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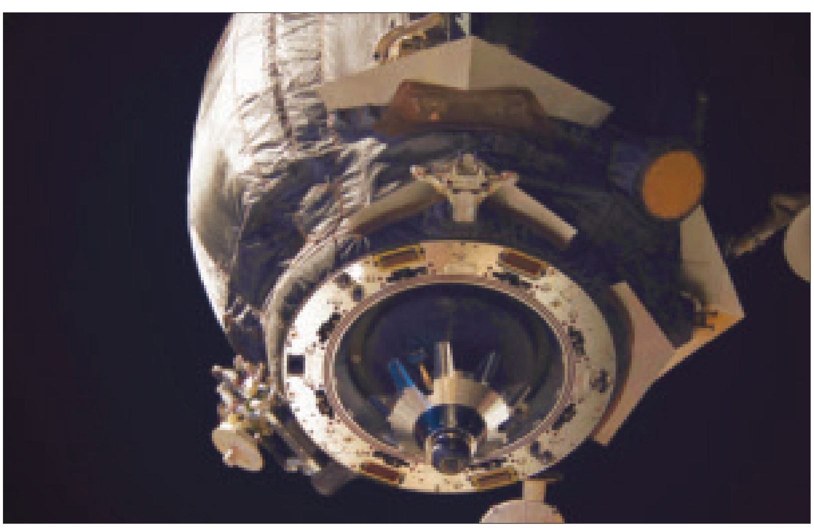
Space logistics

Space logistics is the theory and practice of driving space system design for operability, and of managing the flow of materiel, services, and information needed throughout a space system life cycle. This was a big year for ISS sustainment, involving delivery of over 25 tons of storage volume, propellant, oxygen, water, food, medical supplies, and spare parts. Moving this much cargo required a multinational effort by Japan, ESA, the U.S., and Russia and includes plans for the world's first commercial ISS cargo demonstrations via a SpaceX Falcon 9/Dragon flight scheduled for this month and an Orbital Sciences Taurus II/Cygnus flight early next year.

The unmanned Japan Aerospace Exploration Agency (JAXA) Kounotori 2 (HTV2) led with a January 27 ISS rendezvous—marking JAXA's second delivery (4.2 tons of supplies) to the ISS. HTV2 is now the only vehicle able to deliver both internal and external cargo. The external cargo is mounted to an exposed pallet that sits in the HTV's unpressurized section. The HTV2 flight recorded several firsts: It was the first flight of unpressurized spares and hardware on a vehicle other than a shuttle; it was the first robotic transfer of the exposed cargo pallet using both Canadarm2 and the Japanese robotic arm; and it was the first Dextre-based robotic transfer of external stores from the pallet to other locations.



The Progress 41 supply vehicle departed from the ISS on April 22. Filled with trash and discarded items, it descended to a destructive reentry into Earth's atmosphere over the Pacific Ocean.

ESA's unmanned ATV2, Johannes Kepler, docked with the ISS on February 24, bringing over 7 tons of fuel, oxygen, and supplies. This follows the 2008 Jules Verne ATV mission, which carried only about one-third as much cargo. It is now the largest and heaviest vehicle that can supply the station and serves in several important roles, including cargo carrier, temporary storage facility, and space tug for adjusting the station's orbit. It can deliver about three times more fuel than the Progress vehicle.

Final shuttle flights STS-133 (Discovery), -134 (Endeavour), and -135 (Atlantis) all performed significant logistics support functions for the ISS. Discovery's delivery of the Leonardo multipurpose module adds critical permanent storage space to the ISS. Discovery also transported the ExPRESS Logistics Carrier (ELC) 4, which in turn holds several orbital replacement units (ORUs). Endeavour's final mission included ELC3 with more ORUs that were too large or too heavy for other transport spacecraft to carry. Endeavour also left behind its orbiter boom sensor system, which can facilitate station repairs, as demonstrated by a torn solar panel fix during STS-120. Significant logistics highlights of the Atlantis flight included delivery of the robotic refueling mission for on-orbit satellite refueling testing, and Earth transport of the 1,400-lb broken ammonia pump module for failure analysis and repair. The shuttle's demise means that the Soyuz is now the only viable path for down-mass transportation, but it cannot accommodate ORUs of the ammonia pump's size or weight.

ISS resupply must rely primarily on Russian Progress flights until other options mature. The five Progress missions planned for this year each carry an average of about 3 tons of supplies. This logistics strategy was challenged on August 24 when Progress 44 failed to reach orbit because of a Soyuz rocket anomaly—marking the first Progress ISS mission failure, and raising questions about the ability to provide short-notice resupply after launch failure. Effective long-term sustainment will require robust, responsive launch options.

While the ISS dominated the space logistics field this year, other exciting developments are under way. NASA is actively exploring in-space fuel depots, as seen in the ISS robotic refueling mission and in the contracts awarded to Analytical Mechanics Associates, Ball Aerospace, Boeing, and Lockheed Martin to explore cryogenic fluid management technology and infrastructure. Space-based fueling is vital for enabling an extended human presence in space.

by **Alan W. Johnson**