WHITE PAPER:

Using Adaptable Thermal Control for Multi-Orbits, Multi-Missions Spacecraft with Dynamic Payloads

αSTRID™ transforms satellite radiators into programmable surfaces capable of accommodating a broad range of orbits and missions.

Performance Data	***αSTRID™***
Solar Absorptivity	0.3 (light mode) <> 0.9 (dark mode)
IR Emissivity	0.9
Operating Temperatures	-70°C / +125°C
Thickness	500 µm
Power	27 mW (refresh) / 0 W (idle)
Outgassing	Passes ASTM E595-15

Problem: New & Emerging Challenges

Companies providing standard satellites buses face a significant thermal challenge today. Conventional thermal design methods create one-off, mission-specific satellites that do not meet the needs of multi-mission and multi-orbit versatility. Traditional thermal control materials with their fixed properties are incapable of supporting late system-level trades or changes in requirements. Designing spacecraft with existing processes and using what's currently available on the market struggles to meet the demand for hardware that can roll up into configurations quickly and effectively to satisfy changing mission needs, whether on ground or on orbit.

Solutlon: Software-Definable Thermal Ctrl

αSTRID™ enables the thermal profile of satellites to be 'programmed,' using an easy-to-operate software controller. This helps satellite manufacturers configure their thermal control system more quickly, unlocking the ability for a standard satellite bus to adapt to any mission and thermal environment instantly.

Fly to any orbit — LEO, MEO, GEO — without physically reconfiguring the thermal control system

Flexible in Development Phase

A thermal architecture designed with ***αSTRID™*** at core makes it possible for thermal and systems engineers to quickly respond and adapt to changes in orbital parameters, operational scenarios, structural panel sizing, pointing requirements, heat pipe layout, or interface requirements. ***αSTRID™*** is the best-in-class thermal solution to achieve rapid designs & builds for standard satellite bus manufacturers where their payloads are often an unknown black box. They must wait for inputs from payload, such as their heat dissipation levels, before they can begin design & analysis. With this approach to thermal development workflow enabled by ***αSTRID™***, we help satellite manufacturers take as much wait times out of the schedule. ***αSTRID™*** offers unparalleled flexibility in thermal design considerations, leaving the door open for thermal and systems engineers to address uncertainties, accommodate new requirements, and close trades even at later stages.

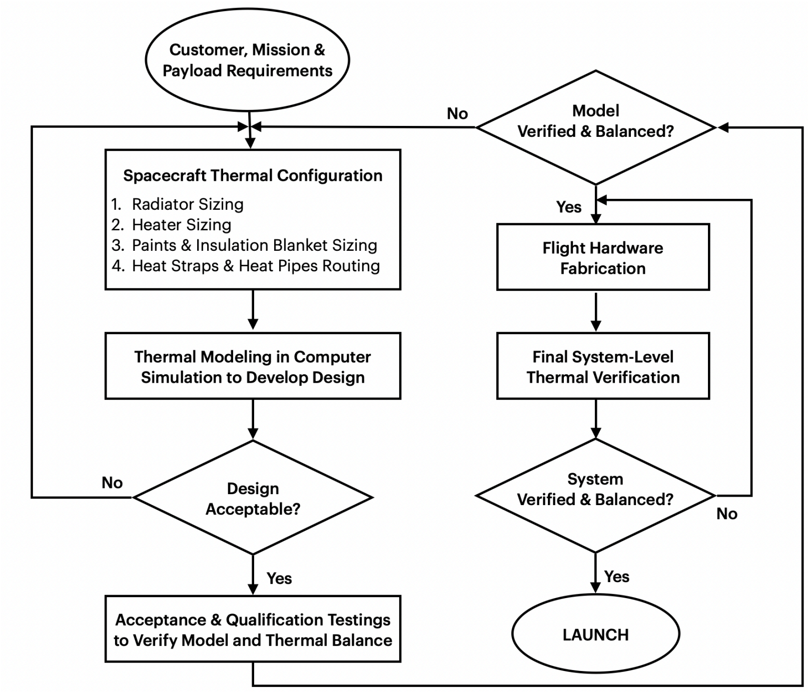

Fig. 1 Existing spacecraft thermal design process, development & verification cycle is stubborn

Reduce thermal development time by 40% compared to conventional thermal design approach

Flight Controller and In-Space Tuning

αSTRID™'s flight controller enables dynamic configuration of the radiator performance on orbit. It can be linked with real-time temperature inputs to perform processing, and directs the thermo-optical properties to optimize the thermal balance autonomously. The satellite thermal control system and mission control center can now operate in tandem as a real-time integrated system, driving coordinated calibration and final verification in orbit after deployment from launch vehicles – not weeks or months of testing, model correlations, and re-testing on the ground. Say goodbye to the days of painstakingly correcting that ±10% mismatch between simulation and TVAC result.

Beyond Designed Thermal Environments

As the space industry enters a new era of more dynamic mission operations, with satellites expecting on-orbit refueling, relocation, and life-extension, anytime anywhere, they can rely on ***αSTRID™***'s thermal adaptability as they navigate to unplanned orbits and beyond designed thermal environments. This will unlock multi-mission capabilities on these satellites, maximizing their useful lifetime.

Supporting Dynamic On-Orbit Operations

As satellite servicing vehicles rendezvous and dock with targets in orbit, it is only through adaptable thermal control that they will be able to maintain thermal balance across the two connected bodies.

αSTRID™ can help satellite operators account for unexpected challenges during docking operations, including thermal incompatibility, undesirable heat transfer, and shadowing from/to the other satellite. By maximizing the temperature modulation range, the satellite can respond to any type of challenges with agility.

Applications and Use Cases

For engineers reading this, you can easily integrate ***αSTRID™*** onto your spacecraft radiators like silver teflon tapes. The most common way of applying ***αSTRID™*** is configuring it as a 'thermal window', allocating a cut-out area in the insulation blankets/MLI that then serves as a radiator and heat sink for components that are active, electrical, temperature-sensitive, and/or variable-duty-cycle. Such components present an ideal application for ***αSTRID™*** thermal control.

An example is shown in Fig. 2. In this arrangement, when the payload component generates heat during the "on" portion of its cycle, ***αSTRID™*** is turned light to maximize heat rejection. Heat dissipated from payload is transferred across conductive paths using heat pipes or heat straps to be removed via radiators into deep space. During the "off" portion, payload starts dropping to freezing temperatures, so ***αSTRID™*** is turned dark to maximize heat absorption. This changes the direction of heat flow inward, warming up the unit.

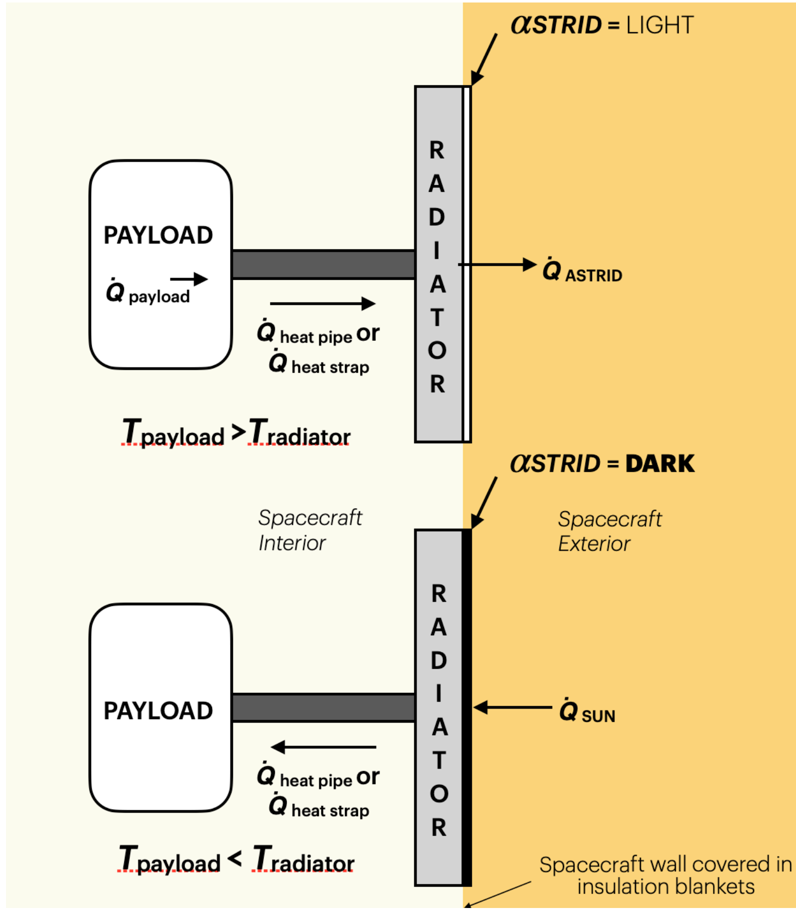

Fig. 2 *αSTRID™* varies surface absorptivity and reflectivity values to control the amount & direction of heat flow

$$\dot{Q} = \frac{kA}{L}\Delta T$$

The concept of controlling the direction of heat flow is governed by the temperature gradient (ΔT) in Fourier's Law where $T_{payload} - T_{radiator}$. ***αSTRID™*** can control the radiator temperature, providing variable conductance feature without the use of bulky heat pipes. This capability is particularly attractive if mass-saving is desired.

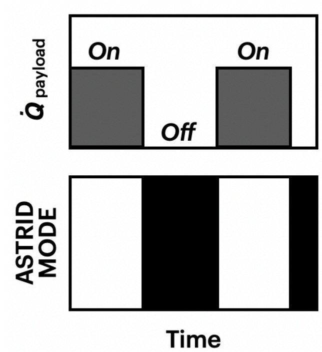

Fig. 3 Operation Cycles

As a satellite orbits the Earth, it passes in and out of Earth's shadow, encountering drastic thermal shocks. The alternating light and dark states of ***αSTRID™*** damps the heating and cooling and allows the payload to operate nearly isothermally throughout the orbit.

Final Words

Forward thinking space companies are already exploring ways to incorporate ***αSTRID™*** into their satellite architecture. Evaluation samples of ***αSTRID™*** are available for request today. This is an open invitation to thermal and systems engineers at all satellite manufacturers to be innovative.

From flexible performance to unique operational features, the technical merits and value proposition of ***αSTRID™*** are yet to be fully uncovered. SQUID3 can help you rethink your thermal systems design. Let us evaluate your existing thermal workflows through a fixed-cost pilot study and explore ways to enhance the scalability & flexibility of your thermal architecture.

Fig. 4 Conceptual Installation on a 3U Cubesat Model

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