calls the hydrogen-A phase. That phase had already been detected by Raman spectroscopy, which uses lasers to measure how the atoms inside the hydrogen molecules vibrate against each other. At about 1.5 million atmospheres the vibrations change abruptly, indicating some major change in the hydrogen's structure. But what? The conventional interpretation was that it was a shift in the packing of the hydrogen molecules inside the solid hydrogen and that the move to metallic hydrogen would come at a higher pressure. Not so, said Silvera.

"At this time, we think the hydrogen-A phase is probably the metallic phase of hydrogen," he said at an APS press briefing. As evidence, he pointed to his team's studies on pressurized hydrogen at temperatures down to 4.5 K, much colder than other labs can achieve with high-pressure hydrogen. If the phase transition were caused by a change in the physical structure, then the transition should occur at much lower pressures when the temperature got close to absolute zero. But Silvera's lab found that even at 4.5 K, the transition came at 1.48 million atmospheres. This makes the formation of metallic hydrogen the most likely interpretation of the data, said Jon Eggert, a co-worker of Silvera's. "There are very few other things it could be," he said.

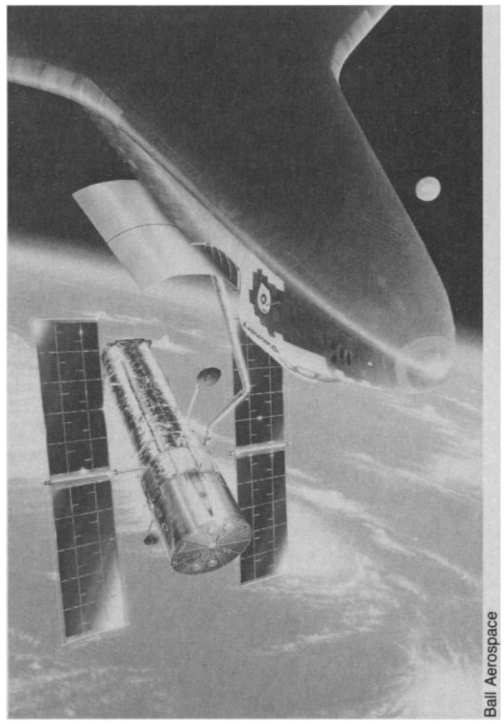
At the same APS briefing, Mao and Hemley retorted that their *Science* paper last summer pointed at the same conclusion Silvera is now approaching. At that time, they were relatively confident that hydrogen was metallic above 2 million atmospheres, but only hinted that hydrogen may become a "semimetal" at 1.45 million atmospheres. Since then, Mao said, they have been carefully examining the range between 1.5 million and 2 million atmospheres for conclusive evidence of the metallization. "To us, that is a lower pressure range now," he added, in a not so subtle reminder that the Carnegie group can still put higher pressure on hydrogen than its competitors.

Many observers, like Arthur Ruoff of Cornell University, remain unconvinced that metallic hydrogen has been seen by either group. The acid test would be to pass an electric current through the samples, Ruoff noted, but so far no one has done conductivity measurements above about 1 million atmospheres. Barring that, he said, researchers need a better theoretical understanding of hydrogen at high pressures, so that the optical measurements can be used convincingly to imply other properties.

■ ROBERT POOL

Hubble Space Telescope Takes Aim at the Stars

Don't look for pretty pictures right away; even if the launch goes perfectly, it will take months to get Hubble going



Free at last! *An artist captures the moment when Hubble sets out on its own.*

AFTER ALMOST TWO DECADES of technical snafus, huge cost overruns, and a seemingly unending series of delays, the National Aeronautics and Space Administration's $1.55-billion Hubble Space Telescope is finally headed for the launch pad. The space shuttle Discovery is standing by to carry the telescope aloft at 9:21 EDT on the morning of 12 April (or as soon thereafter as weather and technical glitches permit). And if all goes well, astronomers and NASA officials will breathe a collective sigh of relief.

But that doesn't mean that the wait will be over: Before the telescope begins routine observations, NASA has penciled in at least 8 months of engineering tests and scientific calibration. Points out Peter Jakobsen, Space Telescope project scientist for the European Space Agency, which contributed the telescope's ultrasensitive Faint Object Camera, Space Telescope is the most complex and exquisitely precise scientific instrument ever built. So getting it operational in space entails exploring an engineering Twilight Zone: "There's only so much you can do on the ground beforehand."

Those 8 months will hardly be boring, however. Here are some milestones to watch for:

■ **Reaching orbit.** Since the launch comes just after the peak of the current sunspot cycle, when the earth's tenuous upper atmosphere has been warmed and expanded to its greatest extent, NASA's most urgent priority will be to keep the telescope from spiraling earthward too quickly due to atmospheric drag. Discovery's target altitude has therefore been set at 611 kilometers, which it should reach in under an hour. This altitude is roughly twice as high as shuttles usually go, and right at the ragged edge of where Discovery can carry a payload as heavy as the telescope with its engines going flat out. Assuming Discovery makes it, however, Space Telescope should be safe for about a decade.

But what if, say, an engine fails during launch and forces Discovery into a lower orbit? If that orbit is lower than 526 kilometers, then the astronauts will have no choice but to bring the telescope home again—otherwise, the atmospheric drag would bring the telescope down to a fiery death within 12 months. But if the orbit is higher than 526 kilometers, then the astronauts will go ahead and deploy the telescope anyway. Despite extensive engineering studies showing that the telescope's precision optics should survive the shock of a forced landing, no one wants to try it unless they absolutely have to. Instead, shuttle planners back on the ground would prepare for an emergency mission to reboost the telescope in 6 months to a year.

■ **Deployment.** Even if the launch goes perfectly, says Orbital Verification manager Michael Harrington of NASA's Marshall Space Flight Center, it will still be another full day before the telescope is ready for free flight. Starting about 4½ hours after launch, when the astronauts first supply power to run the telescope, ground controllers will spend the next 19 hours activating its communications systems, thermal controls, computers, scientific instruments, gyroscopes, pointing systems, and tape recorders.

Only when the telescope has been fully brought to life, about 23½ hours after launch, will mission specialist Steven A. Hawley reach out and grab it with the shuttle's remote manipulator arm. Shifting the telescope to internal battery power and releasing the cable that had supplied power from the orbiter, Hawley will lift the telescope out of the payload bay and slowly turn it this way and that to check for damage. (The procedure will be recorded on large-format IMAX film for later showings to the public.) Next, without releasing his grip, Hawley will flip the telescope barrel downward toward the orbiter so that ground controllers can command the unfolding of the solar panels and radio antennas.

This is a critical moment, says Harrington. The telescope's solar panels have to be open to the sun and generating power within 6½ hours; otherwise the telescope's batteries will be drained to the point that they cannot be recharged. Therefore, mission specialists Kathryn D. Sullivan and Bruce McCandless II will be standing by in the shuttle's lower deck. If the solar panels or antennas should fail to deploy, they will quickly climb into their space suits and exit the shuttle, carrying an assortment of high-tech wrenches to do the job by hand.

With or without the hazards of a space walk, Hawley will next turn the spacecraft until the barrel is pointed away from the sun. He will then open the grappling device at the end of the manipulator arm and set the telescope free. If all goes according to schedule, that moment will come 1 day, 5 hours, and 24 minutes after launch.

But deployment won't be over yet, says Harrington. While ground controllers continue with their checkouts of the telescope's communications and attitude control systems, shuttle commander Loren J. Shriver will fire Discovery's control jets and slowly back away about 45 miles. He will hold the orbiter at that distance for the next 2 days waiting to see if ground controllers can properly open the telescope's aperture door—the round hatch that closes off its front opening as a protection against dust and contamination from the shuttle's jets. If the door refuses to open, Discovery will have just enough fuel to make one trip back to the telescope so that Sullivan and McCandless can go to work with their wrenches. But if it does open, says Harrington, then Discovery is free to come home: the telescope's near-perfect mirrors will at last be open to starlight.

■ **Orbital Verification and first light.** Next comes 3 months of engineering tests and checkouts, as ground controllers work to calibrate the instruments, align the optics, and bring the telescope's images into precise focus. About 2 weeks after launch, the telescope is scheduled to open its shutter for its first image of the heavens: an open star cluster known as NGC 3532 in the southern constellation Carina. "It's a pretty mundane star field," says astronomer Eric Chaisson, spokesman for the Space Telescope Science Institute in Baltimore. It was selected mainly because that's where the telescope will happen to be pointed at the time. It may not even be in perfect focus. "But it will be historic," Chaisson adds. "If we had a picture of the first thing Galileo saw through his telescope, you can bet it would be in all the textbooks, no matter how crummy it was."

■ **Science Verification and the first productive science.** Once the Orbital Verification phase is complete, the Space Telescope team will begin a 5-month period known as Science Verification, during which they will measure optical distortion, evaluate scattered light inside the telescope, practice the acquisition and tracking of moving targets, and generally learn how to use the spacecraft for astronomy. "We have all kinds of plans and procedures," says NASA's Space Telescope project scientist Albert Boggess, "but until we get into space, we can't be sure they'll really work."

The first scientific research with Space Telescope will actually begin during this period, says Boggess. Each of the telescope's six scientific instruments will be calibrated and fine-tuned by the team of astronomers who worked with NASA and ESA to develop it (see box above). Indeed, many of those astronomers have spent the better part of two decades waiting for this moment —and they have every intention of skimming off some scientific cream at the same time they are doing the calibrations. Moreover, the rights of these Guaranteed Time Observers will extend well into the routine "Science Operations" phase of the telescope, which is scheduled to begin 8 months after launch. The guaranteed observers will automatically receive 34% of the telescope's observing time between months 8 and 19; 24% for the 12 months after that; and 12% for yet another 10 months. (The remaining time will go to other astronomers who have made proposals through the science institute.) "It's their reward for spending so much time [on the project]," says Boggess. And from NASA's point of view, he adds, their work will be "the proof of the pudding"—a demonstration that all the parts of the telescope will actually work together for science.

■ **M. Mitchell Waldrop**

WHAT WILL HUBBLE LOOK FOR?

INSTRUMENT	PRINCIPAL INVESTIGATOR	SOME TYPICAL TARGETS
WIDE FIELD/ PLANETARY CAMERA	James Westphal (Caltech)	Massive black hole in the Andromeda galaxy; quasar "engines"; surface maps of Pluto; protoplanetary disks around nearby stars; Voyager-quality images of Jupiter
FAINT OBJECT CAMERA	Ducchio Macchetto (ESA)	Distant, newborn galaxies; binary stars; gas and dust envelopes around the star Betelgeuse; extrasolar planets (if possible); high-energy quasar jets
HIGH RESOLUTION SPECTROGRAPH	John C. Brandt (Colorado)	Aurora on Jupiter; massive stellar winds from red giant stars; hot, pulsating white dwarf stars; shock waves in interstellar gas; interstellar molecules
FAINT OBJECT SPECTROGRAPH	Richard J. Harms (Applied Research Corp.)	Gravitational lenses; filaments in the Crab nebula; supernova remnants; primeval galaxies near quasars
HIGH SPEED PHOTOMETER	Robert C. Bless (Wisconsin)	Cataclysmic variable stars; stellar diameters; accreting gas around neutron stars; Saturn's rings
FINE GUIDANCE SENSORS	William H. Jefferys (Texas)	Calibration of the cosmic distance scale; evidence for extrasolar planets; deflection of starlight by Jupiter