Additive Manufacturing as a Flight-Critical Design Tool

Terra Nova used additive manufacturing not as a convenience, but as a design and manufacturing strategy across the launch vehicle and payload. The team applied polymer FDM printing for payload hardware, mechanism iteration, vehicle tooling, and assembly fixtures, while using laser powder bed fusion to manufacture Inconel 718 recovery-system bulkheads. These applications supported three different engineering needs: fast iteration, custom fabrication, and flight-relevant structural implementation.

Payload mechanism development

The Terra Inquisitor payload required a compact soil-acquisition system capable of deploying after landing, driving an auger into soil, collecting material, and transferring that material into a testing chamber. This mechanism had to fit inside the HAUS section while integrating propulsion, drilling, soil collection, water delivery, sensors, wiring, and structural support. The final payload contained more than 600 components, including 66 custom FDM-manufactured parts.

The final payload chassis used additive manufacturing as a structural packaging method. The chassis was split into printable sections and reinforced with embedded steel rods to improve rigidity while preserving subsystem access and printability. Custom printed features provided bearing pockets, mounting locations, actuator interfaces, auger supports, spring mounts, and soil-container geometry matched to the exact payload layout. In this system, additive manufacturing directly shaped the payload architecture by defining how the structure, soil-acquisition mechanism, and subsystem interfaces fit within the available rocket volume.

FDM printing was also essential to the soil-acquisition mechanism. The linkage, auger support, collection sleeve, and spring interface depended on physical fit, motion, and alignment that could not be fully validated in CAD alone. The team printed mechanism revisions, assembled them with representative hardware, tested for binding and alignment issues, and revised the geometry before final integration. This allowed the team to correct problems early without waiting on machined parts or committing to a single untested design.

Launch-vehicle tooling and integration

Terra Nova also used additive manufacturing to fabricate vehicle tooling for geometry that was not commercially available. The launch vehicle required a custom transition from 6-inch to 5-inch internal-diameter airframe sections. Because no off-the-shelf transition matched the required aerodynamic profile, the team printed PETG molds and used them as tooling for fiberglass composite layups. This allowed the team to manufacture a custom composite transition matched to the vehicle geometry using a repeatable, low-cost mold process.

Separate from the transition, printed tooling improved vehicle construction repeatability. The team used printed fin guides, alignment fixtures, epoxy tooling, and fit-check prototypes during assembly. These parts were not flown components, but they improved the accuracy and consistency of bonded components. This demonstrated an important use of additive manufacturing: not every printed part must fly to improve the quality of the flight vehicle.

Metal additive manufacturing in the recovery load path

The team's most advanced implementation was the use of laser powder bed fusion Inconel 718 bulkheads as recovery-system load-path hardware. These bulkheads served as structural interfaces between the recovery harnesses and the launch vehicle airframe during parachute deployment. The team designed them using conservative recovery-load estimates, safety factors, finite element analysis, and material-property validation. The team tested 3D printed Inconel 718 specimens according to ASTM standards to evaluate material behavior before finalizing the bulkhead design.

The team also addressed a real additive-manufacturing integration challenge. The printed bulkheads had fitment distortion after manufacturing, so Terra Nova printed PETG correction molds and used controlled epoxy buildup to restore circular fit before flight integration. This process connected additive manufacturing to inspection, correction, and flight readiness rather than treating printed parts as automatically usable after fabrication.

During the vehicle demonstration re-flight, all four Inconel 718 bulkheads flew in the full-scale launch vehicle and were recovered with no damage or detachment from the airframe. Across the payload and vehicle, Terra Nova used additive manufacturing for rapid iteration, compact mechanism design, custom composite fabrication, assembly repeatability, metal structural hardware, and flight validation.

Payload Additive Manufacturing: Terra Inquisitor

Figure 1: Final Terra Inquisitor layout showing FDM-enabled packaging of drive, drilling, soil collection, water delivery, and testing subsystems.

Figure 2: Split printed chassis reinforced with embedded steel rods for stiffness, printability, and subsystem integration.

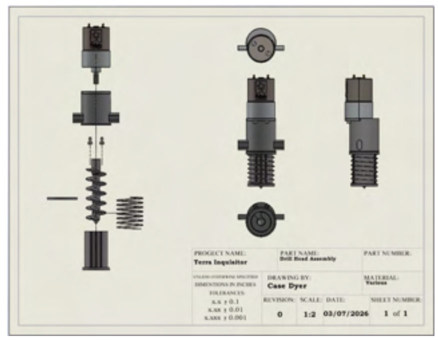

Figure 3: Printed auger supports and spring interfaces allowed the soil acquisition system to fit inside the HAUS Payload.

Figure 4: Early printed linkage prototype used to identify binding, packaging, and pivot-spacing issues.

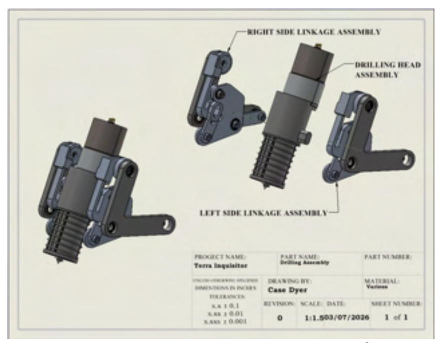

Figure 5: Final linkage geometry after printed iteration of crank, rocker, slot-link, actuator, and auger alignment.

System	Additive Manufacturing Consideration	Final Implementation
Chassis	Needed stiffness while remaining printable and serviceable	Split FDM frame with embedded steel rods
Auger System	Soil collection inside constrained HAUS volume	Printed auger supports, collection sleeve, spring interfaces, and mounts
Linkage	Required physical motion validation within compact packaging	Iterative printed prototypes led to the final 3D-printed crank, rocker, and slot-link system

Table 1: Payload additive manufacturing converted packaging and motion constraints into final integrated hardware.

Launch Vehicle and Metal Additive Manufacturing

Figure 6: PETG printed mold used to form the custom 6-inch to 5-inch transition.

Figure 7: Fiberglass composite transition produced from printed tooling.

Figure 8: Laser powder bed fusion Inconel 718 recovery bulkheads used in the flight vehicle.

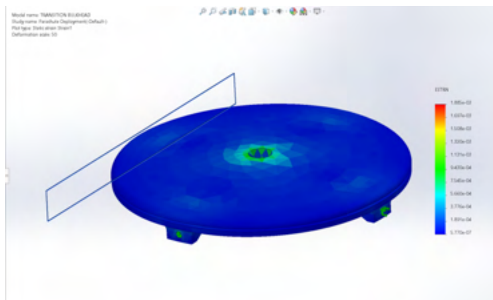

Figure 9: FEA stress plot used to evaluate bulkhead response in the recovery load path.

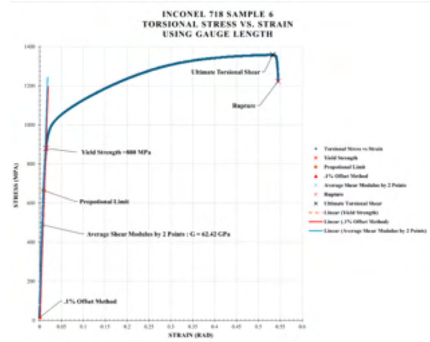

Figure 10: ASTM-based Inconel 718 specimen testing used to validate metal AM behavior.

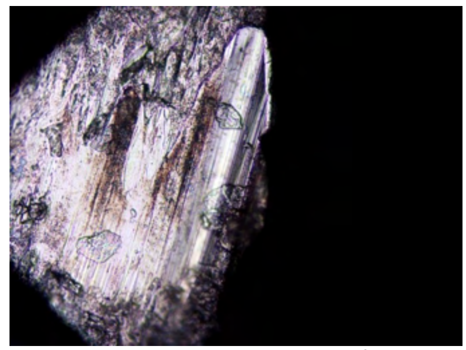

Figure 11: Fracture surface microscopy after heat treatment and material testing.

System	Additive Manufacturing Consideration	Final Implementation
Transition Tooling	No commercial transition matched the aerodynamic profile	PETG printed mold for fiberglass layup
Assembly Tooling	Vehicle bonding required repeatable alignment	Printed fin guides, fixtures, and fit-check tools
Recovery Bulkheads	High-strength custom load-path hardware	LPBF Inconel 718, FEA, testing, post-processing, and flight validation

Table 2: Launch vehicle additive manufacturing supported tooling, construction accuracy, and structural metal flight hardware.