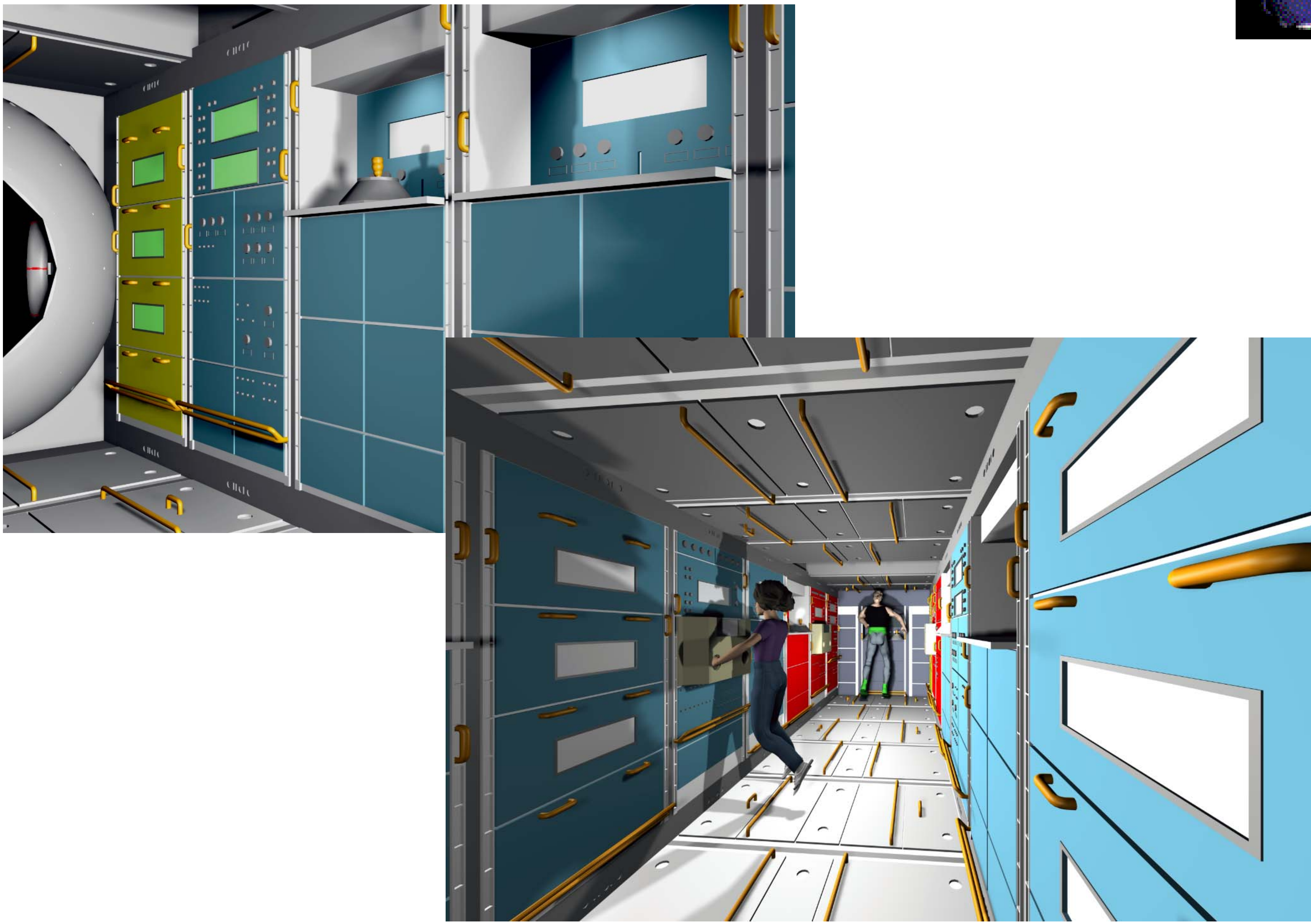






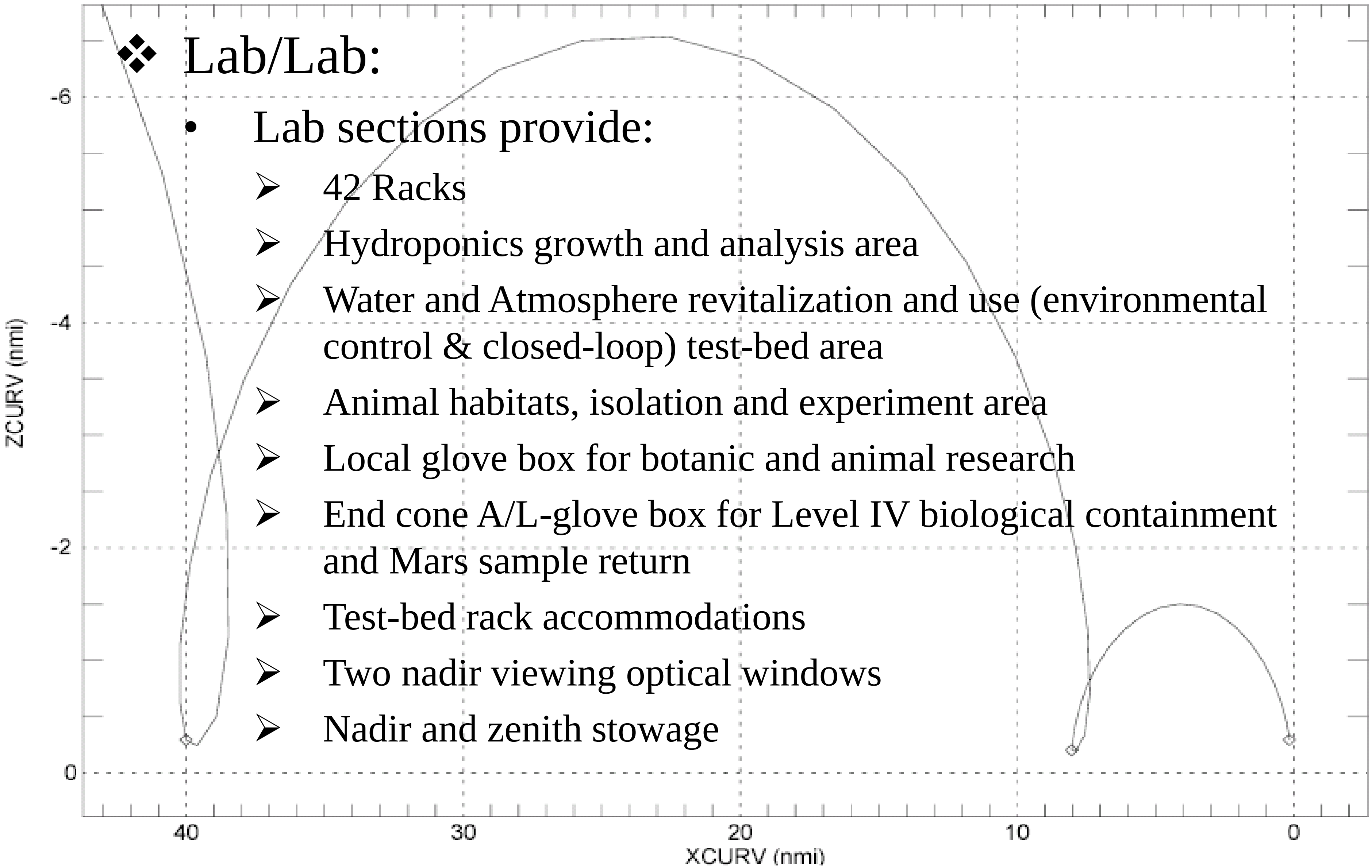




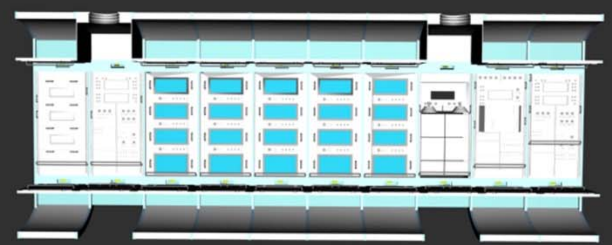


LAB flythrough

Elements and Assembly

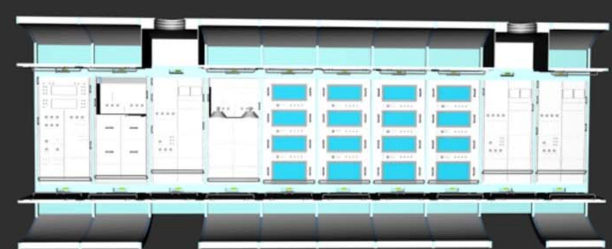


- Lab/Lab:
  - Lab sections provide:
    - 42 Racks
    - Hydroponics growth and analysis area
    - Water and Atmosphere revitalization and use (environmental control & closed-loop) test-bed area
    - Animal habitats, isolation and experiment area
    - Local glove box for botanic and animal research
    - End cone A/L-glove box for Level IV biological containment and Mars sample return
    - Test-bed rack accommodations
    - Two nadir viewing optical windows
    - Nadir and zenith stowage



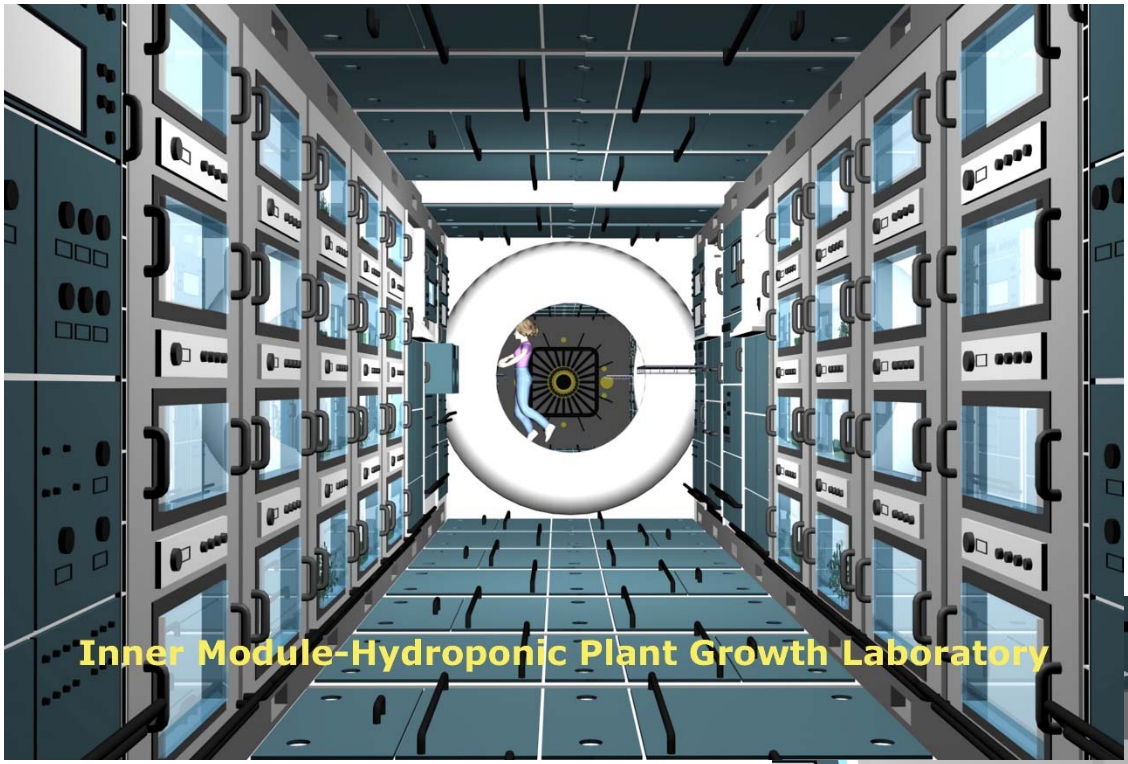
Storage - Viewport - Hydroponic Experiments - Viewport- Glovebox - Utilities

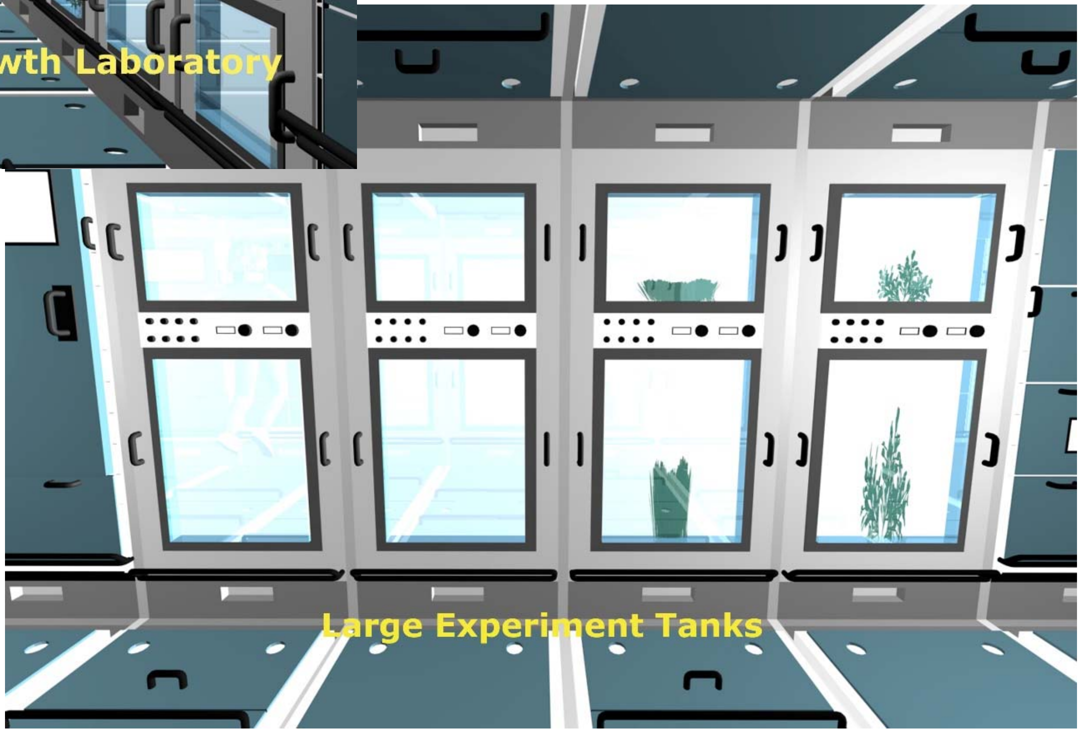
Inner Module - Starboard

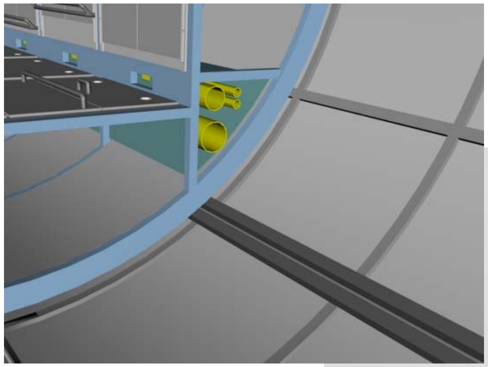


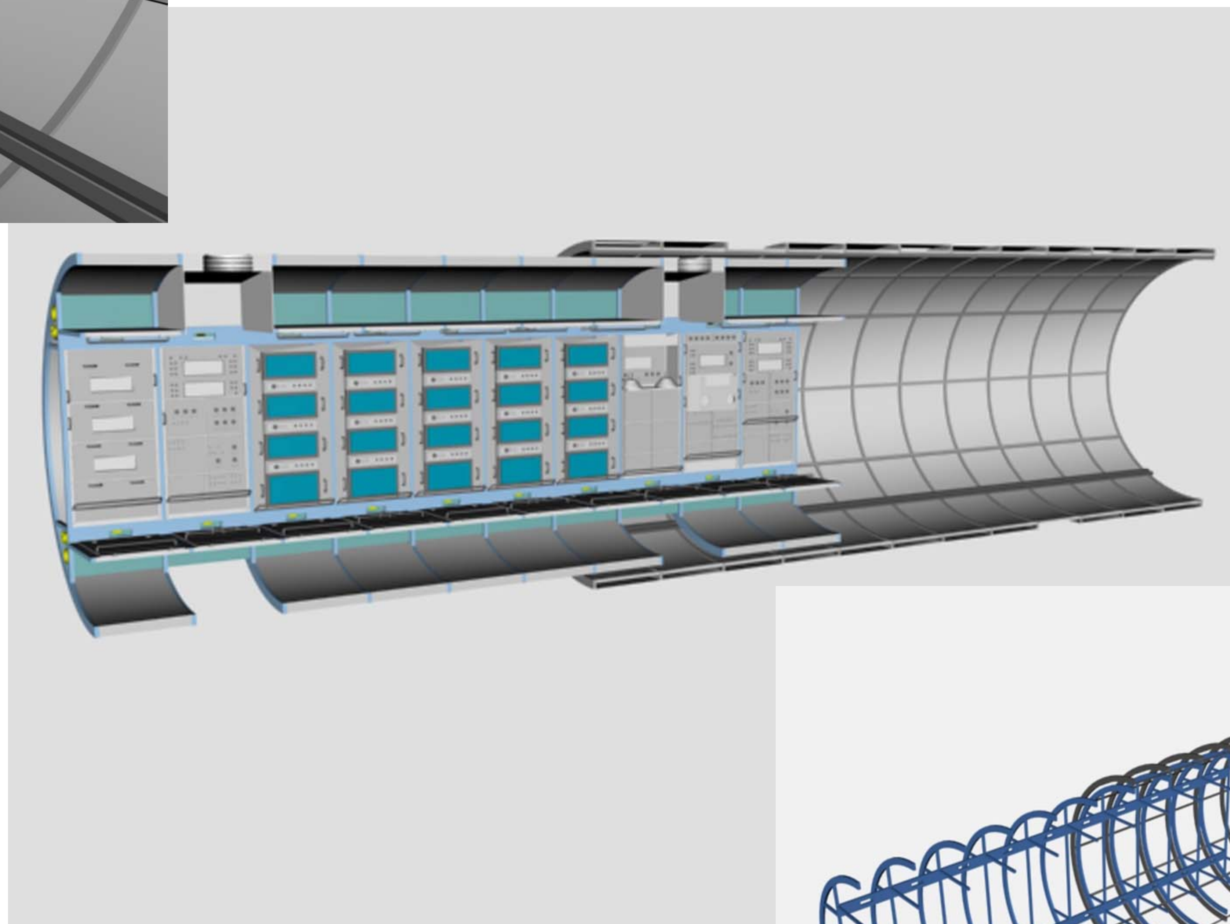
Utilities - Workspace - Viewport - Hydroponic Experiments - Viewport - Storage

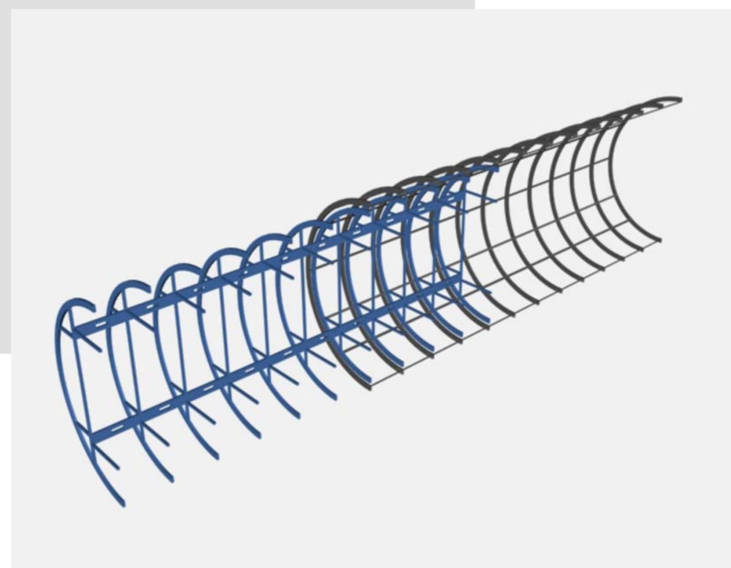
Inner Module - Port

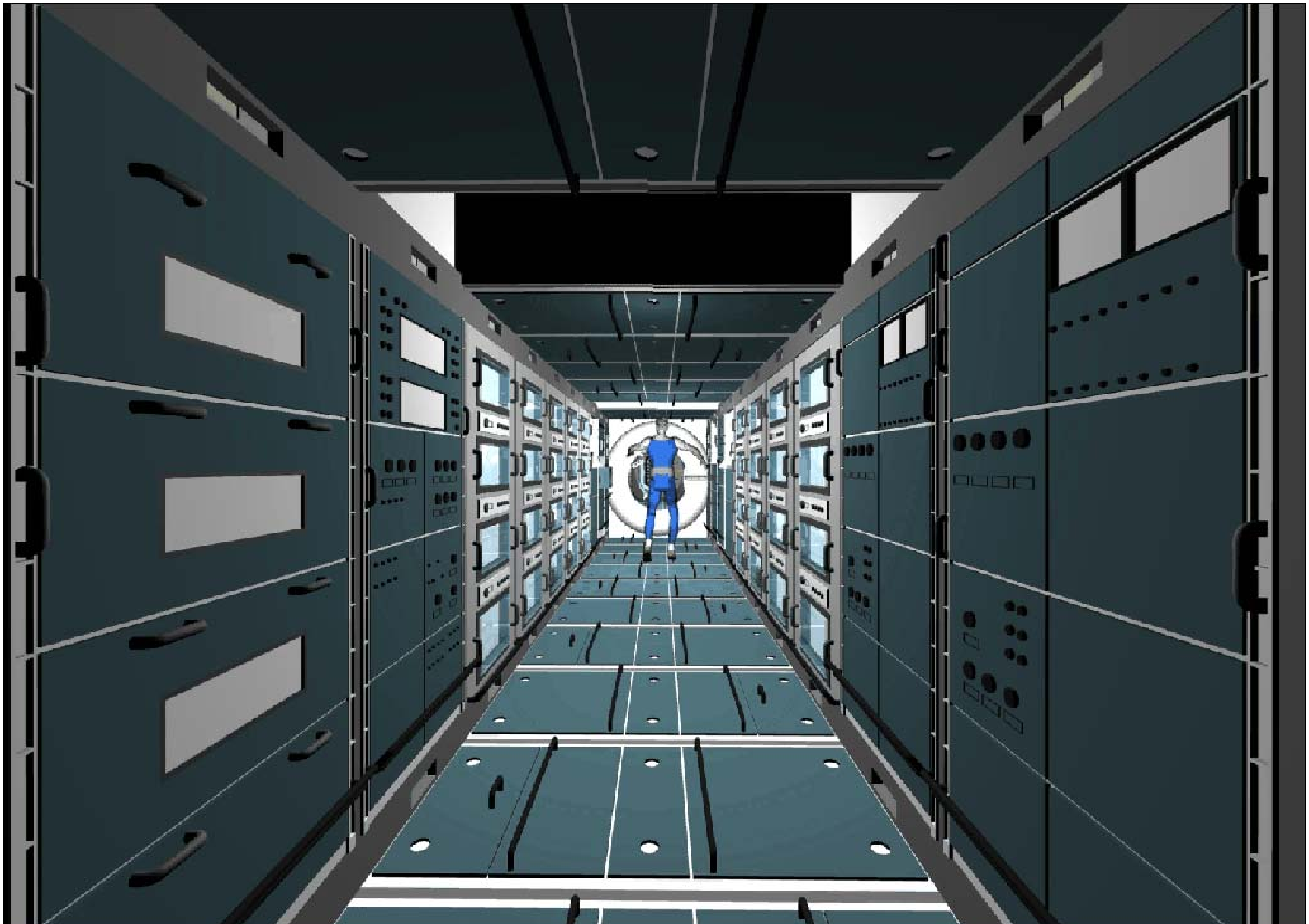

Inner Module-Hydroponic Plant Growth Laboratory


Large Experiment Tanks



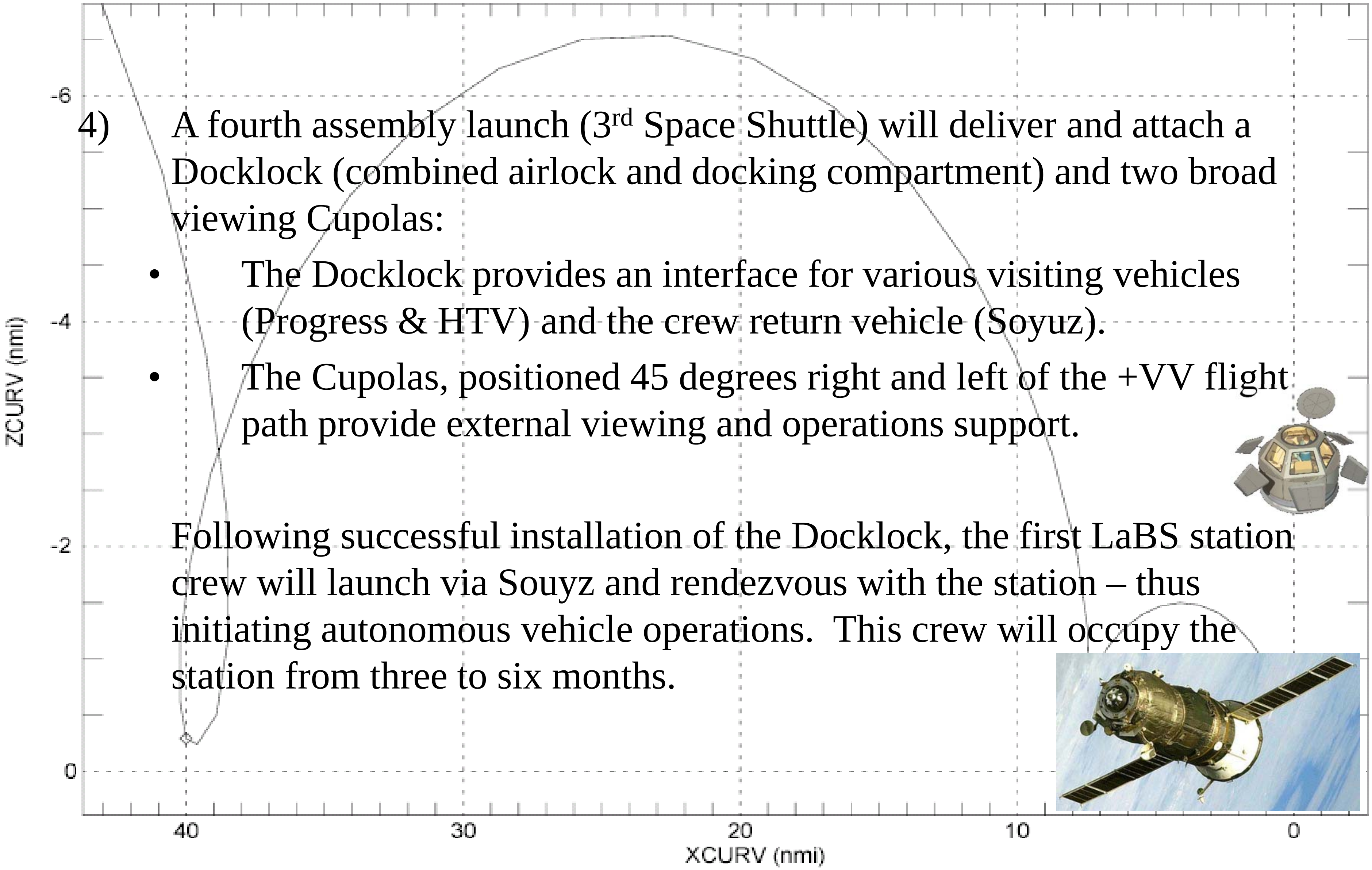






telescopic fly-through big

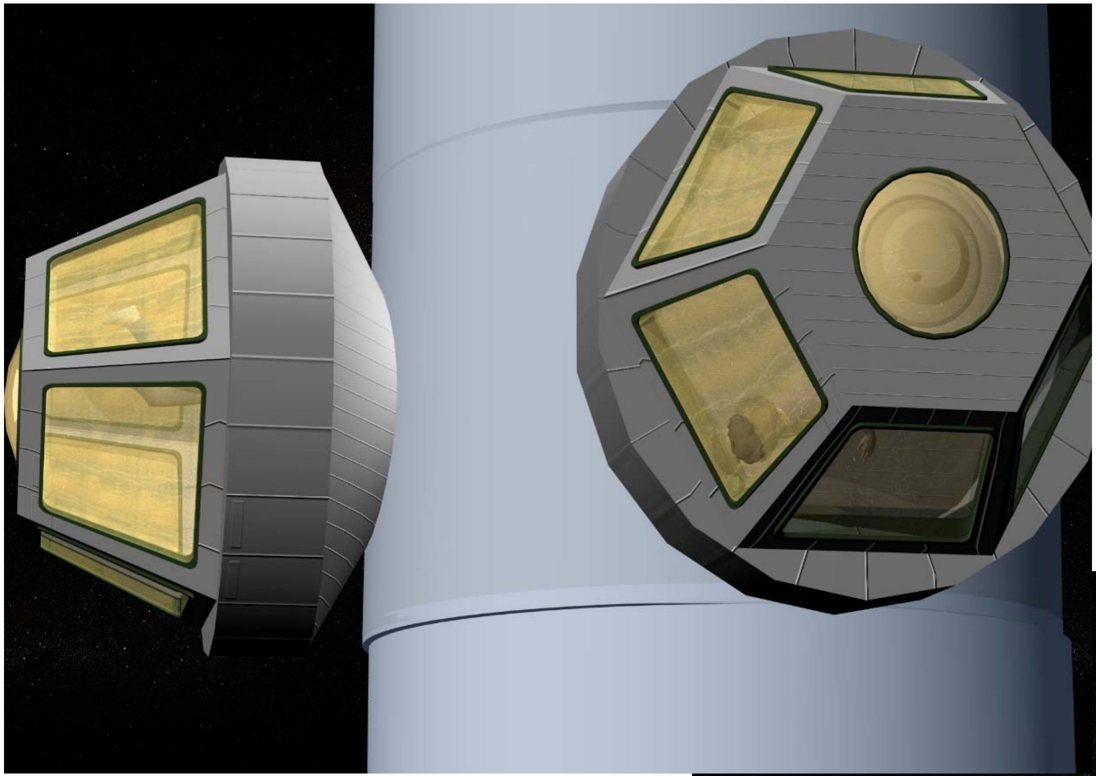
Elements and Assembly

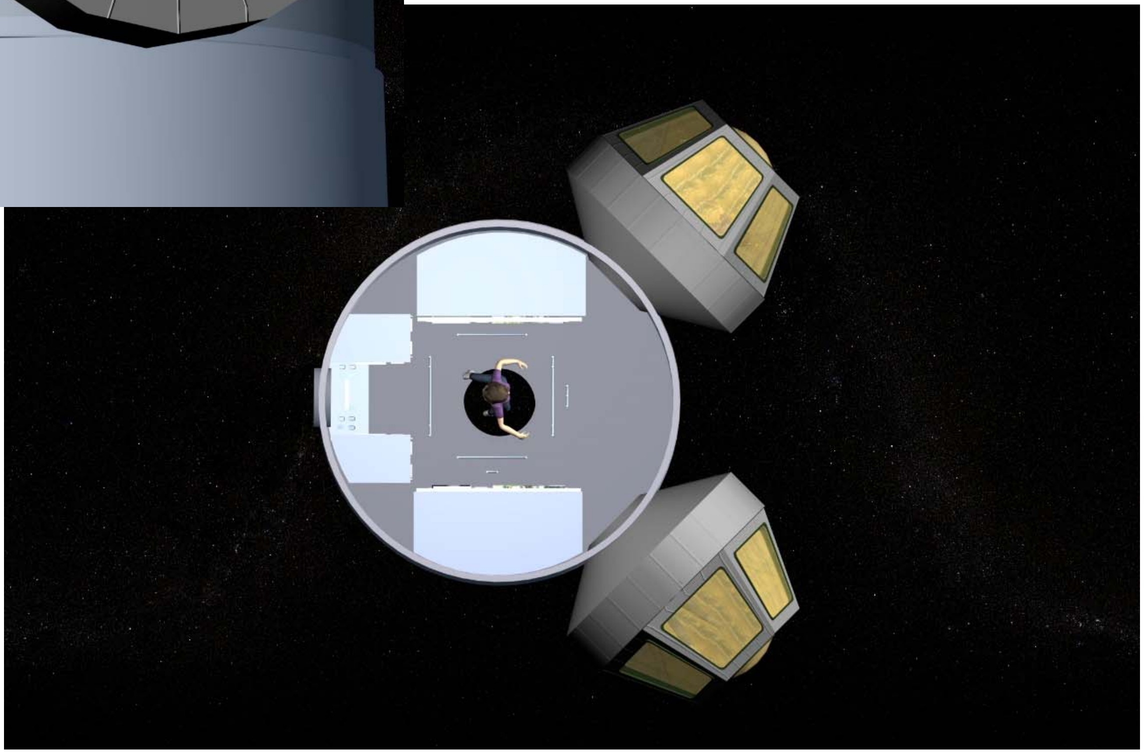


4) A fourth assembly launch (3rd Space Shuttle) will deliver and attach a Docklock (combined airlock and docking compartment) and two broad viewing Cupolas:

- The Docklock provides an interface for various visiting vehicles (Progress & HTV) and the crew return vehicle (Soyuz).
- The Cupolas, positioned 45 degrees right and left of the +VV flight path provide external viewing and operations support.

Following successful installation of the Docklock, the first LaBS station crew will launch via Souyz and rendezvous with the station – thus initiating autonomous vehicle operations. This crew will occupy the station from three to six months.

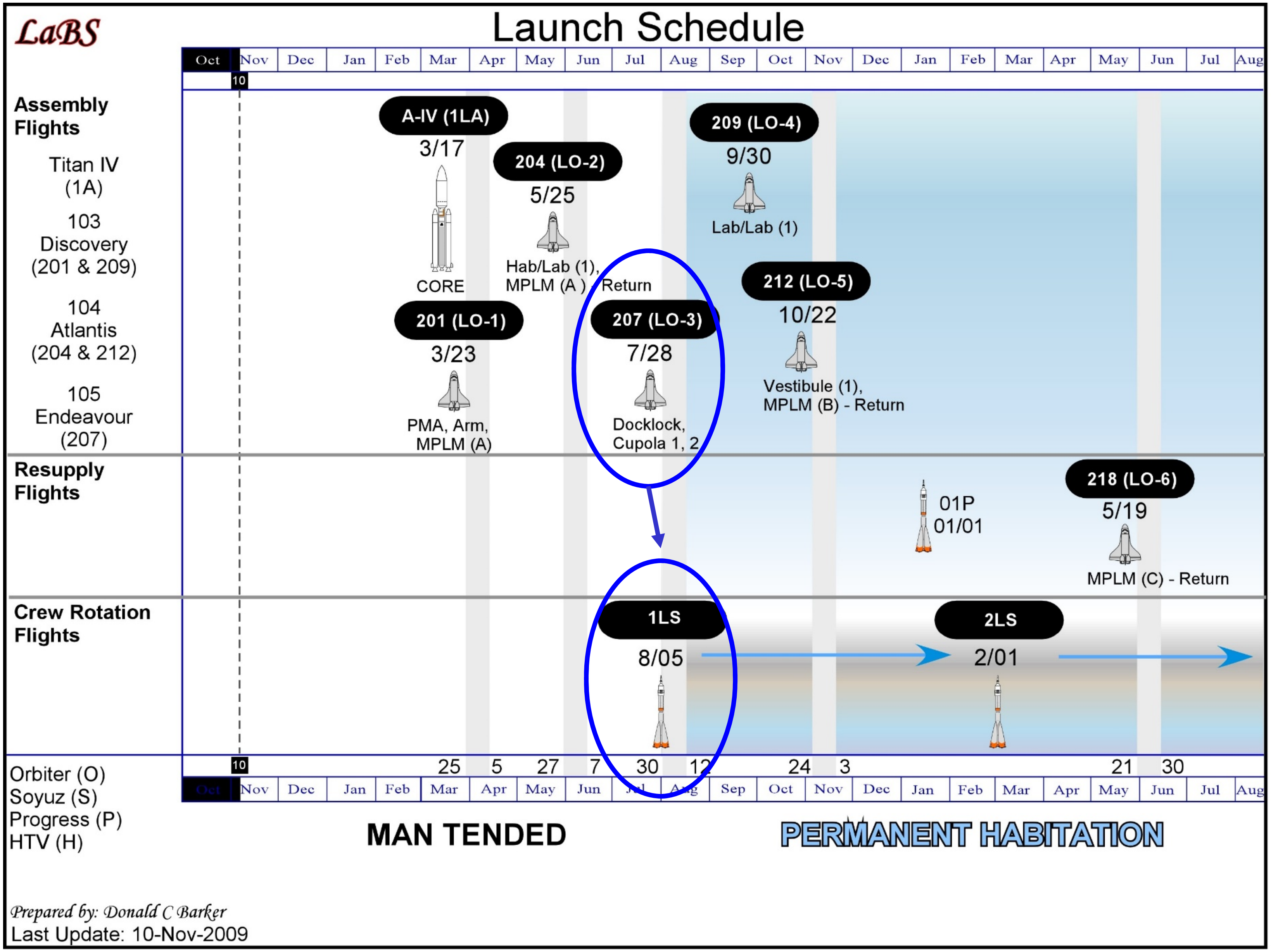




LaBS

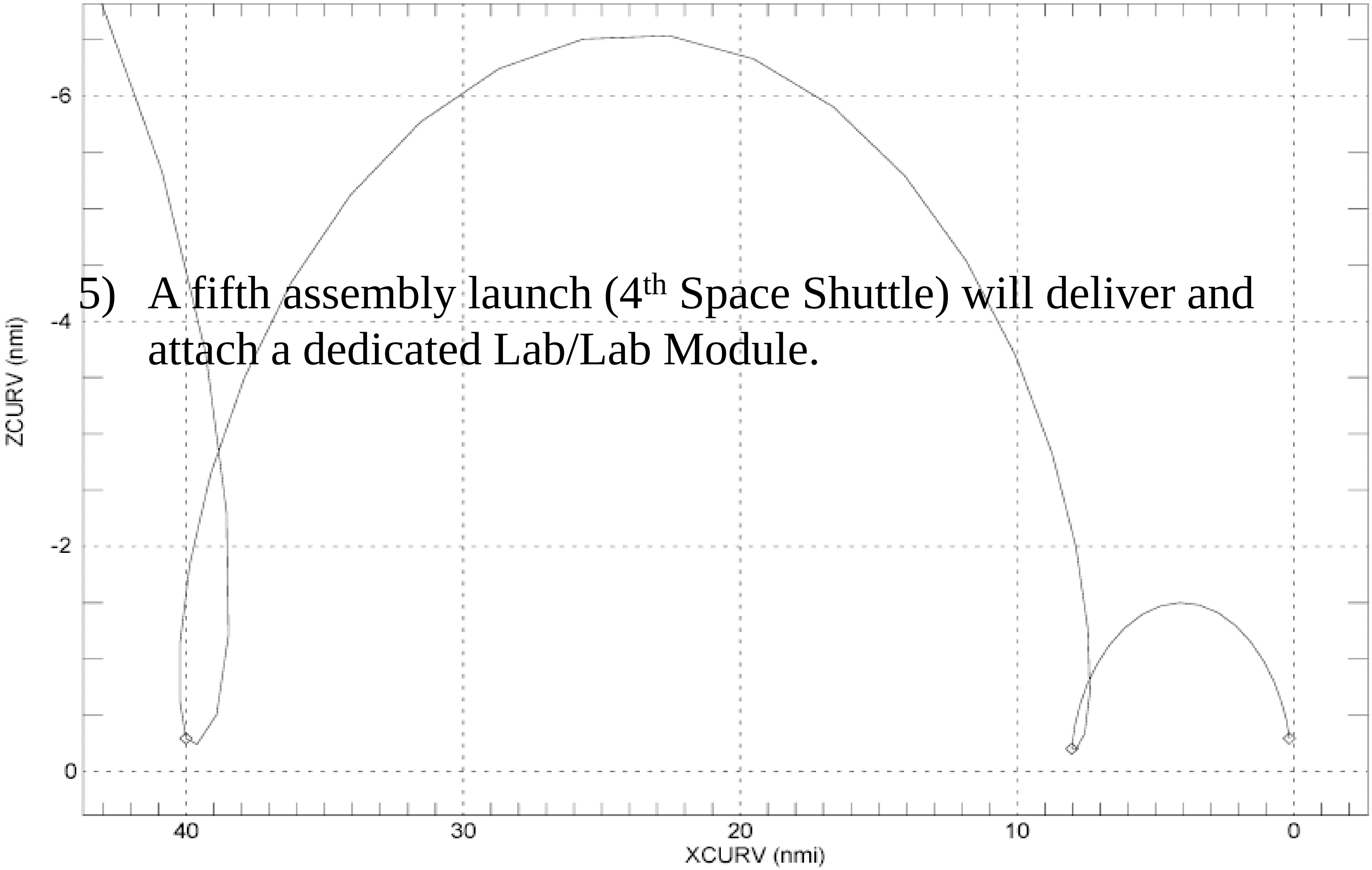
UNIVERSITY of HOUSTON

Assembly Overview



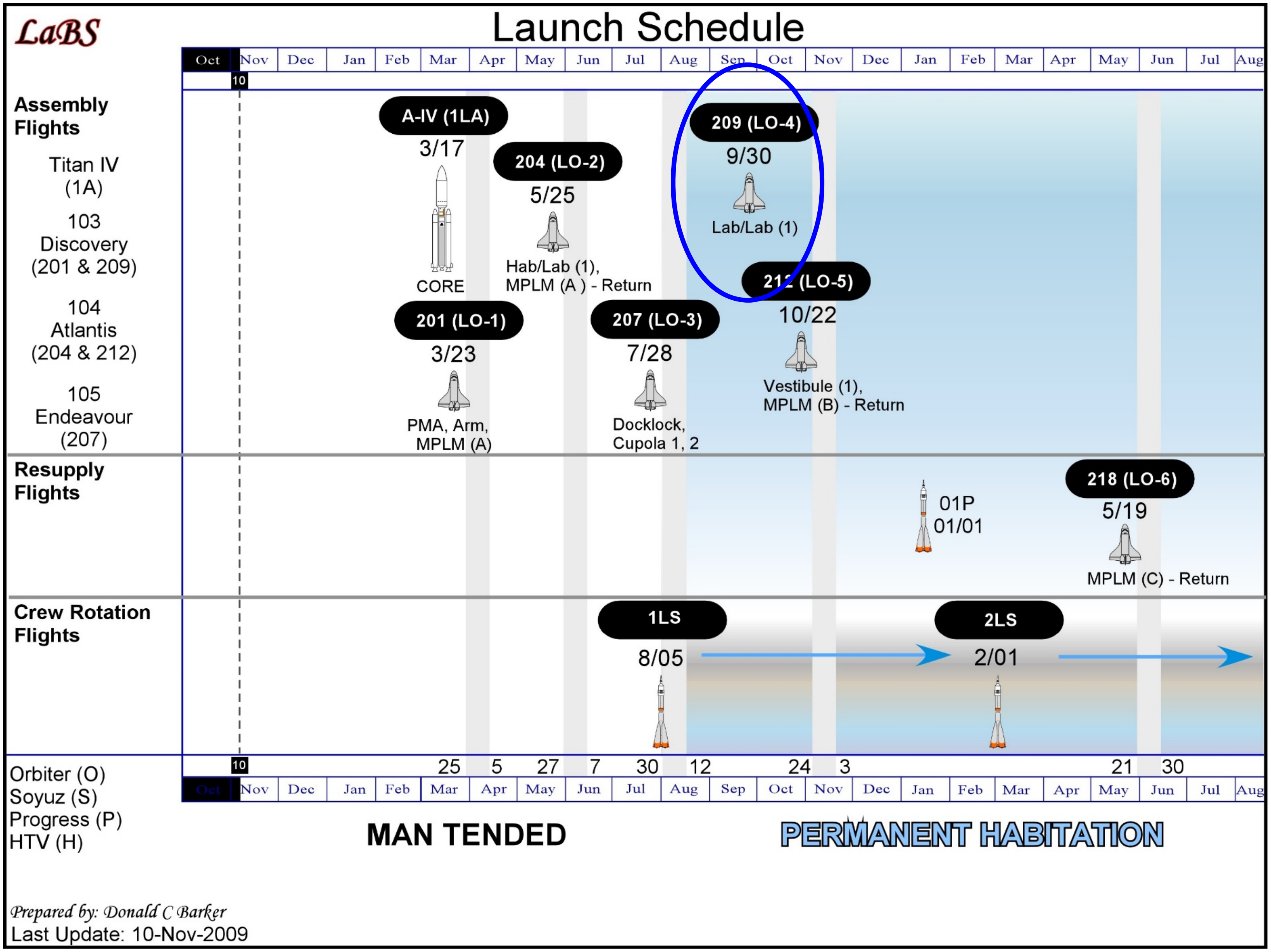
Elements and Assembly

5) A fifth assembly launch (4th Space Shuttle) will deliver and attach a dedicated Lab/Lab Module.



UNIVERSITY of HOUSTON

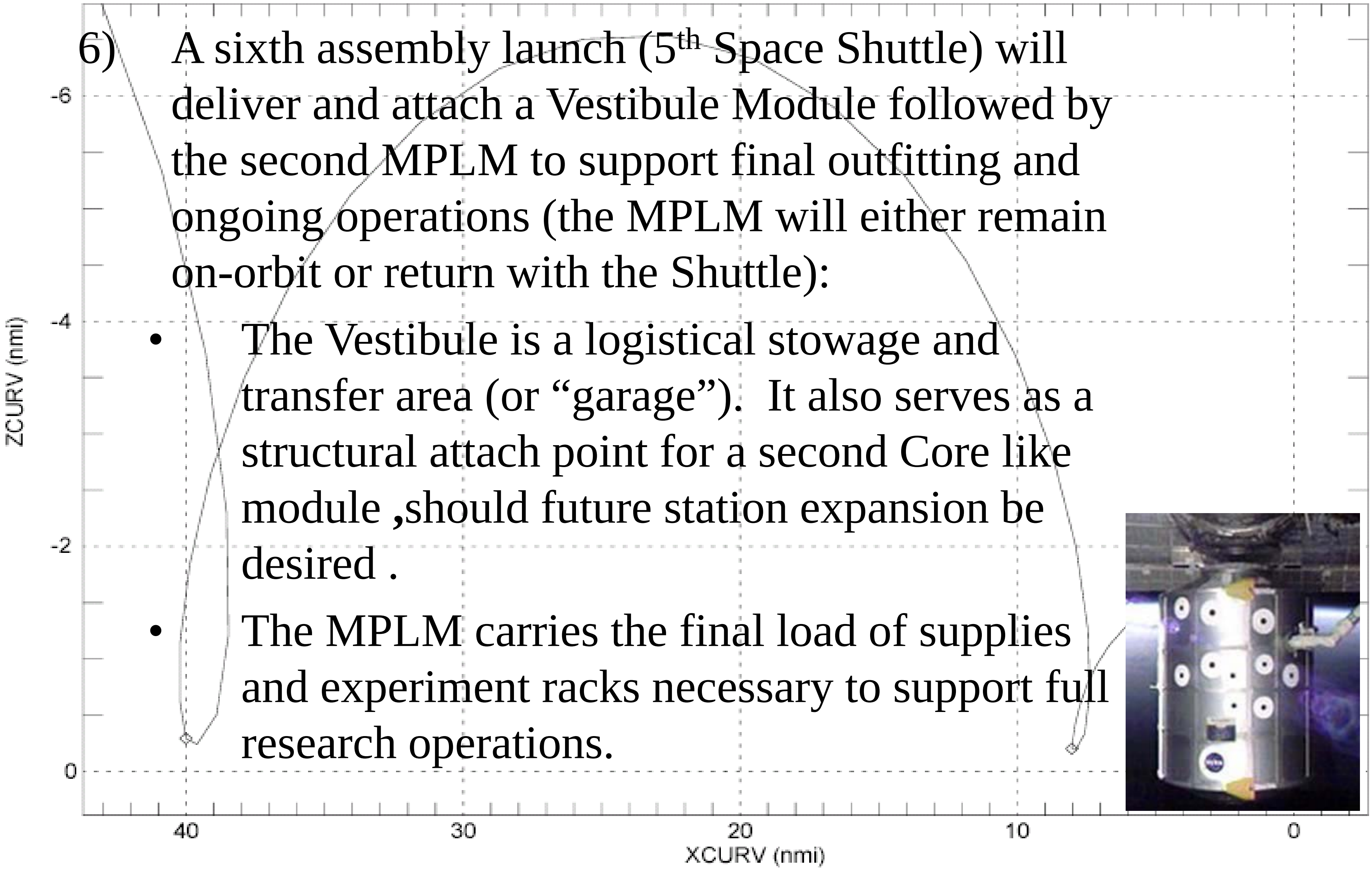
Assembly Overview



Elements and Assembly

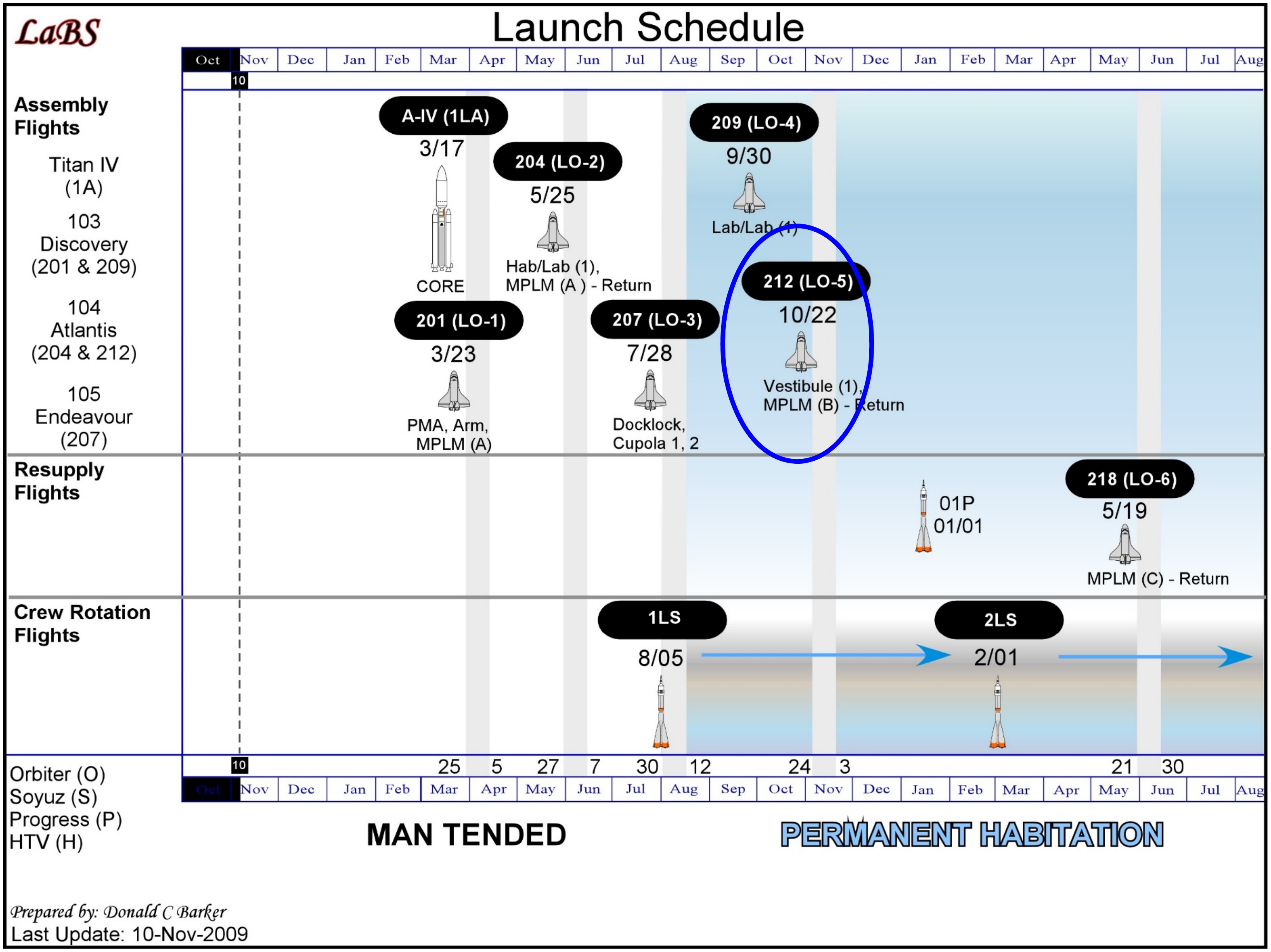
6) A sixth assembly launch (5th Space Shuttle) will deliver and attach a Vestibule Module followed by the second MPLM to support final outfitting and ongoing operations (the MPLM will either remain on-orbit or return with the Shuttle):

- The Vestibule is a logistical stowage and transfer area (or “garage”). It also serves as a structural attach point for a second Core like module ,should future station expansion be desired .
- The MPLM carries the final load of supplies and experiment racks necessary to support full research operations.



LaBS

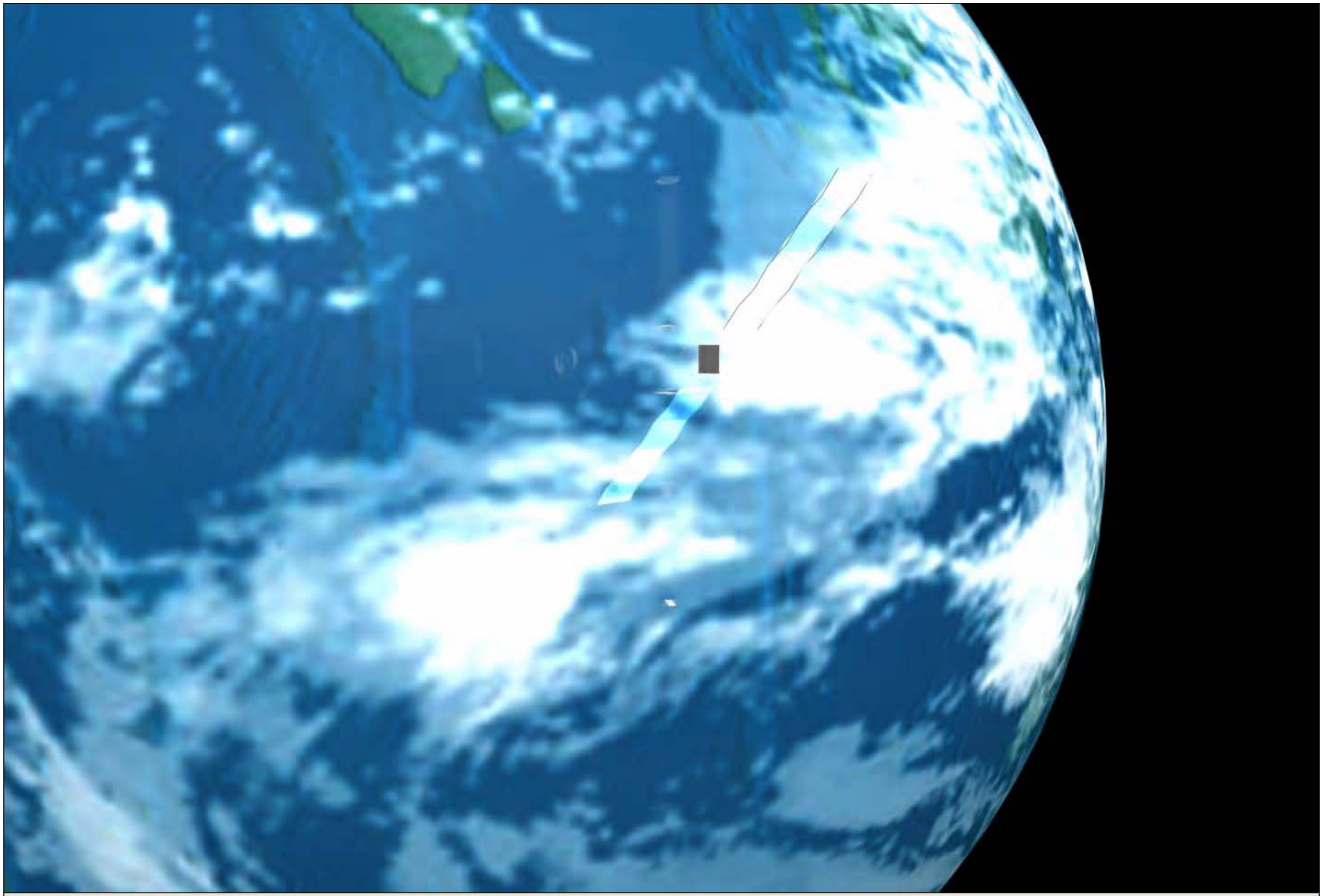
Assembly Overview



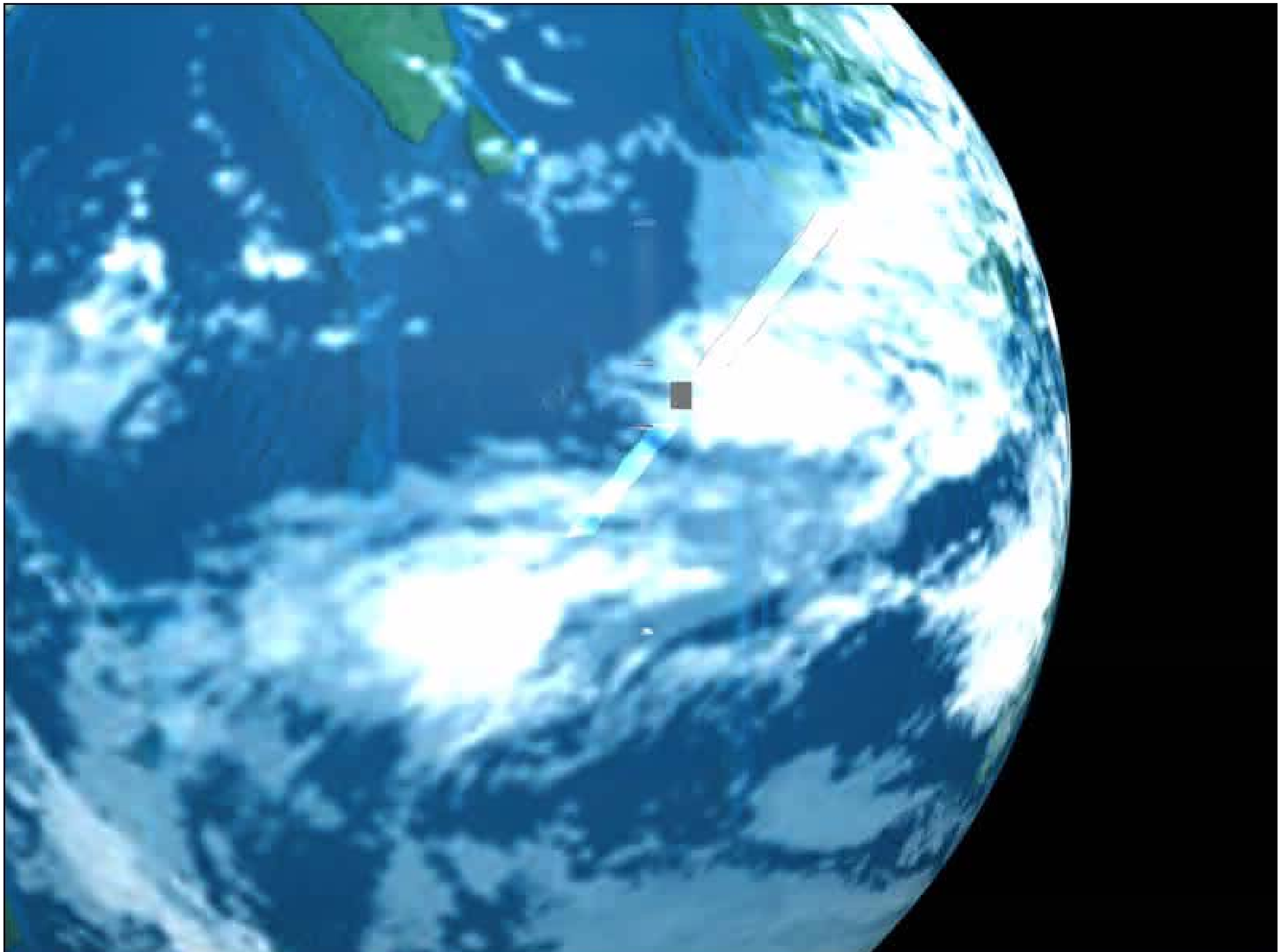
Summary Attributes and Benefits

The LaBS facility proposal directly supports NASA's vision for the future of space exploration:

- Provides a "building block" strategy for researching and understanding new and evolving space architectures as well as human habitation and adaptation to extreme environments in preparation for further expansion and exploration.
  i. Affords a needed asset to supplement inadequate ISS accommodations for life and biological science research in preparation for extended duration human missions to the Moon and Mars.
  ii. Offers a test-bed with "plug-n-play" capabilities to apply and evaluate critical closed-loop life support, fuel production, automation, command & control, and next generation technologies.
  iii. Accommodates in orbit Mars sample return within a confined biohazard facility for analysis and decontamination prior to Earth return.
  iv. Encourages commercial and private sector partnerships and relationships for technology development, research and general cost sharing to reduce impacts on NASA budgets.



assembly still



assembly flying

Summary Attributes and Benefits

- The LaBS facility planning approach and design concepts offer a variety of important benefits including:
  i. Provides for rapid and economical buildup to accomplish permanent habitation and operations after only four assembly launches.
  ii. Proposes applications for advanced power and orbit maintenance systems that can optimize onboard micro-gravity conditions and reboost economies.
  iii. Conceptualizes an expandable module design that optimizes internal habitable, research and storage volumes and functionality within limited orbital outfitting time.
  iv. Accommodates a variety of resupply and crew return vehicles for evolutionary development and operations.
  v. Combines existing and proven technologies and systems while providing for upgrades and testing of next generation advancements.

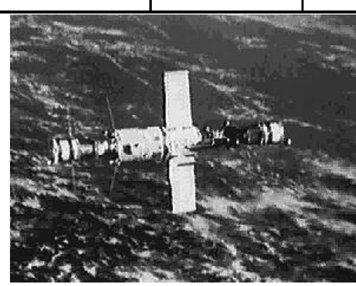
LaBS

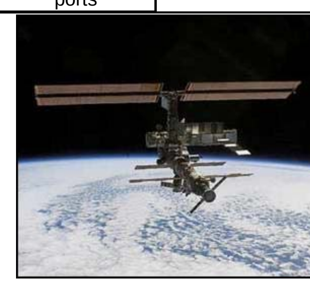
UNIVERSITY of HOUSTON

Historical Comparisons

- The proposed LaBS facility is an evolutionary step in space station design and as such its enhanced in various important aspects when compared to past space station platforms.

	COMPARISONS WITH OTHER FACILITIES							
		SALYUT			ISS			
	SKYLAB	SALYUT 6	SALYUT 7	MIR	ISS US MODULE	ISS ESA MODULE	ISS JAP MODULE	LabS
MODULE DIAMETER	21,6 ft (6.58m)	13.44 ft (4.2m)	13.44 ft (4.2m)	n/a	14 ft (4.3m)	13,44 ft (4.2m)	14,4 ft (4.4m)	
OVERALL LENGTH	118,5 ft (36.1m)	49,2 ft (15m)	49,2 ft (15m)	99/93/81ft, 33/31/27.5m	28 ft, 14 ft	24 ft, 13.44 ft	36.7 ft, 14.4 ft	
TOTAL NUMBER OF MODULES								
CREW SIZE ACCOMMODATIONS	3	5 perm.+11 visit.	6 perm.+4 visit.	28				
LABORATORY FUNCTIONS	Solar observatory, microgravity lab, medical lab, earth observing facility, human research& outside experiments	Continue experiments from previous Salyut, tested new materials & space units, earth observation	Astrophysical, biological, and earth resource experiments	Microgravity environment, biological, flame spreading, physical science experiment	Bioastronautics, space biology, material and physical sciences	Biological, fluid flow and material science experiments	Microgravity, biological and x-ray radiography experiments, fluid physics and cristal growth	
NUMBER OF RACKS	n/a				24	23	23	
STANDARD RACK DIMENSIONS								
LAUNCH VEHICLE OPTIONS								
TYPE OF DOCKING	Multiple Docking Adapter	2 docking ports	2 docking ports	5 Docking ports	Node-1 provides six docking ports	Node-2 & 3 each has 6 docking ports	n/a	



Compliance Matrix

Level 0:

- ✓ Design based on Lessons Learned from previous programs and vehicles.
- ✓ Use of current, proven technologies especially for launch and component/hardware construction.
- ✓ Use of novel structures, power supplies and second (next) generation hardware/software.
- ✓ Enables continued systems engineering research.
- ✓ Focuses on the life sciences and enticing commercial participation by providing the latest scientific tools and facilities.
- ✓ Research and containment facilities support extraterrestrial sample return.

Level 1:

- ✓ Three person crew, 4 launches permanent habitation, with rotations lasting up to 6 months
- ✓ Low drag, pristine micro-g environment with maximized vehicle volume.
- ✓ Power rich (~60 KW).
- ✓ Minimum propellant, efficient, economic propulsion (5 CMGs, ion & chemical).
- ✓ Advanced robotic support (Robonaut, SSRMS & AERCam).
- ✓ Dual string Air-to-Ground communications for increased coverage and bandwidth.
- ✓ Standardization and integration of hardware supports assembly line production.
- ✓ Accommodates multiple docking vehicles (e.g., Shuttle, Soyuz & HTV).
- ✓ Research and habitation are unique and separated.

Future Considerations

This two semester study opened up several topics that warrant further study. Priority subjects for future investigation include:

- Launch vehicle availability: Delta IV, Ariane 5, Atlas V
- Launch location: USA, ESA, Russia, China, India, Brazil
- Core: Less congested and more user-friendly command/control station
- Habitat:
  - Shower unit in the hygiene area
  - Larger exercise area for safety and gathering space
  - More fresh food storage area
- Power: Separation of power systems for redundancy against micro-meteorite and debris hits

Future Considerations (cont'd)

- Space Bee (SICSA 2004/M. Pinni): Partial gravity module
- Augmented Reality Cupola (SICSA 2003/M. Chen): Crew training and comfort
- Thermal Control System: Implement Rankine power cycle with power source and Heat-pipes for maximum use heat rejection for ECLSS and related functions.
- Guidance/Navigation/Flight Control (GNC):
  - VASIMR or similar propulsion system to prolong or eliminate need for reboost
  - Center of mass manipulation by use of water pumps for GNC as well as science purposes
- Structure: Correlation of station structure ultrasonic, thermal, atmospheric and stress/strain data to flight dynamics and disturbance to science experiments
- Accessories: Use of a Personal Satellite Assistant for crew convenience

Relationship Building

SICSA and the LaBS facility team are grateful for the cooperation we have enjoyed from NASA JSC and many of its affiliated corporations. In particular, we wish once again to thank Dr. Dunbar and other senior NASA people who have provided technical assistance to our activities.

It is our desire to continue and expand our relationships with NASA and industry through a variety of opportunities:

- Formal and informal participation in SICSA seminars, projects and design reviews.
- Joint involvement in projects of mutual interest (including NASA & industry sponsored research).
- Support in making professional employees aware of SICSA's new MS-Space Architecture Program within the UH College of Architecture.

SICSA
SASAKAWA INTERNATIONAL CENTER FOR SPACE ARCHITECTURE
UNIVERSITY of HOUSTON

Life and Biological Sciences Facility (LaBS)

An Evolution in Space Platform Design and Operation

May 2004