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THE BINGHAM LANDER: NATURE-BASED INFLUENCES ON MONOCOQUE SPACECRAFT DESIGNS

Abstract

The Bingham Lander is a concept-spacecraft, as part of The Arcanum Mission to Neptune, designed to land on Neptune's moon, Triton. Bingham's current primary structure comprises a $TiAl_6V_4$ spaceframe which makes it compliant with the structural requirements for a Tritonian landing vehicle. Additionally, the $TiAl_6V_4$ spaceframe gives the Bingham a low-thermal conductivity during transit to Triton and once landed on the surface. However, the design would require a thermal management system to allow for specific heating of individual payload instruments, structural members, and critical subsystems. Whilst this is a commonly used method, the mass of decentralised thermal management systems with redundancies negate the simplicity and cost-savings attributed to spaceframe structures.

Two existing phenomena in nature seem promising for the possibility to eliminate the need for a decentralised thermal management system: reptile skin and clamshells. Reptiles have epidermal scales which are formed via folds in the epidermis. Combined with an excess of skin along the extremities, reptiles can be observed to stretch when basking to increase their surface area for absorbing or rejecting heat. In clamshells, the corrugations on the shell surface provide stiffness to the skin by increasing the moment of area in local tranches along the curvature of the shell.

We propose combining the behaviour of epidermal scales from reptile skin and the stretch from clamshells into a monocoque structure of thin gauge corrugated sheets using less exotic and expensive metal alloys. The profile and density of corrugations is then driven by the structural and thermal requirements of the lander and its subsystems. Waste heat from the Am-241 RTGs onboard Bingham provide centralised heating whereby the structure passively manages the thermal load on the internal subsystems. A generative design algorithm can be developed to output a sheet panel-based design of the Bingham Lander where mass is minimised. Prior applications of these methods to planetary landers show mass savings of over 30 percent. Coupled with an 11 percent mass saving from combined systems, this reduces the dry mass ratio from 0.68 by 15 percent. Such a combination of integration-focused design and use of optimised development tools is ideally suited to the development of a new generation of planetary landers.

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