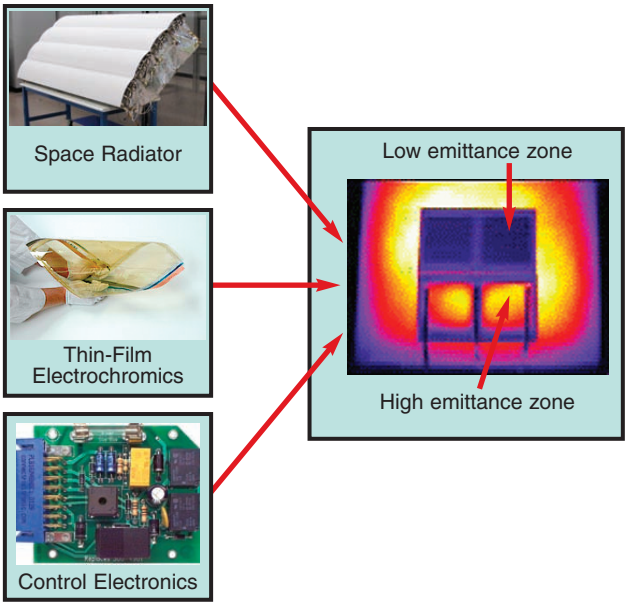
Variable Emissivity Radiator

Paragon has teamed with the NASA Johnson Space Center under a Space Act Agreement to develop variable emissivity radiators for near-term human spaceflight applications. This endeavor couples the radiator portion of a thermal control system with variable emissivity electrochromic technology. Unlike paint, which has a constant emittance, electrochromic films allow for direct variation of the radiator surface emissivity, which in turn varies the heat rejected from the space radiator. This method has significant advantages when compared to the more common method of varying the radiator temperature to control heat rejection.

Variable emissivity is of particular significance for vehicles with large variations in power usage and/or environment such as the Constellation program's Orion crew exploration vehicle. Using a traditional spacecraft radiator on such a vehicle, the required temperature swing is too large to allow the use of low cost, non-toxic, high thermal capacity working fluids such as water (which would freeze in low power states). However, a variable emissivity radiator enables heat to be rejected by the thermal control system without experiencing large swings in system temperature. This innovation could eliminate the need for hazardous working fluids, two-loop systems, and a host of heavy valves, heat exchangers, pumps, and other associated components. Furthermore, variable emissivity radiators can be designed for use on any exterior surface, and on a range of vehicles from nanosats to human rated spacecraft. Additional mass savings can be realized by incorporating structural functionality into the variable emissivity radiator design analogous to work Paragon has performed during development of the Integral Structural Radiator. Once matured, the variable emissivity radiator can be used to extend the useful envelope of "passive" thermal control systems, potentially eliminating the need for pumped-loop active thermal control systems (and their associated mass, power, volume, vibration, and reliability impacts).



The Variable Emissivity Radiator system couples spacecraft radiators, thin-film electrochromics, and solid state electronics to realize a lower-mass, higher reliability active thermal control system design compared to the existing and decades-old state of the art designs (Thin-film ElectroChromics and testing emittance photos courtesy Eclipse Energy Systems).

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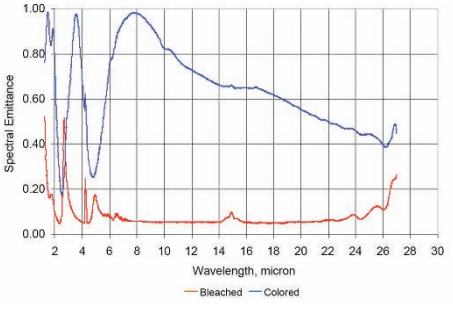
Preliminary variable emissivity radiator details:

1. System heat rejection ratio greater than 8 to 1 is currently achievable in isothermal applications, and much greater ratios can be achieved with allowances for temperature variation.
2. Durable micrometeoroid orbital debris (MMOD) design can be realized by incorporating electrochromic thin-film application into existing MMOD resistant radiator designs.
3. Low mass or reduced-mass integrated system-level design solutions can be realized. Electrochromic thin-films developed by Eclipse Energy Systems are less than 10 grams per square meter and replace the need for paints where they are applied. Depending on system design, application of the variable emissivity radiator can replace other thermal control system components (heat pipes, pumps, heat exchangers, valves, etc.) thus significantly reducing thermal control system mass.
4. Emittance state control allows the radiator system to fix radiator emissivity in an intermediate state for finer control.
5. Switching time between emittance state extremes can be customized to application-specific requirements with system response times on the order of a few minutes.
6. Extremely low control voltage of ± 2V to change/maintain state.
7. Low power required to change emissive states and even less to maintain them.
8. All radiator materials of construction are highly resistant to Atomic Oxygen.
9. Variable emissivity radiators can be manufactured in flat or curved geometries.
10. Functional thin-film electrochromic test modules developed by Eclipse Energy Systems are flying aboard Midstar-1.
11. Paragon is currently designing and manufacturing traditional radiators for the Orion Crew Exploration Vehicle.
12. Development status: Integrated variable emissivity electrochromic radiator test units are currently under development for near term testing.



Typical variation in thin-film electrochromic surface spectral emittance between the low emissivity (red) and high emissivity (blue) states (data courtesy Eclipse Energy Systems).