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Boyd Technologies Ashington UK Ltd

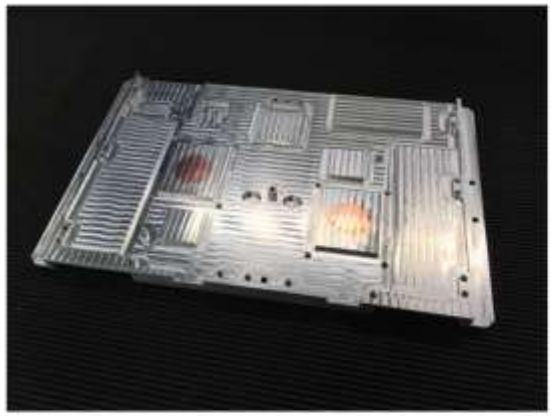
that cool, seal, protect, and interface with disruptive technologies

Space Thermal Control

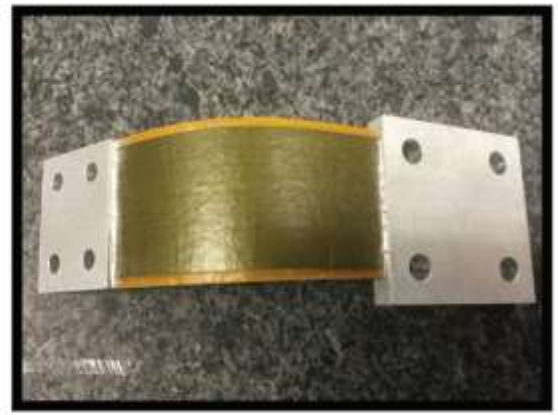
Thermal Control Products

Mini Heat Pipe Assemblies

k-Core® APG Loop Heat Pipe Spreaders

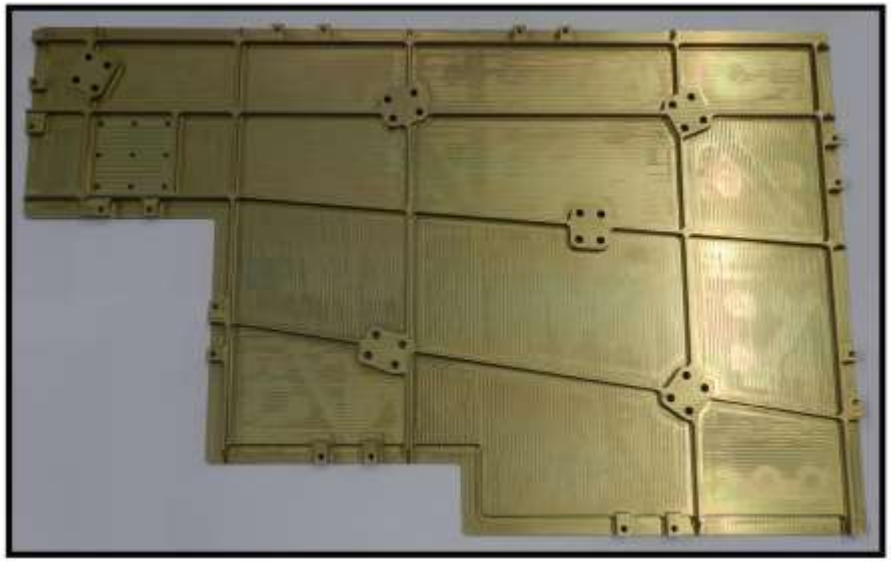


k-Core® APG Electronic Chassis

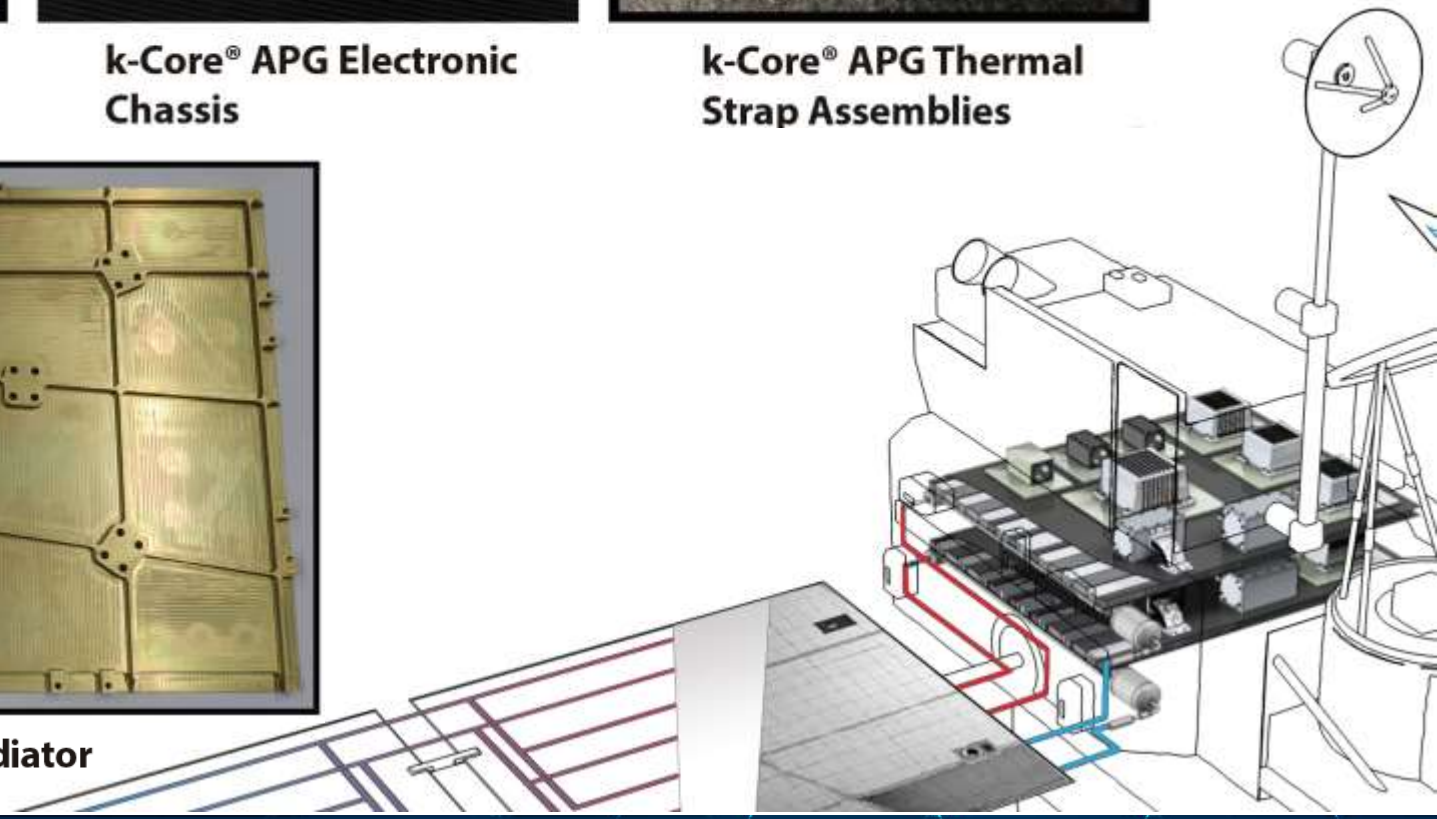


k-Core® APG Thermal Strap Assemblies

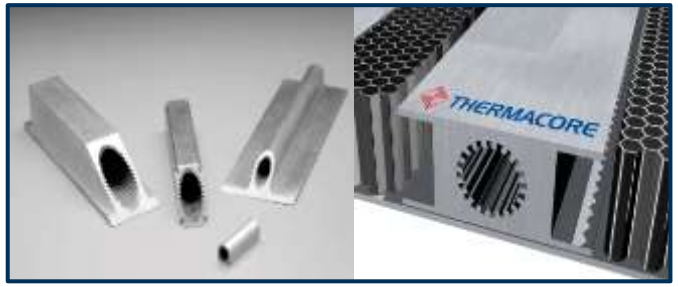
k-Core® APG Radiator
Made up of several APG segments and ribs machined in to the radiator to improve both mechanical and structural performance



k-Core® APG Multi-Segment Radiator

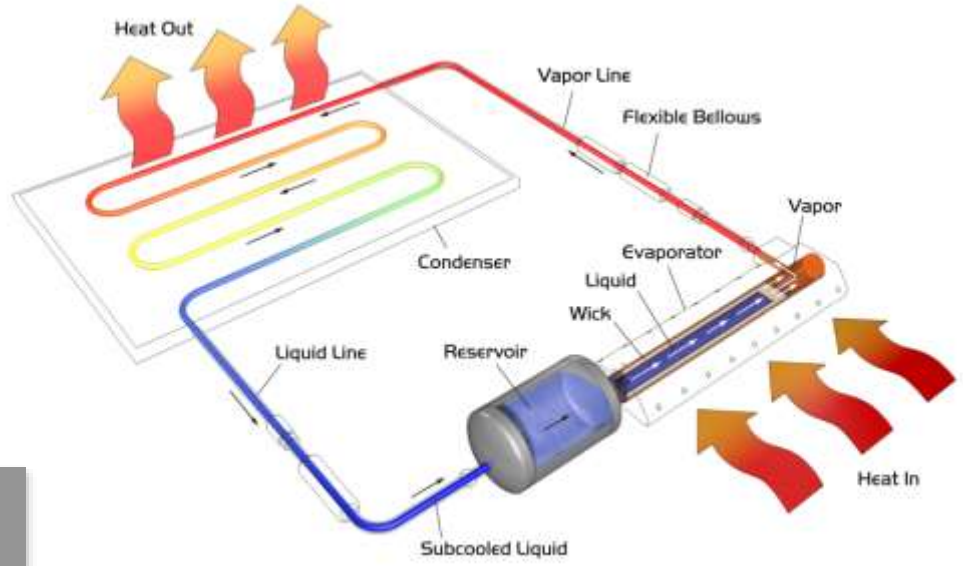


Thermal Control Products

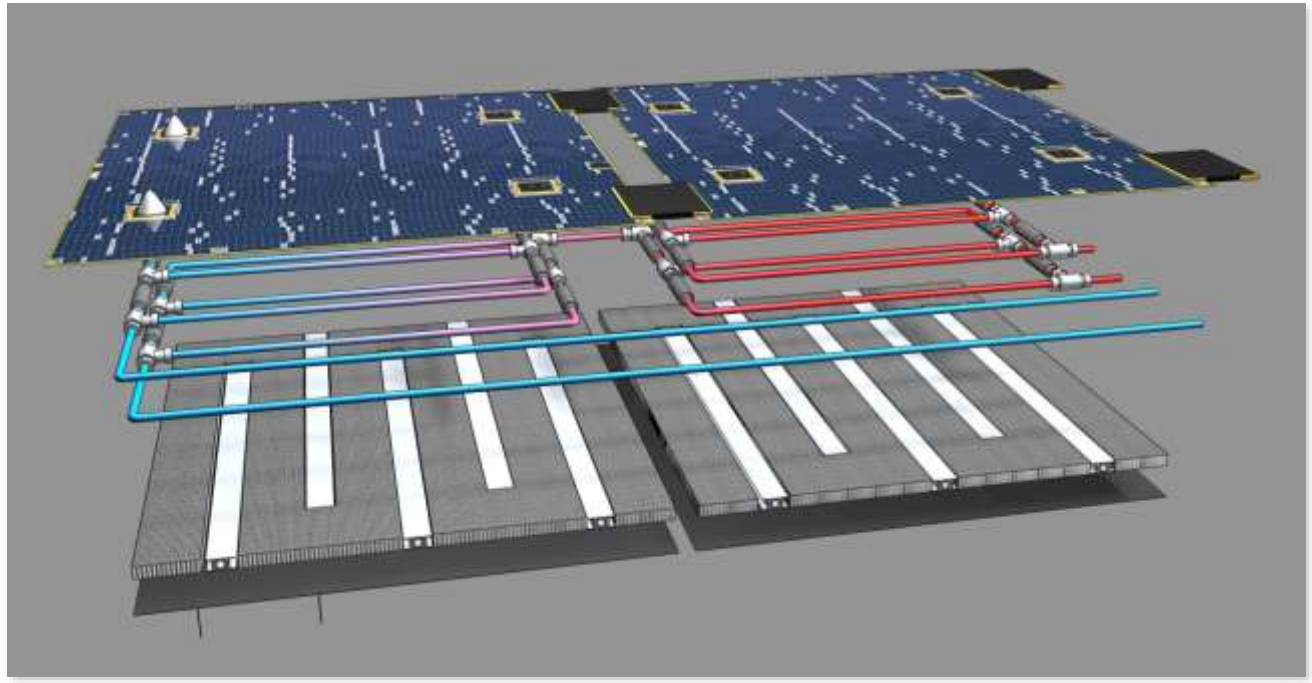


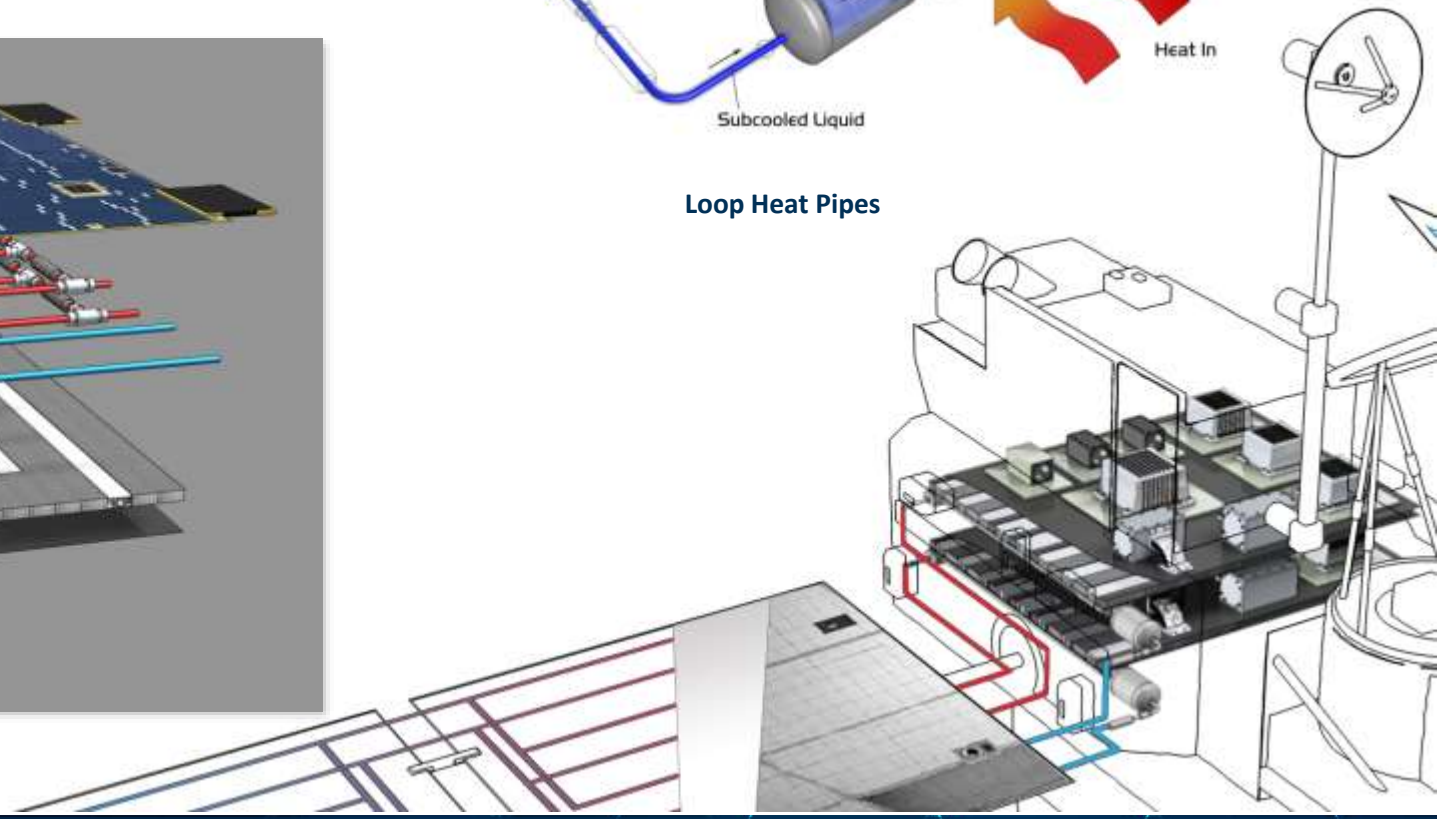
CCHP's

Honeycomb Panel

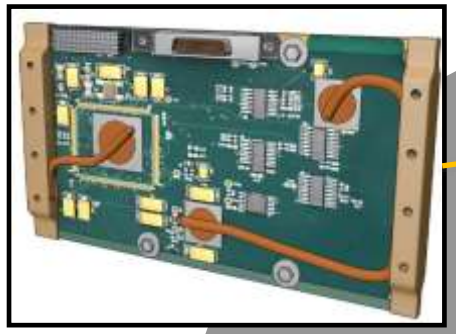


Loop Heat Pipes

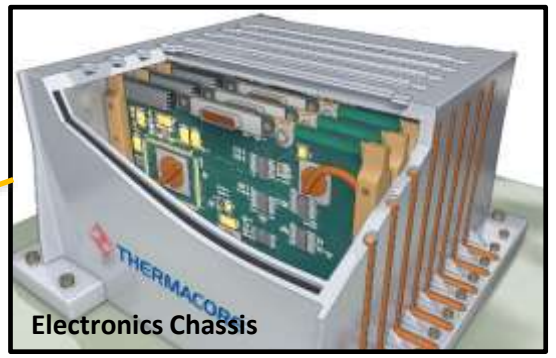




Payload Electronics Chassis Details



Direct Thermal Link to Micro-Electronics



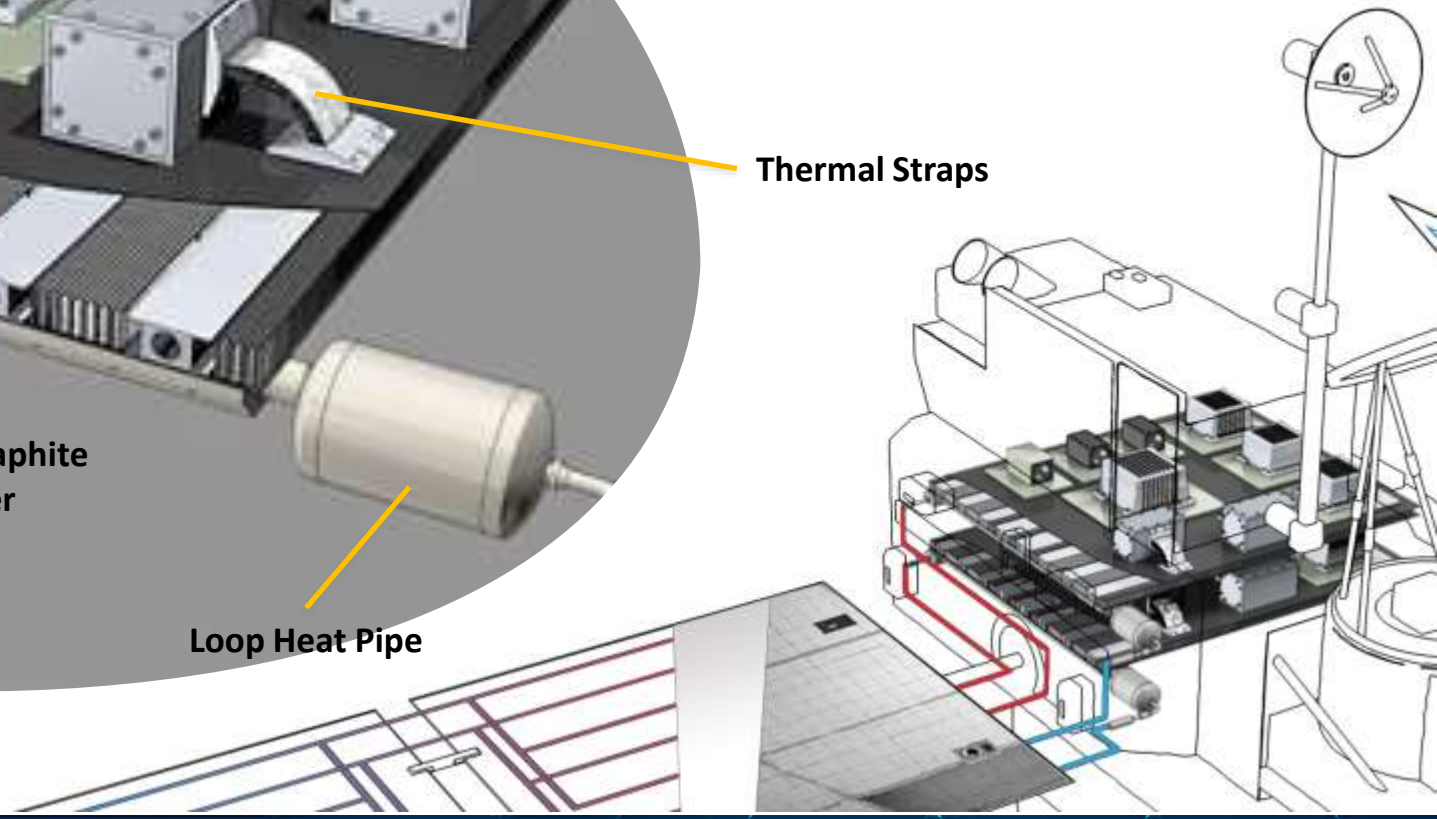
Reduced Thermal Resistance Through Chassis Walls

Thermal Straps

Encapsulated Graphite Thermal Spreader

Deployed in Radiator Panels and Chassis Bases

Loop Heat Pipe

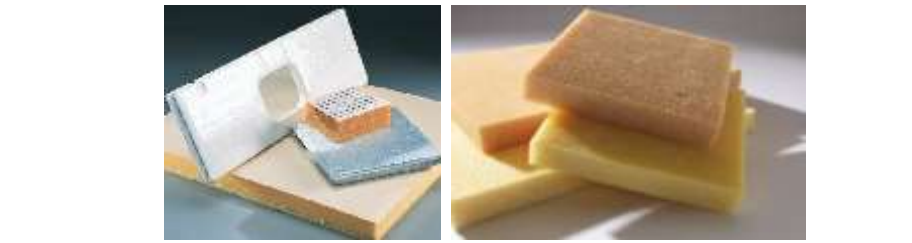


SOLIMIDE® Foam Overview

BENEFITS

- *Lightweight*
- *Easy installation*
- *Outstanding Thermal & Acoustic Insulation*
- *Superior fire resistance – chars rather than burns*
- *Virtually no smoke or toxic gas production*
- *Environmentally friendly & Non-toxic*
- *Inert, no outgassing*
- *Proven durability*
- *Wide operating temperature range*
- *Dimensional stability across full temperature range*
- *Remains flexible at cryogenic temperatures*
- *Hydrolytically stable*
- *Does not support microbial growth*
- *UL94V-0 or 5VA rated, thickness and grade dependent*

- Thermal & Acoustic Insulating Foam
- Polyimide-based
- Open-cell foam, low density (5 to 9 kg/m³)



Addressing the Technical Challenge

Engineered Materials Solutions

SOLIMIDE® Foam

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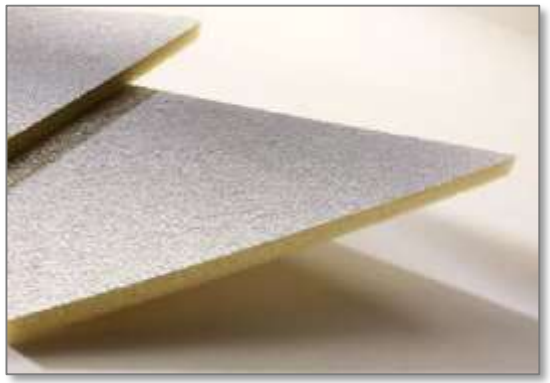
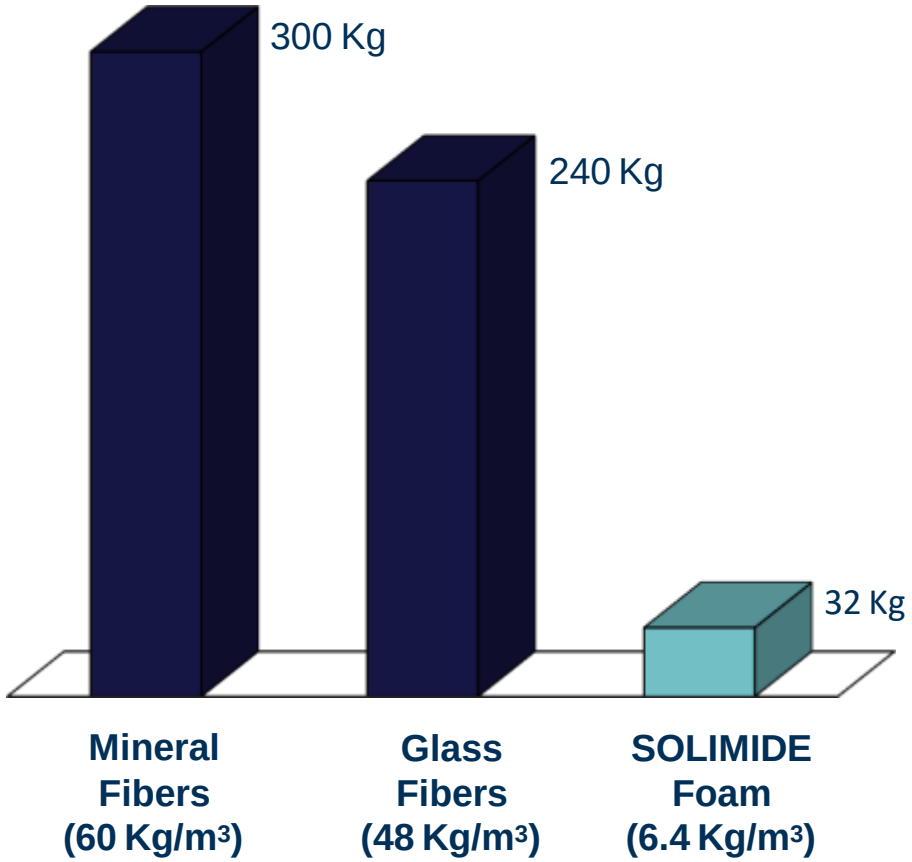
SOLIMIDE® Foam Technical Details

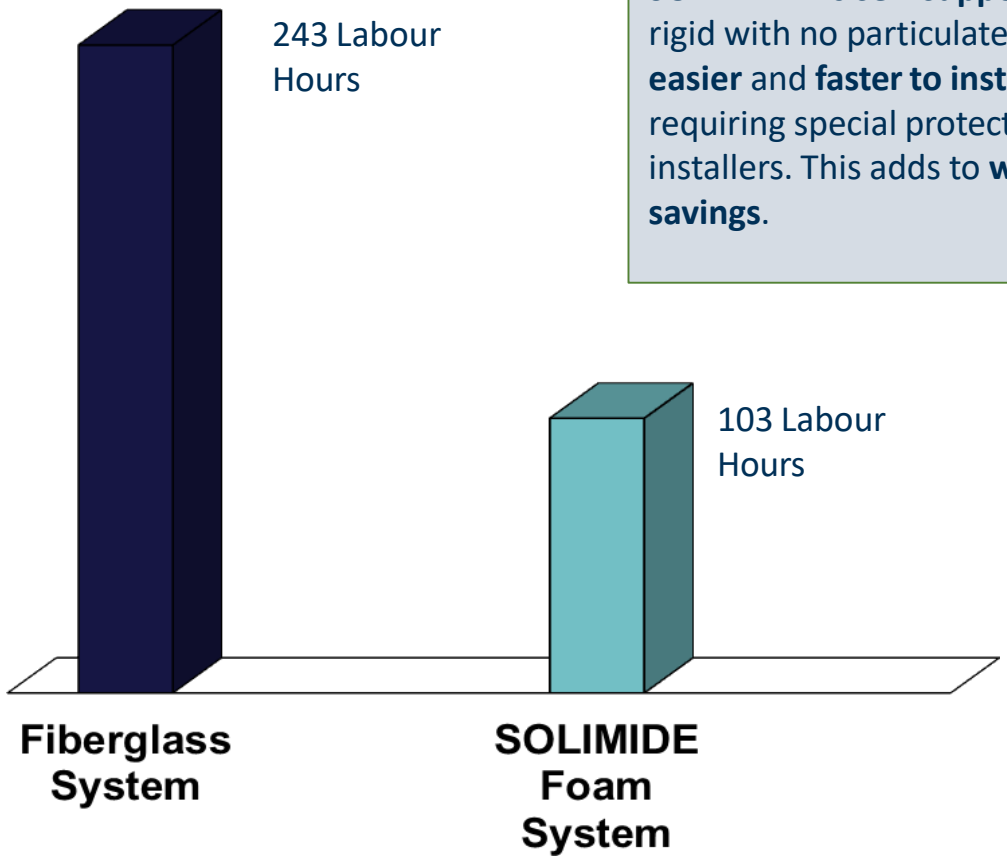
- The “continuous use” temperature range of Solimide is uniquely wide:
  - From below -325°F(-200°C) up to +572°F (+300° C)
  - Most foam/sponge materials only operate in portions of this broad temperature band
  - Exceeds FAR 25.856 flammability specifications
- Highest-temperature SOLIMIDE® foam, HT-340, is rated to UL94 V-0 at 0.12” (3mm) or thicker, and UL94 5V at 6mm and above
- The standard densities (by grade) range from 0.34 to 0.5 lbs/ft³ (5.4 kg/m³ and 8 kg/m³)
  - A block of TA-301 the size of a typical passenger car weighs about 150lbs. (68 to 100 kg)!




Weight Savings & Assembly Efficiency



Installation of 100m² insulation at 50 mm thickness creates 86% weight savings with SOLIMIDE® compared to traditional insulation, enabling greater fuel efficiency & payload ability



Installation of 100m² insulation. 140 labor hours saved per 100m² installed, >50% labor savings to the OEM, translating to greater production throughput, efficiency, cost savings, safety & employee satisfaction.

SOLIMIDE® is **self-supporting** and semi-rigid with no particulate fibers, making it **easier** and **faster to install** by not requiring special protective gear for installers. This adds to **weight & time savings**.

Popular Converting Methods

- Waterjet for intricate/thick sheets
- CNC machined
- Die-cut under ½“ thickness
- Saw/wire cut
- Flame treating
- Skinned using hot platen
- Bonds well with common adhesives for lamination

Basic SOLIMIDE ® Grades

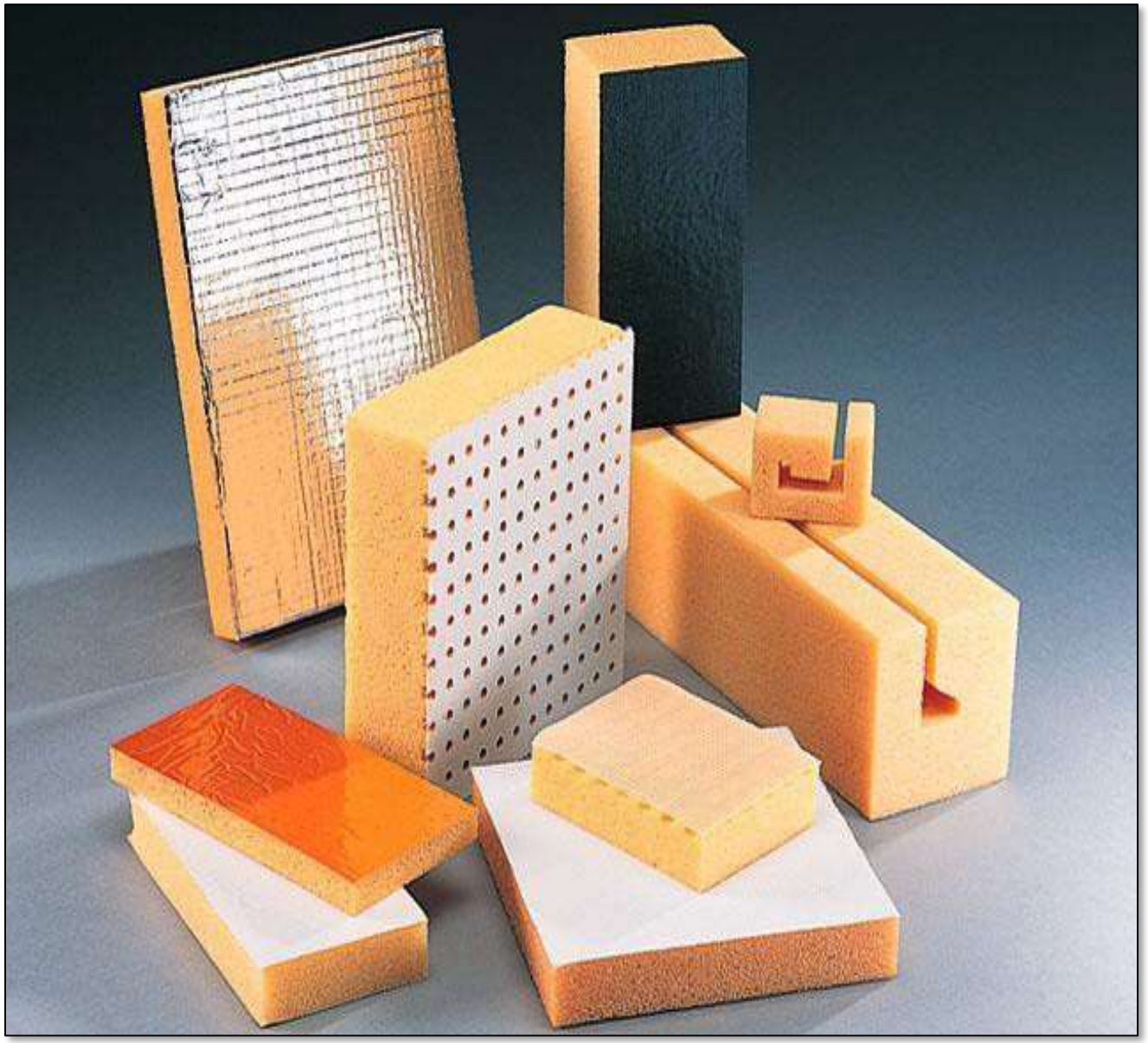
TA-301	➢ TA (Transportation-grade)-301 ➢ Medium density - 6.4 kg/m³ (0.40lb/ft³) ➢ Marine, Rail, Electronics/Communications equipment and other General Industrial applications ➢ Maximum continuous use temperature is 200°C(392°F)
HT-340	➢ HT (High-Temperature)-340 ➢ "Orange" color, Medium density - 6.4 kg/m³ (0.40 lb/ft³) ➢ Commercial Marine, Appliance, other High Temperature applications ➢ Maximum continuous use temperature is 300°C(572°F)
CC-306	➢ CC (Closed-Cell)-306 (not "technically" closed-cell, but a higher content of closed cells than theothers) ➢ Highest density - 8.0 kg/m³ (0.50lb/ft³) ➢ Submarine, Special Navy applications ➢ Maximum continuous use temperature is 200°C(392°F)
AC-530	➢ AC (AirCraft)-530 ➢ Lowest density - 5.7 kg/m³ (0.36 lb/ft³) ➢ Aircraft, Aerospace, Cryogenic applications ➢ Maximum continuous use temperature is 200°C(392°F)
AC-550	➢ AC(AirCraft)-550 ➢ High density - 7.1 kg/m³ (0.44 lb/ft³) ➢ Aircraft and Aerospace Applications ➢ Maximum continuous use temperature is 200°C(392°F)

HT-340

AC-530

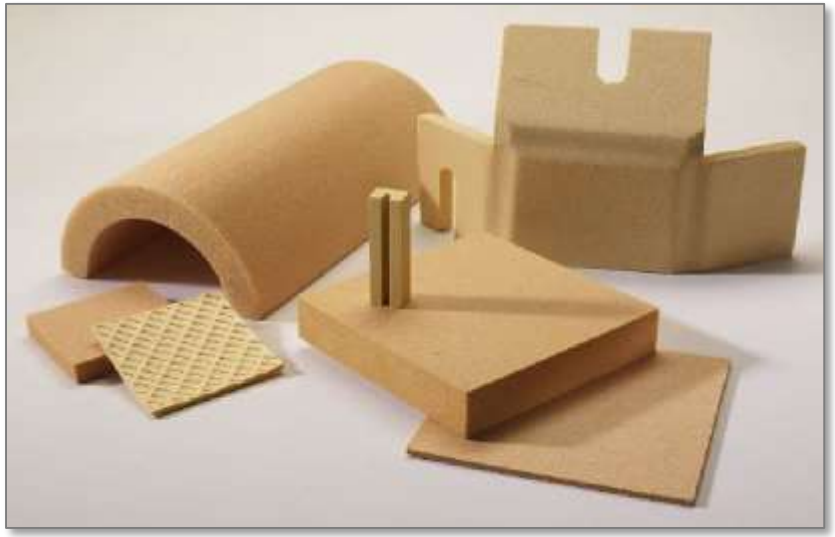
Popular Available Formats

- Sheets or panels
- Profile cut shapes
- Die cut parts
- Laminated with facings and/or coated
- Available with added films, adhesives and release liners
- Faced systems are recommended for applications in moist environments, accept protective surface treatments
- Thickness from 5mm, Sizes to 1.2m x 2.4m
- Inner diameter cuts from 6mm



Densified SOLIMIDE® Foam

- SOLIMIDE® cut directly into sheets from a “bun” is extremely lightweight & flexible
- Boyd utilizes a proprietary roller-compression process to create soft, flexible sheet with less compression to set the foam at a slightly higher density than typical SOLIMIDE®.
- To increase mechanical strength, Boyd compresses and holds foam with a heated press until thermo-set. The material compressed in this way is “Densified SOLIMIDE®”
- Densification is a customizable physical characteristic and can be set to virtually any density higher than the original for all grades of SOLIMIDE®
- Densities in production range up to 9X the standard density of stock foam
- As the density increases, so does mechanical stability. This allows material splitting into ultra-thin sheets, as thin as 0.020” (0.5mm)



High Temperature SOLIMIDE® in Semi-Conductor Equipment

Current Use Case For Standard Thermal Installation

- Thermal insulation layer for heating jacket used in semiconductor or similar industrial manufacturing equipment environments
- Provide heat to manufacturing equipment andprocess lines
  - Typically used to prevent condensation, precipitation, or reaction/recombination of process gasses flowing at low pressure, often under vacuum
- Used and handled by trained/professional personnel
- Regular installation/removal required to service underlying system
  - Process lines often require regular maintenance
  - Maintenance cycles can be as high as 1 cycle per week

Why SOLIMIDE® Solutions?

Polyimide foam is a better alternative to Silicone foam and Fiberglass battings

- Maintains a cleaner operating environment.
- Silicone foam outgasses at high temperature
- Fiberglass batting generates particles and is a skin irritant, creates safety concern for personnel

Polyimide Foam is ideal because:

- Lightweight & flexible
- Low VOC generating
- Does not generate particles for a cleaner & safer operating environment
- Good thermal insulation
- Cost effective
- Efficient to install, self-supporting

Clean Solutions for Today's Challenges

As industries, service providers and manufacturers restart post-COVID, they are introducing new precautions and infrastructure to better protect their customers and employees.

SOLIMIDE® **does not support microbial growth**, is hydrolytically stable & does not retain liquid

- Although not anti-microbial, SOLIMIDE® will not grow microorganisms like bacteria, viruses & fungi on its own. *(If microbes are introduced through something else, they will still grow, but the foam will not foster microbes itself.)*
- It can withstand exposure to & will not be degraded by water & other cleaning solutions
- SOLIMIDE® has tested resistant to: Hydraulic Fluid, Diesel, Jet Fuel and additional solvents

SOLIMIDE® is an ideal "set it and forget it" insulating solution helping to:

- Create a safer environment for users
- If the foam is exposed to liquids during decontamination processes, it will not degrade, retain liquid or grow mold – negating the need to replace insulation
- Promote long term efficiency heavy machinery
- Resistant to deterioration over time compared to fiberglass in an environment with shock or vibration

Traditional SOLIMIDE® Aviation Design Project

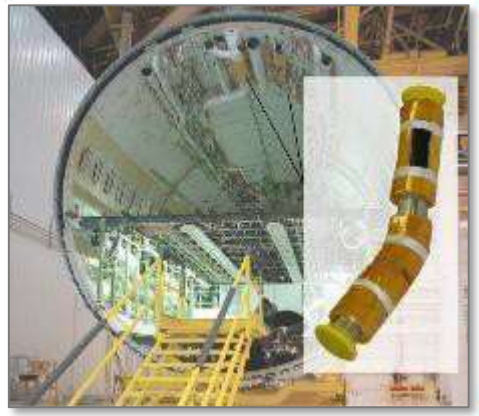
Objective: SOLIMIDE® Foams replaces fiberglass as bulkhead insulation

Challenge:

Commercial aviation OEM was challenged with vapor condensing within cabin walls, collating in existing fiberglass insulation which caused the insulation to deteriorate and for microbial / fungal (mold) to grow and drip onto passengers.

Results:

Replace with SOLIMIDE® Foams whose open-cell structure withstands exposure to water with zero impact and does not support microbial growth, meaning the new insulation solution lasted longer and maintained a pure breathing environment.



Boyd helped this OEM decrease maintenance costs and downtime while improving passenger health and safety.

Addressing the Technical Challenge

Two Phase Cooling / Fluid Phase Change Solutions & Applications

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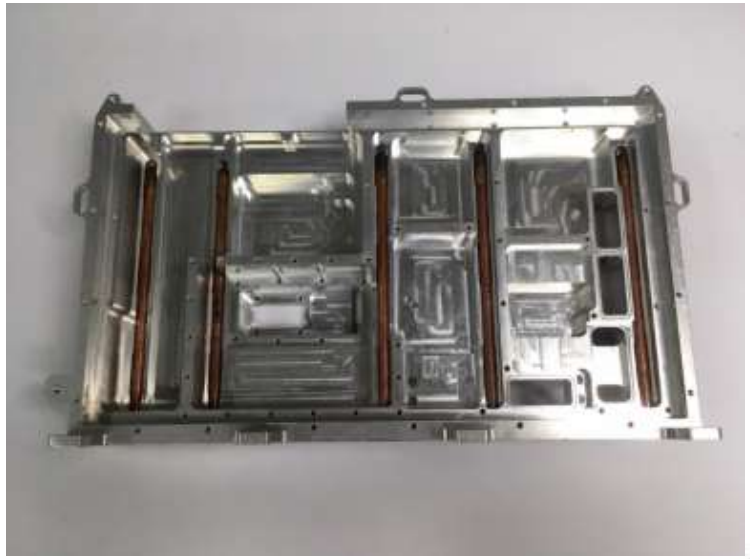
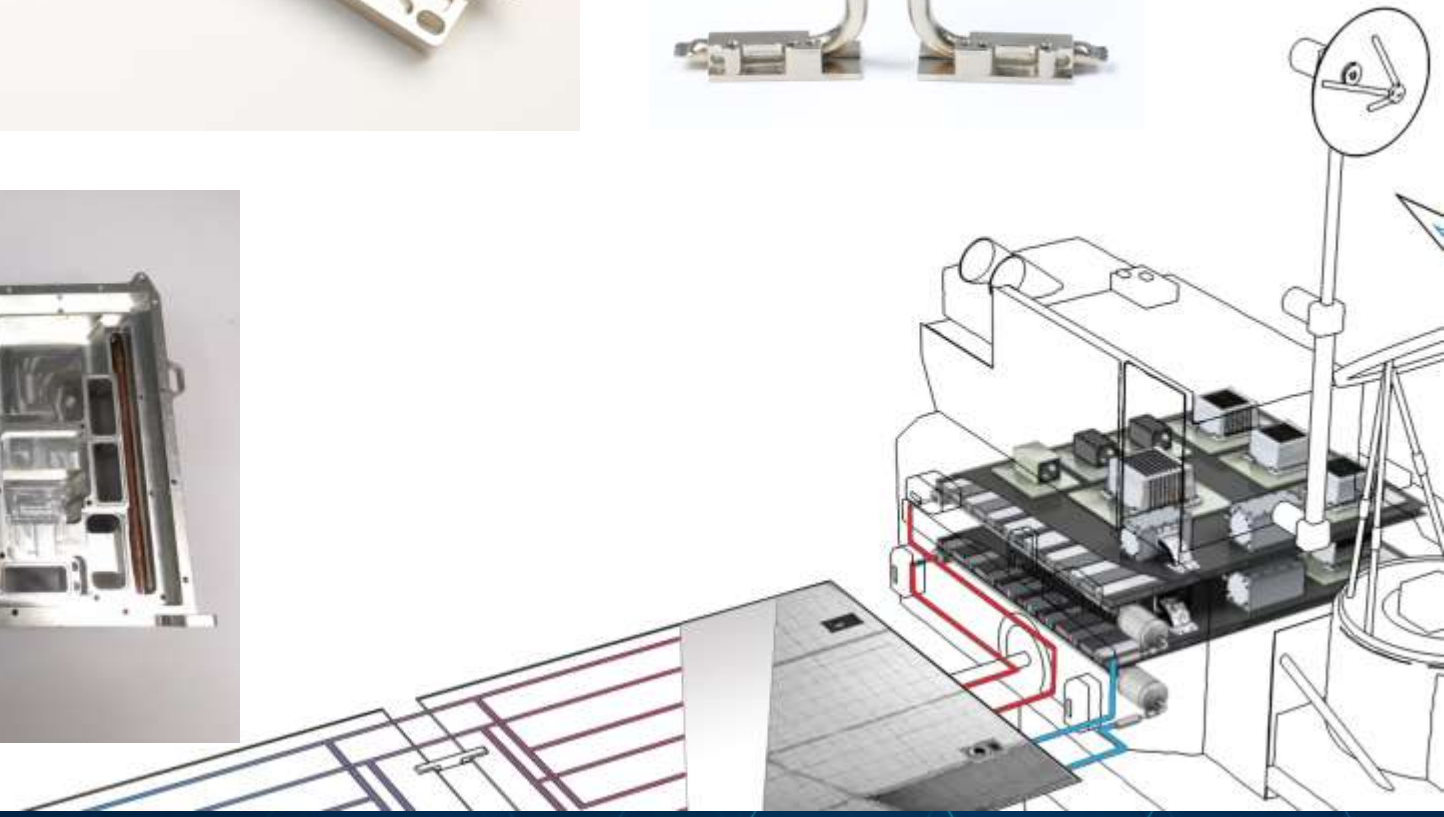
Mini Heat Pipe Assemblies

- Single piece thermal design for evaporator and condenser
- Multiple Source Collection
- Operating Temperature: -20°C to +110°C
- Embedded Heat-Pipes





Gravity Friendly Sintered Copper Water Heat Pipe Assembly Examples

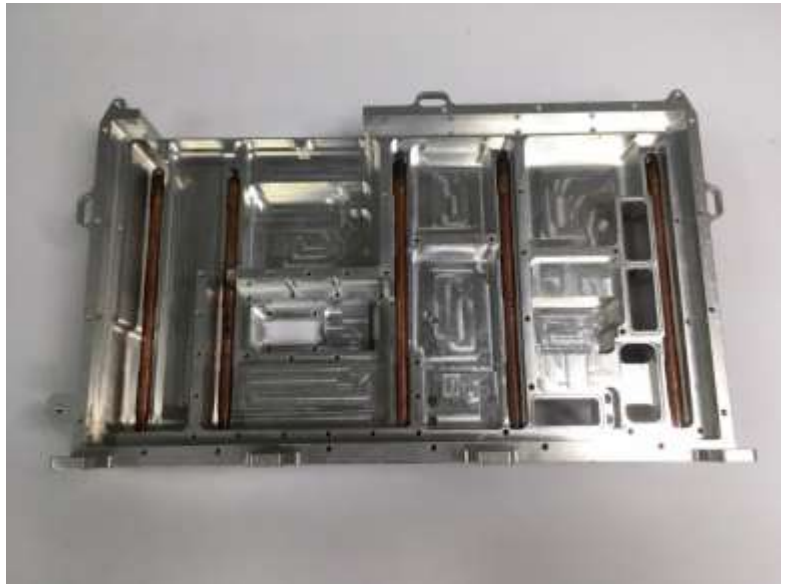
- Used in commercial satellites
- Single evaporator
- Two condensers (joined)
- 2 x Ø6.35mm x 220mm Heat Pipes
- 170mm x 128mm x 17mm (Approx. Overall Dimensions)
- Power: 35W Total (17.5W per Heat Pipe)
- Allowable ΔT: 10°C
- Required Operating Temperature: +30°C to +100°C
- Heat Flux Density Required: 6W/cm^2 (minimum)
- Designed with redundancy

- Used in commercial satellites
- Single evaporator
- Two condensers (joined)
- 2 x Ø6.35mm x 200mm Heat Pipes
- 150mm x 145mm x 15mm (Approx. Overall Dimensions)
- Power: 25W Max. (12.5W Per Heat Pipe)
- Allowable Δ T: 7.5°C
- Required Operating Temperature: +30°C to +100°C
- Heat Flux Density Required: 3.0W/cm^2 (minimum)
- Designed with redundancy

Gravity Friendly Sintered Copper Water Heat Pipe Assembly Examples

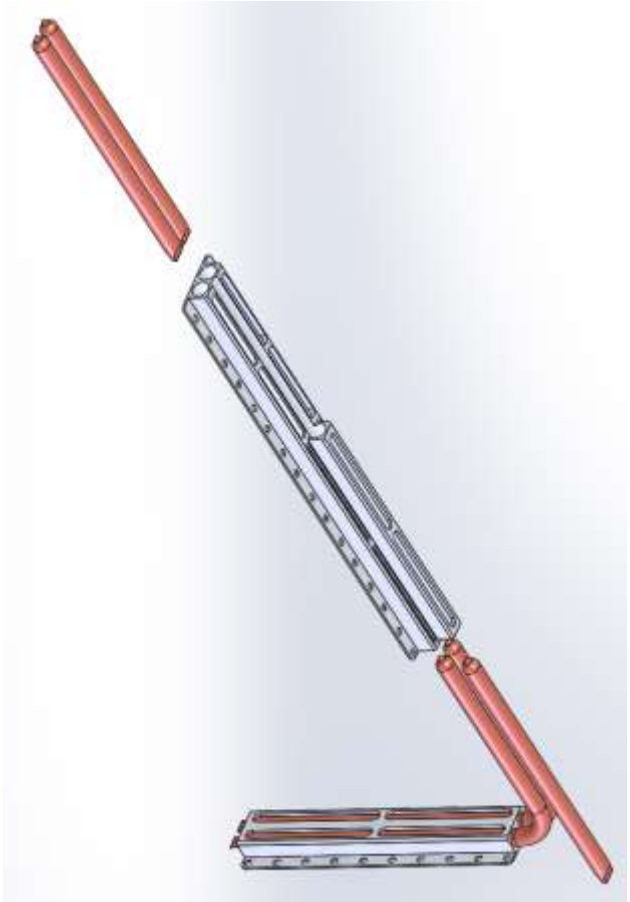
- Micro Heat Pipe Assembly
- Used in commercial satellites
- Single piece thermal constructor design for evaporator and condenser
- 1 x Ø6.35mm x 155mm Heat Pipe
- 85mm x 105mm x 11.5mm (Approx. Overall Dimensions)
- Power: 15W Max. (10W Operating)
- Allowable Δ T: 8°C
- Operating Temperature: -20°C to +80°C
- Heat Flux Density Required: 2.5W/cm^2 (minimum)

- Thermally Enhanced SSPA Structure Assembly
- Used in commercial satellites
- Multiple source collection
- Fully embedded heat pipes (combined condenser & evaporator)
- 5 x Ø5mm x 118mm Heat Pipes
- 245mm x 140mm x 60mm (Approx. Overall Dimensions)
- Power: 50W (Total)
- Allowable Δ T: 5°C Along Heat Pipe Length
- Operating Temperature: +25°C to +110°C



Gravity Friendly Sintered Copper Water Heat Pipe Assembly Examples

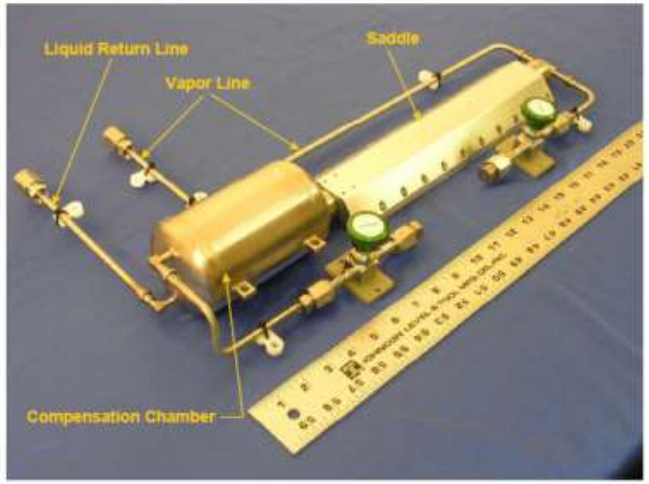
- Thermal Link
- Used in commercial satellites
- Single evaporator – Collects heat from multiple layered heat sources
- Single condenser
- 3 x Ø8mm x 146mm Heat Pipes
- 2 x Ø8mm x 275mm Heat Pipes
- 267mm x 170mm x 32mm (Approx. Overall Dimensions)
- Power: 45W (Total)
- Allowable Δ T: 11.25°C
- Operating Temperature: +30°C to +100°C
- Heat Flux Density Required: 1.5W/cm^2 (minimum)

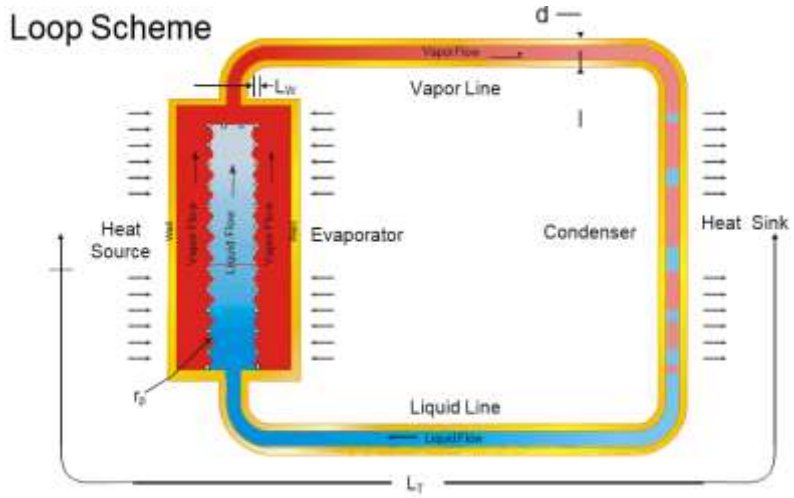


Loop Heat Pipes & Constant Conduction Heat Pipes

LHP's: Loop Heat Pipes:

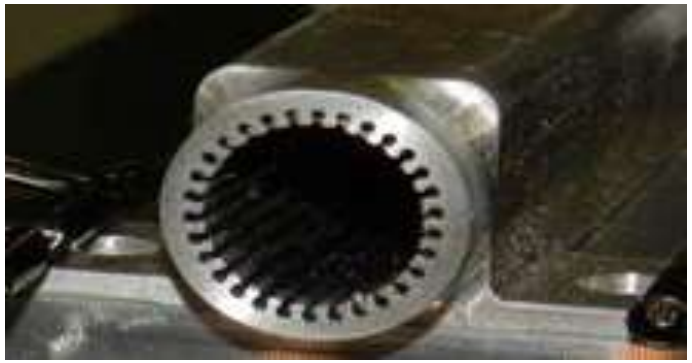
- Space applications
- Aerospace (over 150 deployed on F-16 Fast Jet's)
- High g-Load / Transport Over Large Distances
- Transport from 1 W to Several kW's
- Passive heat transfer
- Flexible, bendable and routable
- Low mass
- Utilizes thermal diode to transfer heat in single direction





CCHP's: Constant Conduction Heat Pipes:

- Aluminium-Ammonia, Axially Grooved HP's
- Embedded Panel's, Surface Mounted, Link's



ESA ARTES C&G CCHP Volume Production Facility

Objectives:

- Saleable Pilot CCHP Volume Production Facility Development
- CCHP Volume Production Design & CCHP Profile Development
- Acceptance testing of the CCHP and pilot-facilities in alignment with the ESA ECSS Standards
- Preparation for Qualification and Commercialisation of the Volume CCHP Technology

Current Aavid UK Aluminium-Ammonia
CCHP R&D Laboratory (5m x 5m)

Capacity: Low – 10 to 20 CCHP's per year
(Scale to 100 CCHP's per annum)

Proposed Unit 21 CCHP Pilot-Scale
Volume Production Facility

Capacity: Target 1000 to 1500 CCHP's per annum

Addressing the Technical Challenge

Graphite Cooling Solutions & Applications

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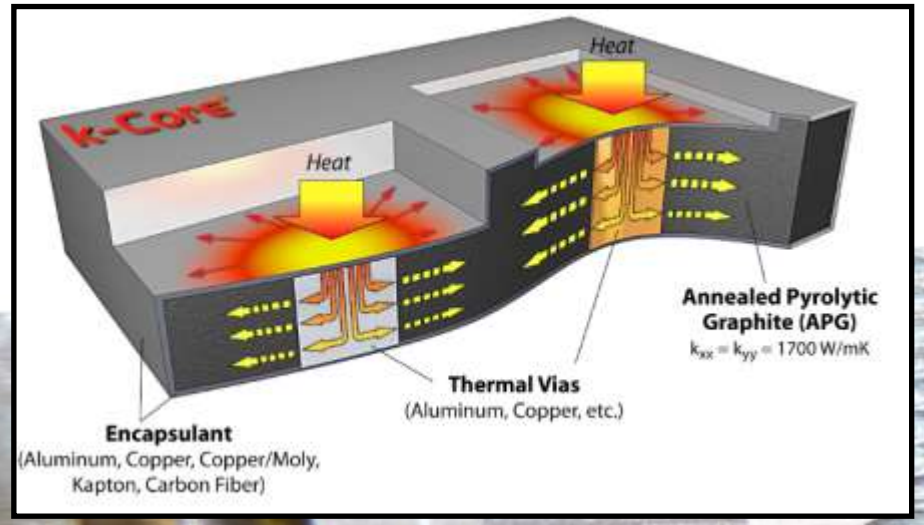
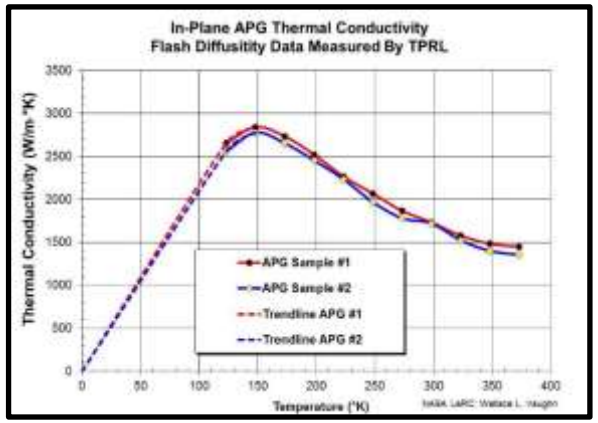
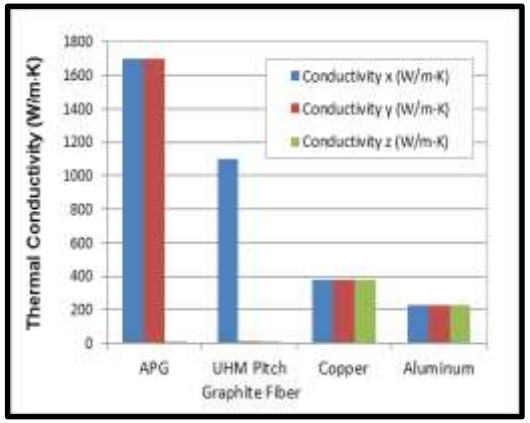
k-Core® - Annealed Pyrolytic Graphite (APG)



A propriety product featuring K-Core APG, a highly ordered crystalline material with a thermal conductivity of >1000 W/m-K, within an aluminium parent material.

K-Core APG has a wide operational temperature range from -123 to 125 Deg C.





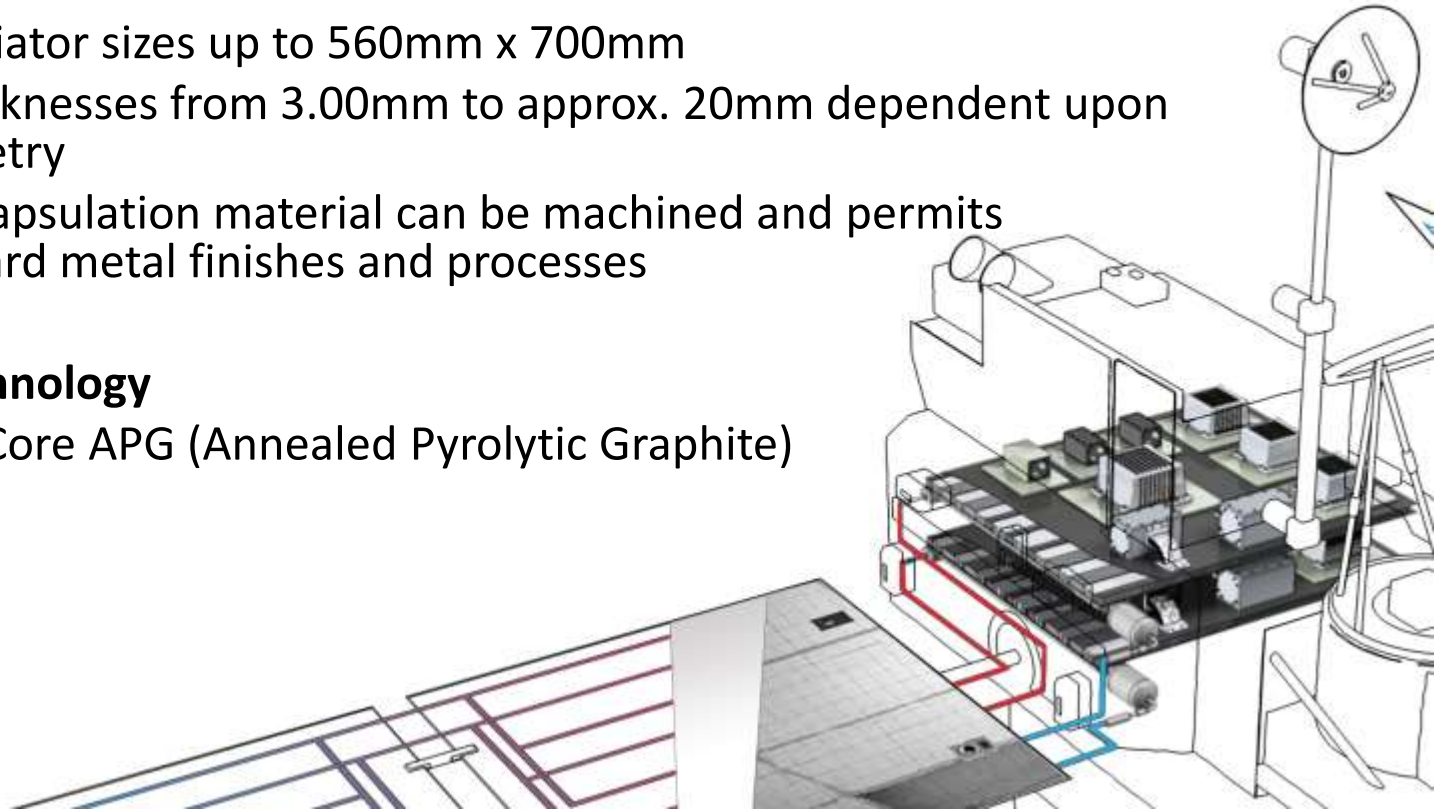
K-Core APG is a macro-composite which is fully encapsulated by an outer material than can vary In thickness depending upon application requirements

k-Core® - APG Multi-Segment Space Radiators

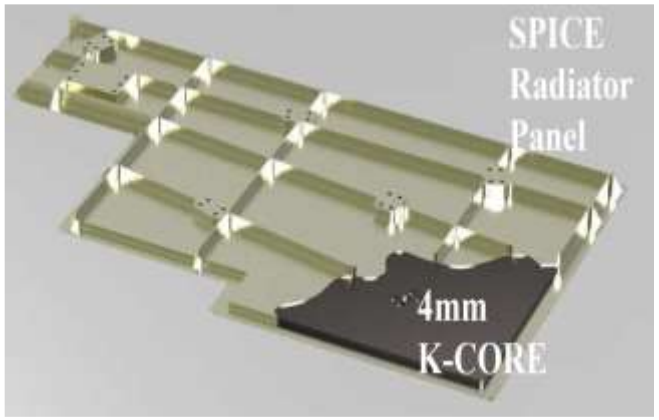
- **Solid Conduction Cooling**

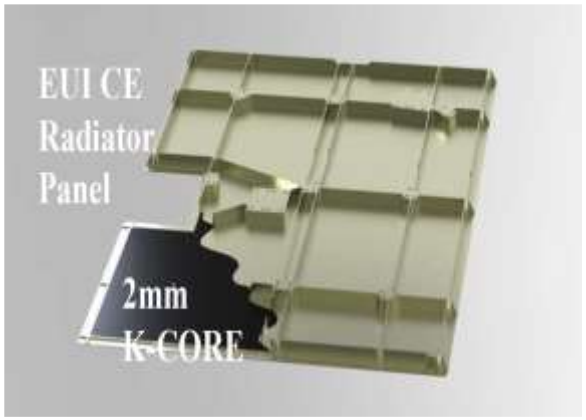
- Mass slightly lower than solid aluminium and drop in replacement for many all-metal designs
- Made up of several APG segments and ribs machined into the radiator to improve both mechanical and structural performance
- Radiator sizes up to 560mm x 700mm
- Thicknesses from 3.00mm to approx. 20mm dependent upon geometry
- Encapsulation material can be machined and permits standard metal finishes and processes

- **Technology**
  - K-Core APG (Annealed Pyrolytic Graphite)

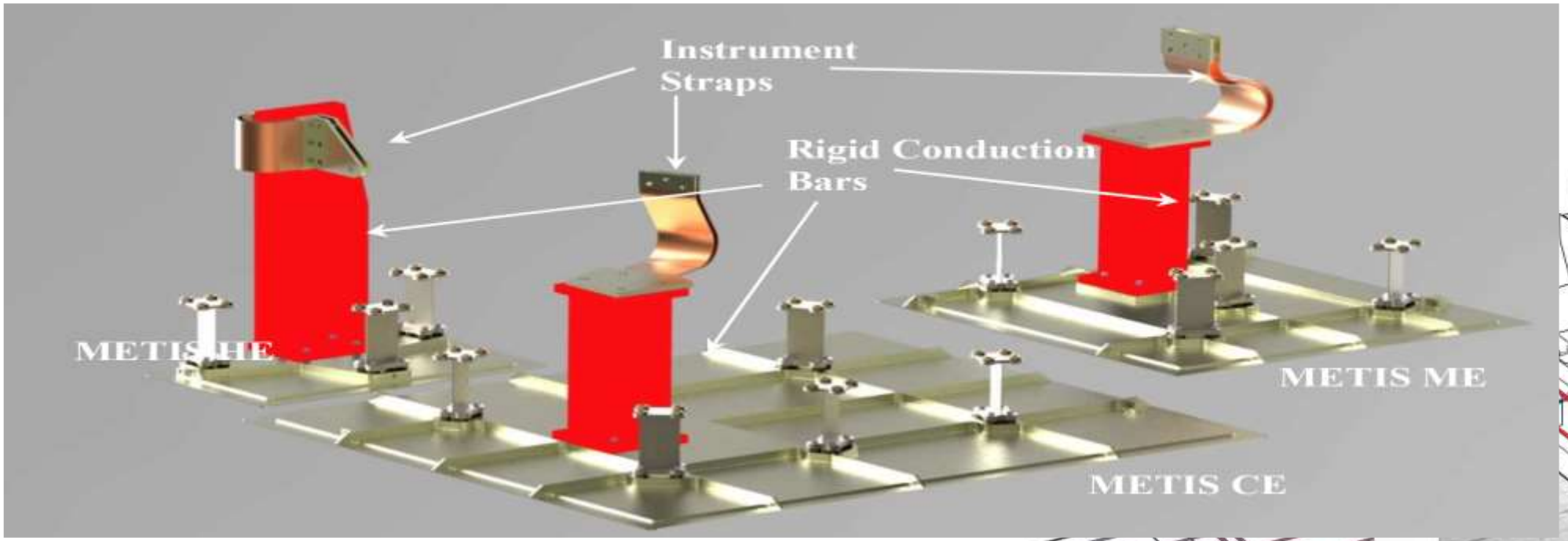


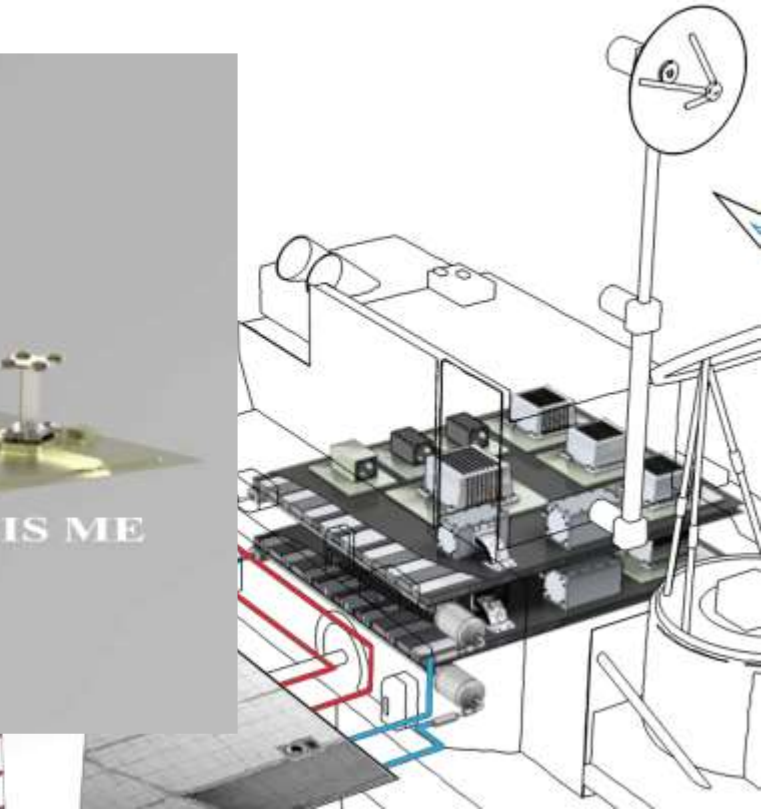
k-Core® - APG Multi-Segment Space Radiators





Bpyd Technologies background at European level is the implementation of the K-core APG within the remote-sensing instrument payload for three of the measurement systems of the European Space Agency's Solar Orbiter Mission.





k-Core® - Annealed Pyrolytic Graphite (APG)

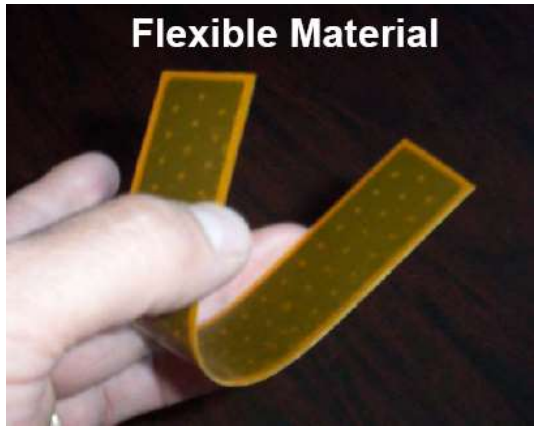
- k-Core Cover
- Used in commercial satellites
- Multiple source power collection
- Solid Conduction - Encapsulated Annealed Pyrolytic Graphite
- 300mm x 300mm x 10mm (Approx. Overall Dimensions)
- Power: 22W (Total)
- Allowable ΔT: 12°C Max.
- Operating Temperature: -35°C to +70°C

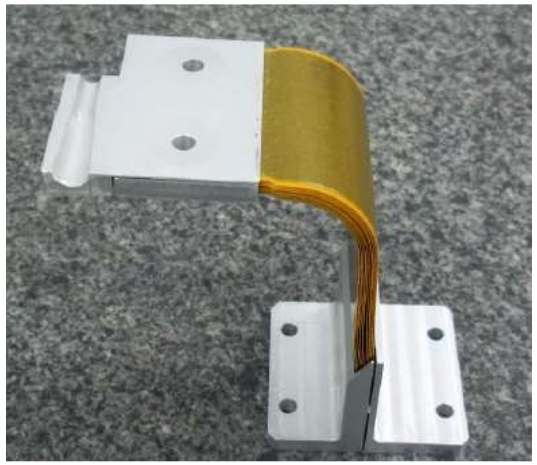
- K-Core Spreader
- Used in commercial satellites
- Solid Conduction - Encapsulated Annealed Pyrolytic Graphite
- 120mm x 75mm x 13mm (Approx. Overall Dimensions)
- Power: 10W Min.
- Allowable Δ T: 10°C
- Operating Temperature: -30°C to +100°C

k-Core® - APG Thermal Straps

- **Solid Conduction Cooling**
- Diffusion bonded & soldered configurations available
- Low bending stiffness – flexible material
- Multi-Layer strap designed to suit thermal performance requirements
- High dielectric breakdown strength (Kapton) material

- **Technology**
  - K-Core APG (Annealed Pyrolytic Graphite)





Addressing the Technical Challenge

ESA Qualification & TRL

BOYD
TRUSTED INNOVATION

Space Technology TRL & Qualification Status

Technology	TRL		Qualification		Notes:
	Boyd UK	Boyd USA	Boyd UK	Boyd USA	
Mini-Heat Pipes (Cu/H_2O)	9	9	✓	✓	UK & USA: Building Space Flight Heritage UK – deployed on 4 x commercial telecom satellite applications
K-Core Spreader / Link	9	9	✓	✓	UK: Building Space Flight Heritage on Various Platforms
K-Core Radiator	9	9	✓	✓	UK: Product Launched / Building Flight Heritage
Flexible Strap (graphite)	4	9	Qual. Tests Required	✓	US: Extensive Flight Heritage. UK: Tech Transfer & Qualification Testing is Required
LHP	4	9	Tech Transfer. Required	✓	US: LHP Technology is Qualified – Currently Supplying to NASA. UK: LHP Design, Charging & Test Capability. Niche Product; Manufacture Resides in USA
CCHP	6	9	Partial to ECSS Standard	✓	US: Fully Qualified. Currently Supplying to NASA UK: Partially Qualified to ESA ECSS Standards. UK: Manufacturing Processes Have a Level of Qualification by Similarity (Same as US Processes)
Solimide Foam	N/A	9	N/A	✓	Boyd Corp. Technology – Aavid UK Sales Can Support Applications.

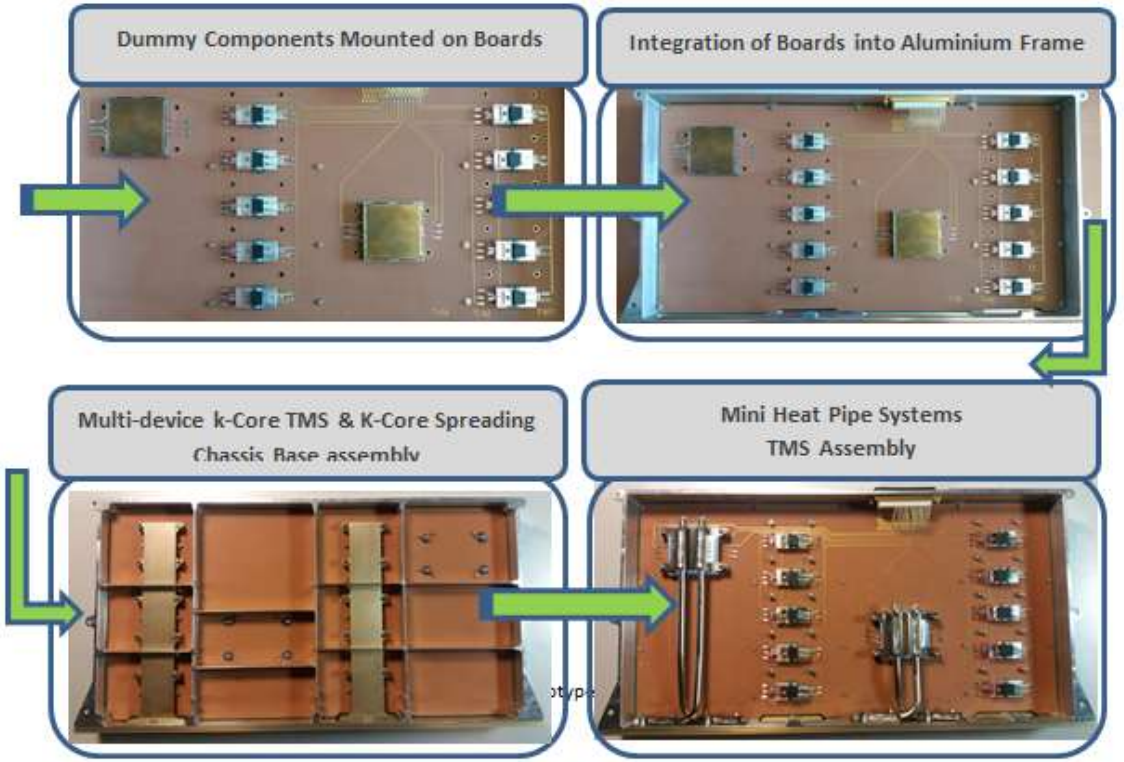
Qualification for Space Flight Examples

ESA ECI 'Advanced Cooling' Activity (ESA Qualification for Space Flight Achieved):

ESA Activity Ref: AO/1-7623/13/NL/CBi (ECI)

Next generation thermal management systems (TMS) qualified by ESA in chassis, for flip-chip direct thermal management:

- Copper-water mini-heat pipe TMS – *Qualified*
- K-Core TMS – *Qualified*
- K-Core Chassis Base – *Qualified*
- Manufacturing processes - *Qualified*

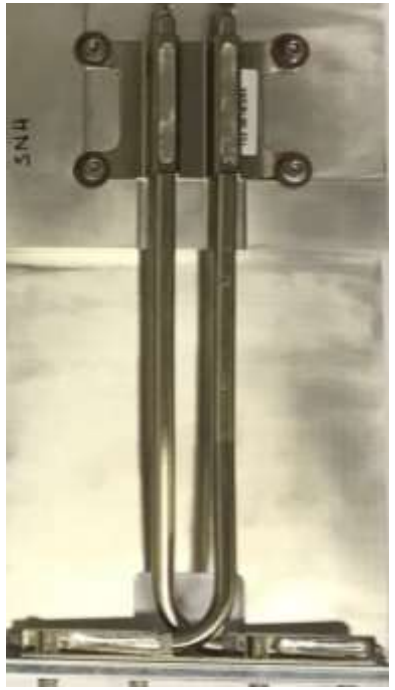


Qualification for Space Flight Examples

ESA ECI 'Advanced Cooling' Activity (ESA & TAS Qualification for Space Flight Achieved):

Next generation flip-chip direct thermal management systems:

Mini-Heat Pipe TMS (Long):



- 2 x Copper Water Heat Pipes
- Test Power = 1 x 20 W
- Heat Input Area = 40 x 40 mm
- Transport Height = 176.5mm
- Functional Against Gravity
- Mass = 92 g

k-Core TMS
(Multi-Device Thermal Bus):

- High Thermal Conductivity Annealed Pyrolytic Graphite (APG) Core
- Test Power = 5 x 4 W = 20 W
- Heat Input Area = 20 x 20 mm
- Transport Height = 176.5mm
- Gravity Independent
- Mass = 97 g

Mini-Heat Pipe TMS (Short):

- 2 x Copper Water Heat Pipes
- Test Power = 1 x 20 W
- Heat Input Area = 40 x 40 mm
- Transport Height = 96.5mm
- Functional Against Gravity
- Mass = 68 g

k-Core Chassis Base (Detachable thermal Spreading Version):

- High Thermal APG Core Thermal Spreader
- Interfaces with 4 x TMS Components (2 k-Core & 2 Mini-HP)
- LxWxH = 430 mm x 45 mm x 5 mm
- Mass = 171 g

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