23 Space Logistics and Manufacturing

23.5 Multi-Spacecraft Manufacturing

The Iridium® Satellite Assembly Process

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The original Iridium® System was an operating constellation of 66 low-earth communications satellites. Deployment started in 1997 and concluded with two spares launches in 2002. During steady-state production and deployment, on average more than one satellite a week was completed, shipped, launched and brought into service.

The Iridium® Satellite Assembly Factory comprised 15 process stations. These stations completed specific functions. The satellites flowed from station to station throughout the factory until Station 15. At Station 15, workers packed and sent the satellites to the launch sites. During steady-state production, the total time to proceed from Station 1 to Station 15 was 24 days.

Station 0: Material Receipt

All material and subsystems are received into the satellite factory. Major systems received into the factory include:

- Gateway antennas (4)
- Crosslink antennas, fixed (2) and moving (2)
- Panels (communications and gateway)
- Main mission antennas (3)
- Solar arrays (2)
- Satellite bus assembly

The satellite bus assembly, complete with propulsion and guidance systems, is received already mounted on a wheel-mounted dolly. This dolly, collaboratively developed for use throughout the satellite delivery process, is used for satellite assembly, shipment, and launch-site processing. The dolly also allows for access to all sides of the satellite via rotation, and can be easily maneuvered through the factory.

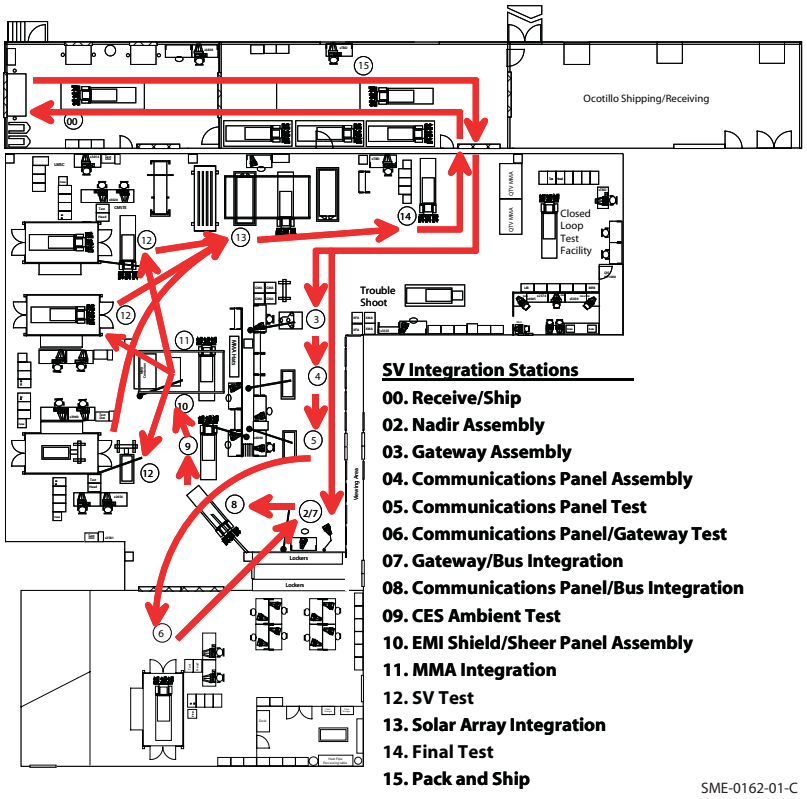

Fig. 23web-7. Iridium® Satellite Factory. A flow factory designed with lean manufacturing principles enabled paradigm breaking results. Total integration factory space was only about 13,000 square feet.

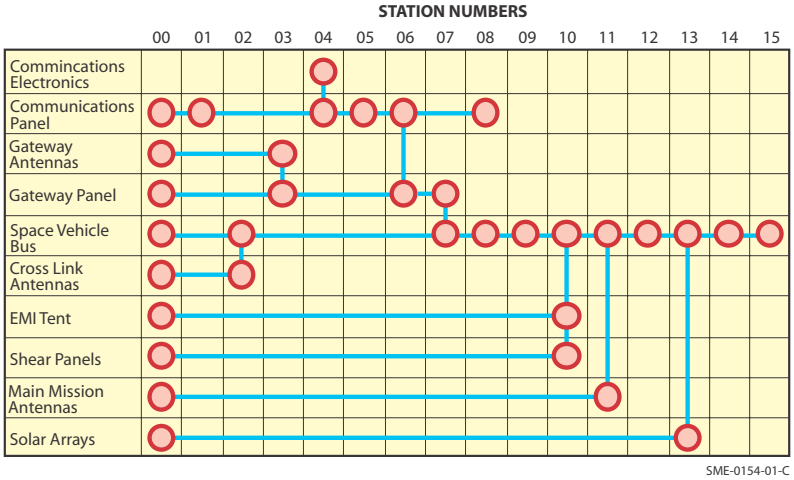

Fig. 23web-8. Logical Product Flow. 15 process stations were designed to effectively and efficiently build satellites at a rate of one per week.

Station 1: Heat-Pipe Bonding

The heat-pipe is thermally bonded to the communication panel. This is the only process that does not occur within the integration factory.

Note: Stations 2–4 operate in parallel

Station 2: NADIR Panel Assembly

The four crosslink antennas—two moving and two fixed—and the radiator plate are installed to the nadir bulkhead end of the bus.

Station 3: Gateway Panel Assembly

Gateway antennas (4), waveguides, antenna positioning equipment, cable harnesses, and other components are installed to the gateway panel. During this process, a trunion dolly holds and rotates the panel.

Station 4: Communications Panel Assembly

Motorola supplied units are installed on the communications panel. A rotating trunion dolly designed for the communications panel holds it.

Station 5: Communications Panel Test

The completed communications panel is tested.

Station 6: Communications Equipment Subsystem (CES) Test

The CES consists of equipment on the communications panel and the gateway panel. Cables are installed to temporarily link the two panels. This station initially verifies the functionality and performance of the CES hardware over temperature cycles, prior to being integrated in the spacecraft.

Station 7: Gateway Panel Assembly Integration

The completed gateway panel is installed onto the bus assembly. First, the panel is rotated to the vertical position, aligned to the spacecraft bus, and then mated to the bus. Cables and harnesses are then attached.

Station 8: Communications Panel Assembly Integration

The completed communications panel is installed onto the bus assembly. The panel is first rotated 180 degrees while in the trunion dolly. A strongback fixture is then attached to the panel for support and alignment. The panel is lifted over the spacecraft, aligned, and finally installed. The panel is securely fastened in place and all cables and harnesses are attached.

Station 9: Space Vehicle Test

(Or Integrated Communication Equipment Subsystem (CES) Test)

Testing is performed on the newly integrated communication panel, gateway panel, and spacecraft bus. This test verifies the CES functionality and performance.

Station 10: EMI Tent and Shear Panel Installation

An EMI tent is installed over the communications panel. Shear panels are then installed on the remaining two open sides of the bus structure.

Station 11: Main Mission Antenna Integration

The satellite is rotated horizontally on the dolly to attach the main mission antennas (MMA), one at a time. First, an attachment fixture is mounted on to the MMA. This fixture contains the lift points for using the lifting crane. The MMA is held vertically over the spacecraft and lowered to connect one end. RF, power, and signal cables are attached. The free end of the MMA is then lowered until flat against the spacecraft. The MMA deployment mechanisms are adjusted and set. Finally, this process is repeated for each of the three MMAs required.

Station 12: Space Vehicle (Integration) Test

Full-functional testing of the MMAs, communications payload, and bus is conducted. The testing includes seven complete hot-cold thermal cycle tests.

Station 13: Solar Array Integration

Two solar array wing assemblies are integrated onto the spacecraft in a manner similar to MMA installation. First, an attachment fixture is mounted onto the solar array. This fixture contains the lift points for using the lifting crane. The solar array is held vertically over the spacecraft and lowered to connect one end. The cables are attached. The free end of the solar array is then lowered until flat against the spacecraft. The deployment mechanisms are adjusted and set. Finally, this process is repeated for the second solar array.

Station 14: Launch Confidence Test

Flight software is loaded and verified and solar array operation is tested. Finally, the vehicle is powered down and prepared to flight-ready condition.

Station 15: Space Vehicle Pack and Ship

The completed satellite is prepared for shipment to one of three launch-sites. Consent-to-ship authorizations and checkout procedures are completed. The satellite, still mounted on the dolly, is loaded into the shipping container. The shipping container provides for an environmentally controlled and shock protected delivery to the launch-site.