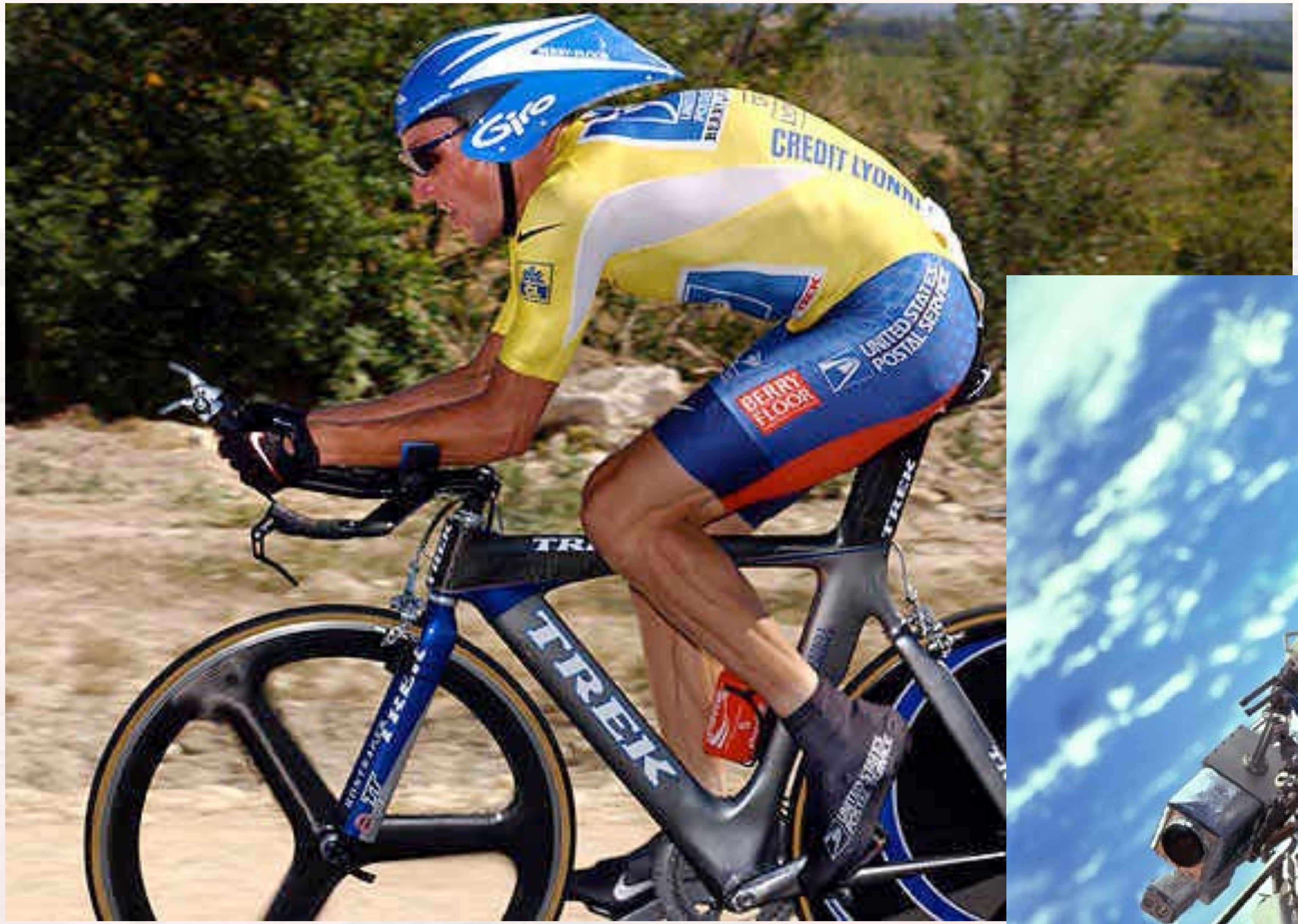
Extravehicular Activity 3

- Future spacesuits
- Spacesuit alternatives

Two Human-Powered Vehicles



A Vision of the Future of EVA

- The conventional space suit is a human-powered device
- As such, it can never do more than asymptotically approach nude-body performance
- The next step in space suit evolution is to use it to give the wearer superhuman capabilities
  - Sensors (telescopic, microscopic, multispectral)
  - Brains (advanced computing and data bases)
  - Muscles (robotic augmentation/amplification)
  - Appendages (integrated manipulators)
- The next step is the RoboSuit: an EVA/robot symbiosis

Augmenting Human Sensing

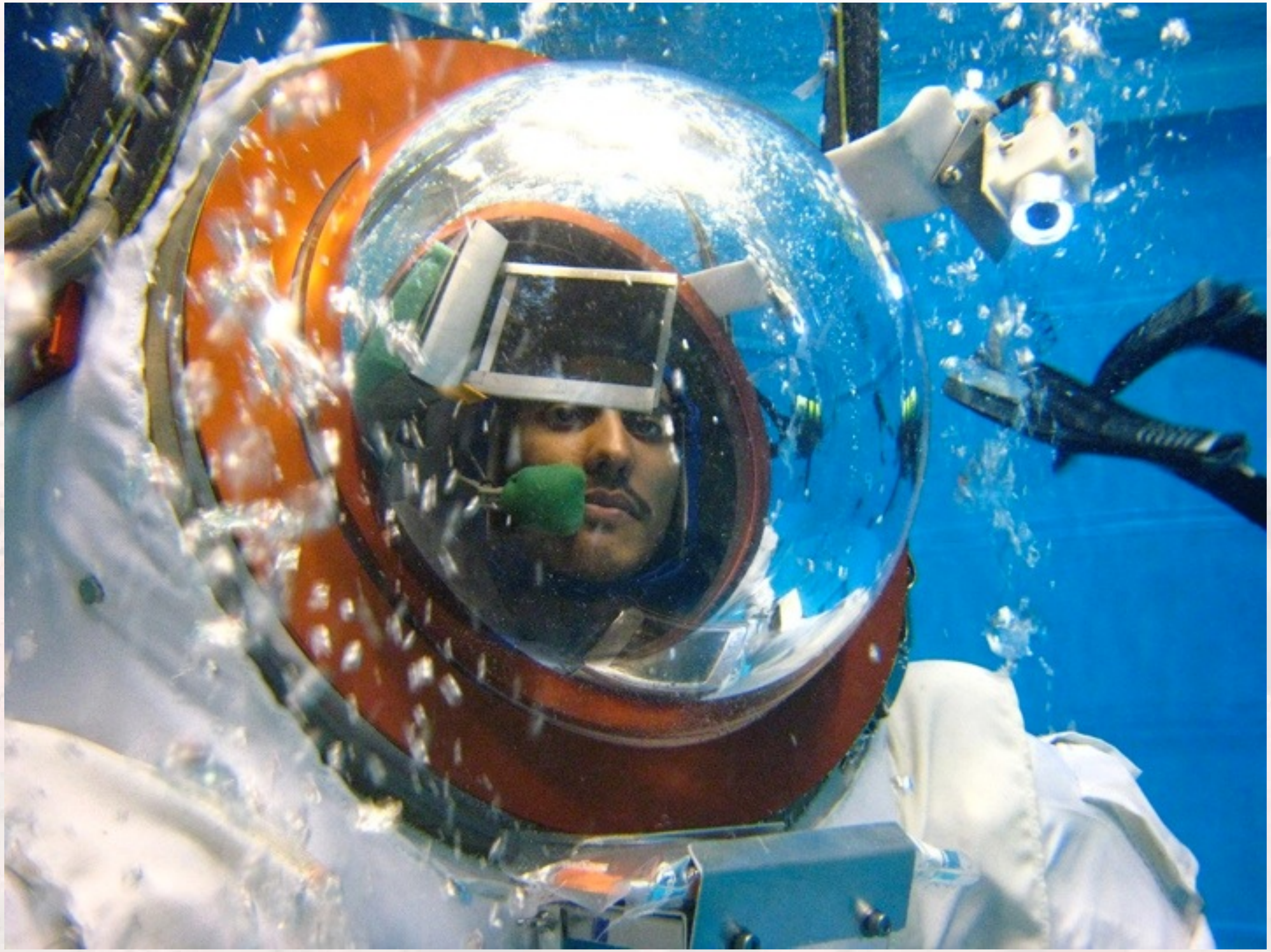
- Interior sensors
  - Kinematic sensors (body joint angles)
  - Biomedical sensors (heart rate, breathing rate)
  - Workload sensors (VO2, LCVG enthalpy change)
  - Neuromuscular sensors (EMG, AMG)
- Exterior sensors
  - Proximity sensors
  - Noncontact temperature sensors
  - Navigational data
- Visual sensors
  - Microscopic and telescopic
  - Multispectral
  - Thermal emission spectroscopy

Suit Instrumentation

- Goal is to fully instrument human/suit system for quantitative performance metrics
- Extensive sensor suite
  - Body joint angles
  - Neuromuscular activity and fatigue measurement
- Metabolic workload sensors
- Direct measurement of reach envelopes, forces and torque

Increasing Data Bandwidth to the Human

- Visual displays
  - Head mounted
  - Helmet mounted
- Aural displays
  - Local sound
  - Synthesized sound
- Haptic displays
- Tactile displays



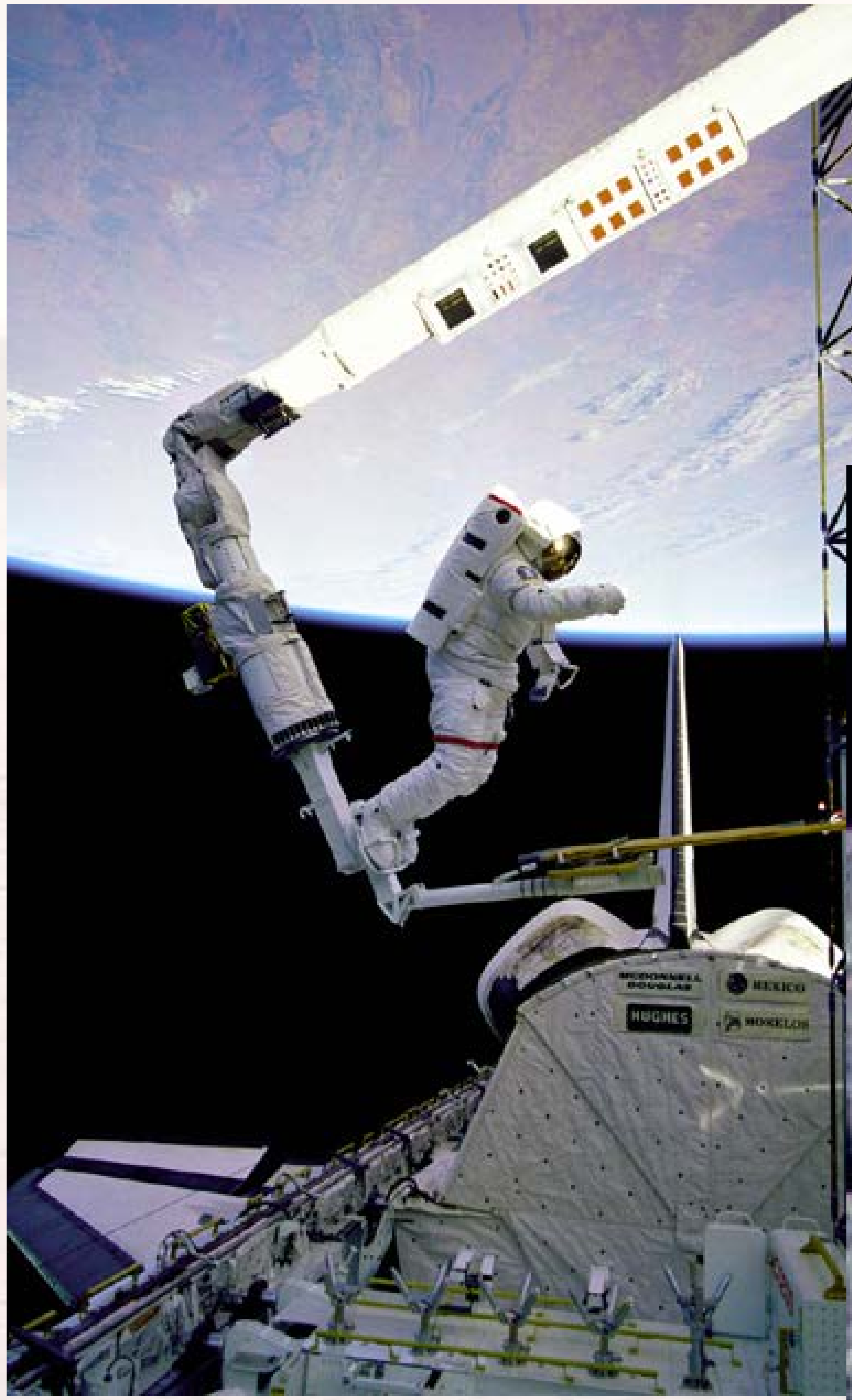
Augmenting Human Cognition

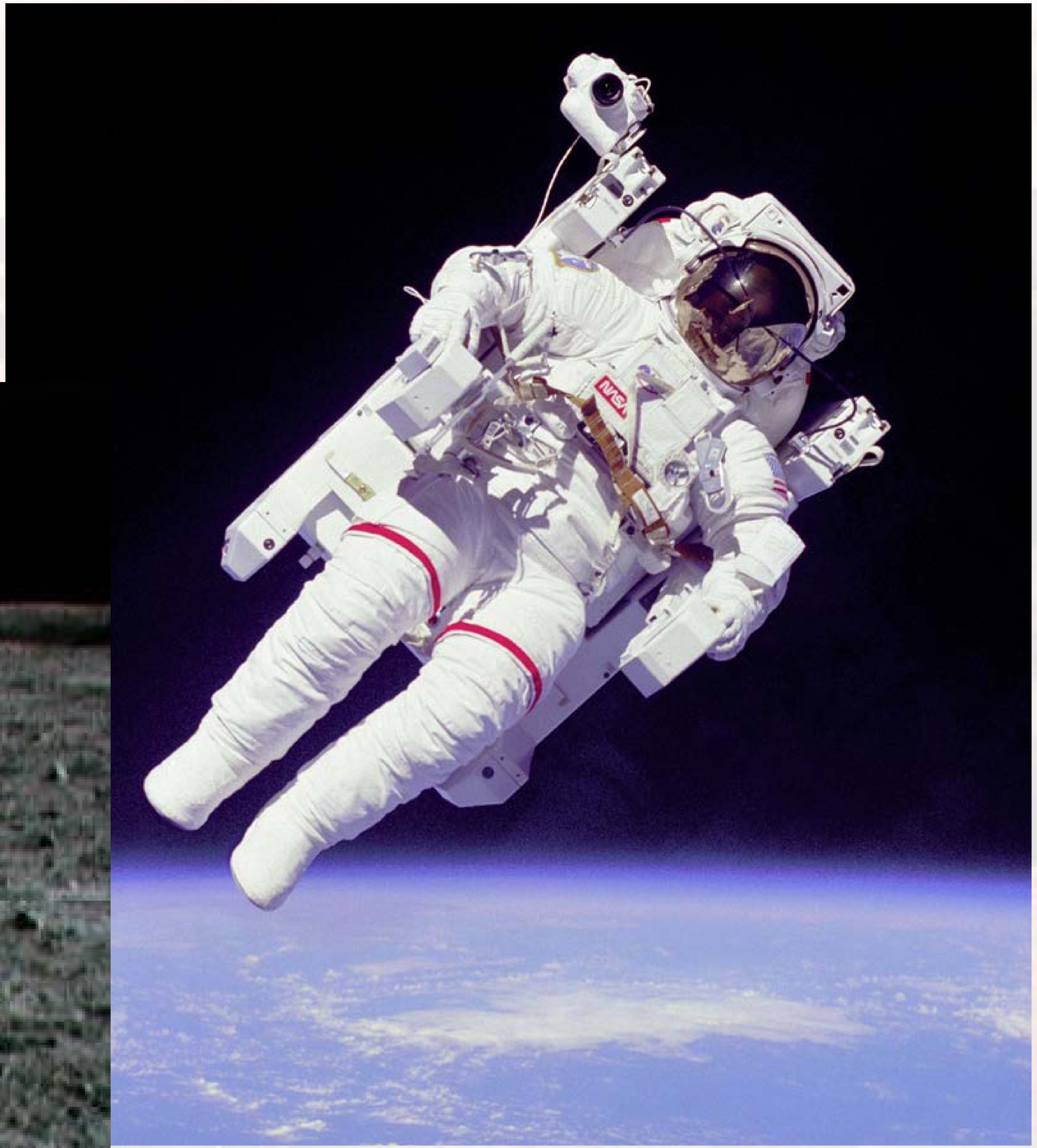
- Rote memory
  - Equipment checklists
  - Operating procedures
- Diagnostics
  - Suit built-in self test
  - Ancillary equipment
- Planning
  - Route planning
  - Orbital mechanics
- Scientific knowledge
  - Access to data bases
  - "PI in a box"

Augmenting Human Actuation

- Mobility
  - Planetary surfaces
  - Atmospheric flight
  - Microgravity mobility
- Manipulation
  - Controlling external agents
  - Targeted suit augmentation
  - Global suit augmentation

Past Suit Mobility Augmentation





Approaches to EVA Remote Driving

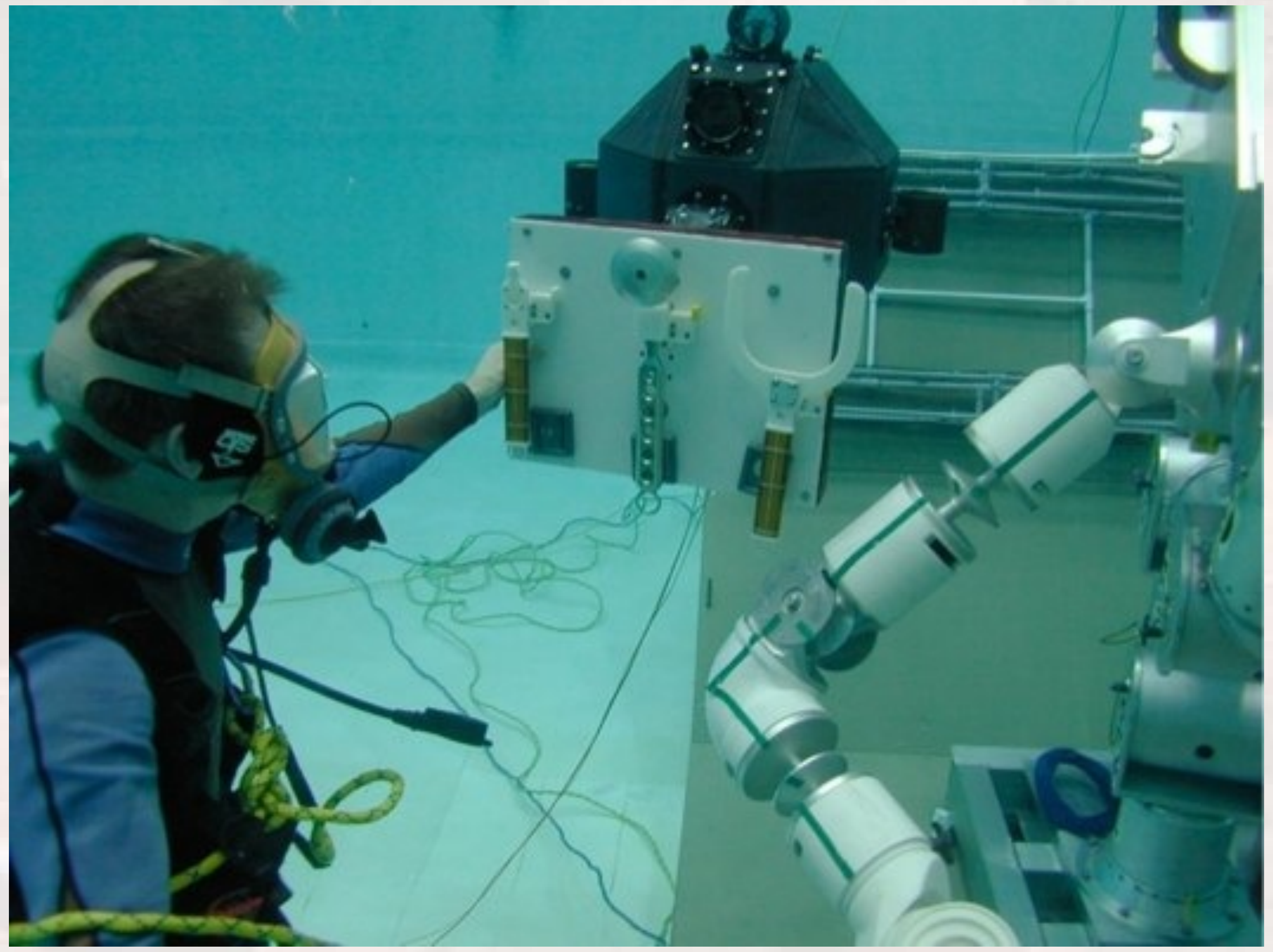
- Compared joystick, trackpad, mouse, and gestural control for simple computer-simulated driving task
- Tasks performed in EMU gloves at 4.3 psi (glove box)
- Results indicated clear advantages of gestural control (precision, accuracy, bandwidth)

I-Suit EVA/Robotic Field Tests

- Implemented gestural control of rover for field trials (2004)
  - Tracking target and grasp sensors on glove TMG
  - Tracking camera on helmet visor assembly
- Demonstrate gestural control in total system application (with JSC/EC, ILC-Dover)
  - Controlling camera on pan-tilt unit
  - Driving EVA support vehicle
  - Geology camera on staff
  - Images fed to head-mounted display
- Investigate EVA-designated robotic geological sampling at UMd following field trials

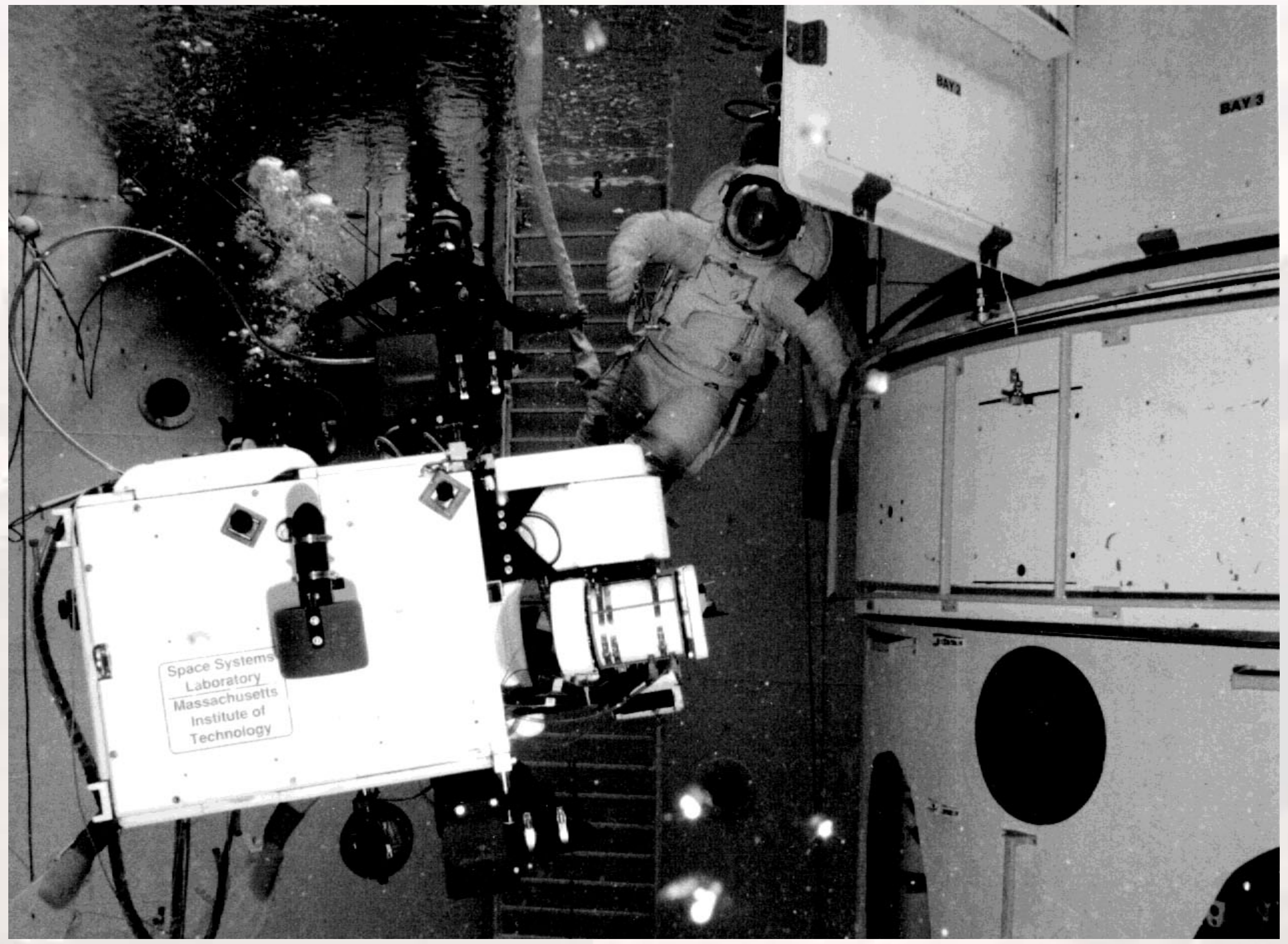
Free-Flying EVA Tool Tender

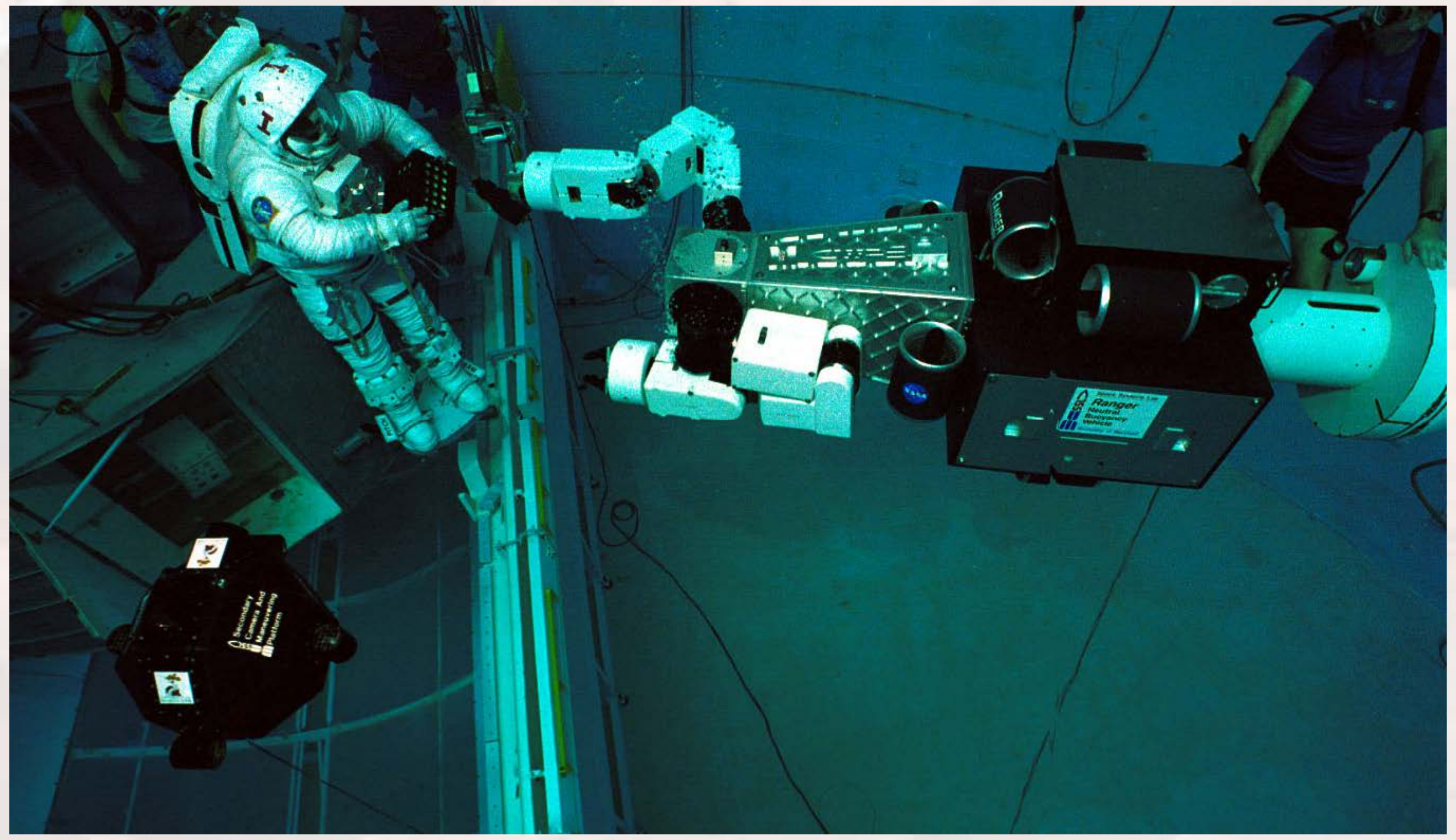
- Adapted SCAMP free-flying vehicle for EVA support
- Carried EVA tool board for simulated crew activities
- Reduced crew time required for translation, tool handling
- Minimizes use of valuable “real estate” on front of suit for tool storage
- Provides external view of EVA operations



EVA/Robotic Cooperation Background

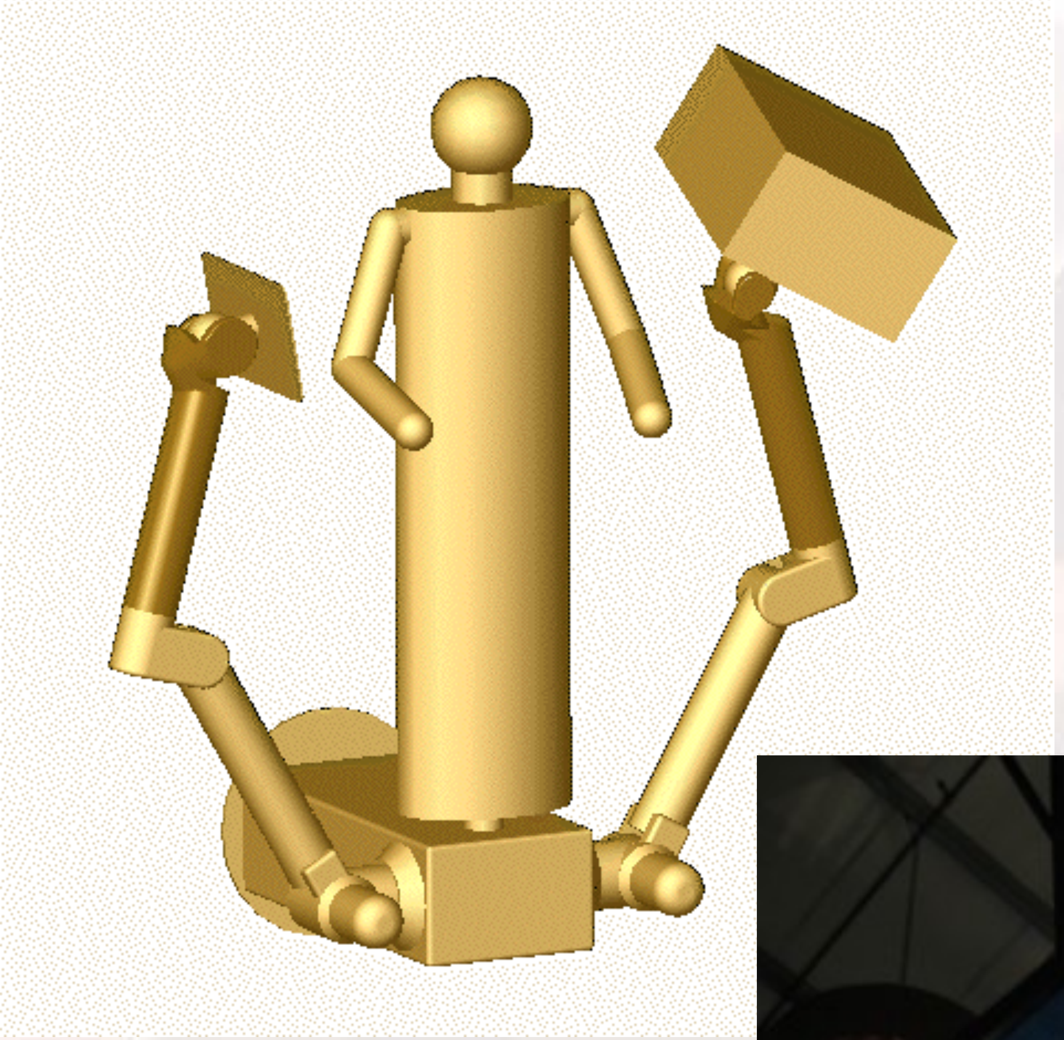
- SSL involvement in EVA/robotic interactions dates back to early 1980's
- Extensive EVA/robotic servicing tests of Hubble beginning in 1989
- Multiagent operations (EVA, dexterous robot, free-flier, positioning arm) beginning in mid-90's
- Demonstrated ability of telerobot to rescue incapacitated EVA crew



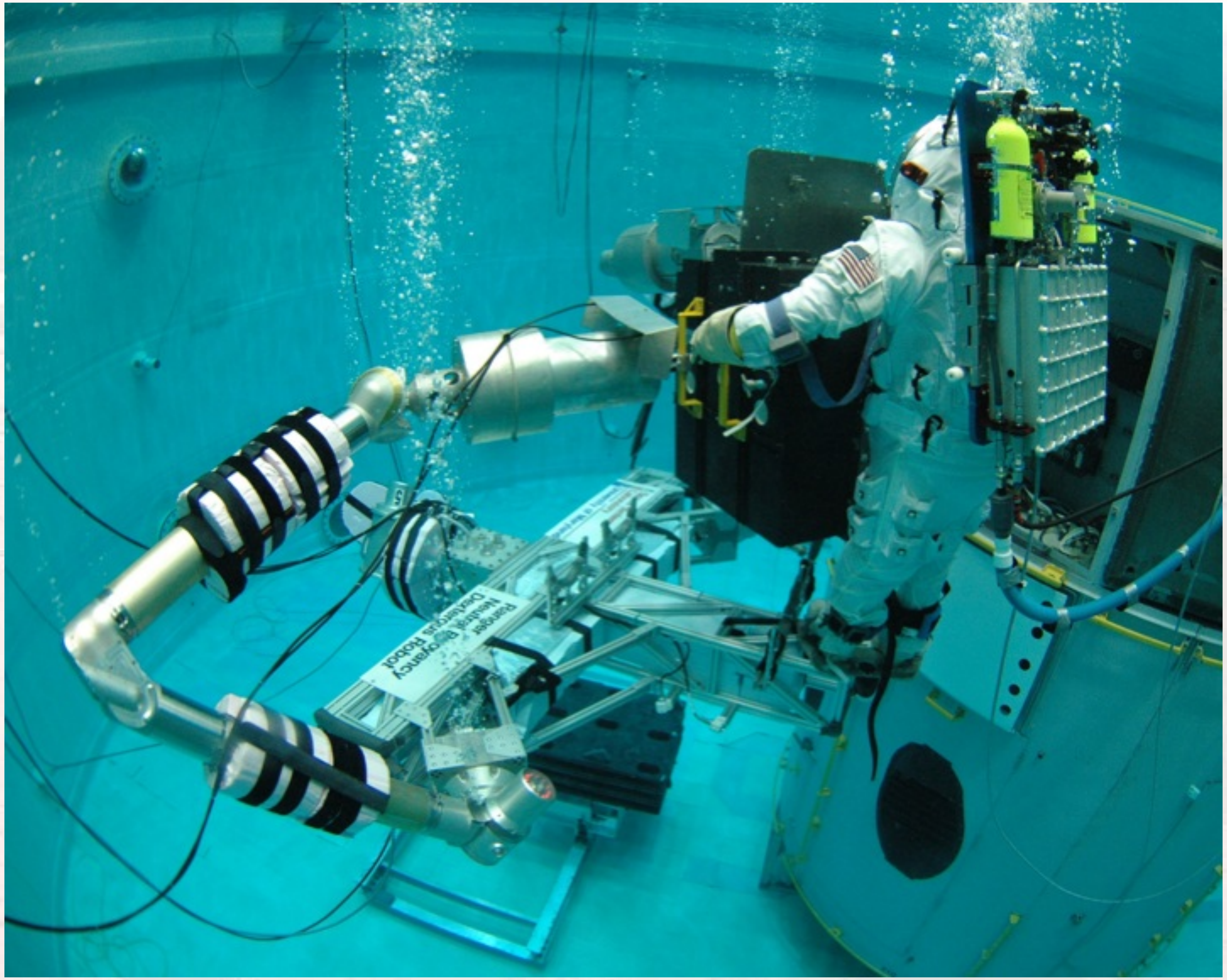


Robotic Augmentation for EVA Servicing

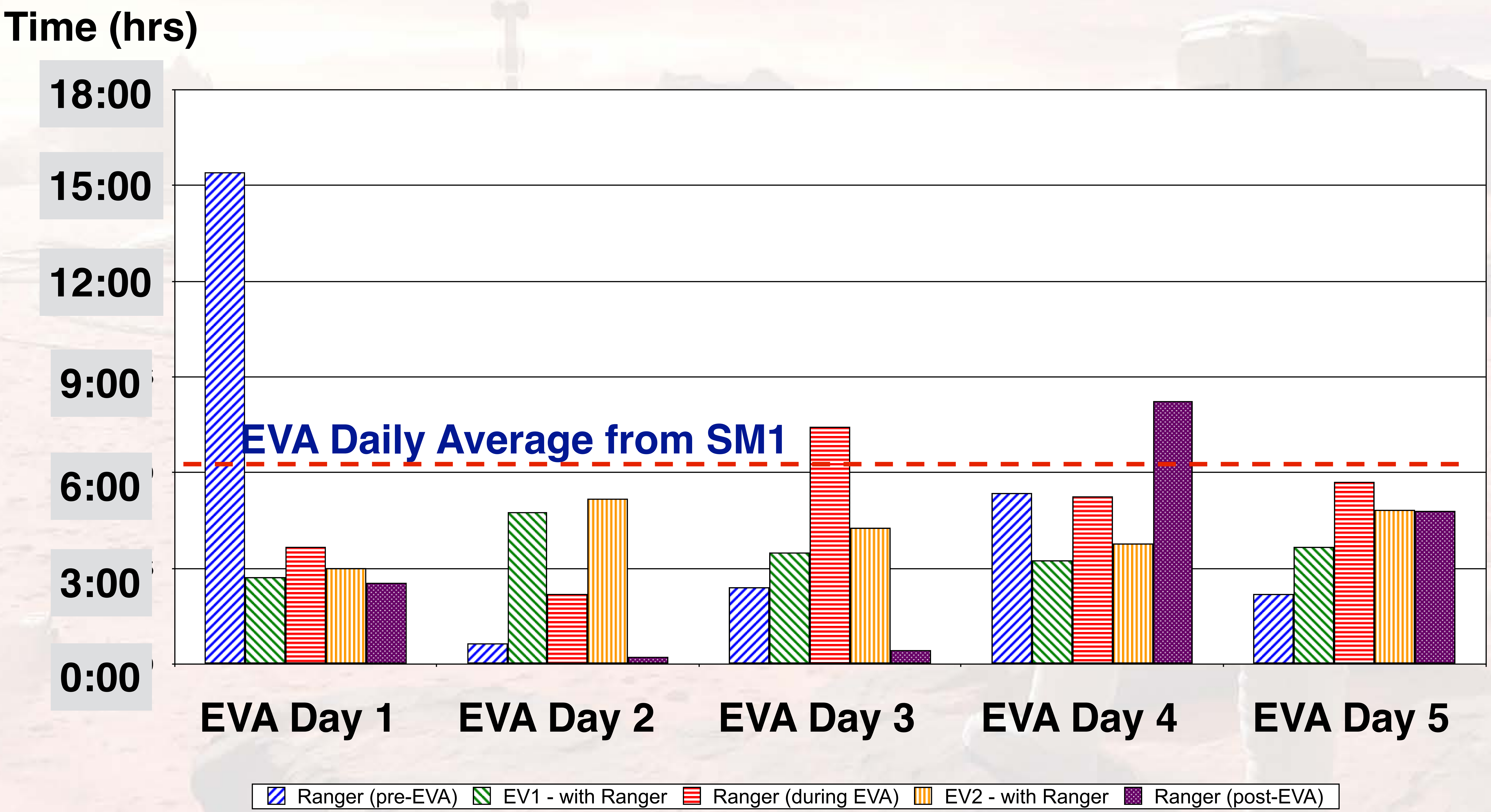
- Studied application of robotics to EVA HST servicing
- Final approach: robot-augmented manipulator foot restraints
- System reduced SM-4 EVA time requirement by 40%
- Further time savings probable through optimal scheduling



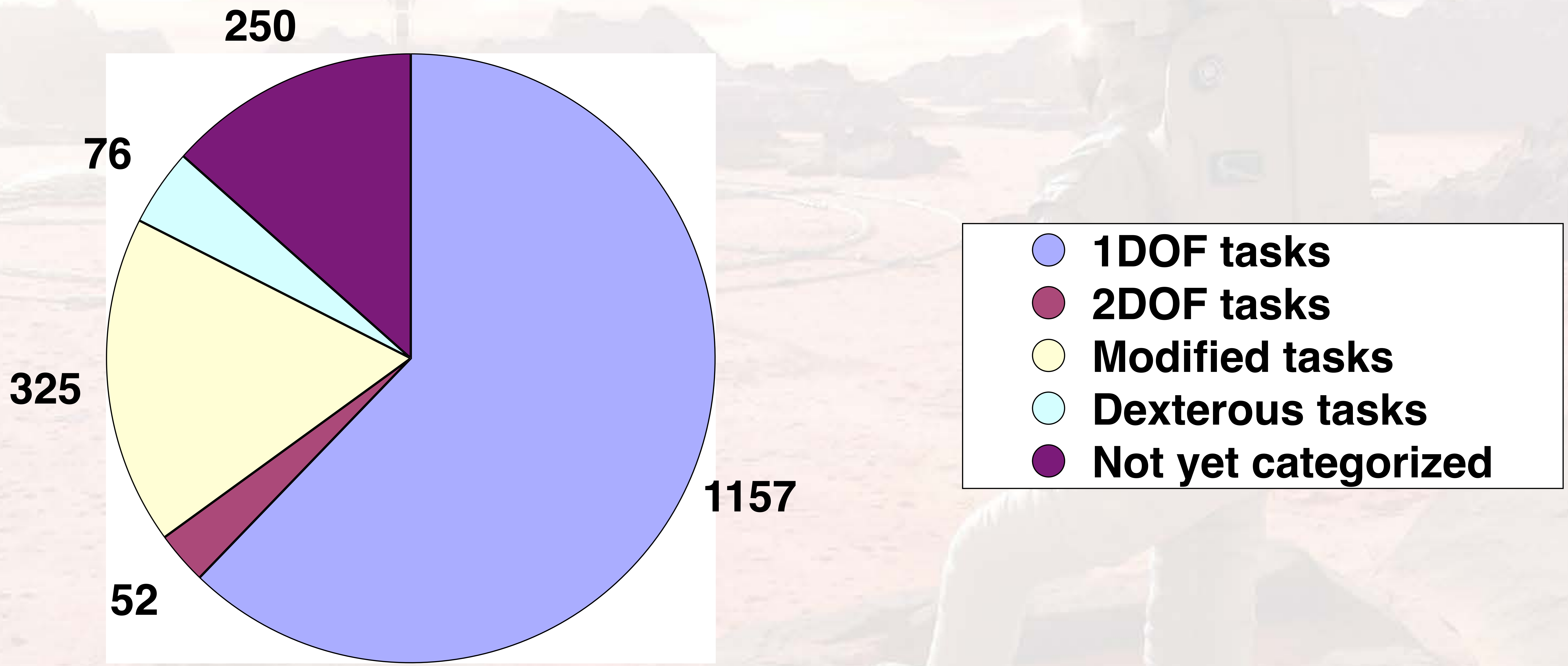
EVA/Robotic Servicing of HST



Ranger Application to HST SM1



Grasp Analysis of SM-3B

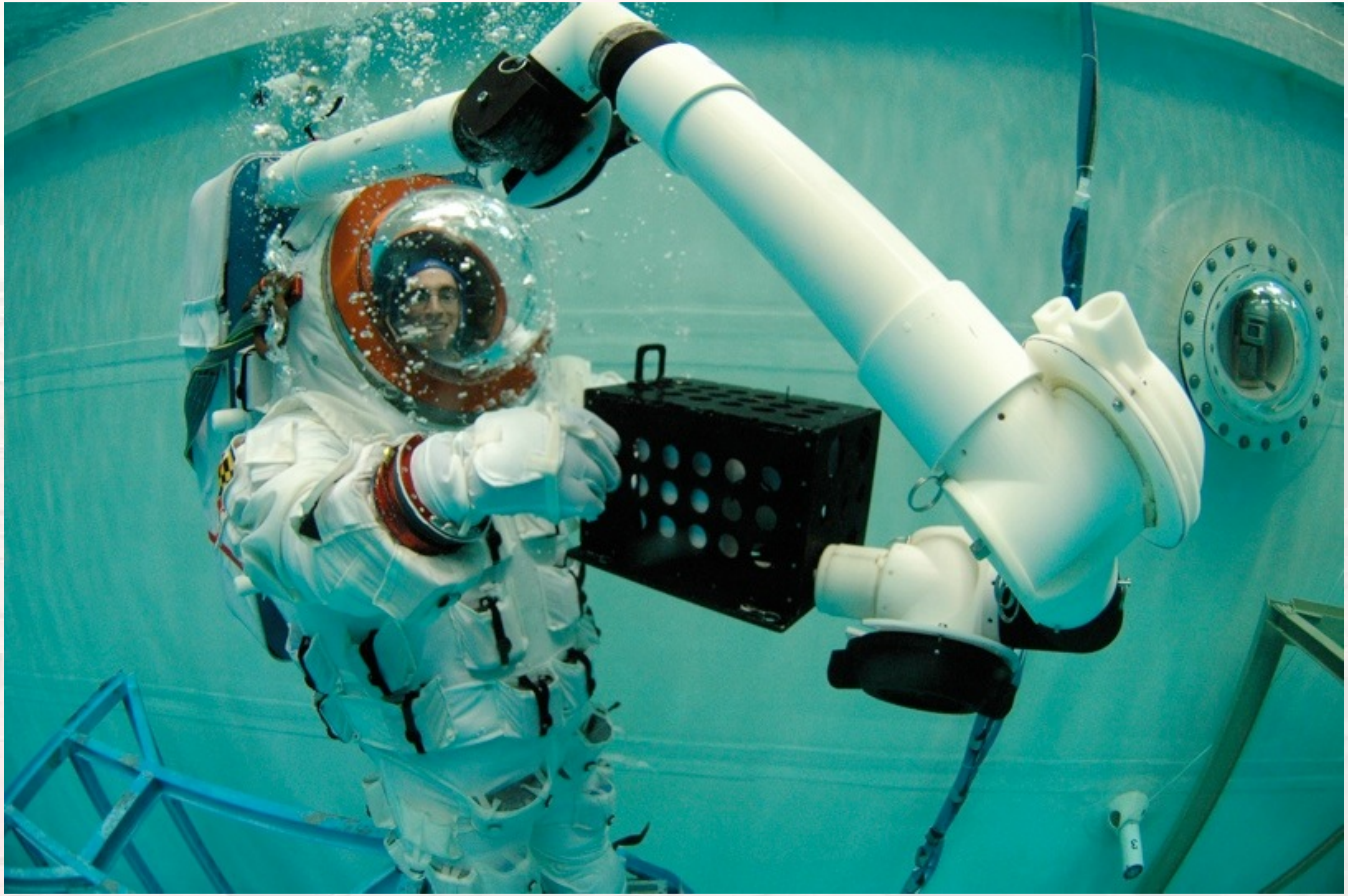


Numbers refer to instances of grasp type over five EVAs
Total discrete end effector types required ~8-10

Results of EVA Dexterity Analysis

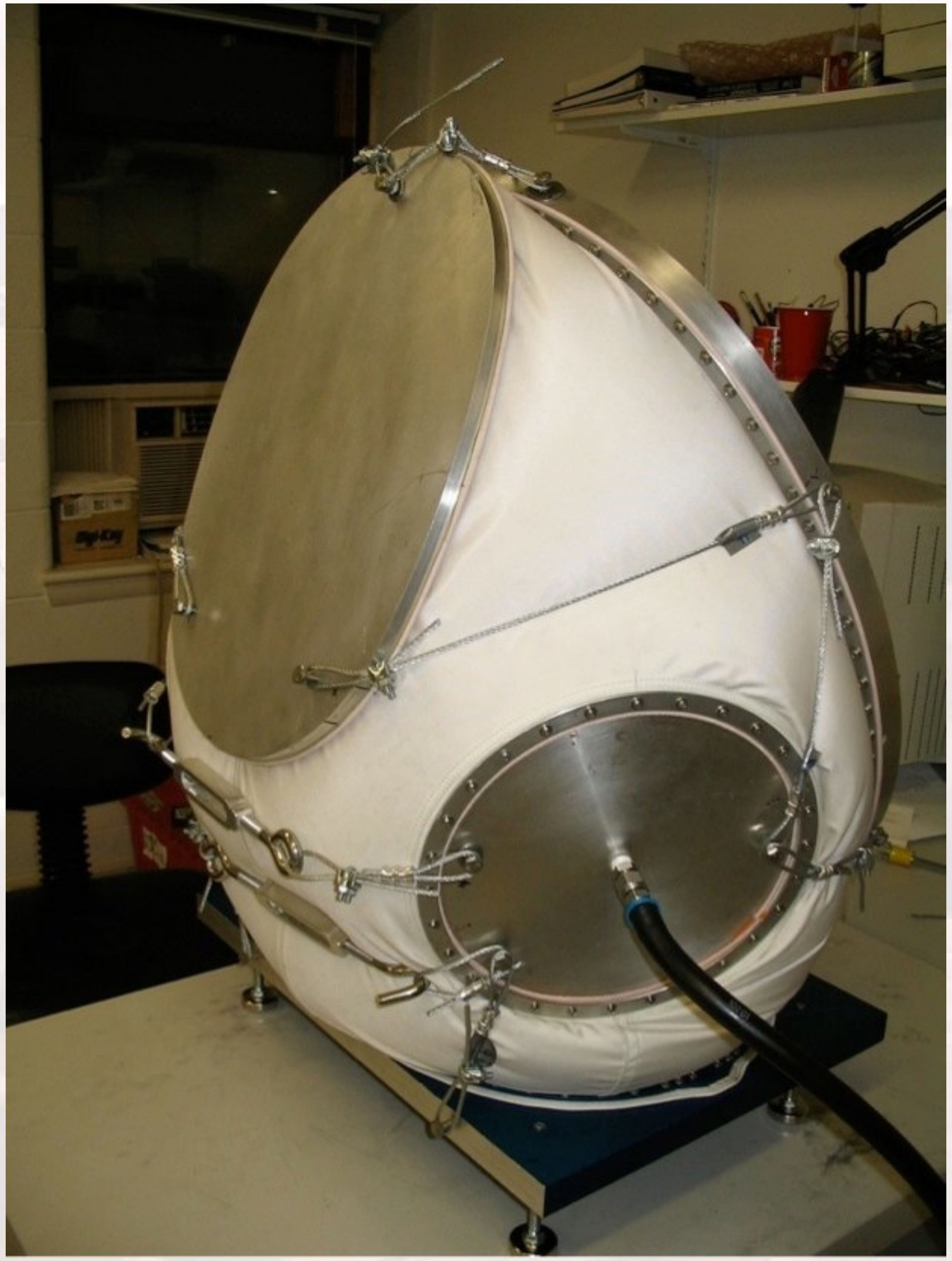
- Broke 63 crew-hrs of EVA activity on SM-3B into 1860 task primitives
- 82.5% of task primitives are viable candidates for 2DOF robotic end effectors
  - 62.2% 1DOF tasks
  - 2.8% 2DOF tasks
  - 17.5% tasks performed differently by robot than EVA (e.g., torque settings)
- 4.1% inherently dexterous tasks
- 13.1% cannot be categorized from existing video
- All SM-3B robotic tasks can be performed by suite of 8-10 different end effectors

Suit-Integrated Manipulator



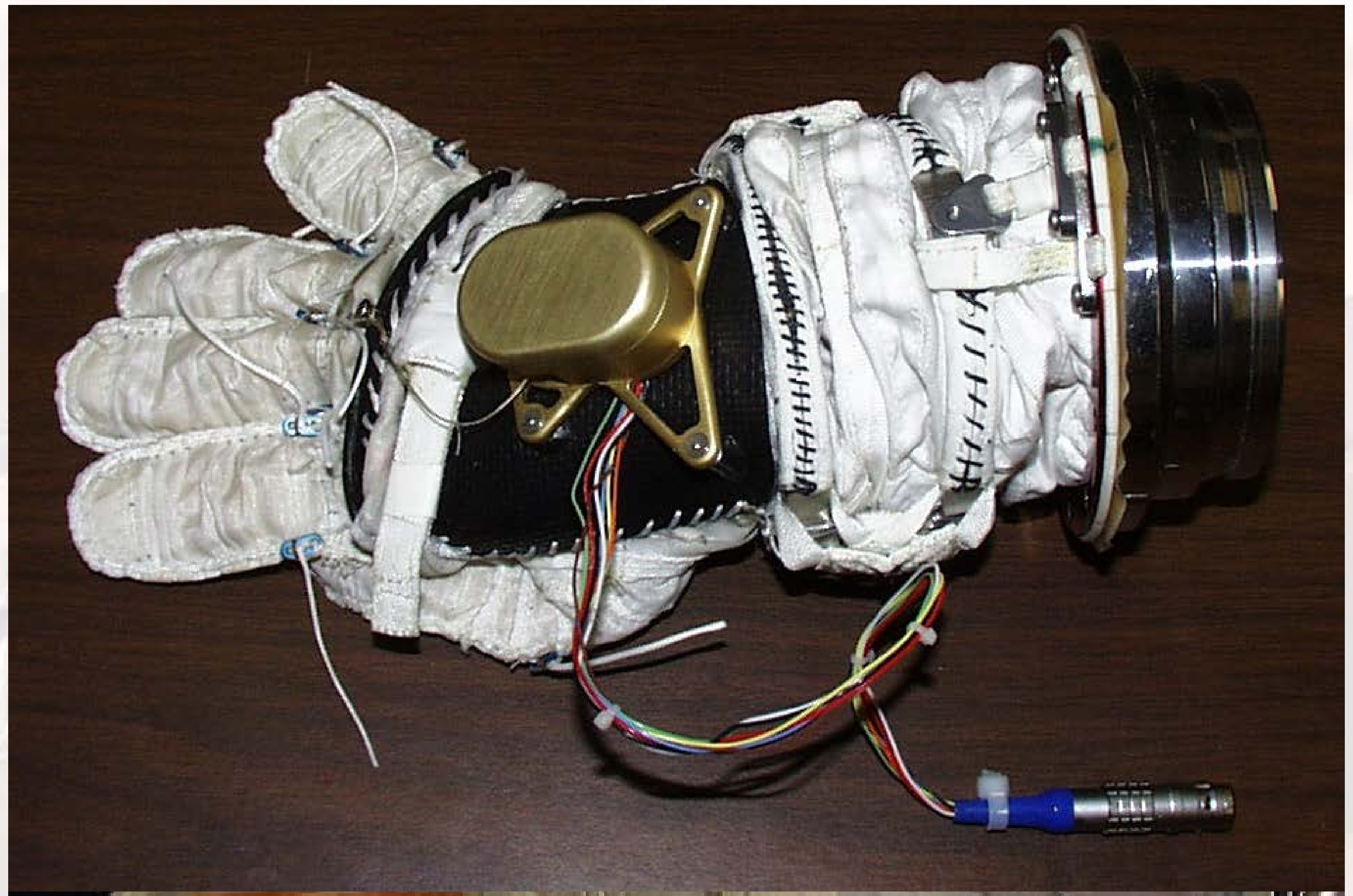
Morphing Space Suit Components

- Initial focus on morphing upper torso ("MUT")
- Linear actuators in restraint wires to control position and attitude of neck ring, shoulder bearings, waist ring
- Analytical approach: four intercorrelated Stewart platforms
- Nonideal effects of pressurized fabric on wire runs
- Being extended to power-assisted arm segments



Power-Augmented EMU Glove

- ILC-Dover designed EMU glove with MCP joint
- UMd added robotic actuator for MCP joint, control system to follow hand movements
- Reduced force required for MCP actuation from 16 pounds to 12 ounces
- No penetration of pressure bladder (all actuators, sensors, and controls external)



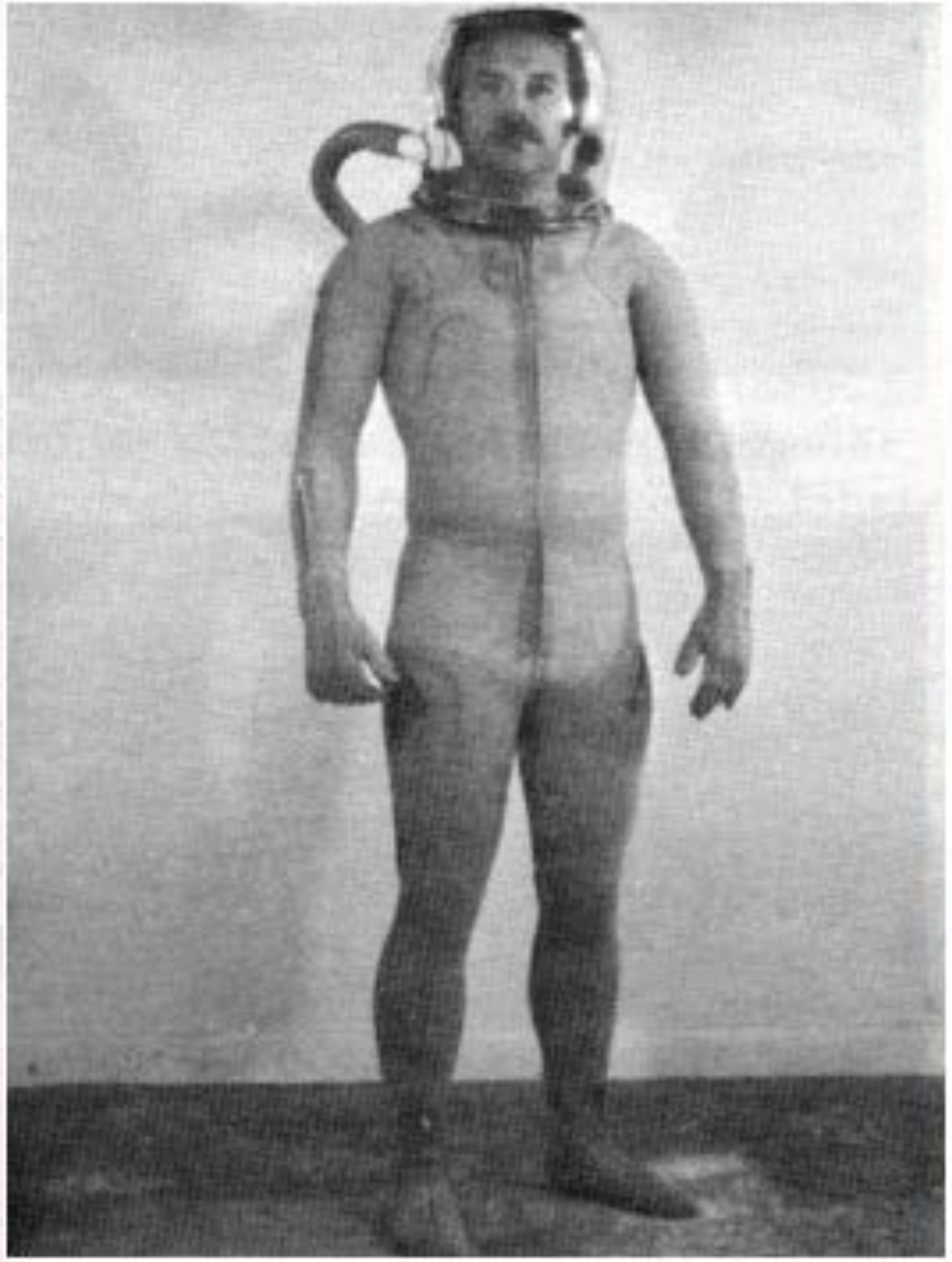
Power Suit

- Hard suit (AX-5 shown here) ideal starting point
  - All rotary joints
  - Rigid structure for actuator integration
- Use body joint angle sensors for actuator command inputs
- Provide hard stops to protect wearer
- Start with augmentation; evolve to amplification

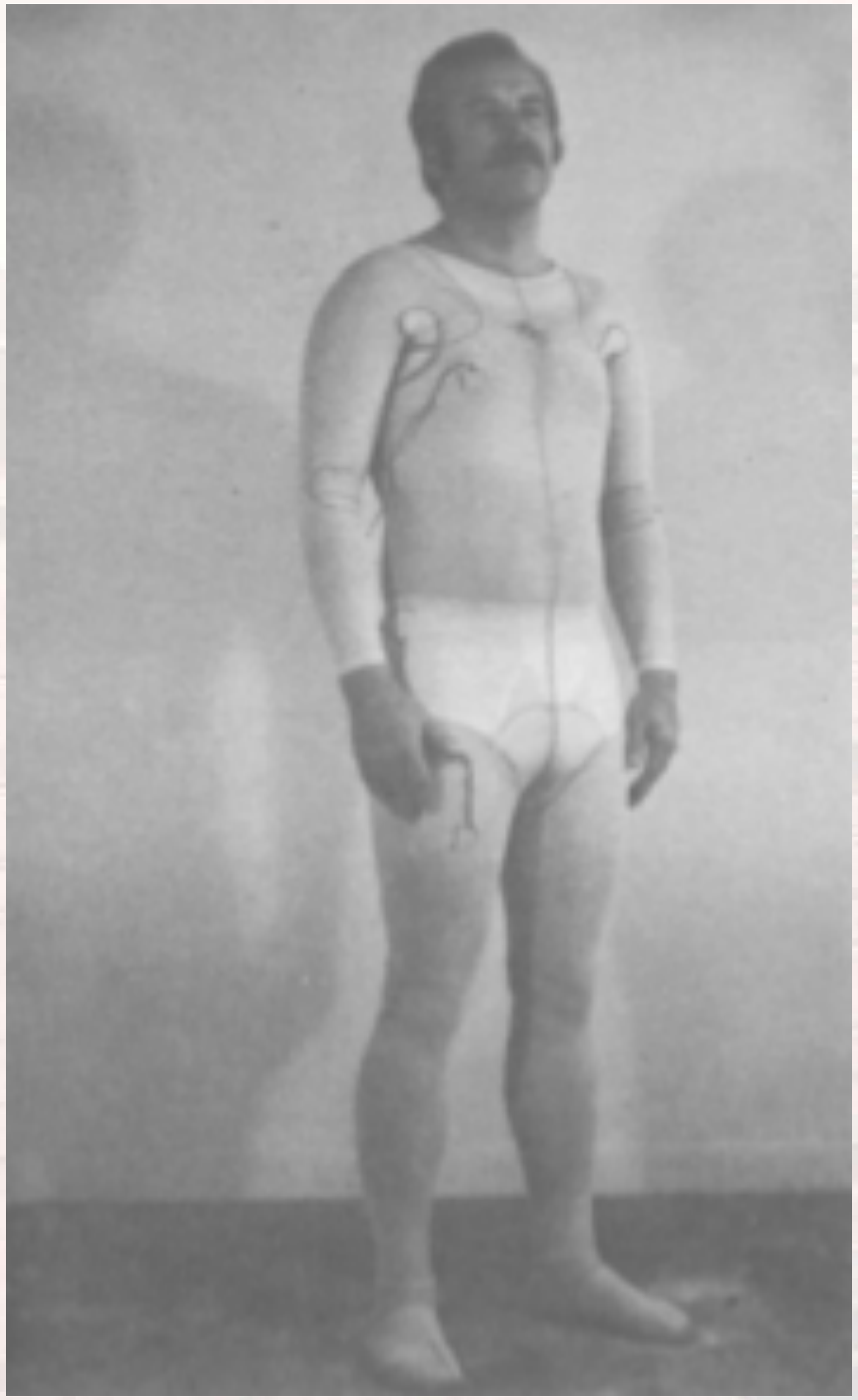
Possible Applications of a Power Suit

- In-flight EVA training - suit as haptic display device
- Control-mediated operations - limiting velocity, energy input, increasing human accuracy
- Human workload reduction - commanding suit to hold tool in hand, position in foot restraints
- Controllable compliance - select rigidity for microgravity foot restraint activities
- Autowalk
- Integrated short-range flight capability - "jump jets"
- Self-rescue - suit returns to airlock if wearer is incapacitated

Mechanical Counterpressure Suit



Webb Space Activity Suit (1971)



Web Space Activity Suit (1971)