Working In Space

One of the great advantages of working in space is that objects,including the astronauts themselves, have no apparent weight. Regardless of the weight of an object on Earth, a single crew member can move and position that object in orbit with ease provided the crew member has a stable platform from which to work.

The physics of working in space is the same as that of working on Earth. All people and things contain matter and consequently have mass. Because of that mass, they resist any change in motion. Physicists refer to that resistance as inertia. The greater the mass, the greater the inertia.

Like on Earth, to change the motion of objects in space requires an application of force. How much the object moves is explained in part by Sir Isaac Newton's Third Law of Motion. The law states that a force causing an object to move one way is met with an equal and opposite force in the other direction. The law is more familiarly stated as, "For every action there is an opposite and equal reaction." The consequence of this law in space is important. A simple Earth task, such as turning a nut with a wrench, can become quite difficult in space because the astronaut—and not the nut—may turn.

Application of force on Earth is easy because we plant our feet firmly on the ground. We can lift heavy objects upward because the equal and opposite force is directed downward through our legs and feet to Earth itself. Earth's inertia is so great that its response to the downward force is infinitesimal. In space, on the other hand, astronauts do not have the advantage of having a planet to stand on to absorb the equal and opposite force during work activities. As explained in the Third Law of Motion, pushing on an object causes the object and the crew member to float away in opposite directions. The rates at which the crew member and the object float away from each other is determined by their respective masses. For example, a massive satellite will move away much more slowly than the less massive astronaut pushing on it. To gain advantage over objects, the spacesuited crew member must be braced, through foot restraints, by a stable platform, such as a massive and actively stabilized Shuttle orbiter or International Space Station.

EVA

As Apollo spacesuits were being developed for walking on the surface of the Moon,a special set of tools was designed to assist astronauts in their sample collecting task. The Apollo suits were stiff, and bending at the waist was difficult and awkward.

The problem of picking up rocks and soil samples was solved by creating long-handled sampling tools such as scoops and rakes. Because bulky spacesuit gloves made grasping difficult, tool handles were made thicker than normal.

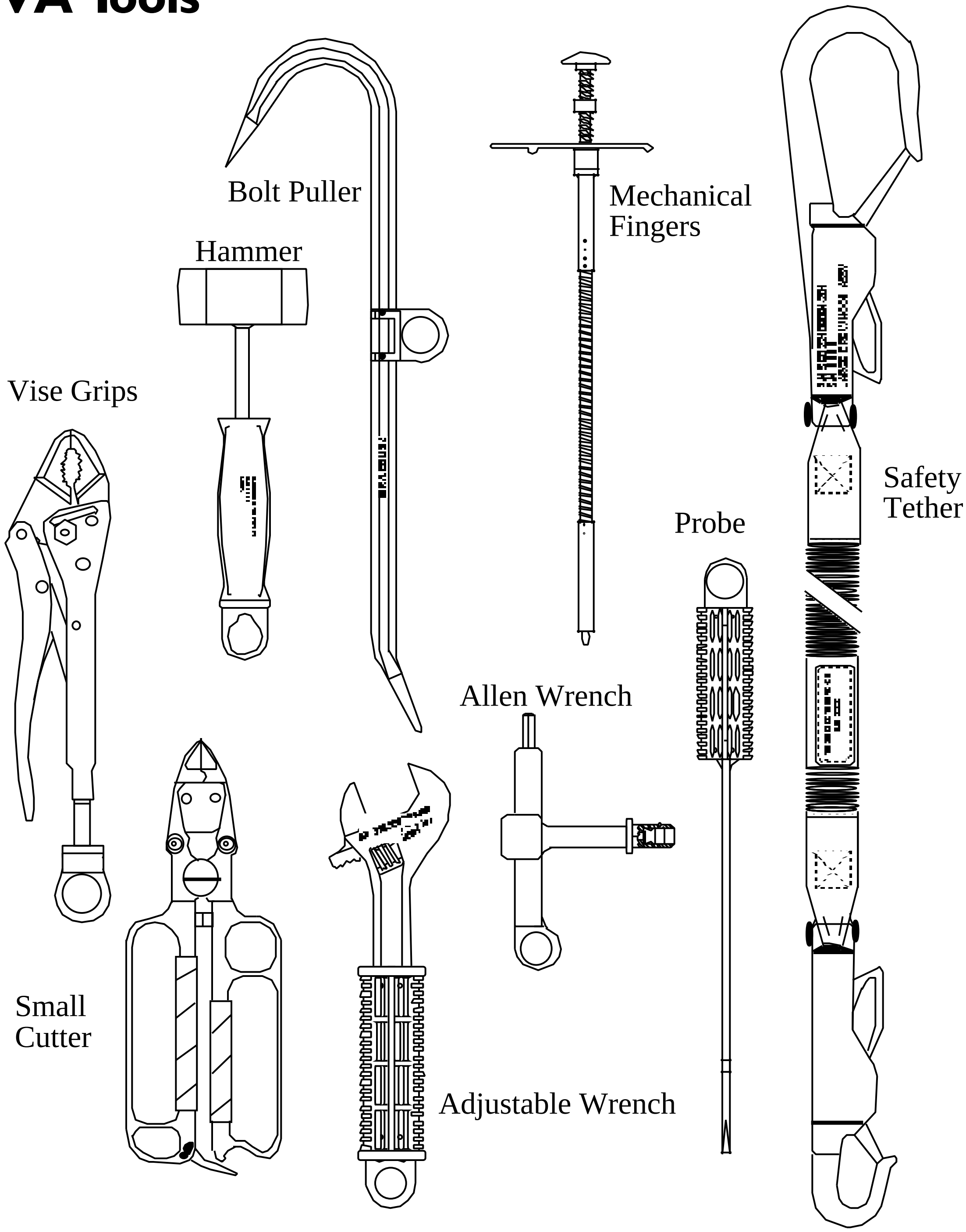
Today's spacewalkers have an extensive collection of EVA tools to employ during Shuttle and International Space Station missions. Several criteria are used in creating useful tools for space flight. Tools have to be easily gripped by astronauts wearing heavy gloves. The tools have to be safe to use and reliable under temperatures that can vary by hundreds of degrees. Tools also need some sort of attachment system so that if an astronaut should "drop" them,the tools will not float away. Colliding with a socket wrench left in orbit by some earlier space mission could be disastrous.

In the planning phase of each mission,tools are selected on the basis of the jobs that must be done. Specialized tools are often created when no existing tool will do the job. Many of the tools found in a traditional tool box on Earth are used in space as well. The tools are modified to make them easier and safer to use in space. For example, the handles of tools are often enlarged so they will take less energy to hold. A spacesuit glove is similar to a thick leather welder's glove in bulk.Because the suit glove is pressurized, the astronaut's fingers extend out when at rest. Closing the fingers around a tool handle takes a continuous application of force. Quite simply, small-handled tools take more force to hold than do large-handled tools.

To keep control of tools, each tool has some sort of tether or locking system. A socket wrench has a key that has to be inserted into a holder before a socket can be installed at the end of the wrench. Once the key is removed, the socket is then locked onto the wrench and cannot be removed without use of the key again.A short tether and clip enables the astronaut to hang on to the wrench in case it is dropped. There is even a tether on the key. Rechargeable power tools for driving bolts are also used by spacewalkers.

STS-82 Astronaut Steven L.Smith holds a power ratchet tool as he prepares to replace some ofthe instruments on the Hubble Space Telescope.

EVA Tools



The tools shown here are representative samples ofthe tools available to spacewalkers.Many EVA tools are standard Earth tools that have been modified for space use. Loops,to attach tethers,are added to prevent loss in orbit. For some tools,such as the adjustable wrench and probe, the handle has been enlarged to make grasping with a spacesuit glove less tiring.

Bruce McCandless II pilots the MMU in space for its first flight.

Astronaut Maneuvering Units

During the first American EVA, Edward White experimented with a personal propulsion device, the Hand-Held Maneuvering Unit (HHMU). The HHMU tested by White was a three-jet maneuvering gun. Two jets were located at the ends of rods and aimed back so that firing them pulled White forward. A third jet was aimed forward to provide a braking force. By holding the gun near his center of mass and aiming it in the direction in which he wanted to travel, he was able to propel himself forward. Stopping that movement required firing the center jet. The propulsive force of the HHMU was produced by releasing compressed oxygen from two small built-in tanks.

Although the HHMU worked as intended, it had two disadvantages. To produce the desired motion, it had to be held as close to the astronaut's center of mass as possible. Determining the center position was difficult because of the bulky spacesuit White wore and was a matter of guesswork and experience. Furthermore, precise motions to position an astronaut properly during an activity such as servicing a satellite were difficult to achieve and maintain and proved physically exhausting.

On the Gemini 9 mission, a backpack maneuvering unit was carried. However, problems with the unit prevented Gene Cernan from testing it.

Following the Gemini program, the next space experiments that tested maneuvering units for EVAs took place during the second and third manned Skylab missions. The device was tested only inside the spacecraft, but the experiment confirmed that a maneuvering device of that design was both feasible and desirable for future EVA use. Five of the six astronauts who flew in those two missions accumulated a total of 14 hours testing the advanced device, called the AMU, or Astronaut Maneuvering Unit. The AMU was shaped like a large version of a hiker's backpack. Built into the frame was a replaceable tank of compressed nitrogen gas. Controls for the unit were placed at the ends of "arm rests." To move, the astronaut worked rotational and translational hand controls. Propulsive jets of nitrogen gas were released from various nozzles spaced around the unit. The 14 nozzles were arranged to aim top-bottom, front-back, and right-left to produce six degrees of freedom in movement. The AMU could move forward and back, up and down, and side to side, and could roll, pitch, and yaw. With the 11 additional nozzles, precise positioning with the AMU was far simpler than with the HHMU of the Gemini program. The astronaut was surrounded by the unit, taking the guesswork out of determining center of mass and making control much more accurate. The astronaut could move closely along the surface of a curved or irregularly-shaped object without making contact with it.

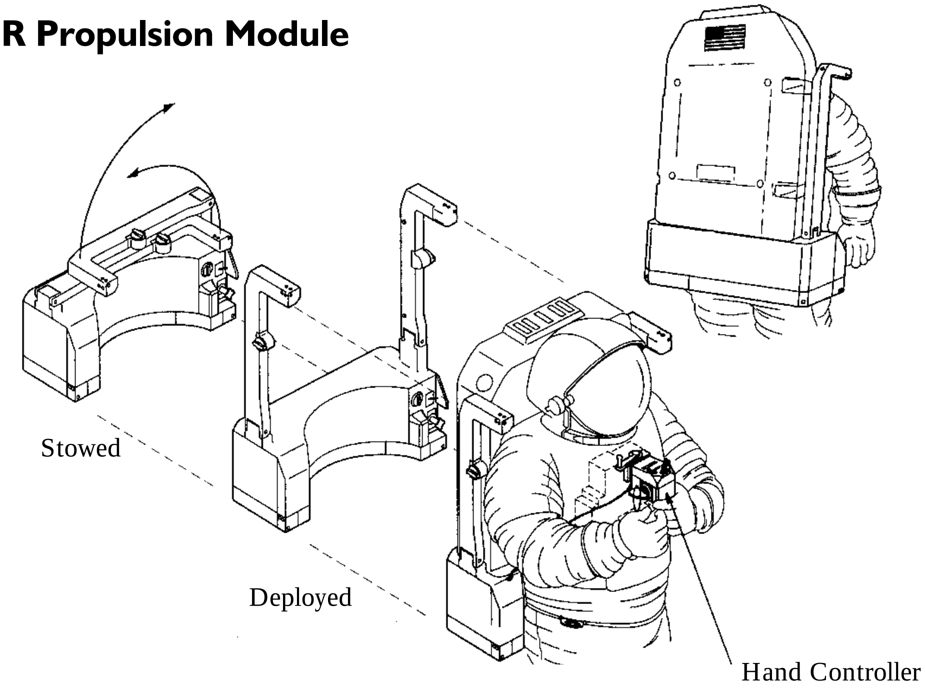
The AMU led to the MMU or manned maneuvering unit for use during early Space Shuttle flights. It was designed to operate in the microgravity environment of outer space and under the temperature extremes found there. The MMU was operated by a single space-suited astronaut. The unit featured redundancy to protect against failure of individual systems. It was designed to fit over the life-support system backpack of the Shuttle EMU.

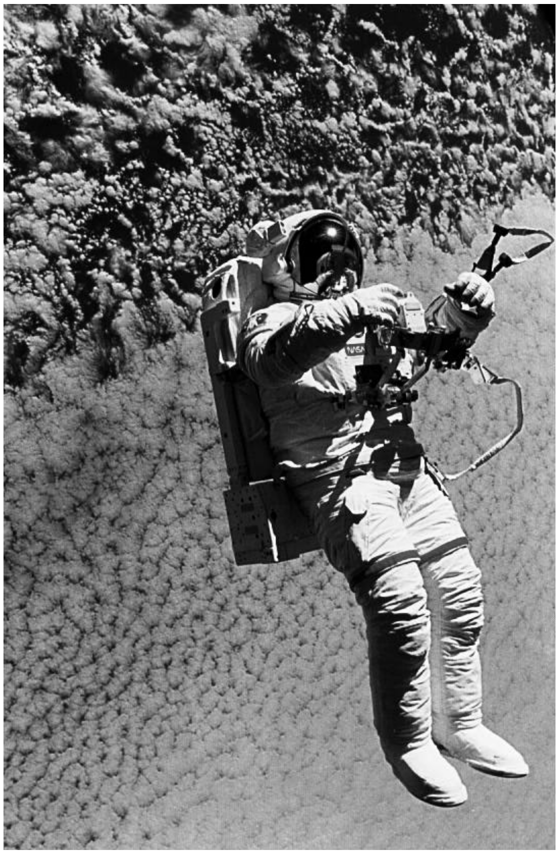
The MMU was approximately 127 centimeters high, 83 centimeters wide, and 69 centimeters deep. When carried into space by the Shuttle, it was stowed in a support station attached to the wall of the payload bay near the airlock hatch. Two MMUs were carried on a mission with the second unit mounted across from the first on the opposite payload bay wall. The MMU controller arms were folded for storage, but when an astronaut backed into the unit and snapped the life-support system into place, the arms were unfolded. Fully extended, the arms increased the depth of the MMU to 122 centimeters. To adapt to astronauts with different arm lengths, controller arms could be adjusted over a range of approximately 13 centimeters. The MMU was small enough to be maneuvered with ease around and within complex structures. With a full propellant load, its mass was 148 kilograms.

Gaseous nitrogen was used as the propellant for the MMU. Two aluminum tanks with Kevlar® filament overwrappings contained 5.9 kilograms of nitrogen each at a pressure of 20.68 kilopascals, enough propellant for a six-hour EVA, depending on the amount of maneuvering done. In normal operation, each tank fed one system of thrusters. At the direction of the astronaut, through manual control or through an automatic attitude-hold system, propellant gas moved through feed lines to varying combinations of 24 nozzles arranged in clusters of three each on the eight corners of the MMU. The nozzles were aimed along three axes perpendicular to each other and permit six degrees of freedom of movement. To operate the propulsion system, the astronaut used his or her fingertips to manipulate hand controllers at the ends of the MMU's two arms. The right-hand controller produced rotational acceleration for roll, pitch, and yaw. The left controller produced acceleration without rotation for moving forward-back, up-down, and left-right. Coordination of the two controllers produced intricate movements in the unit. Once a desired orientation had been achieved, the astronaut could engage an automatic attitude-hold function that maintained the inertial attitude of the unit in flight. This freed both hands for work.

The MMU was used on three Shuttle missions in the mid 1980s. It was first tested by Bruce McCandless and Robert Stewart on the 1984 STS

SAFER Propulsion Module





Mark C.Lee test flies the Simplified Aid for Extravehicular activity Rescue (SAFER) device during the STS-64 mission.

41-B mission. Taking turns, the two astronauts flew the MMU out from the orbiter's payload bay to a distance of about 100 meters and tested complex maneuvers. On STS-41C, the next Shuttle mission, James Van Hoften and George Nelson used the MMU to capture the Solar Maximum mission satellite and bring it into the orbiter's payload bay for repairs and servicing. Their work increased the life span of the satellite. The final MMU mission was STS-51A that flew in November of 1984. The propulsion unit was used to retrieve two communication satellites that did not reach their proper orbit because of faulty propulsion modules. Joseph Allen and Dale Gardner captured the two satellites and brought them into the orbiter payload bay for stowage and return to Earth.

More recent experiments with astronaut maneuvering units took place on the 1994 STS-64 mission. A new device, called the Simplified Aid for Extravehicular activity Rescue (SAFER) was flown by Mark C. Lee and Carl J. Meade a few meters away from their orbiter. SAFER is a smaller unit than the MMU and is designed as a self-rescue device for use on the International Space Station. Although unlikely, an astronaut could become separated from the station during an EVA and a Shuttle not be available to retrieve the crew member. In that event, the crew member would use the propulsive power of SAFER to return to the station structure.

SAFER fits over the portable life support system of the Shuttle EMU. A control module consisting of a joystick and display is stowed in the bottom of SAFER. During operation, the control module is moved to the suit's front for easy access. With the controls the astronaut can expel nitrogen gas through 24 nozzles that are fixed in different orientations around the device. An autopilot system is available to keep the astronaut at the same orientation for a limited period of time. SAFER features the same maneuverability as the MMU but because its nitrogen tank only holds 1.4 kilograms of nitrogen gas, the total velocity change possible with the unit is 3.05 meters per second.