

Introduction

Liquid Cooling
Solid Conductance
Two Phase
System Level Assemblies
R&D

Thermal Management Technology Company

- ✦ Founded in 1970 (40+ years)
- ✦ Recognised Global Leader in Thermal Management Technology
- ✦ 5 Locations (4 in North America and 1 in Europe)

Core Technologies and Capabilities

- ✦ Two-Phase Heat Transfer (Heat Pipes, Vapor Chambers, Loop HPs)
- ✦ High Performance Conduction Cooling (k-Core® APG)
- ✦ Pumped Liquid Cooling, Enclosure Heat Exchangers
- ✦ Aluminum Vacuum Brazing (Cold Plates, HEX's, Chassis's)
- ✦ Advanced Material Development, Processing, and Testing

Solution Provider

- ✦ Custom Design, Highly Engineered
- ✦ Microwatts to kilowatts, -250°C to 2000°C
- ✦ Device, Sub-system, & System Level Solutions
- ✦ Proven Technology to Commercialisation Experience

Total Life Cycle Solutions (Concept to Production)

- ✦ Concept Generation
- ✦ Design
- ✦ Development
- ✦ Manufacturing (AS9100, ISO9001, ISO14001 certified)

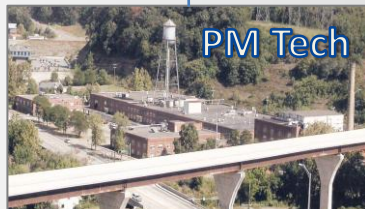
**Thermacore design,
thermally model,
prototype, test and
volume
manufacture
modules that allow
equipment to
operate in
environments or to
parameters would,
otherwise, not be
possible.**

Thermacore Activity World-wide

Blue highlight indicates Countries where we do business.



Lancaster, PA 5682 m²
110 employees
Full Service facility



PMT Division
Pittsburgh, PA
Engineering & Mfg



K-Core production &
Development



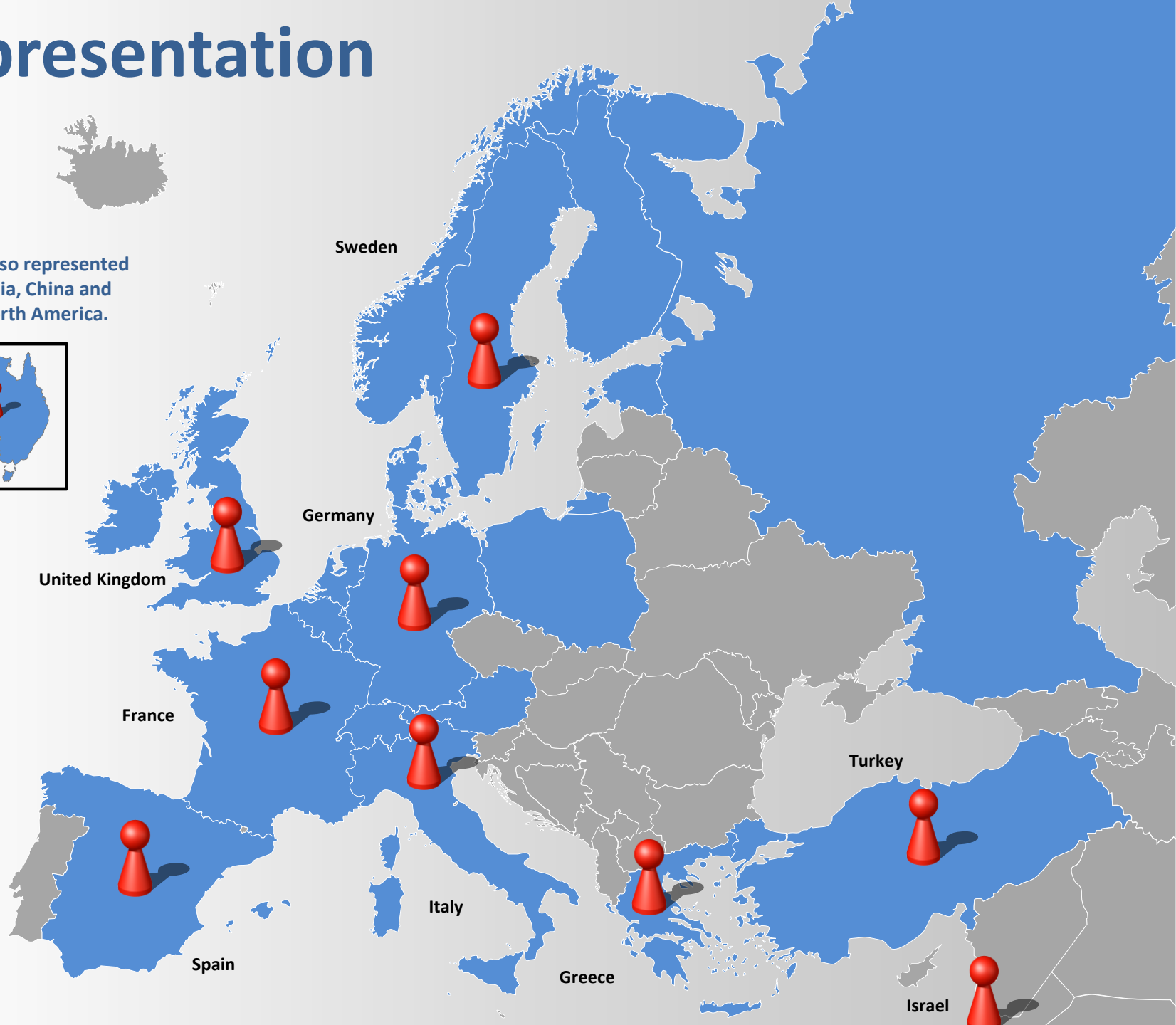
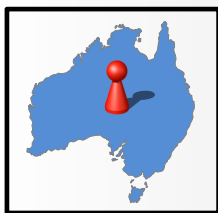
Ashington, UK
2300 m², 60 people
Full service facility



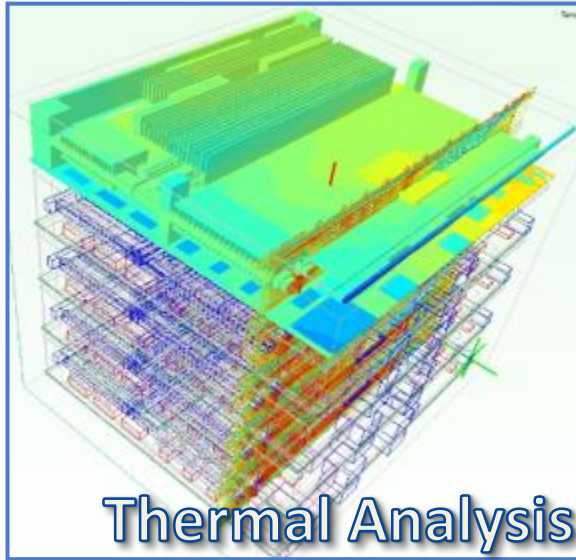
Shenzhen China, High
Volume Manufacture

Representation

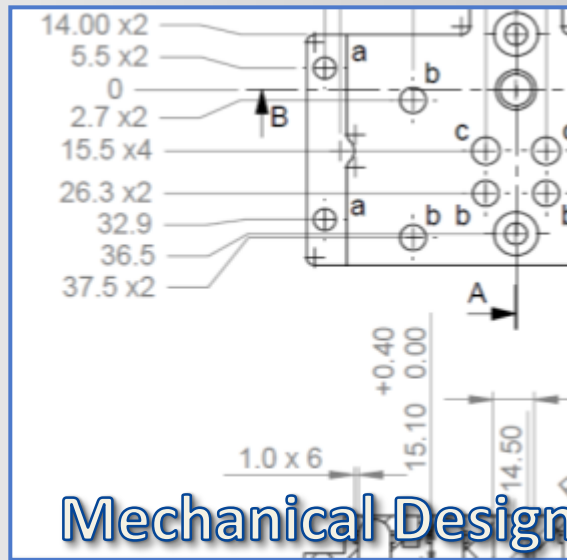
We are also represented
in Australia, China and
across North America.



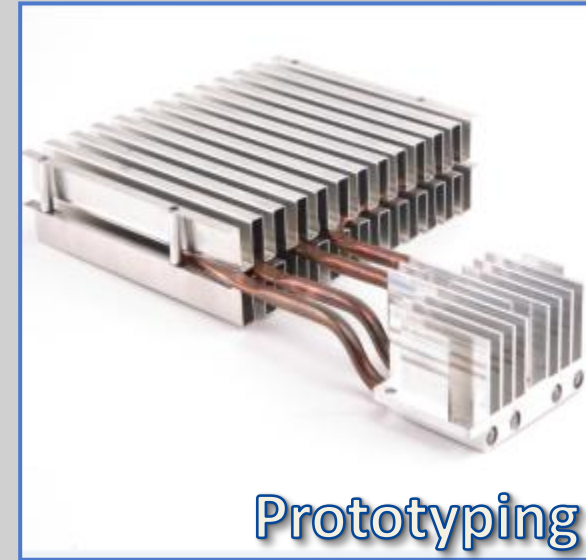
Capabilities for Custom Design



Thermal Analysis



Mechanical Design



Prototyping



Testing



Volume Production

Key Manufacturing Capability



Machining

4x machining
centres
1x CNC lathe



Sintering tech

750x750x750 sinter
oven
1x CNC lathe



Vacuum Brazing

1219mm x 1016 x
2540mm Hot Zone
650oC
10-5 Vacuum or Inert
Gas
WonderWare software
to support NADCAP and
AWS certification.



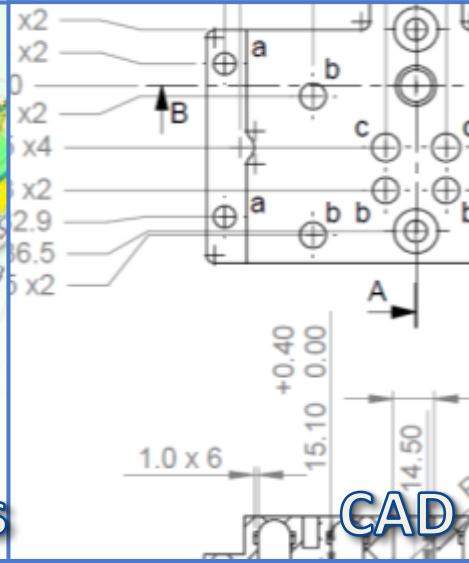
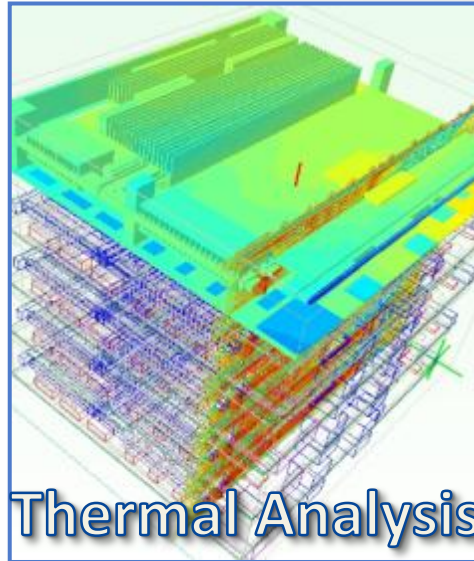
K-Core

In house graphite
manufacture

Multiple
encapsulant
materials



Support Processes



Flowtherm, Icepak,
CFX CFD s/ware

PHD level engineers

40 years of impirical
data and bespoke
software

Solidworks CAD
system

Ansys FMEA

Thermatron chamber
-55°C to 150°C

Helium leak test

Liquid test up to
50bar

1500x800x700
bed

Metro soft &
Quartis rev 6
s/ware

Renishaw TH20
5 axis probe

Introduction

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System Level Assemblies

R&D

Serpentine cold plate

Simplest cold plate type

Most cost effective

Large sizes (Size (W x L x H): 476 x 807 x 43mm)

Tubing changeable for differing fluids.



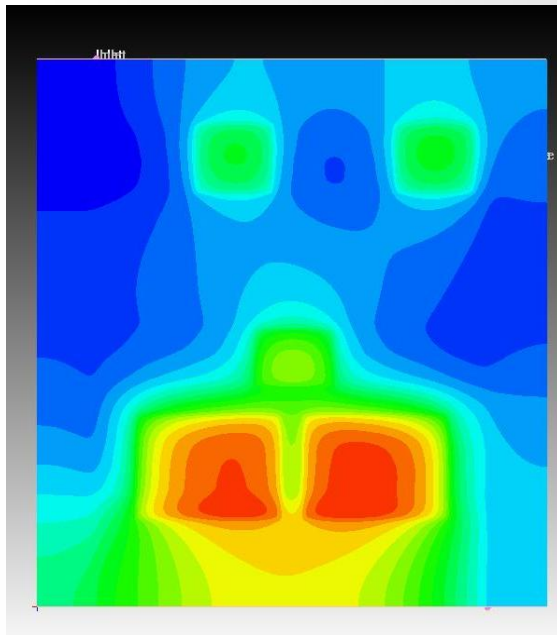
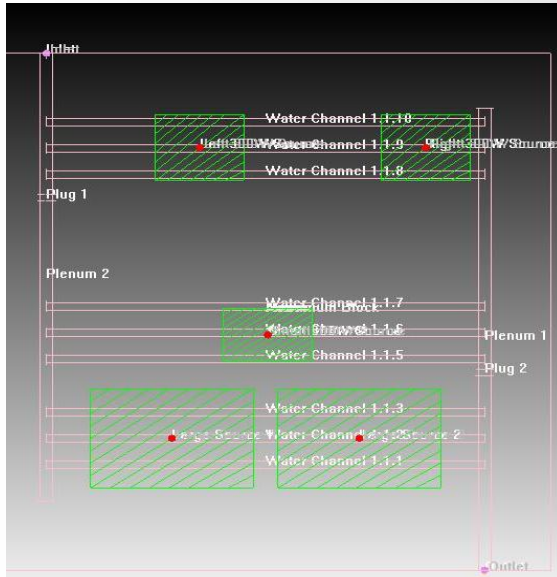
Drilled and Plugged Cold Plate

More flexible design than serpentine plates.

Pressure drop less than Serpentine plates.

Large sizes possible

Can be extruded in volume.



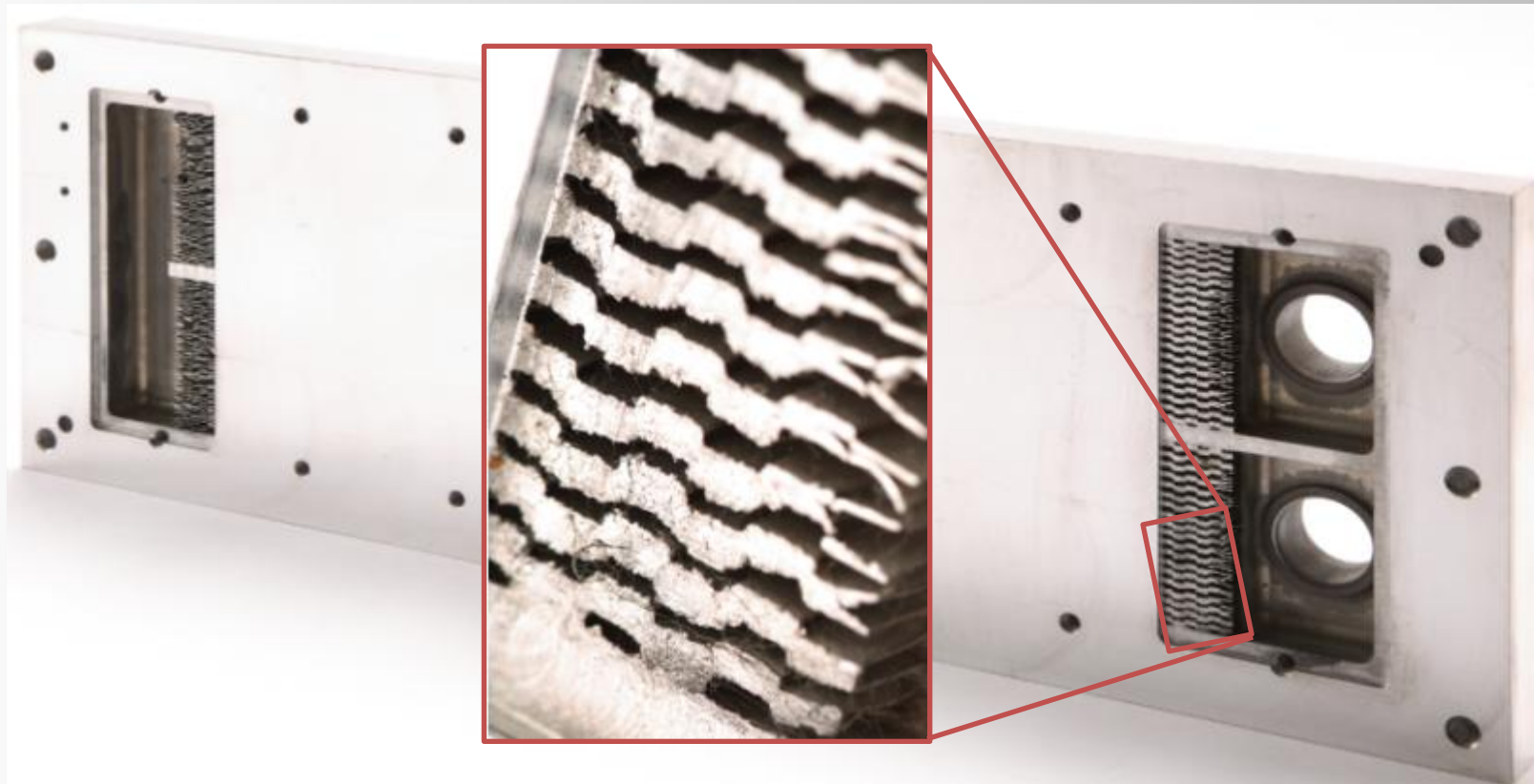
Vacuum Brazing Liquid Cooling

Complex water channel designs possible with folded fin or machined configurations

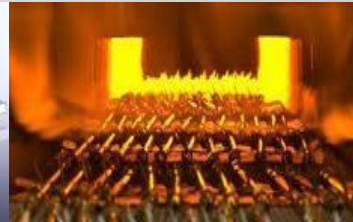
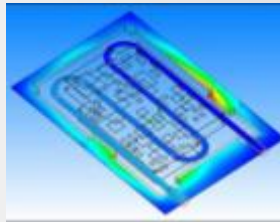
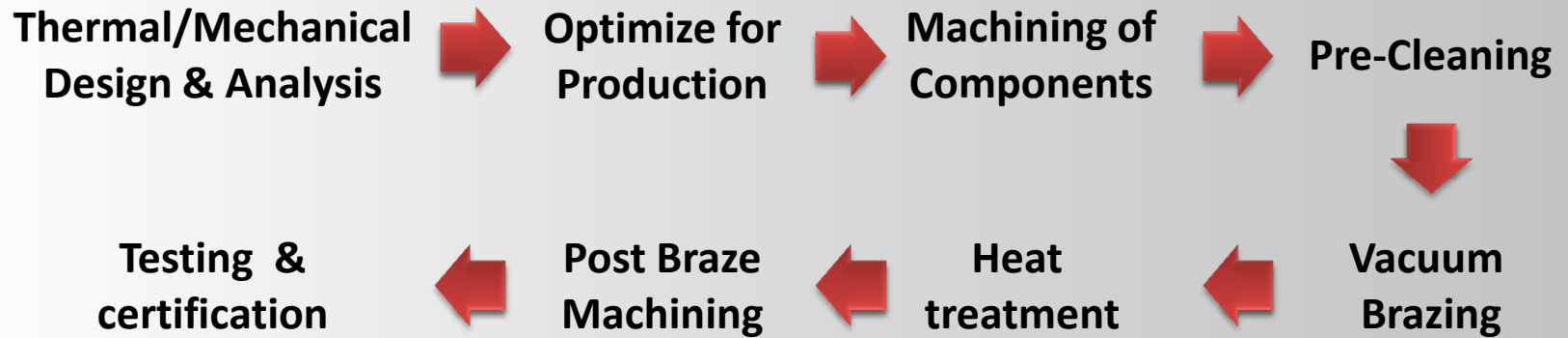
No flux residue left behind using Vac. Brazing

Parts heat treated to ensure correct post braze specification.

Best thermal performance ideal for high power applications



Brazing process



PV/T Furnace with
1219mm x 1016 x
2540mm Hot Zone
650°C & 10⁻⁵
Vacuum or Inert
Gas

WonderWare
software to
support NADCAP
and AWS
certification.

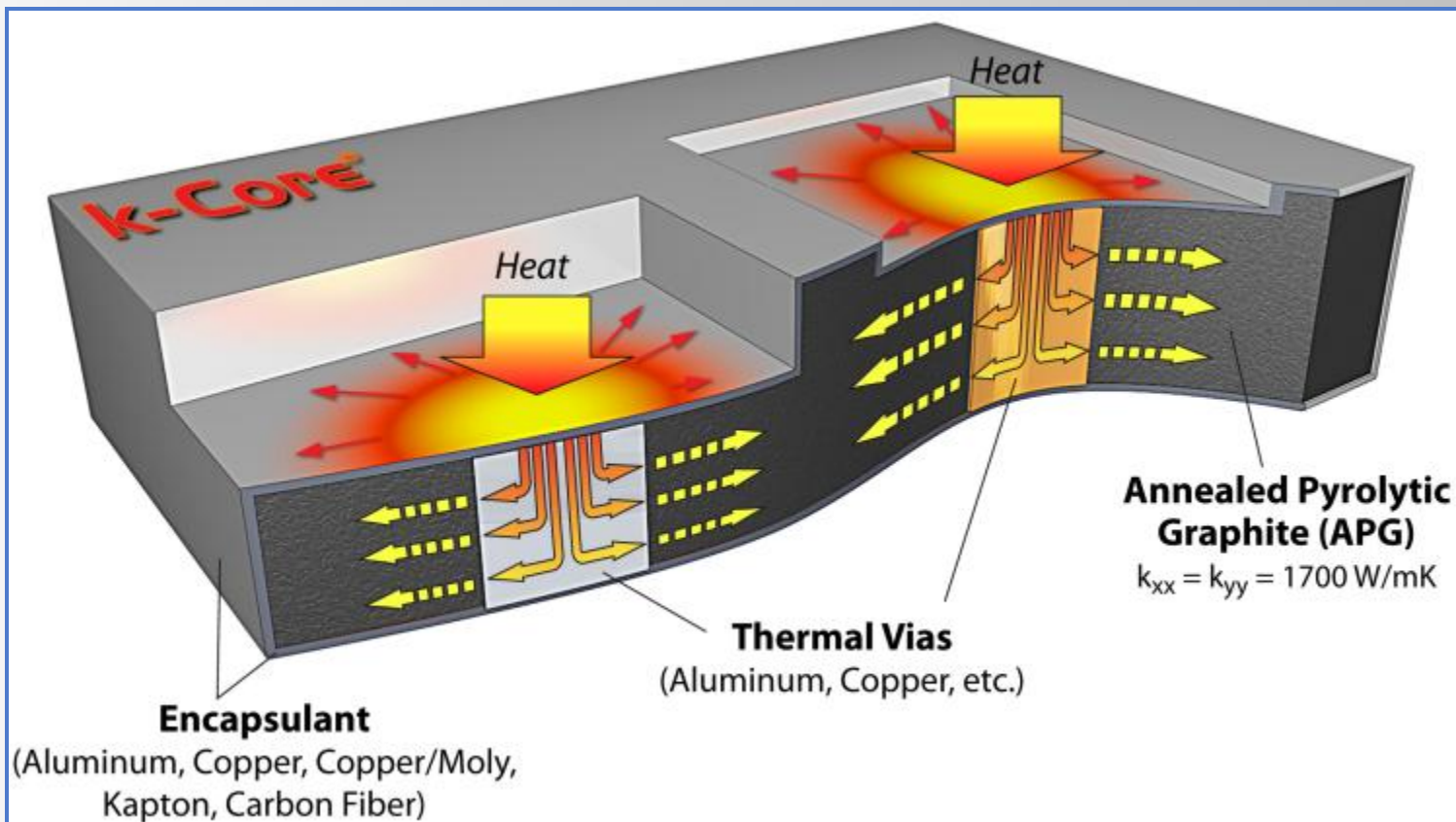
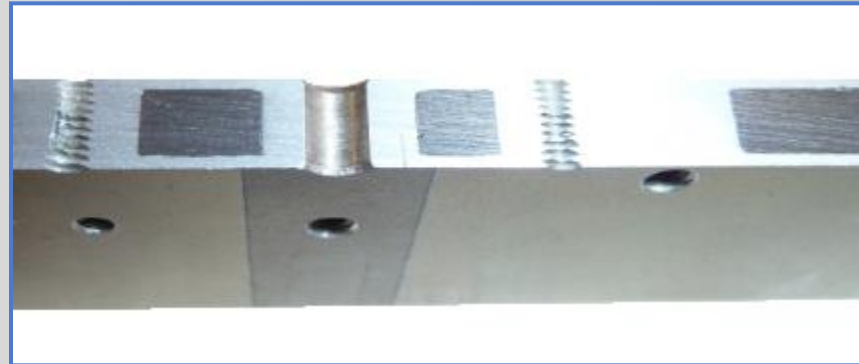


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Liquid Cooling

Solid Conductance

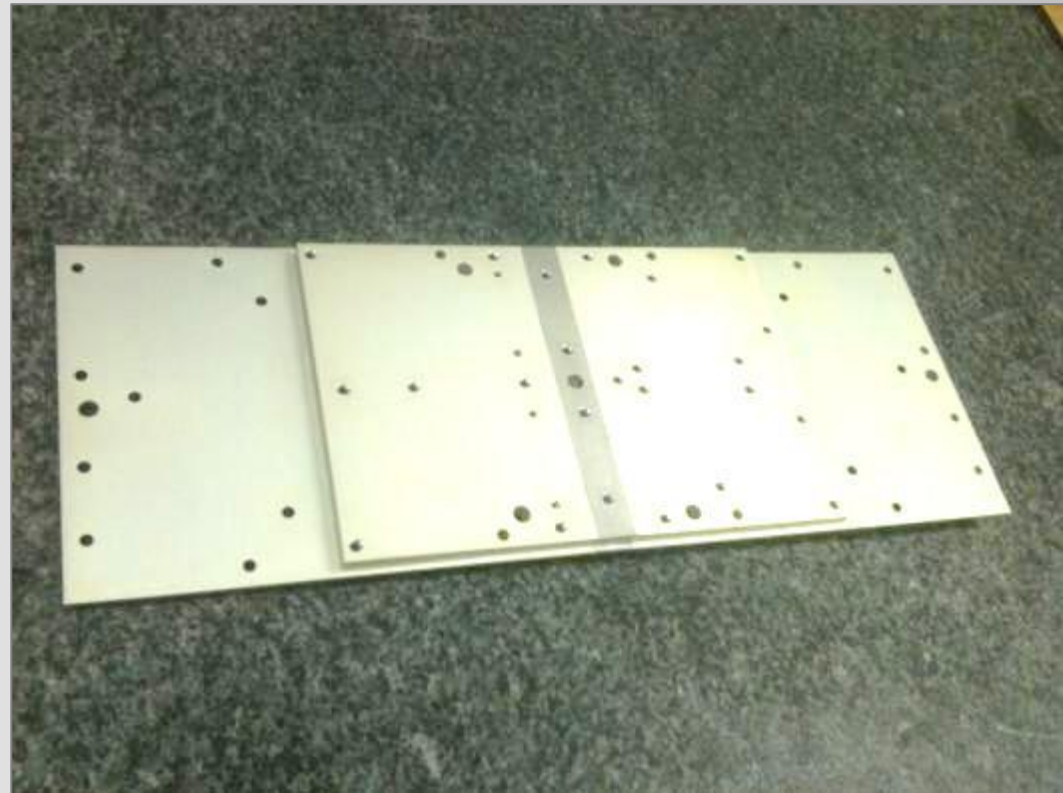
Two Phase
System Level Assemblies
R&D

Solid Conductance



EA-18G Growler Application

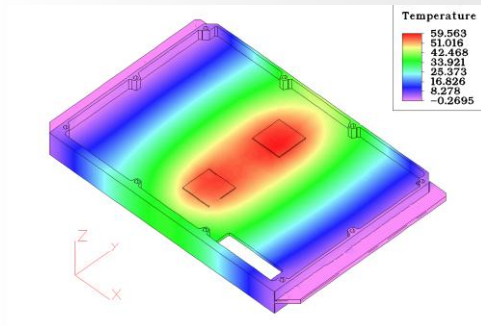
The k-Core heat spreader manages high power FET amplifiers passively
Qualified design – Multiyear production of +800 heat spreaders per year ongoing
Aluminum Encapsulated APG with Copper Vias
EA-18G Growler Low Band Transmitter



Solid Conductance

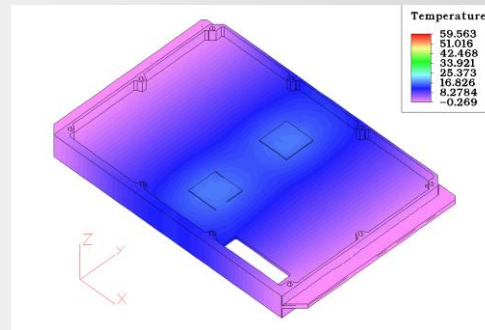
Aluminum Baseline

Max Surface Temperature – 59.8°C



k-Core® Material

Max Surface Temperature – 17.5°C



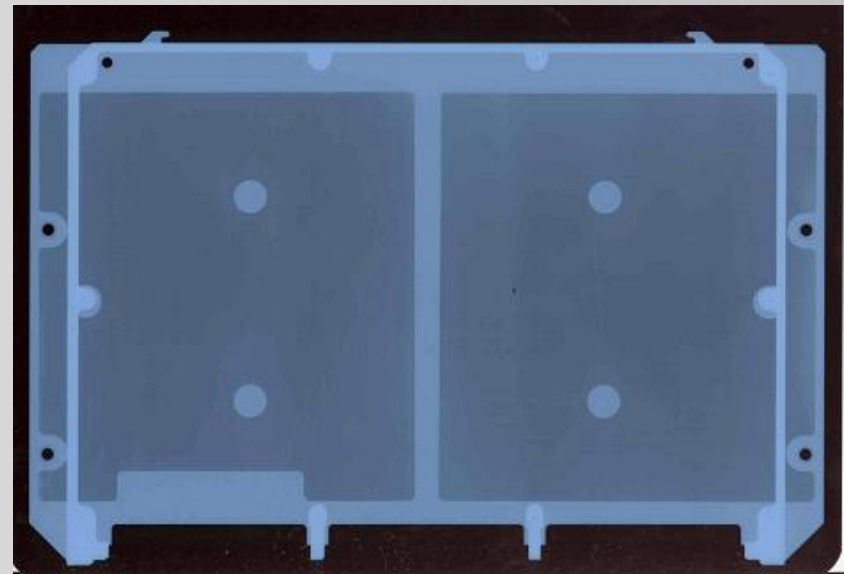
Conduction cooled module, F35 standard

Standard APG configuration with core personalization

Up to 250 W heat dissipation through core

Aluminum encapsulation

Permits the use of COTS parts



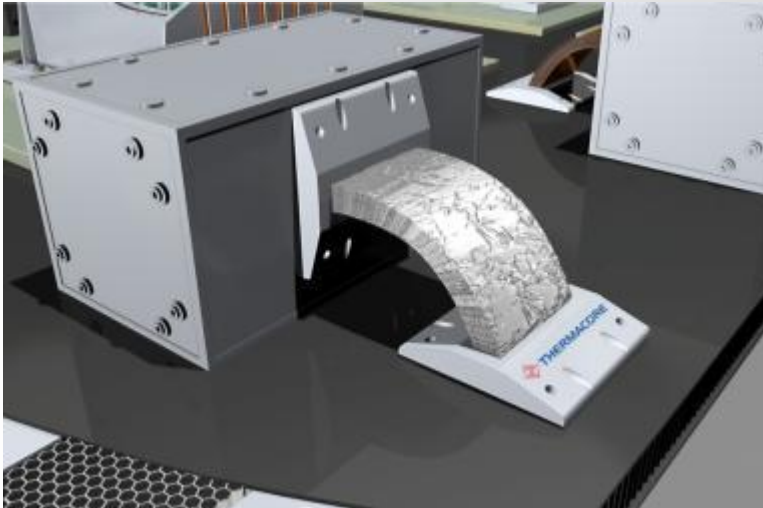
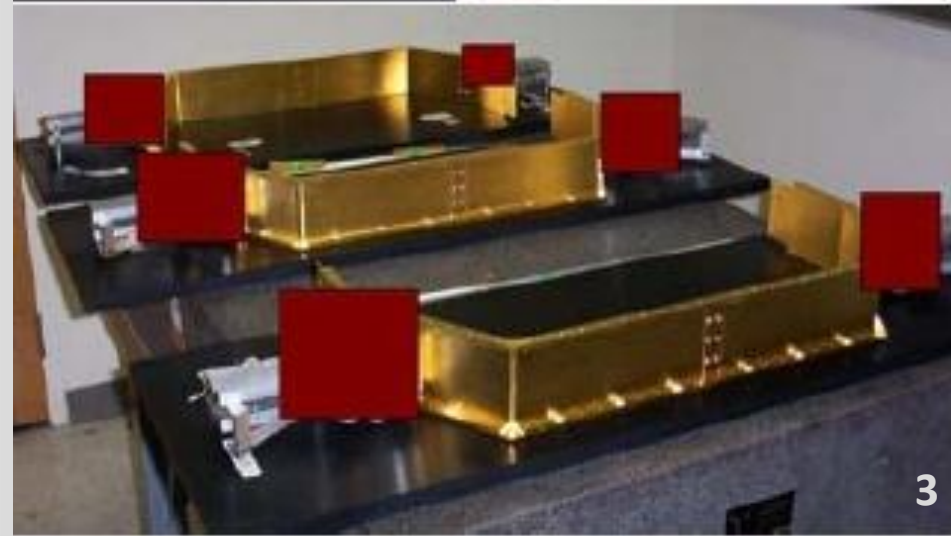
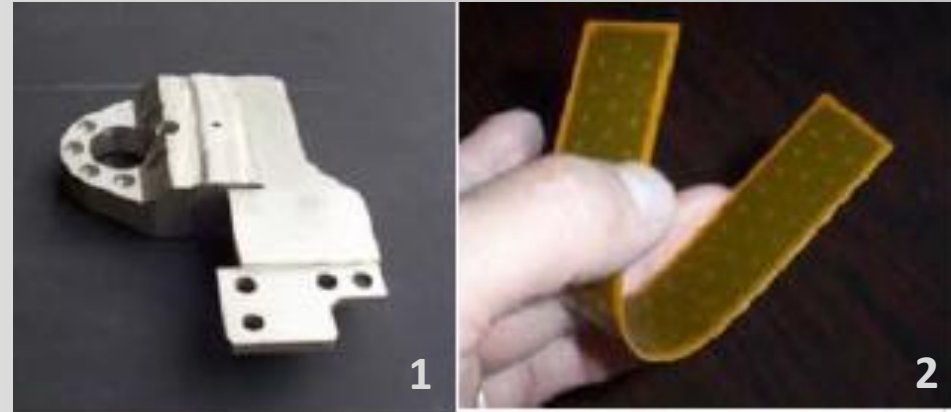
Solid Conductance

1 – Aluminium flexible strap with HIP'ed end plates

2 – Kapton encapsulated K-Core strap, electrically isolating and very flexible.

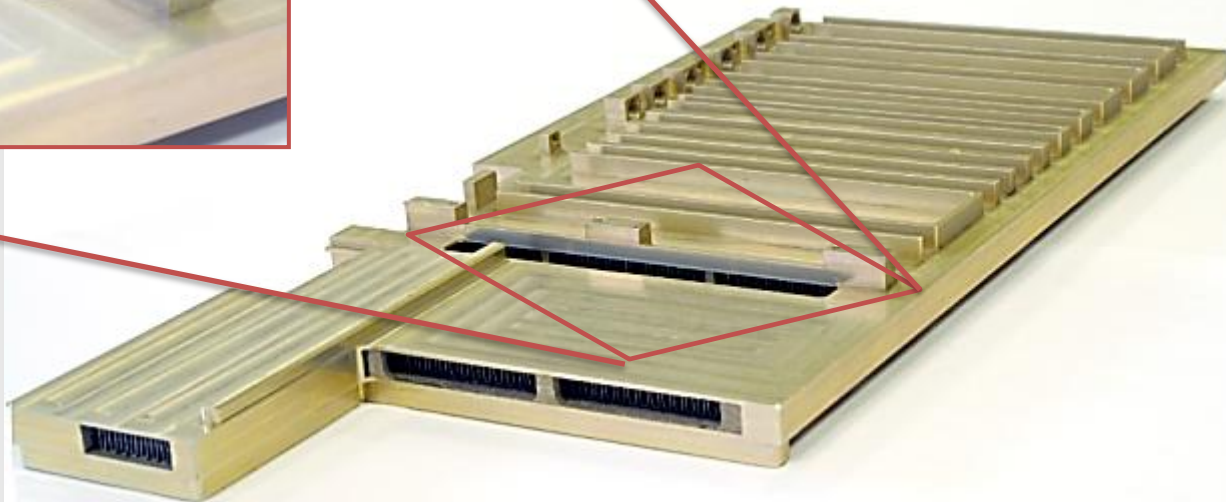
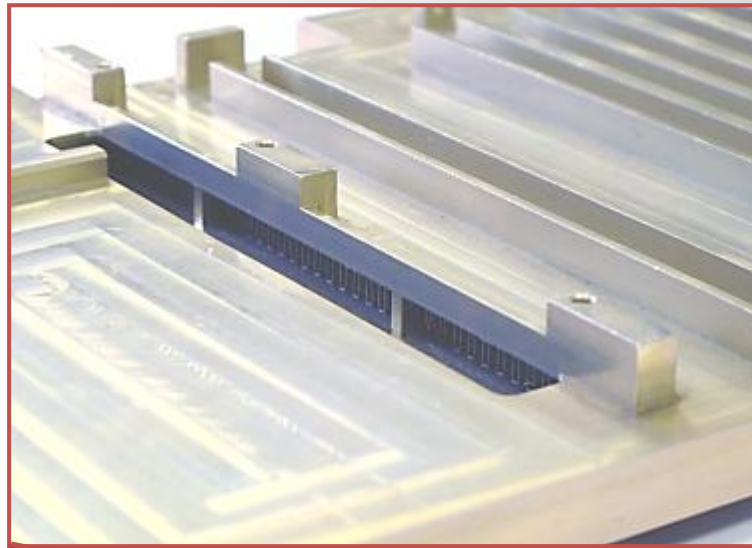
3 – Copper flexible straps as part of a chassis wall

4 – Aluminium strap with clam-shell end plates



Solid Conductance

Vacuum Brazing of air cooled cold walls – complex design with one process
Cold plate, ATR/VME type “Kintex” cold walls and mechanical structures
Augmented with heat pipe tech if necessary

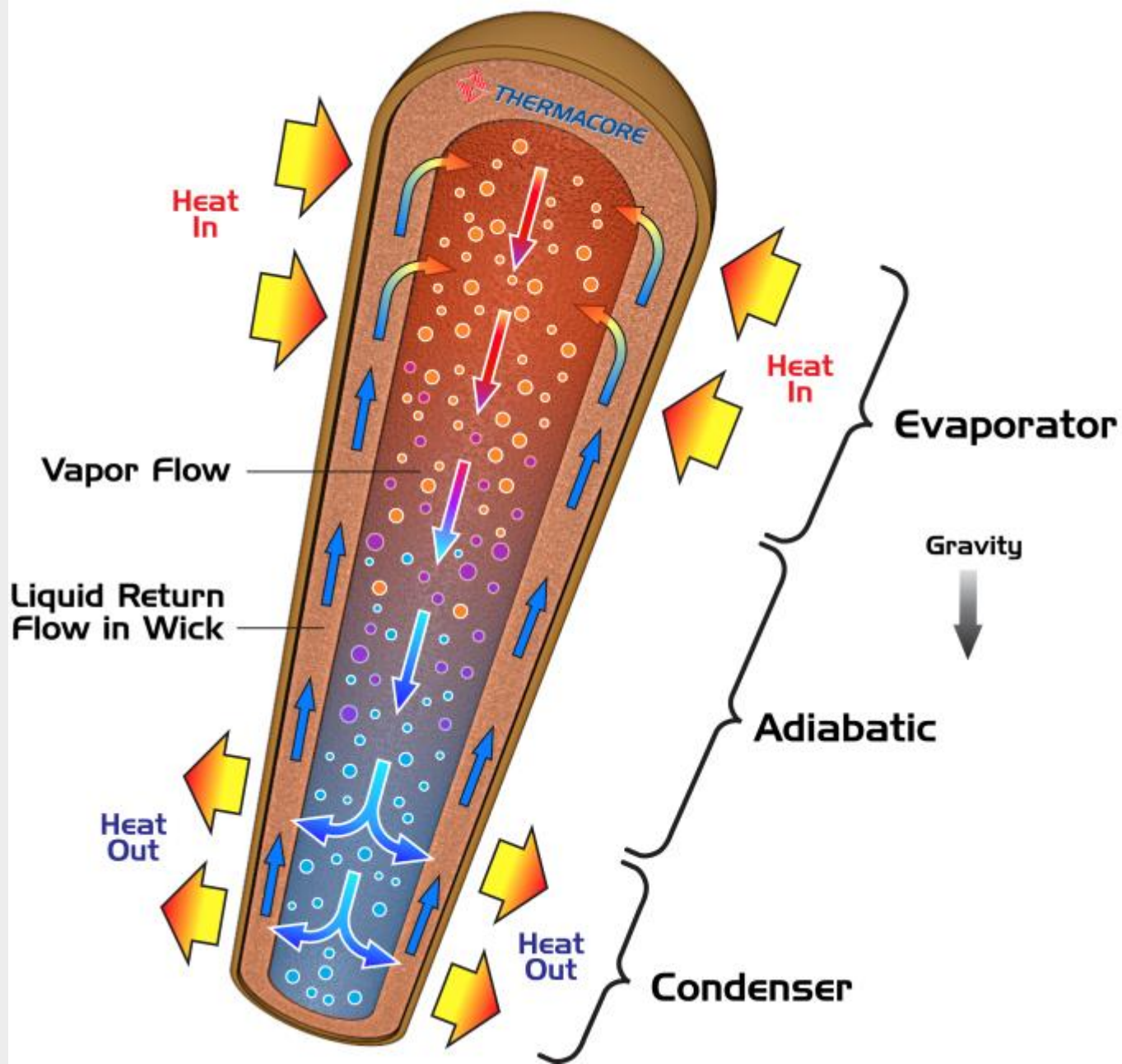


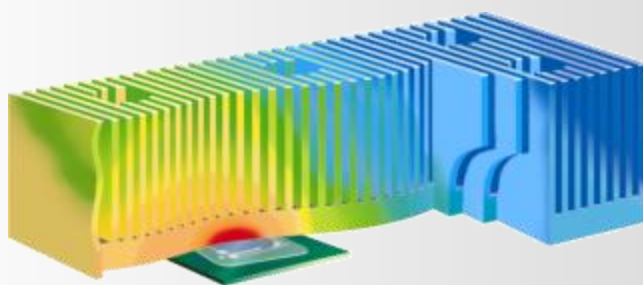
Introduction
Liquid Cooling
Solid Conductance

Two Phase

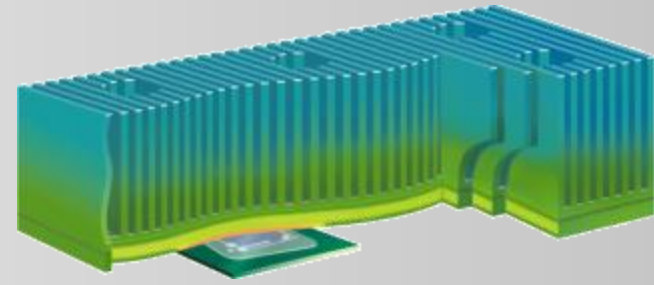
System Level Assemblies
R&D

Two Phase Technologies





**Traditional Heat Sink
with localized hot spot**



**Therma-Base Heat Sink
spreads heat eliminating hot spots**



20°C

30°C

40°C

50°C

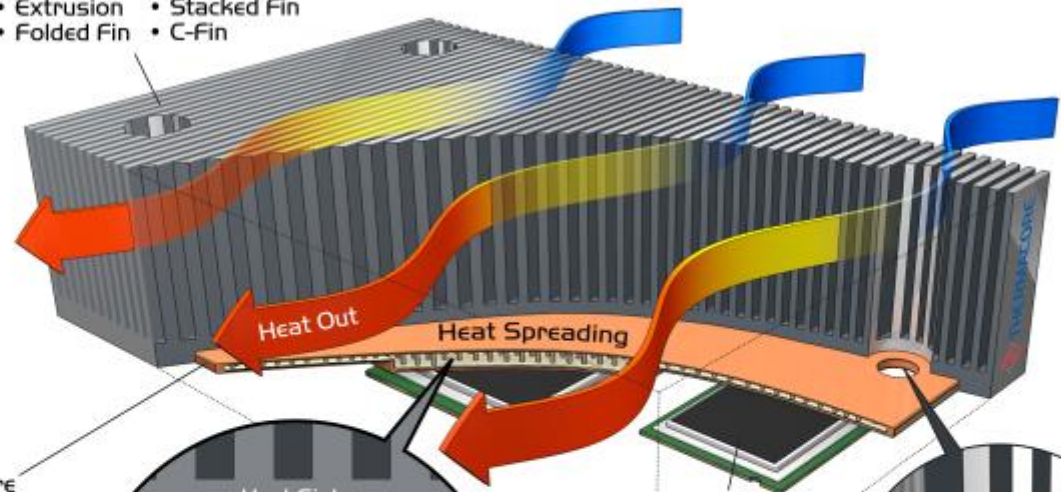
60°C

70°C

80°C

Heat Sink Options Include:

- Extrusion
- Stacked Fin
- Folded Fin
- C-Fin



Therma-Base
Therma-Base®
Vapor Chamber

Heat Sink

Hot
Component

- Materials Include:
- Copper
 - Copper/Moly/Copper
 - Titanium
 - Other CTE Matching Materials

Vapor
Liquid
Filled Wick

Hot
Component

Therma-Base Patented
Through-Hole
Technology

Two Phase Technologies

Advantages

Silent and Passive

Very low temperature drop or ΔT

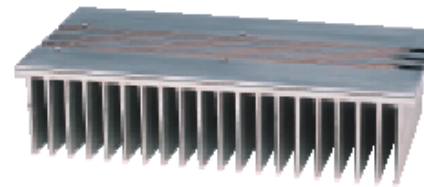
Can operate against gravity

40 years of operation with Cu/Water

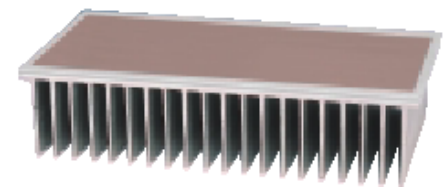
Calculated MTTF >125,000 hours



**Aluminum
Extrusion**

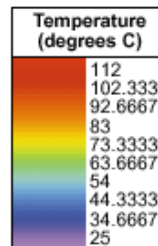


**Embedded
Heat Pipes**

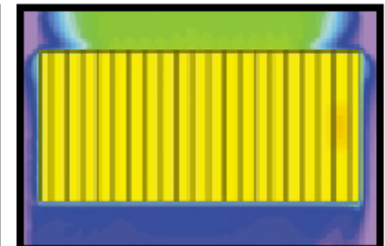
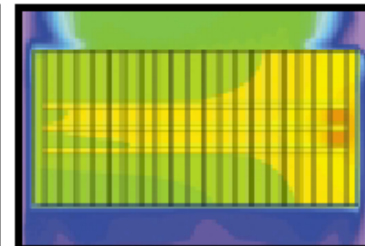
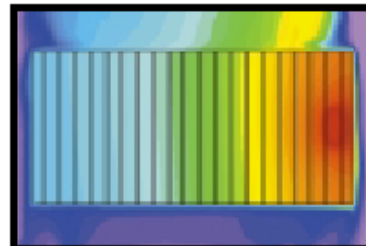


Therma-Base™

By embedding heat pipes into the extrusion, the thermal performance of the extrusion was improved 36%. With the use of the Therma-Base™, the thermal performance improved by 44%. Due to reduced thermal resistance, higher component power levels can be achieved – particularly for 3G RF amplifiers. Design flexibility has increased because the power dissipating components can now be located anywhere on the heat sink rather than being restricted to the center of the heat sink.



**THERMAL
RESISTANCE:**



Using Heat Pipes – Spreading Resistance

Embedded heat pipes
soldered in place

Seven plating operations
allows for direct mounting of
components to heat sink

Thermal breaks protect the
recessed components from
the higher running temps of
MOSFETS (1.5kW)

TCE heat sink size LxWxH = 454x326x80

Original heat sink size = 800x450x100

45% weight reduction achieved

TCE max temp = 118°C

Original heat sink temp = 120°C



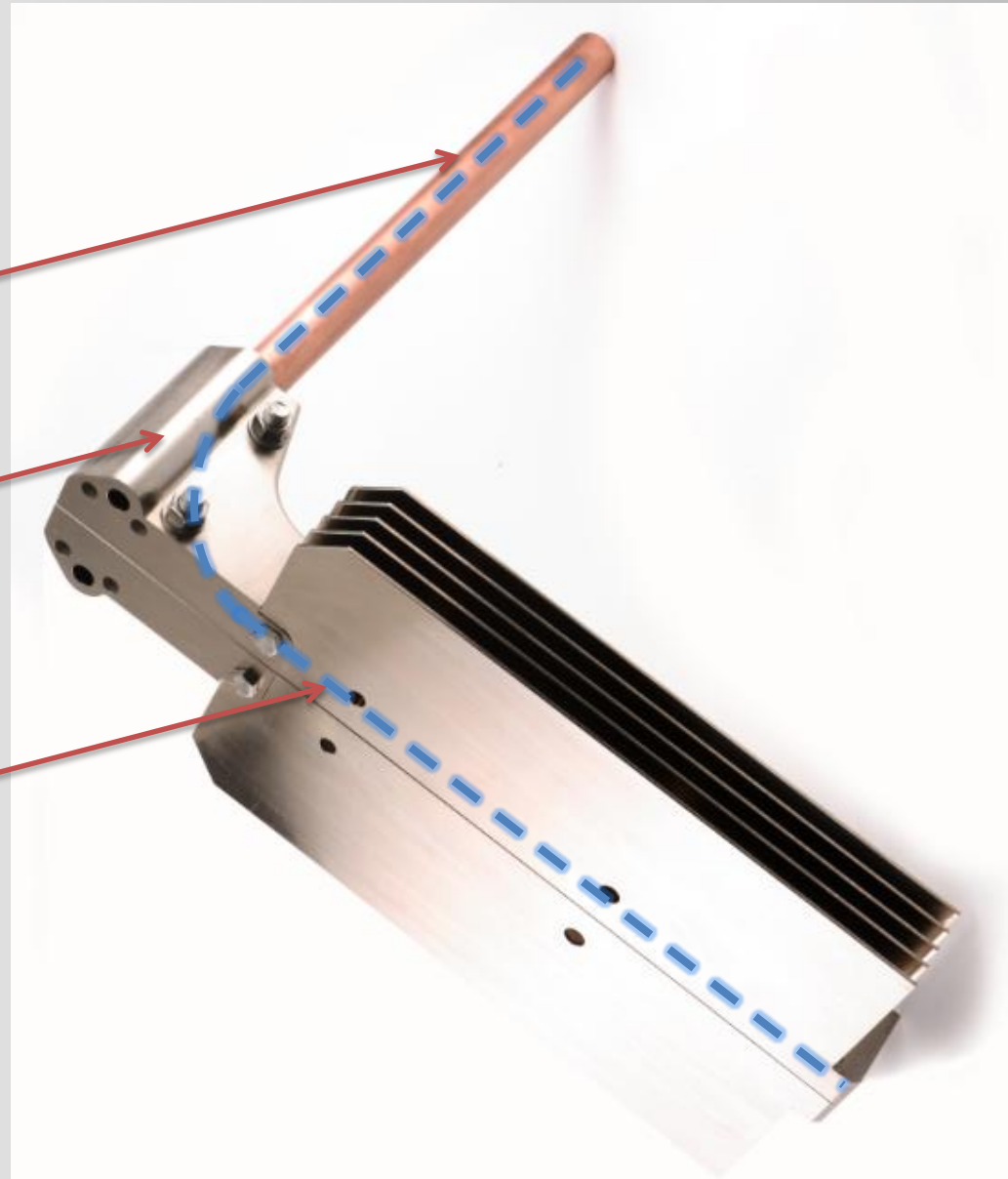
Using Heat Pipes – Heat Transport

250°C evaporator
Heat pipe Ø45mm mesh wick

3D machining, assembly, TIM
and testing all provided

Heat pipe length 1200mm

800W power dissipation



Vapour Chambers Example

1200W heat load using TEC's

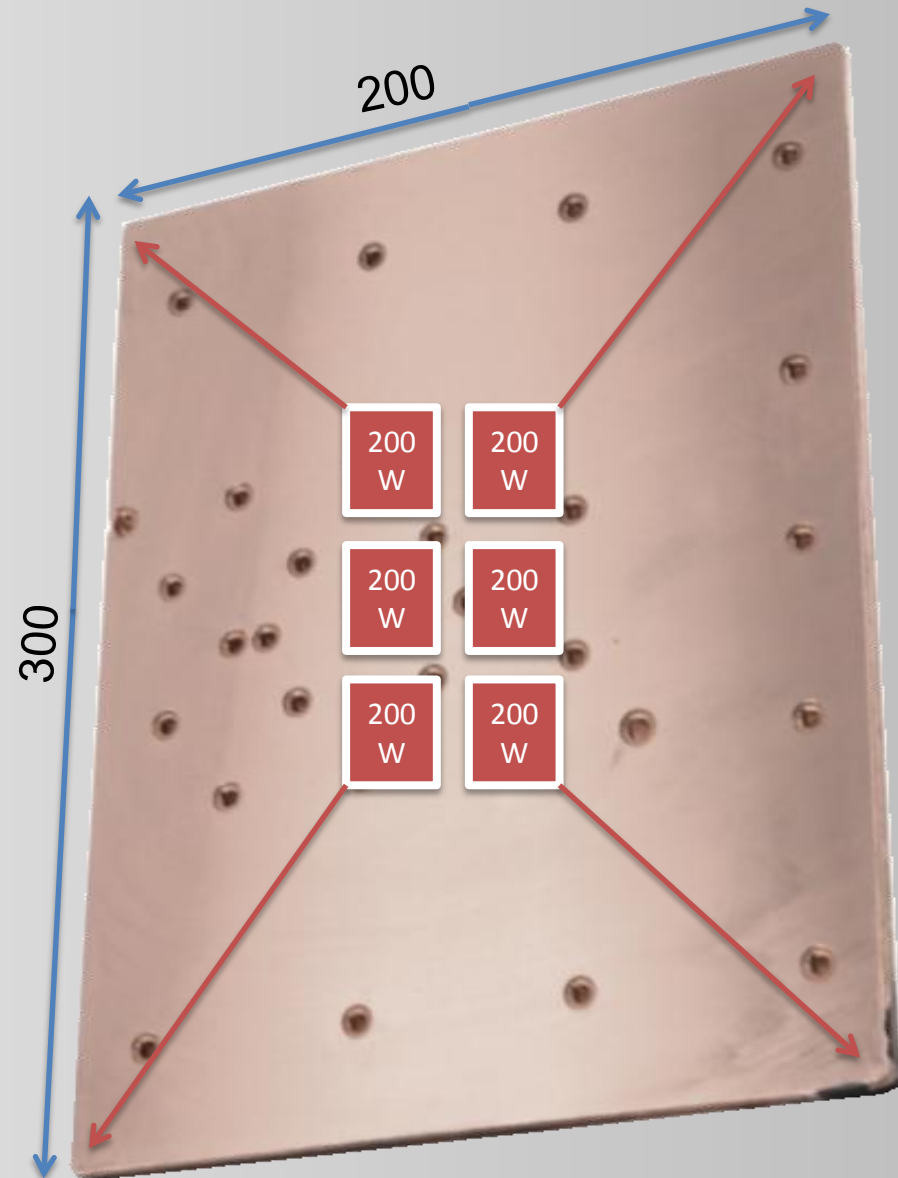
No more than 0.2°C between the hot and cold spots on the vapour chamber

Flatness and parallelicity of chamber to 0.1 across all area

Run rate of 3000 per year

On-Line Helium leak test machine

On Line Bespoke software test station



Thermo Electric Coolers

TEC Advantages

Sub ambient cooling

Reliable operation

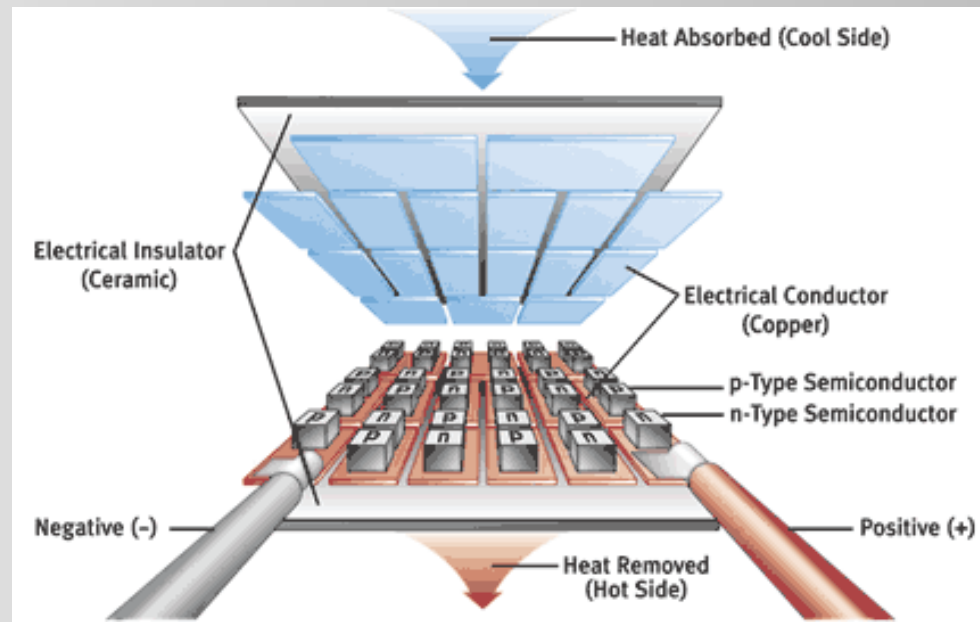
Low maintenance

Can be used to heat and cool

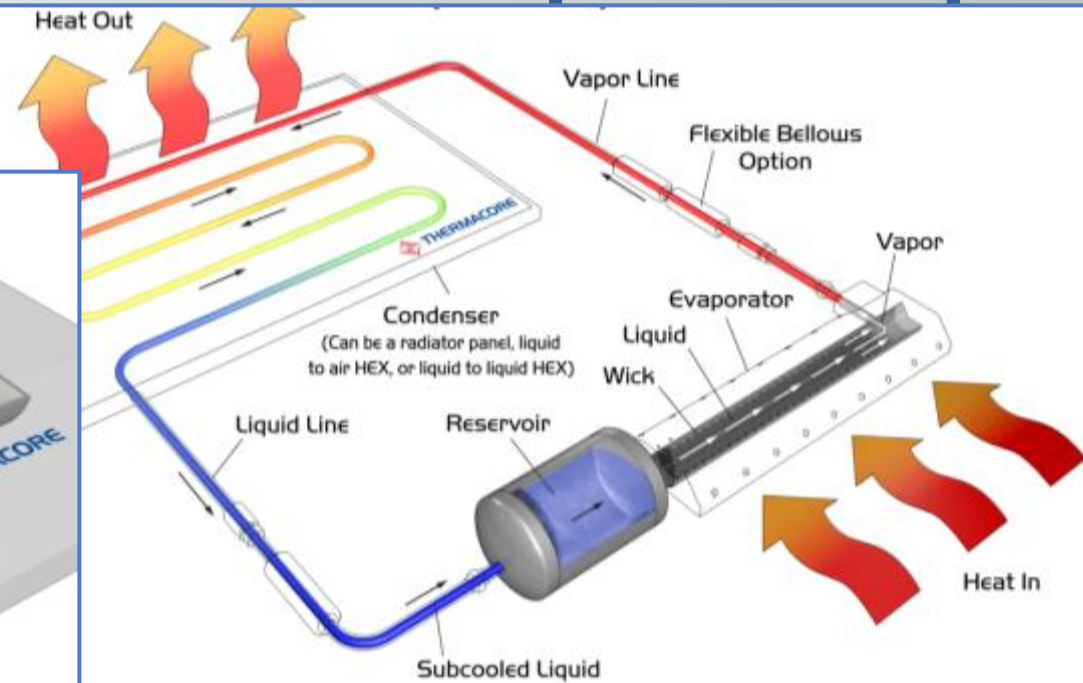
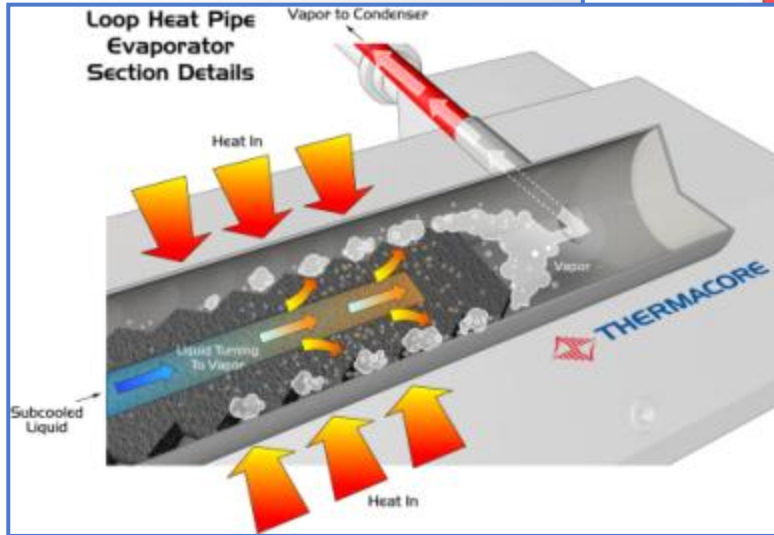
TEC controllers can regulate heat to a high accuracy ($\pm 0.1^{\circ}\text{C}$)

Environmental sealing around the TEC edge is possible

Multi stage TECs possible



Two Phase Loop Heat Pipes

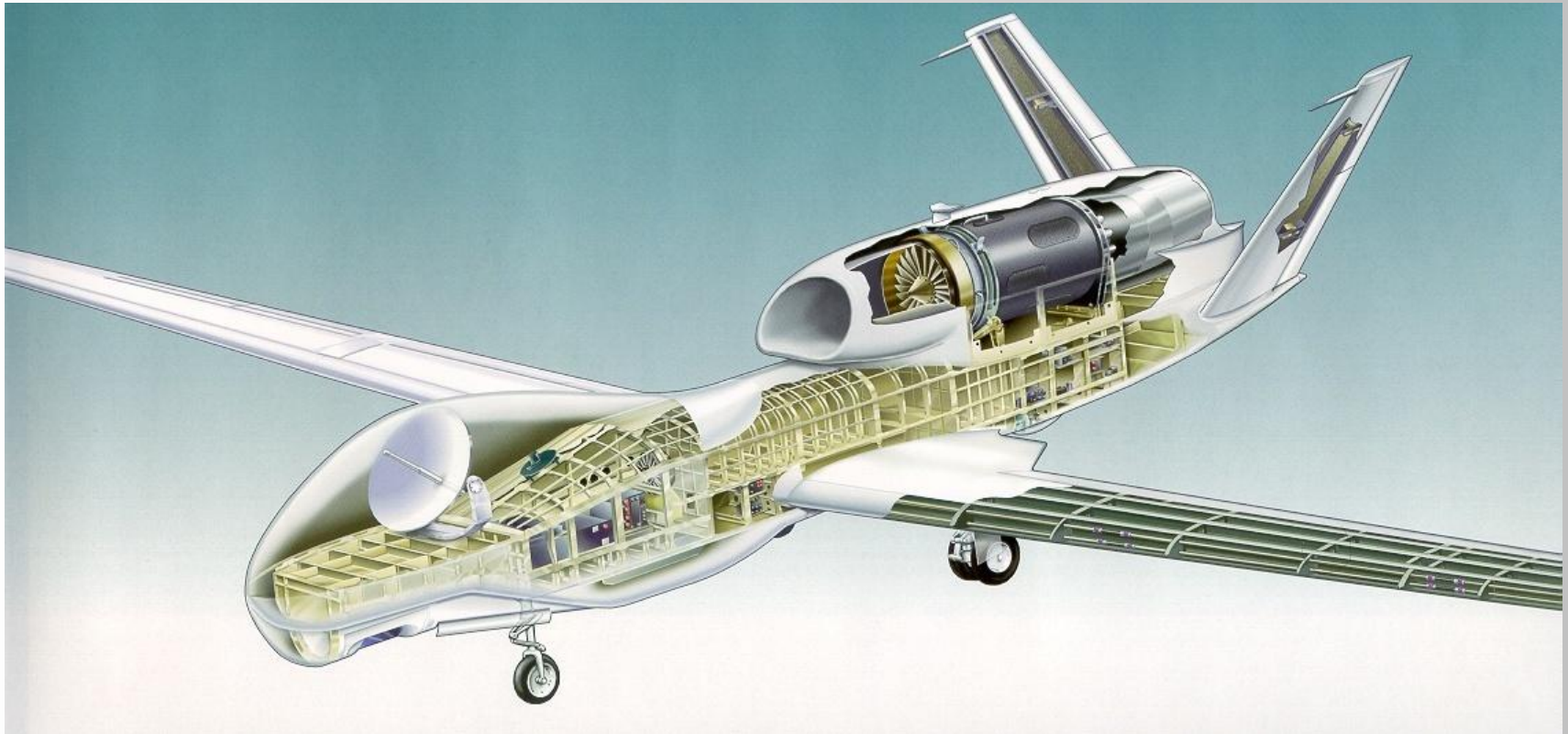


- Gravity Insensitive
- Flexible, bendable, routable
- Long Distance Heat Transport
- Low Mass
- Thermal Diode (Prevents backwards heat leak)
- Multiple evaporators (Accommodates dispersed heat sources)
- Thermal Regulation (Passive/Active)

Two Phase Loop Heat Pipes

UAV Radiator Program

The *Global Hawk* High Altitude Endurance UAV



Present Payload ~ 10 kW. Expected to grow to 50 kW

Two Phase Loop Heat Pipes

2 Meter Span Incorporates 3 LHP Condensers.

Rejects slightly less than 3 kW at 65,000 ft under Hot Day Conditions

Graphite Composite Wing by Aurora Flight Sciences



Axially Grooved Ammonia Heat Pipes

Material:

6063-T6 Aluminum

Lengths:

Inches to several Feet

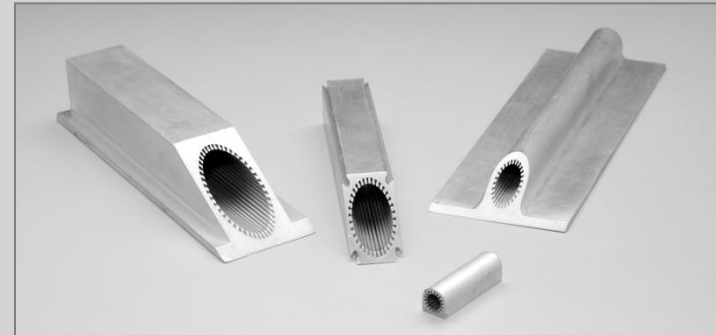
Fluids:

Ammonia

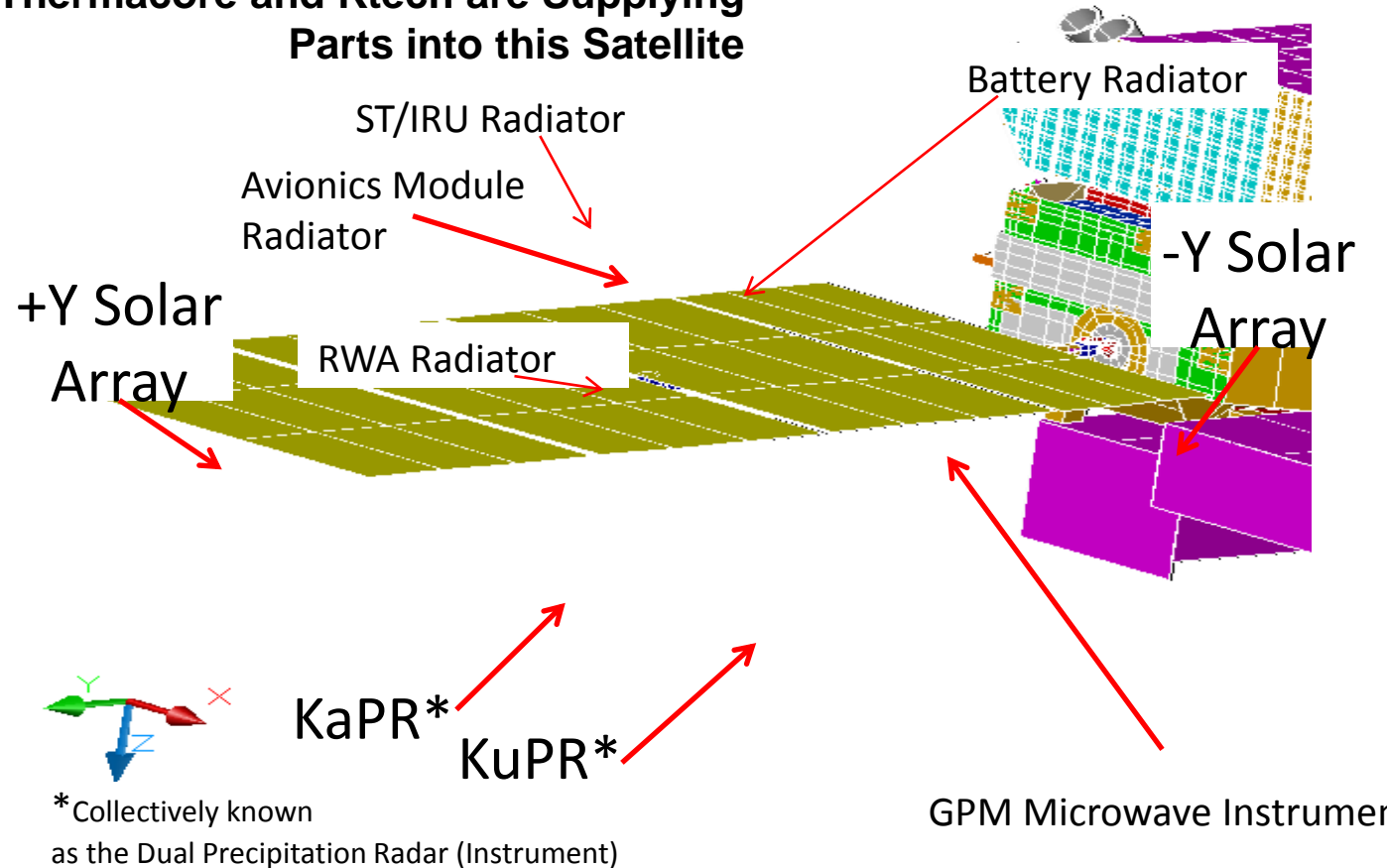
Propylene

Integration

Bonding into
Honeycomb Panels



Thermacore and Ktech are Supplying Parts into this Satellite



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R&D

System level builds

Application:

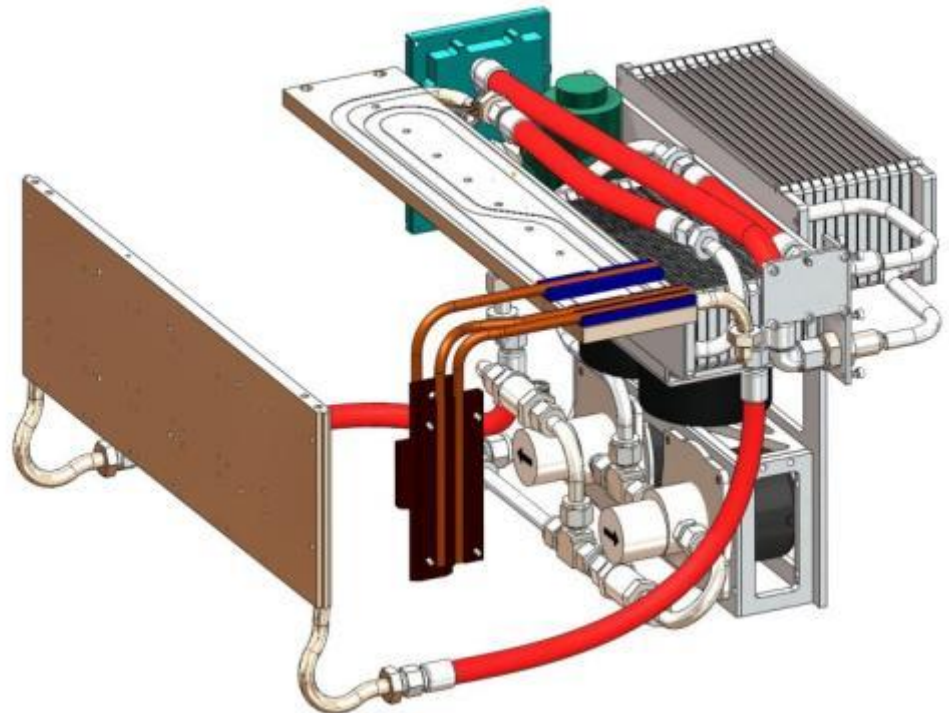
Ruggedized Data Processor
Unmanned Aerial Vehicle (UAV)

Thermal Load:

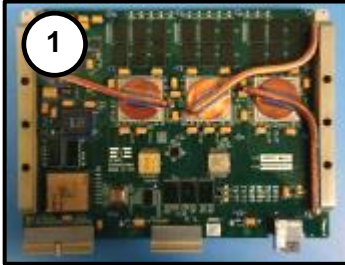
Dissipate 1000W from MAP,
MCPM, Switch and Power Supply
components to ambient air

Primary Components:

Vacuum Brazed Aluminum Heat
Exchangers (Thermacore/PMT)
Dip Brazed Aluminum Cold
Plates (Kittredge)
Copper/Water Heat Pipe
Assemblies (Thermacore)
Brushless DC Pumps
(IDEX/Micropump)
PTFE Hose (Parker/Stratoflex)



System level builds



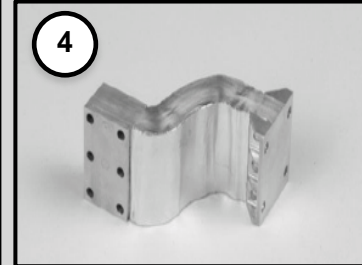
Copper-Water
Heat Pipes



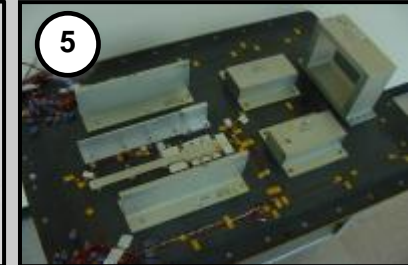
k-Core®



Electronics
Chassis

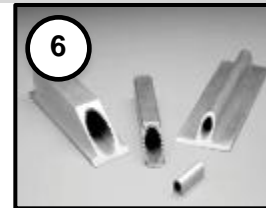
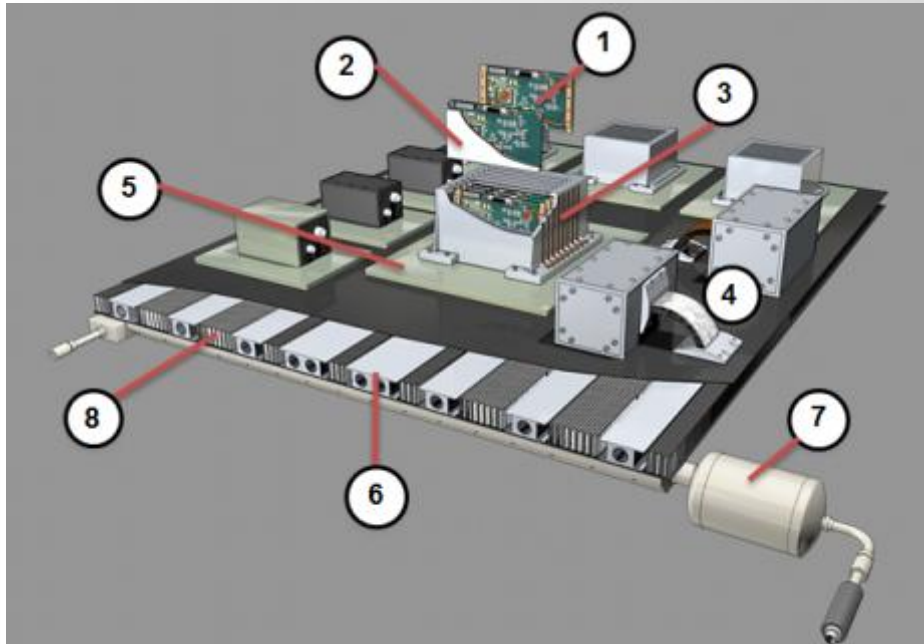


Thermal Straps

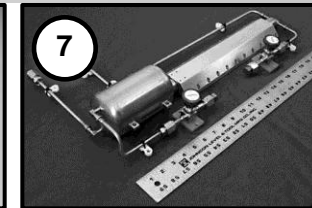


k-Core® Doubler

External Thermal Bus Structure Elements



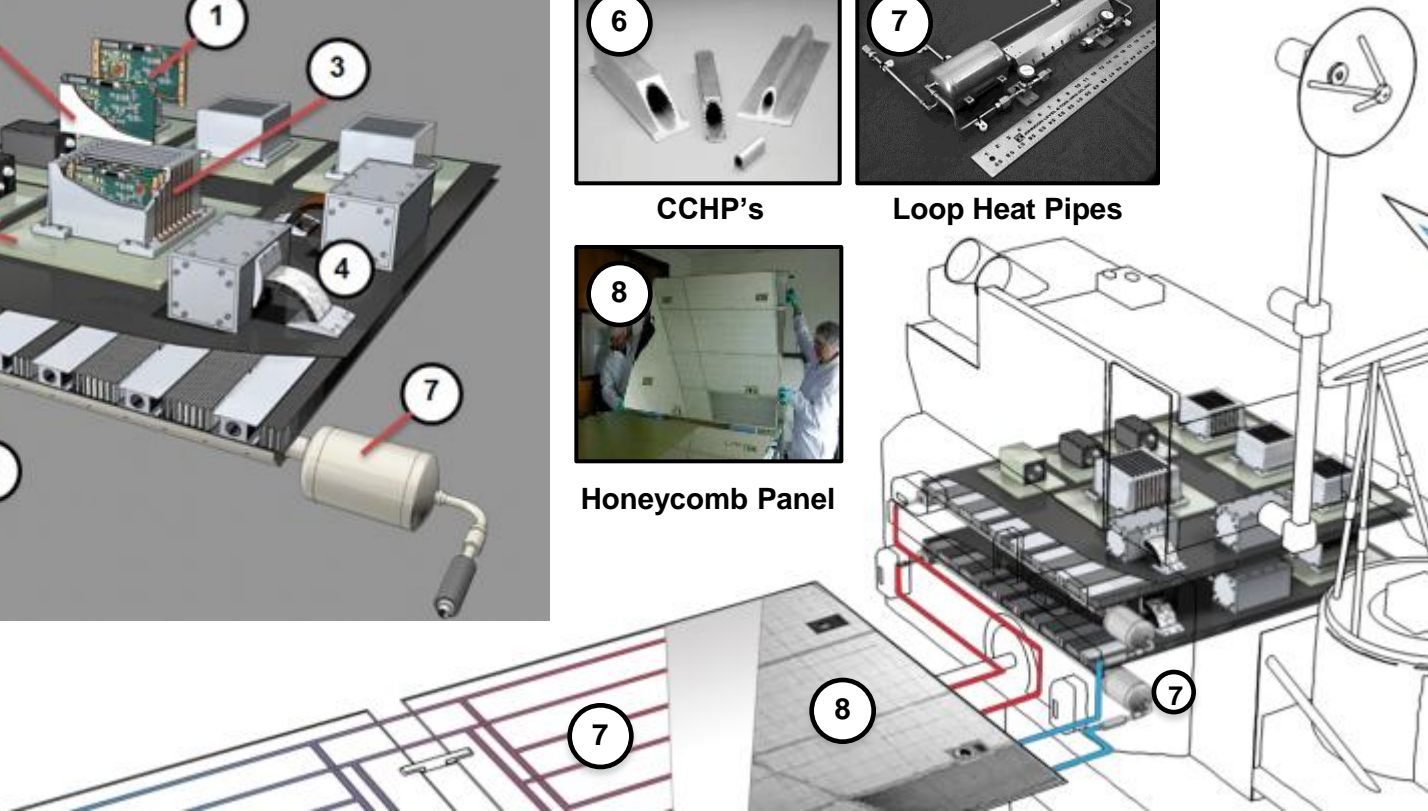
CCHP's



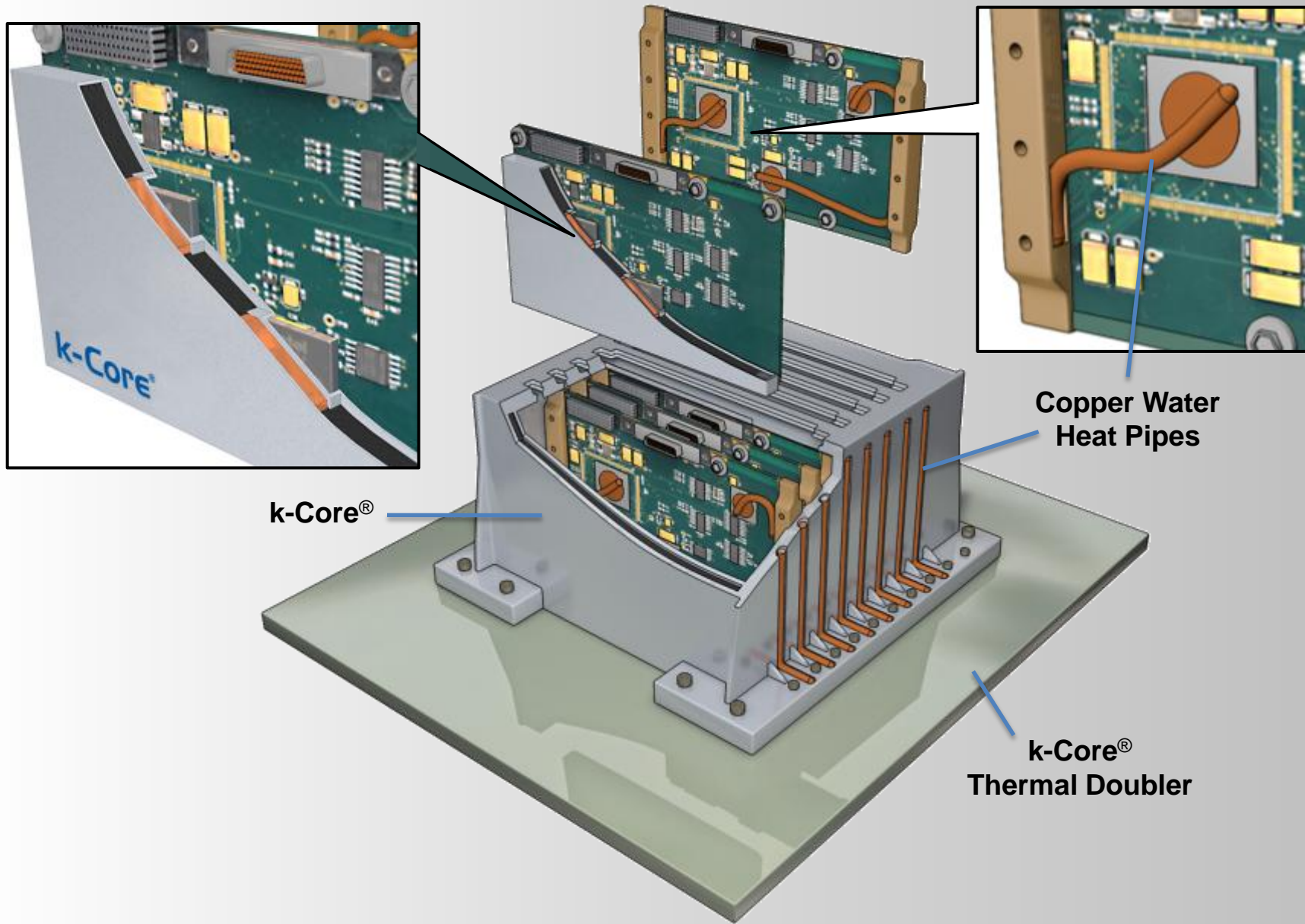
Loop Heat Pipes



Honeycomb Panel



System level builds



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R&D

R&D – Nanohex



NanoHex is being led by Thermacore Europe Ltd based in Northumberland UK, in close conjunction with:

Centre for Process Innovation, Wilton, UK;

Ingegnera Sistemi Impianti Servizi R&D, Italy;

Technical University of Eindhoven, Netherlands;

The University of Birmingham, Dept of Chemical Engineering, Birmingham UK;

The Weizmann Institute of Science Israel;

The University of Twente, Netherlands;

ItN Nanovation AG, Germany;

Siemens AG, Germany;

Italian National Agency for New Technologies, Energy and Sustainable Economic Development

Royal Institute of Technology, Sweden;

Dispersia Limited in Leeds, UK.



Power Electronics



Data Centres

R&D – Thermal Ground Plane

Thermal Ground Plane Program

Cu Moly Cu High Performance
Spreader

Technology:

<2mm Thick

CTE Matched

Direct Attach to Package

Vapor Chamber Heat Pipe

Applications:

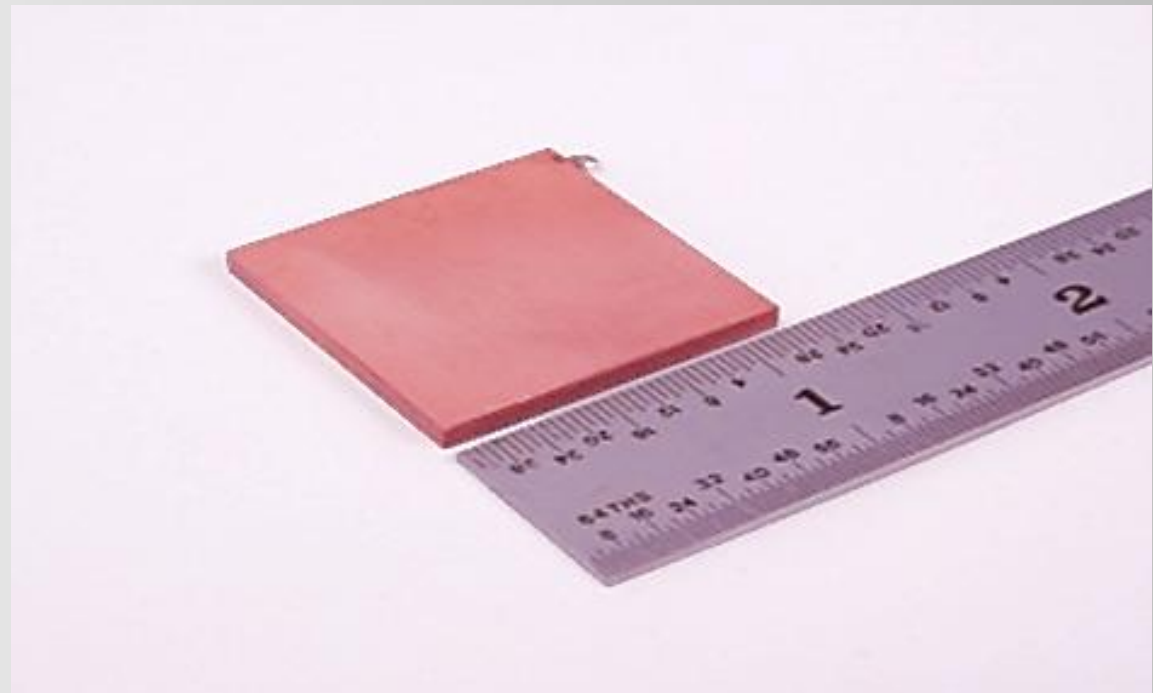
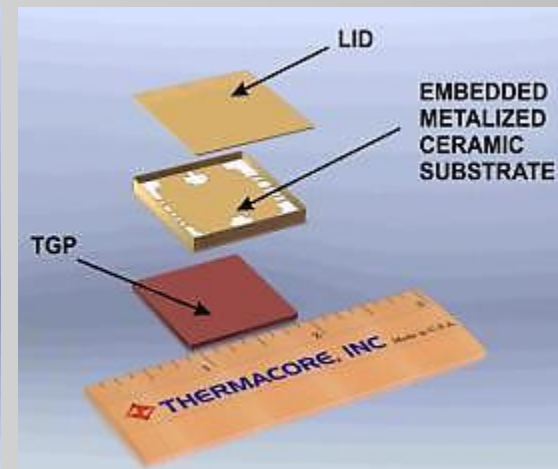
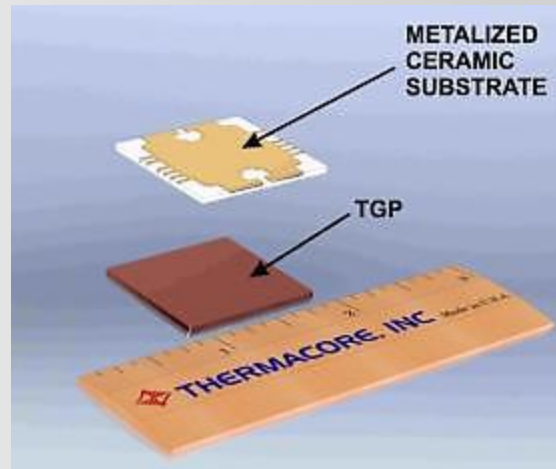
Insulated Gate Bi-Polar Transistors,
IGBTs

Power Amplifiers, PAs

Transmit/Receive Modules, T/R

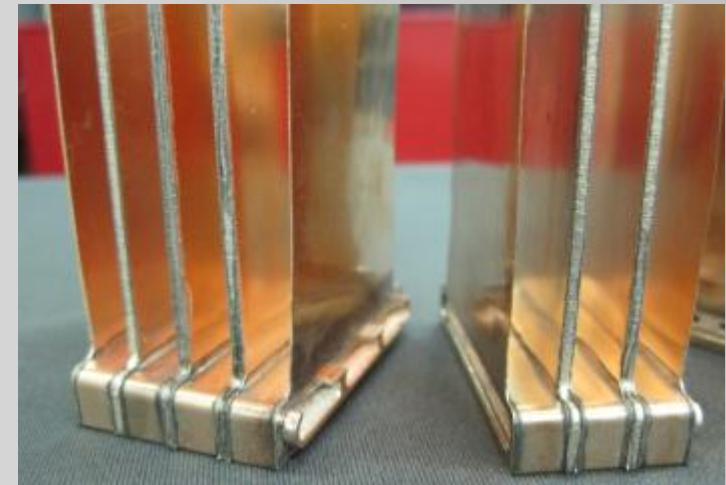
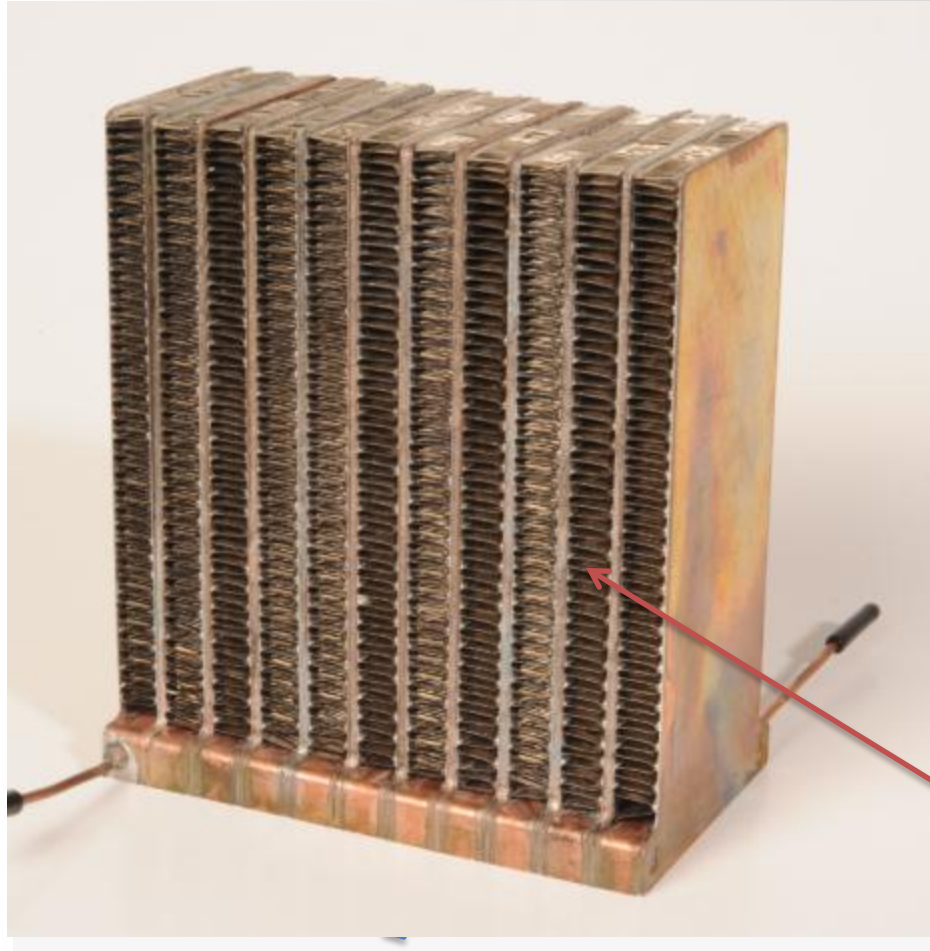
Laser Diodes

LEDs



R&D – 3D Heat sink

Integral Vapor Chamber/Heat Pipe Fins
based on stackable fabrication
approach.



Automotive Style Fins yield
tremendous surface area.

**Enables Heat Sinks that are $\frac{1}{2}$
to $\frac{2}{3}$ smaller than original
size.**

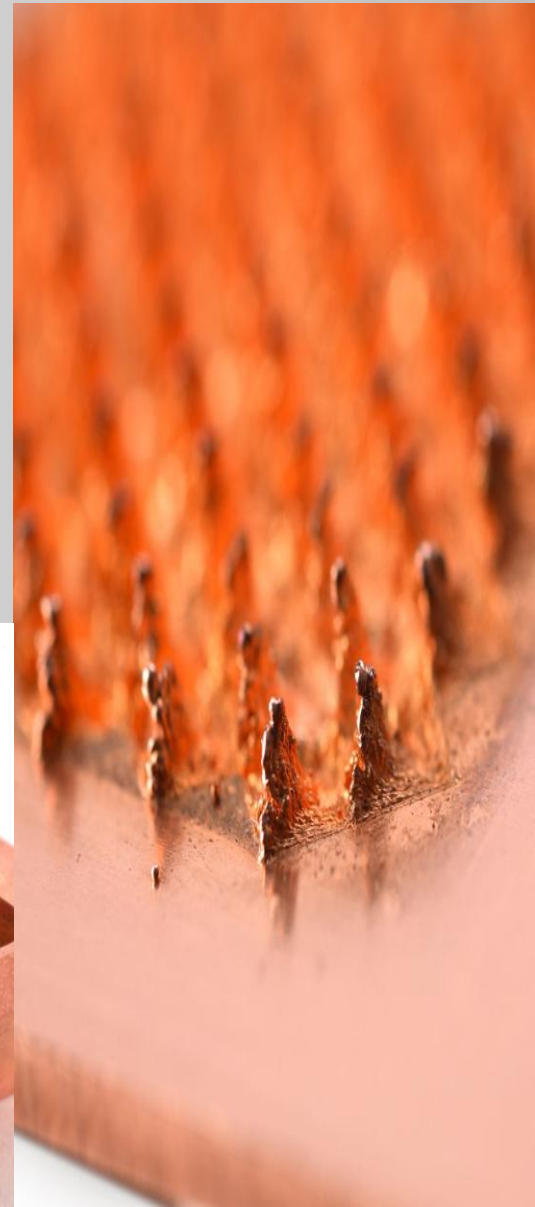
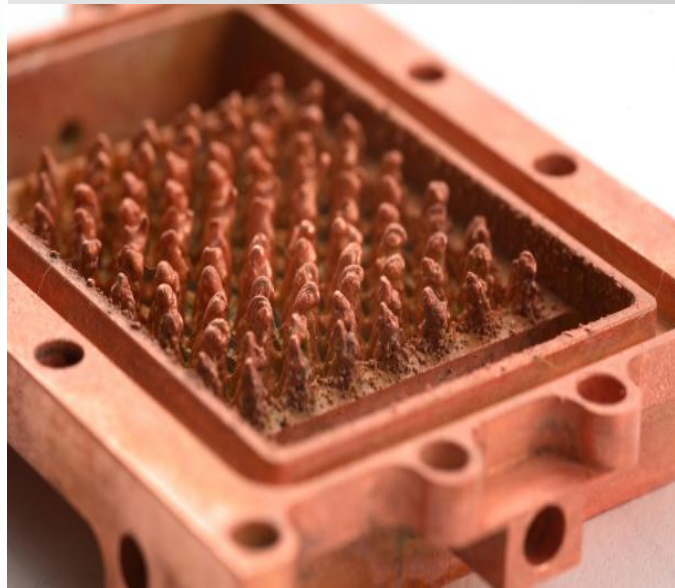
R&D – Surfisculpt

Application

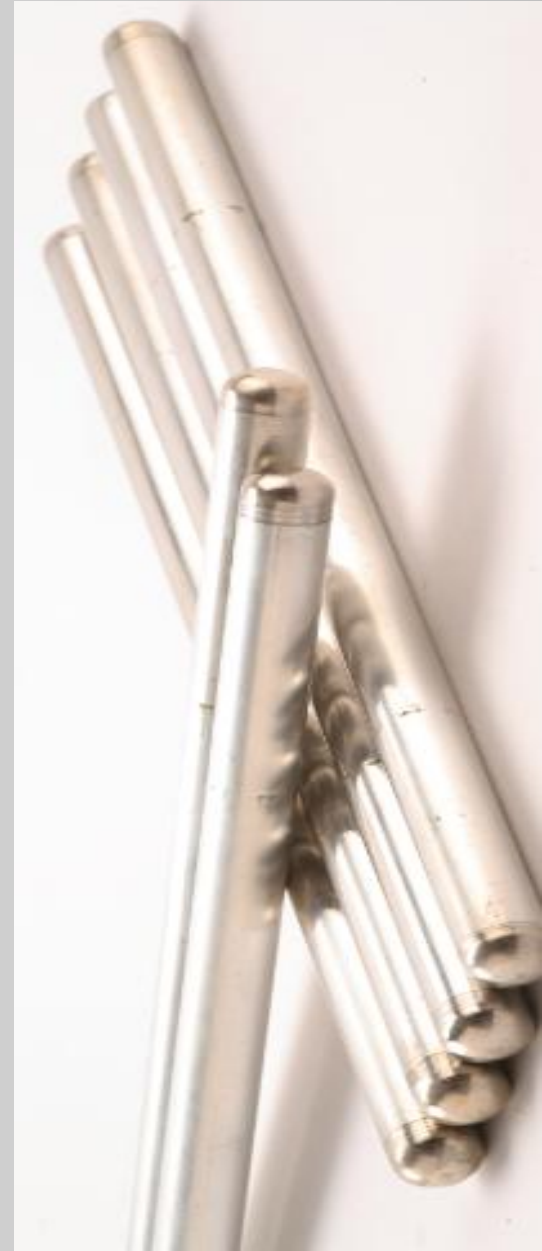
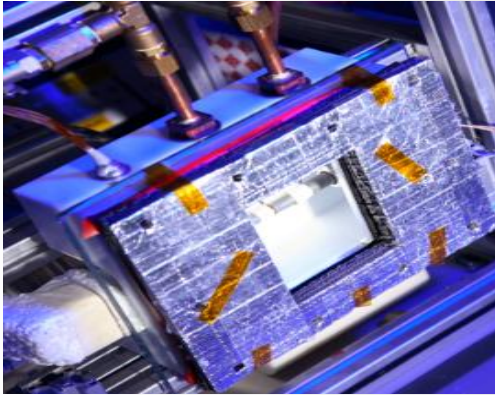
Development of enhanced heat transfer surfaces using EB technology

Project details

To identify and develop opportunities to improve the heat transfer properties of various surfaces. Liquid heat exchange surfaces will be investigated first



R&D – Mag Alloy heat pipes



Aims

Develop light-weight, low-cost, performance heat pipes

Project details

Due to the increasing requirements of light-weight heat pipes, magnesium has become a good alternative to Copper.

Thermacore is investigating compatibility of magnesium alloys that will operate with a good working fluid without corrosion taking place. The project is based on both experiments and numerical simulations, such as Molecular Dynamics simulation (MD).

Website and Design Centre



THERMACORE EUROPE
Thermal Management Solutions



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Design Centre Home

Welcome to Thermacore's Design Centre

The Design Centre provides interactive calculation sheets for the prediction of **k-Core®**, **heat pipe**, **vapour chamber** based thermal solutions, and enclosure or cabinet **heat exchangers**. The design tools are free to be used by all registered users.

Advanced Solid Conduction:

- [k-Core® Calculator](#)

Two-Phase Heat Transfer:

- [Heat Pipe Calculator](#)
- [Vapour Chamber Calculator](#)

Enclosure Cooling:

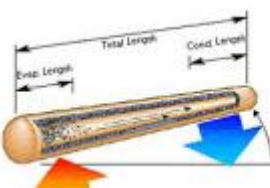
- [Heat Exchanger Calculator](#)

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Conversion Calculators



Total Length
100 millimeters

Evaporator Length
40 millimeters

Condenser Length
40 millimeters

Orientation
45 degrees

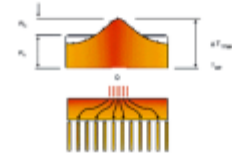
Operating Power
30 watts

Operating Temperature
60 deg. C

Power Tip
Heat Pipe Diameter
Operating Temperature Tip

Let Program Recommend
Diameter Tip

Calculate



Heat Source Size
Length (in):
Width (in):

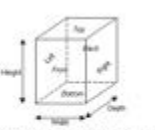
Heat Sink Base Size
Length (in):
Width (in):
Thickness (in):

Power (W):

Material conductivity (W/mK):

Material Conductivity Reference:
Al (Pure @ 285K) 237 W/mK
Cu (Pure @ 285K) 401 W/mK

Calculate



Cabinet Width
1 meters

Cabinet Height
1 meters

Cabinet Depth
1 meters

Maximum Ambient Temperature
22 deg. C

Total Power
(Include Solar Loading)
1500 watts

Surfaces Available for Natural Convection (Uncheck all surfaces for isolated Cabinets)
☒ Top Surface
☒ Bottom Surface
☒ Front Surface
☒ Back Surface
☒ Right Surface
☒ Left Surface

Desired Cabinet Temperature at Maximum Ambient
40 deg. C

Surfaces Available for Radiation (Uncheck all surfaces for isolated Cabinets)
☒ Top Surface
☒ Bottom Surface
☒ Front Surface
☒ Back Surface
☒ Right Surface
☒ Left Surface

Calculate

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Who Are Thermacore
Two Phase
Solid Conductance
Liquid Cooling
System Level Assemblies
R&D

Thank you