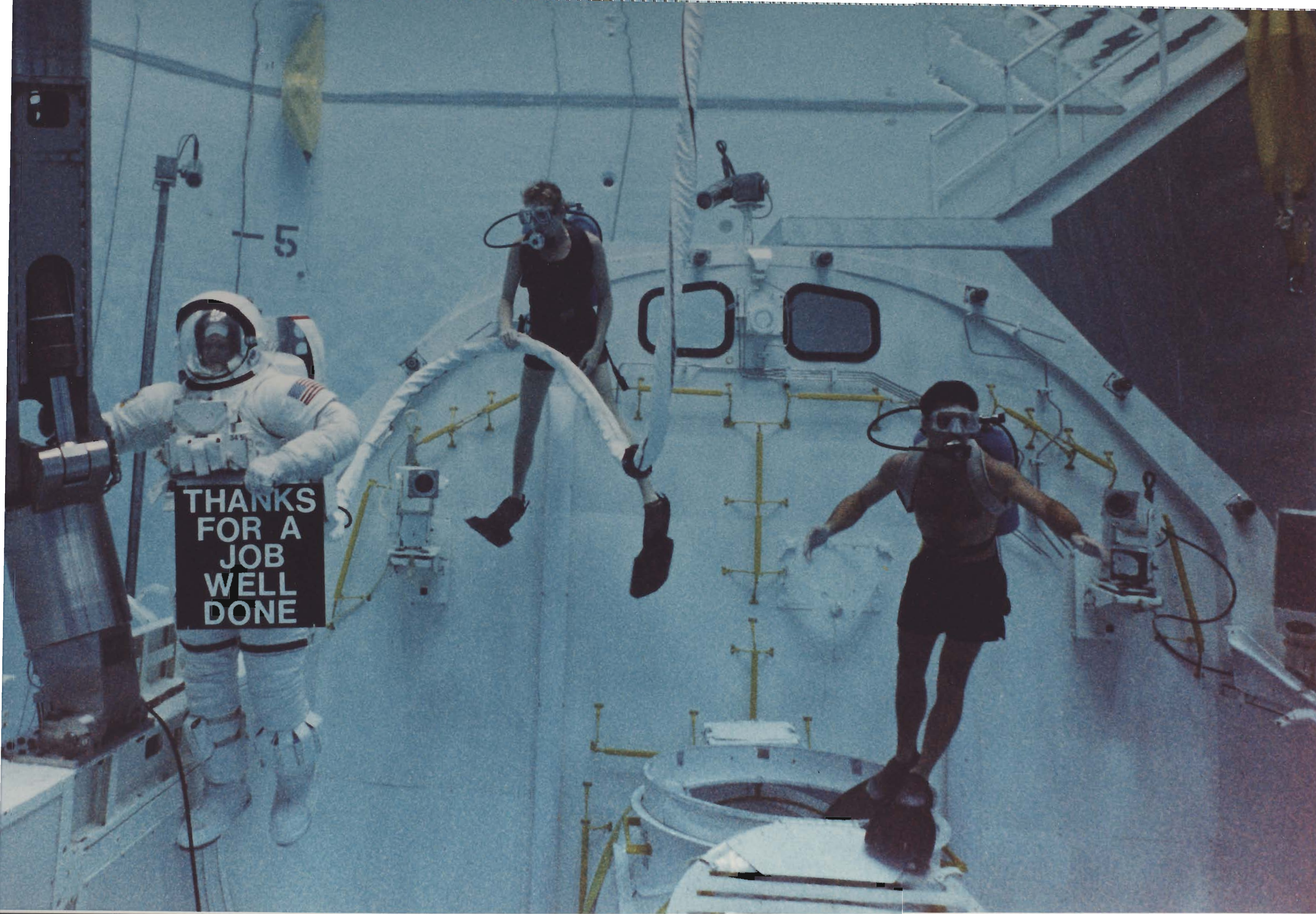

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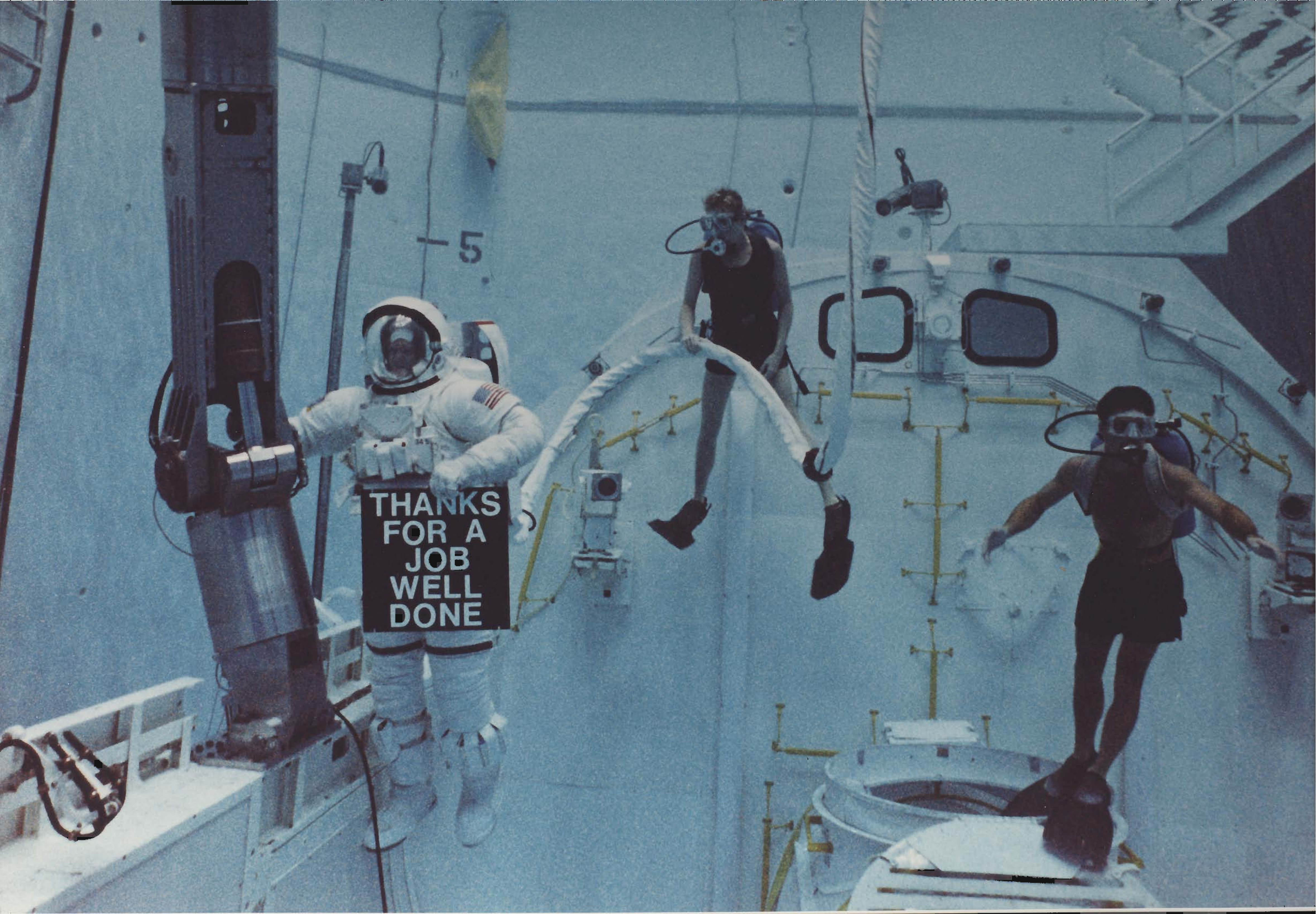
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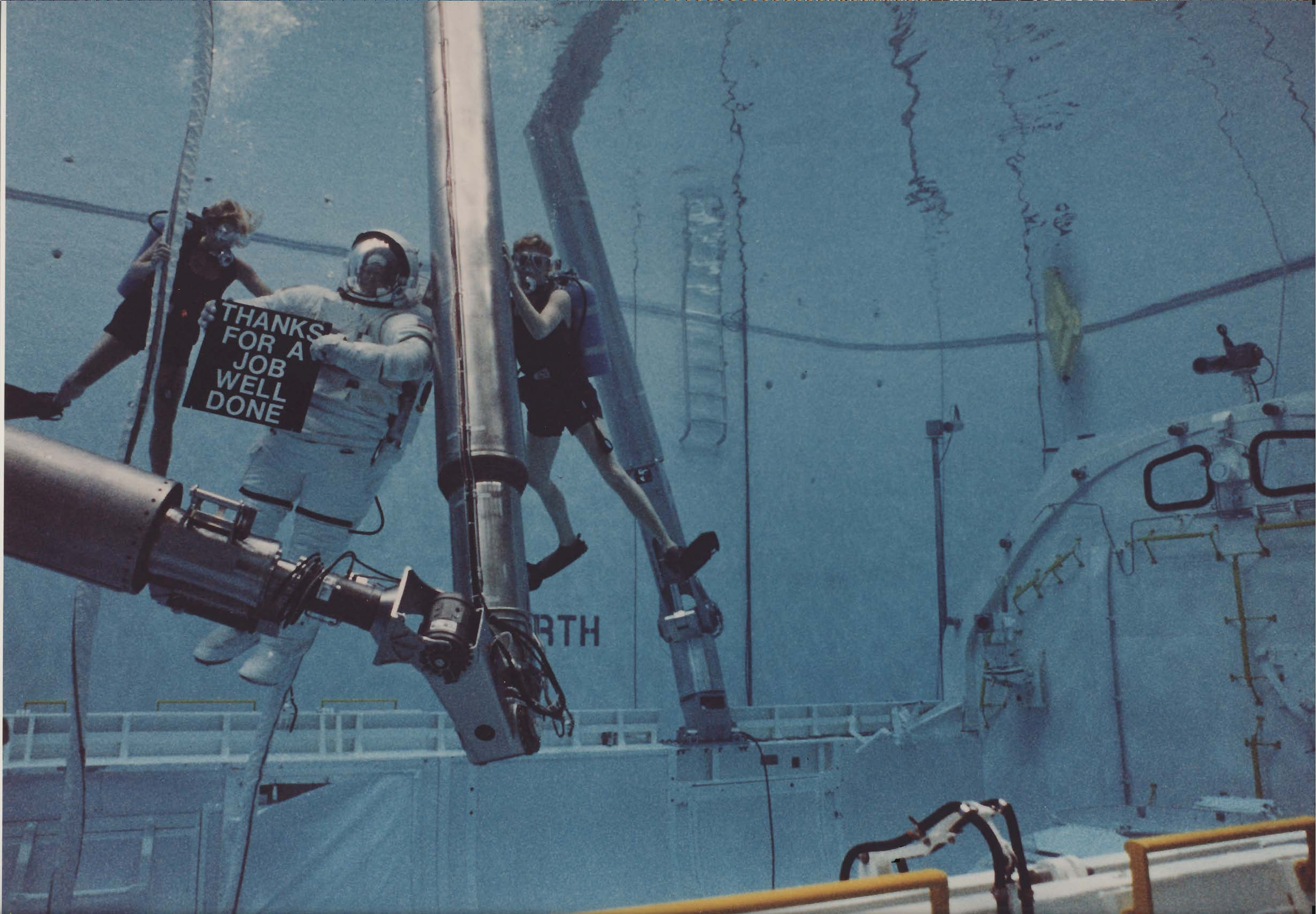
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RTH

JOHNSON ENGINEERING CORPORATION
555 FORGE RIVER ROAD, SUITE 150, WEBSTER, TEXAS 77598-4336 (713) 480-8101

March 26, 1996

The Sollami Company
Route 2, Weaver Rd.
Herrin, IL 62948

Subject: Letter of Appreciation

Dear Mr. Sollami:

Johnson Engineering Corporation would like to thank you for the rotary actuators your company provided in support of the Weightless Environment Training Facility's (WETF) Remote Manipulator System (WRMS). Many at NASA have recognized the work for its high quality. Your company's contribution was essential to the success of the project.

Please pass on our appreciation to others at The Sollami Company that worked on the project, particularly the craftsmen in your shop that did such a wonderful job in fabricating the hardware. The WRMS has been certified by NASA for full up operation and is now being used regularly for astronaut training. We are sending the enclosed photo of the completed system as our thanks.

Sincerely,

JOHNSON ENGINEERING CORPORATION

Thanks again Phil!

Rusty Crawford | John Haas | David McMahon

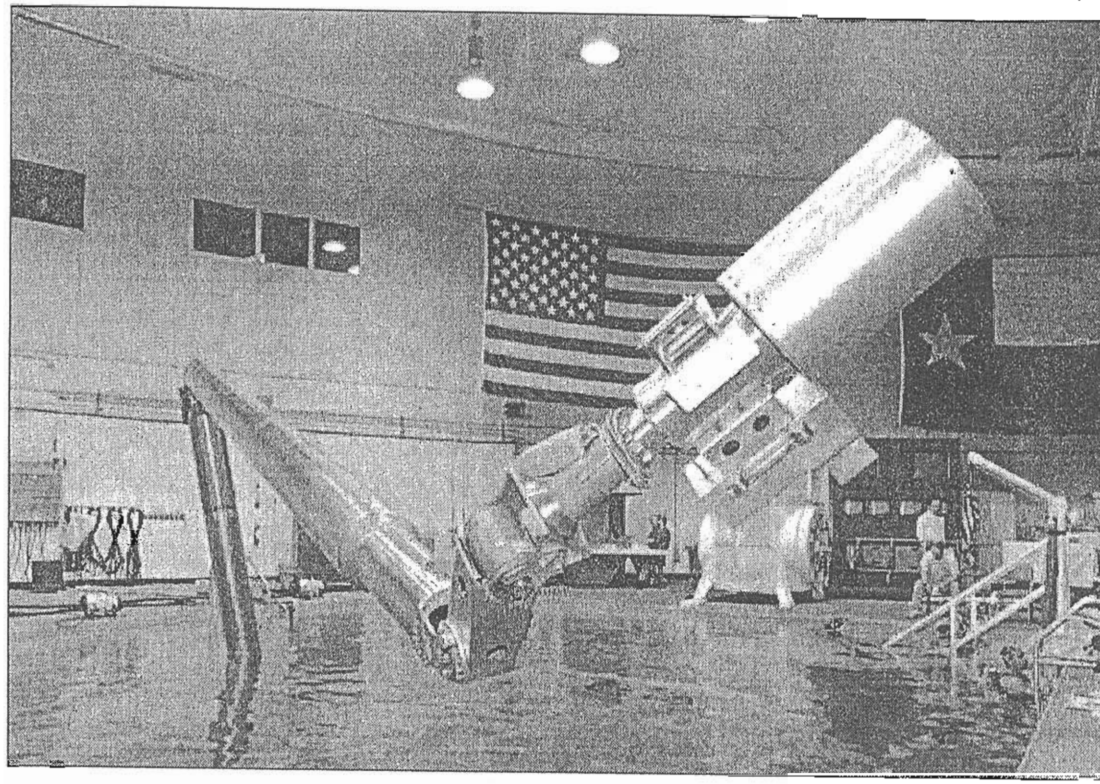
Rusty Crawford	John Haas	David McMahon
Project Engineer	Project Engineer	Project Engineer

cc: W. T. Short, President

Enclosure

Double Jointed

Weightless Environment Training Facility installs new underwater robot arm



By Karen Schmidt

As JSC turns its attention to the International Space Station, equipment must be upgraded to support training for long-duration missions. The Weightless Environment Training Facility has done just that, and is reaching farther to develop new training aids for the astronauts who will support space station.

Last month, a new WETF Remote Manipulator System, or WRMS, passed its operational readiness inspection, taking weightlessness training to new depths. The new arm replaces a 10-year-old arm that had reached the end of its life cycle due to corrosion and other old age problems. While the old arm was revolutionary in its day, the new design offers enhanced mechanical, structural and control capabilities.

"The new WRMS is primarily titanium and is resistant to corrosion in the pool's water and chemicals," said Carolyn Fritz, project engineer in the Flight Crew Support Division. "The new arm is volumetrically similar to the remote manipulator arm on the orbiter. It was designed for a tip load of 200 pounds, that is four times the capacity of the old arm."

Even with the new tip load, the new arm weighs

from the loads program the team designed lightweight modules that could be welded and post machined to provide accuracy. Because there are fewer nuts and bolts, the arm can be quickly taken apart and serviced.

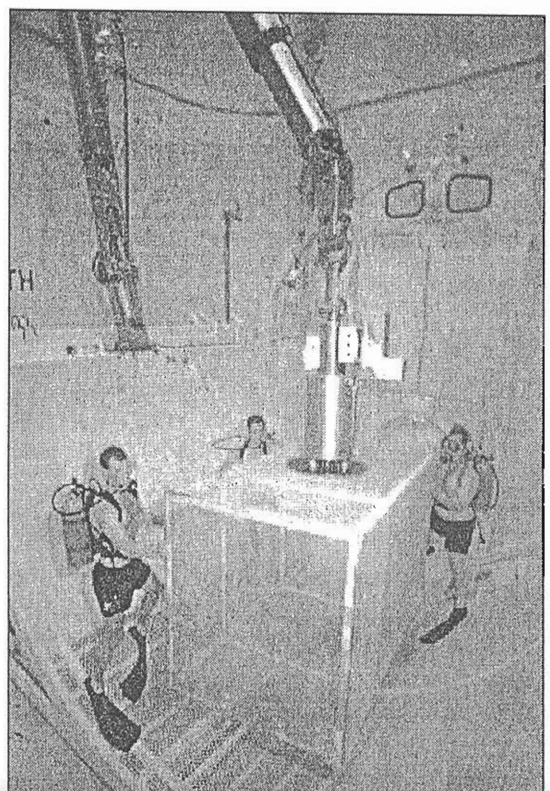
"The overall design has significantly fewer pieces than the older version. We feel we have succeeded in producing a design that is elegant in its simplicity," said McMahon. "The new arm can be serviced in an estimated fourth of the time of the old arm."

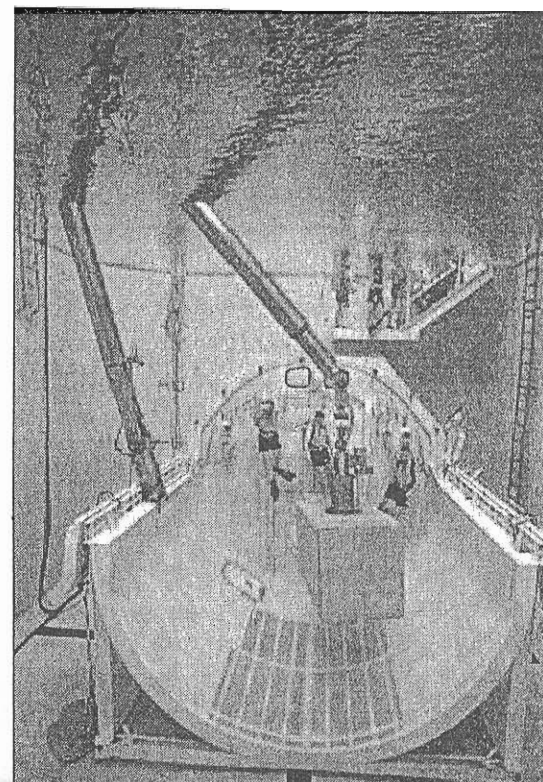
Fritz and McMahon, with the help of John Haas, developed the mechanics of the arm. The arm is hydraulic and uses magnetically coupled resolvers for position feedback. Each joint is designed differently to optimize performance. The hydraulic fluid works at 3,000 pounds per square inch and is water soluble.

"The difficult part of the project was coming up with a combination of actuators suitable to the WETF environment," said Haas, Johnson Engineering's mechanical engineer.

Actuators are devices that control the fluid power to the rotary motor.

"The wrist uses helical planetary rotary actuators, the elbow incorporates a linear actuator connected to a four





300 pounds less than its older counterpart.

"For crew training purposes, it was necessary to design the arm so that it was volumetrically no bigger than the arm on the orbiter," said David McMahon, mechanical design engineer from Johnson Engineering in charge of the structural design of the arm. "This was very challenging since the flight arm is designed to operate in microgravity and cannot even pick itself up (on the ground). This necessitated a lightweight design with joints that could produce high torque from a small package."

The project began in October of 1992 with a team from the Flight Crew Support Division and Johnson Engineering. The team chose several software packages to aid in the design process.

"The group chose a well-integrated design system, resulting in a very efficient design process that was one of the keys to the project's success," McMahon said.

To optimize weight savings, the team began designing the new arm from the tip of the arm and worked its way back toward the shoulder. A simple design and easy maintenance were major goals of the team and were accomplished with welded segment for the structural elements and a modular design for each joint.

The structural design began with the development of a loads program to calculate joint forces and torques. The team determined this was not an easy task since the arm moves in and out of the water during operation and changes the loading of the arm. Using finite element analysis and the calculations

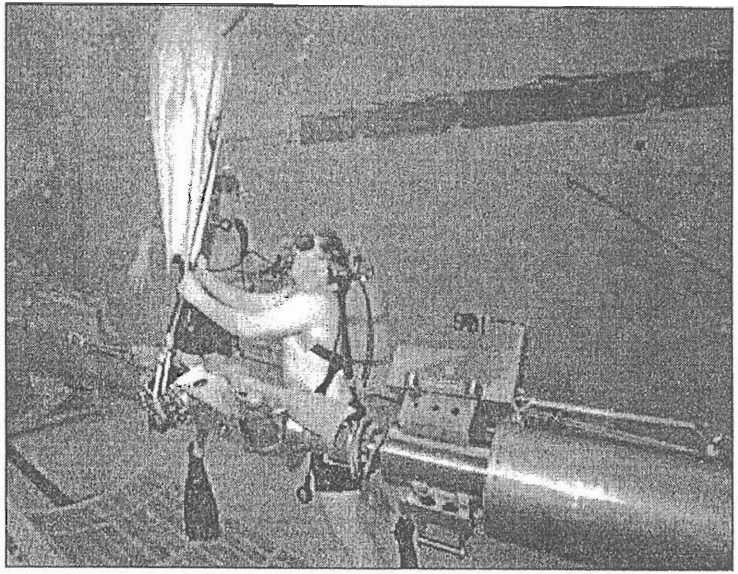
bar link arrangement, the shoulder pitch joint directly connects two structural elements and the shoulder yaw joint uses a rotary vane style actuator," Haas said. "The wrist and shoulder yaw actuators are integral structural members housing the associated bearing assemblies."

The team also had to decide how the arm would operate. Using two 486 PCs and two programmable logic controllers, the team developed a graphical user interface that allows the operator to select modes at the click of a mouse.

"Once a mode is selected, a pair of flight-like hand controllers is used to control the arm," said Rusty Crawford, project lead and control system engineer from Johnson Engineering. "The system also includes switches, indicators, a hydraulic pump and emergency shut down. A real-time Windows-based engineering simulation and modeling application was used to develop control schemes and allowed real-time changes."

Most of the new arm's parts were contracted out for fabrication with the help of the Manufacturing Materials and Process Technology Division and Johnson Engineering. As parts came in, the team assembled, tested and installed components. With certification complete, the team is now looking at its next project, the Space Station Remote Manipulator System that will be developed for the new Sonny Carter Training Facility.

"The best part of the project is that we came in under budget and gave the taxpayer good value for their money," Haas said. ❑



Top to bottom, left to right:

1) The WRMS demonstrates that it has the ability to operate out of the water, increasing the east of maintenance.

2) Three of the WRMS team members don scuba gear to check out the arm's ability to grapple a test article. From left are John Haas, David McMahon and Rusty Crawford.

3) The trio watches as the arm lifts the test article in the underwater payload bay mock-up.

4) Rusty Crawford mans the WRMS control panel in Bldg. 29.

5) Rusty Crawford attaches a lift bag to the WETF Remote Manipulator System. The bag is used to help remove the underwater arm from the water for adjustments and maintenance.

6) The WRMS team poses with its creation. Front row, from left: Crawford, McMahon, Haas and Fred Robinson. Back row, from left: Mike Schattel, John Costales, Carolyn Fritz, Mo Ahmadian and Benny Matusek.

JSC Phtos by Mark Sowa