National Aeronautics and Space Administration

Thermal Technology Development for the ARTEMIS Initiative

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Program: Strategic R&TD

OBJECTIVE: Develop an ***autonomous lunar night survivable thermal architecture*** without radioisotopes to enhance JPL's lunar instrument implementation capabilities with a science focus on ***magnetometers, seismometers, and IR spectrometers***.

FY19/Q4 – Early Start to FY20 Work Plan
ARTEMIS was originally planned as a 3-year JPL Strategic R&TD Program that was intended to start in FY20. Program granted approval to start early (in FY19-Q4). *Goal for FY19-Q4 was to complete preliminary drawings* for the four subscale testbeds defined in FY20 description to the right and below.

→ **FY20 – Technology Development**
Develop/evaluate ARTEMIS thermal architecture key elements through 4 subscale testbeds: (1) Dual Thermally-Switched Enclosures; (2) Parabolic Reflector Radiators (PRRs); (3) High Performance MLI; (4) High Performance Thermal Isolators. Also, start to gather requirements on 3 instrument types.

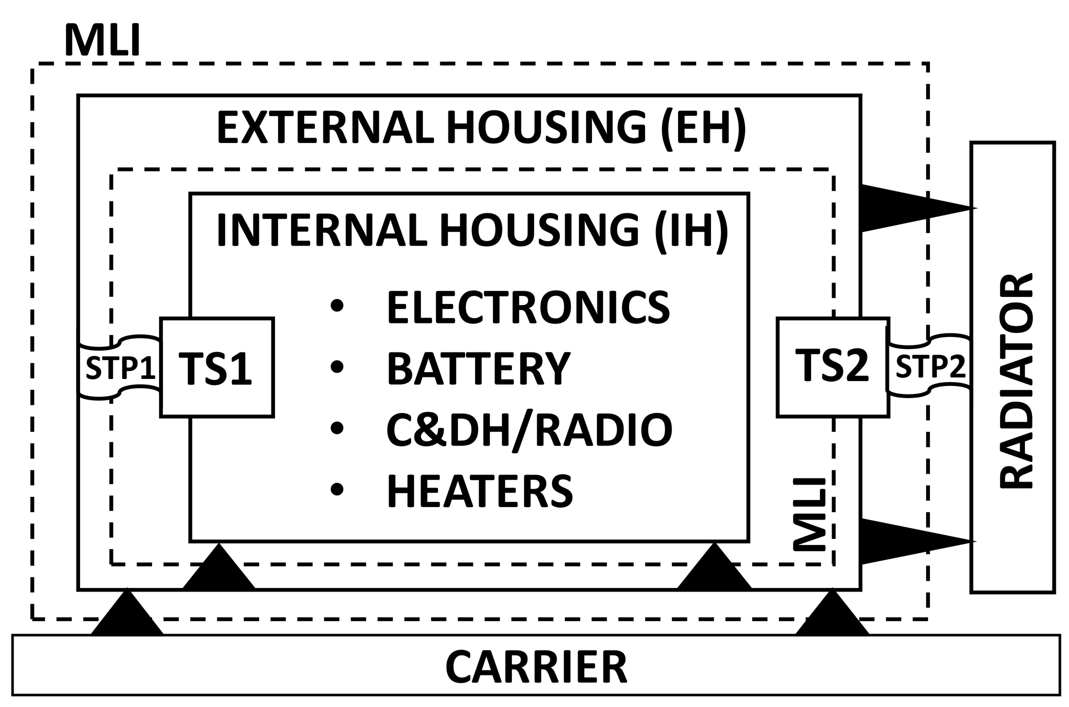
→ **FY21 – Small Scale Demonstration**
Validate ARTEMIS thermal architecture at small scale by combining FY20 subscale testbed elements into an integrated full-up testbed and finalize gathering requirements on 3 instrument types. Initiate design of full scale ARTEMIS demo unit w/ JPL SVH magnetometer, deployable boom.

→ **FY22 – Full Scale Demonstration**
Validate ARTEMIS thermal architecture at full scale by completing design of full scale demo unit, which includes FY21 small scale system testing and instrument requirements gathering results. Build demo unit that includes a JPL SVH magnetometer and deployable boom. Carry out TVAC test demo.

ARTEMIS Technology Development Focus Areas and Key Measurable Metrics (KMM)

Dual Thermally-Switched Enclosure
KMM → Lunar Heat Loss Flux < 5 W/m²
Affordable Parabolic Reflector Radiator
KMM → Sink Temp on Lunar Surface < 280 K
High Performance Multi-Layer Insulation
KMM → Effective Emissivity < 0.01
High Performance Thermal Isolator
KMM → Conductance < 0.001 W/K
Science Instrument Requirements
KMM → 50% defined by FY20, 100% by FY21

ARTEMIS AUTONOMOUS THERMAL ARCHITECTURE



LEGEND
TS = THERMAL SWITCH
STP = THERMAL STRAP
▲ = THERMAL ISOLATOR

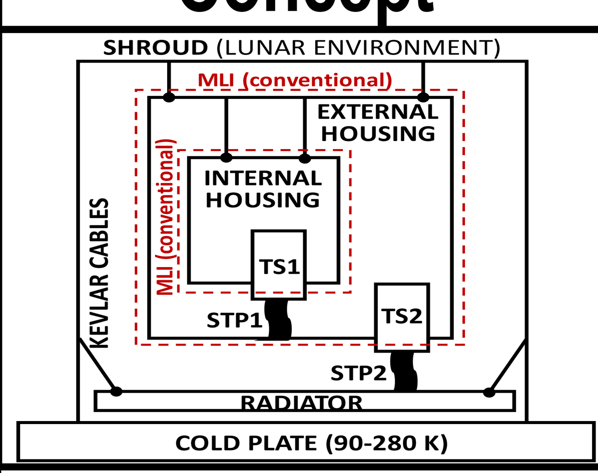
NOT SHOWN
1. WIRE FEED-THROUGHS
2. APERTURES/OPENINGS
3. EXTERNALS/DEPLOYABLES

HOW IT WORKS: *During Lunar Day, heat from Instruments conducted along the thermal path IH → TS1 → STP1 → EH → TS2 → STP2 → RAD with TS1 and TS2 both ON. As Lunar Night ensures, TS2, TS1 turn OFF autonomously at 273 K, drastically reducing heat loss. Thermal Switches are JPL Reverse-Operation Differential Thermal Expansion (DTE) Thermal Switches (5 W/K ON, 0.002 W/K OFF, 2500:1 ON/OFF).* ***To validate architecture, series of 4 TESTBED subtasks in concert with an INSTRUMENT THERMAL NEEDS subtask planned for FY20.***

Subtask | Concept | Design | CAD | Drawings | KMM Validation

1 → Develop subscale assembly of ARTEMIS architecture; design and build testbed to show performance.

Concept



Design

SIZING (IH, EH, SHROUD)
- 127, 254, 381 mm x 6 mm Al cubes
- 305 mm x 305 mm x 3 mm Al radiator

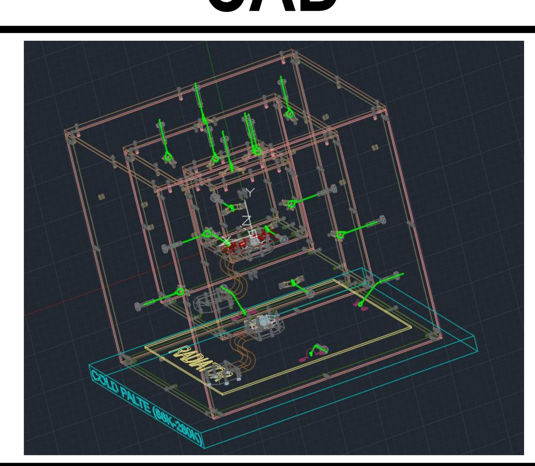
LUNAR NIGHT SIMULATION
- TCP = 90 K, TIH > 240 K (survival heater)

LUNAR DAY SIMULATION
- TCP = 280 K (PRR assumed), QIH = 5-8 W

THERMAL SWITCH
- JPL Rev.-Op. DTE Design-2 (Ultem 1000/Alum)

THERMAL STRAP
- Graphite foil based, 2 W/K (Thermotive)

CAD



Drawings

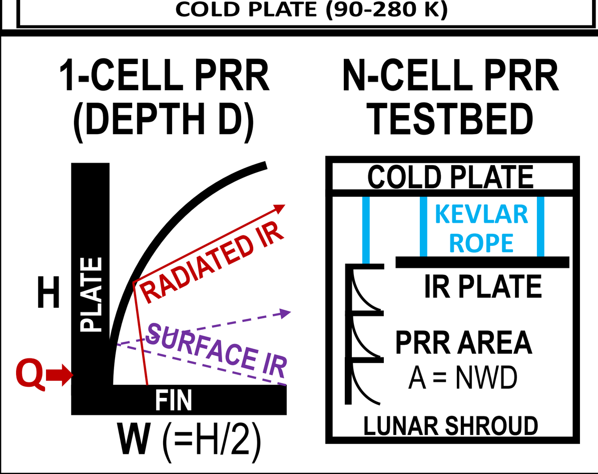
1. **INTERNAL HOUSING (IH)** - 20019541
2. **EXTERNAL HOUSING (EH)** - 20019542
3. **LUNAR SHROUD (LS)** - 20019543
4. **THERMAL SWITCH** - 20019547→20019551
5. **THERMAL STRAP, RADIATOR** - 20019546, 20019554
6. **OVERALL ASSEMBLY** - 20019545

KMM Validation

Heat loss flux < 5 W/m², means 127 mm IH cube will require < 0.5 W to stay warm in the cold case. With conventional ε^*=0.02 MLI, T_{IH} must be > 253 K.

2 → Develop design and fabrication method for low cost PRRs; design, build testbed to show performance.

Concept



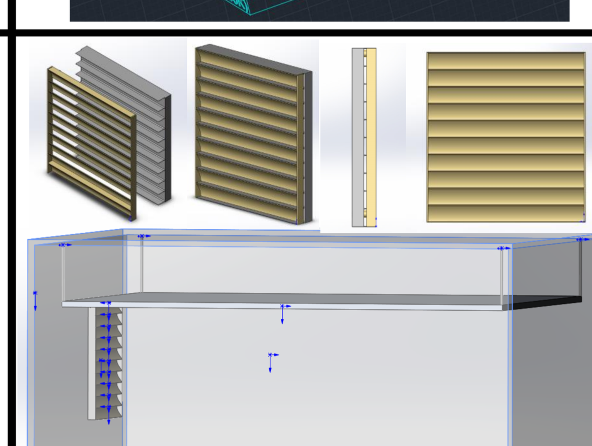
Design

SIZING (IR PLATE, PRR, LS)
- IR PLATE (381 mm into page x 508 mm)
- PRR (N=10, D / H / W = 127 / 12.7 / 6.35 mm)
- LS (approx. 500 mm x 600 mm x 200 mm)

LUNAR NIGHT SIMULATION
- NOT REQUIRED

LUNAR DAY SIMULATION
- TCP = 90-280 K
- TIRP = 373 K
- QPRR = 0-2 W
- QIRP = 200 W (approx.)

CAD



Drawings

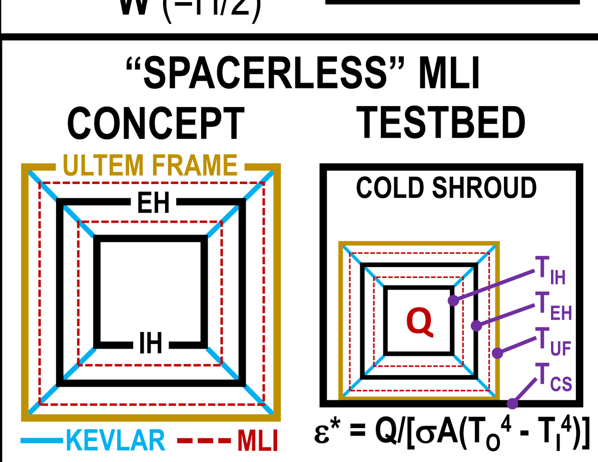
1. **PRR 10-CELL RADIATOR ARRAY** - 20019931
2. **PRR 10-CELL REFLECTOR ARRAY** - 20019932
3. **PRR TESTBED: IR PLATE** - 20019934
4. **PRR TESTBED: LUNAR SHROUD** - 20019935→20019938
5. **PRR TESTBED: OVERALL ASSEMBLY** - 20019939

KMM Validation

Rad. sink temp < 280 K is applicable when lunar shroud temperature is set to 90 K. With lunar shroud at 280 K, radiative sink temp will exceed 280 K.

3 → Develop design and fabrication method for low ε^* MLI; design and build testbed to show performance.

Concept

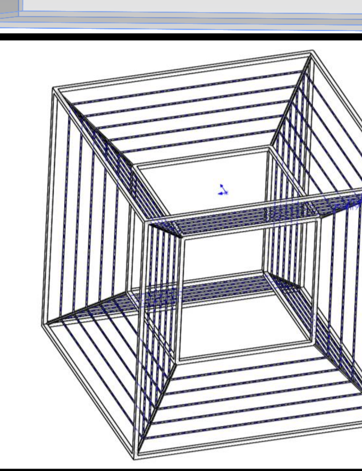


Design

SIZING (DEMO MODEL, TESTBED)
- INNER FRAME, HSG (IF, IH) 87 mm, 127 mm
- OUTER FRM, HSG (EF, EH) 165 mm, 384 mm

KEVLAR CABLES
- CORNER CABLE 62 mm x 8
- PERIPHERAL CABLE #1 99 mm x 12 (inner)
- PERIPHERAL CABLE #2 111 mm x 12
- PERIPHERAL CABLE #3 123 mm x 12
- PERIPHERAL CABLE #4 135 mm x 12
- PERIPHERAL CABLE #5 147 mm x 12 (outer)

CAD



Drawings

1. **SPACERLESS MLI (S-MLI) DEMO MODEL** - 20019555
2. **S-MLI TESTBED: IH + KEVLAR BRKTS** - 20019561*, 20019562*
3. **S-MLI TESTBED: EH + KEVLAR BRKTS** - 20019563*, 20019564*
4. **S-MLI TESTBED: LS + KEVLAR BRKTS** - 20019565*, 20019566*
5. **S-MLI TESTBED: OVERALL ASSEMBLY** - 20019560*

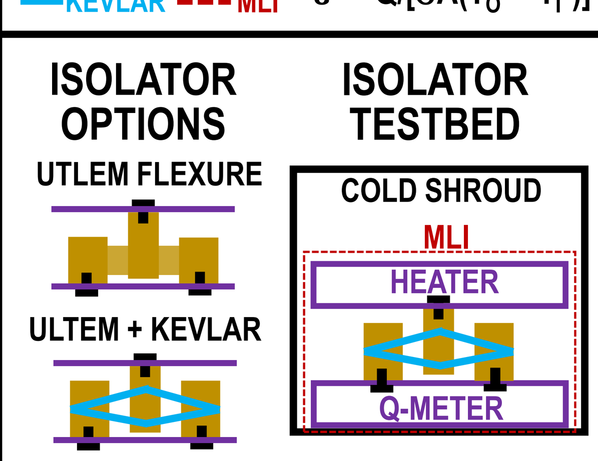
* Drawing number assigned, drawing incomplete

KMM Validation

MLI ε^* < 0.01 will require test setup w/ just a few wires to minimize parasitic heat gains/leaks so that the relation $\varepsilon^* = Q/(T_i^4 - T_o^4)$ is the sole governing eqn.

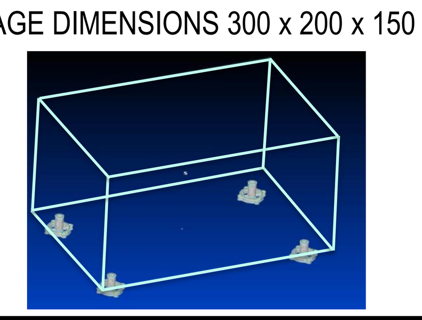
4 → Develop design and fabrication method for low G isolators; design, build testbed to show performance.

Concept

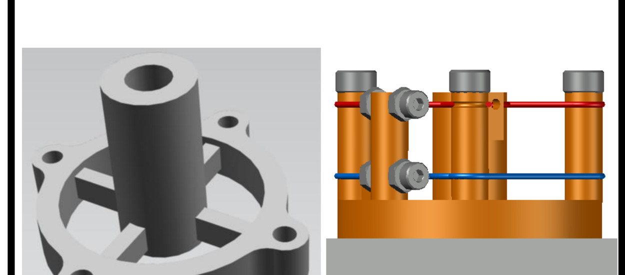


Design

SIZING (STRUCTURAL FEM)
- SUPPORT FOR 10 KG INSTRUMENT PKG.
- FOUR ISOLATORS PER INSTRUMENT PKG.
- PACKAGE DIMENSIONS 300 x 200 x 150 mm



CAD



Drawings

1. **POLYMER FLEXURE ISOLATOR** - 20019553-1
2. **POLYMER KEVLAR CABLE ISOLATOR** - 20019951*
3. **ISOLATOR TESTBED: COLD SHROUD** - 20019952*
4. **ISOLATOR TESTBED: Q-METER** - 20019953*
5. **ISOLATOR TESTBED: OVERALL ASSY** - 20019954*

* Drawing number assigned, drawing incomplete

KMM Validation

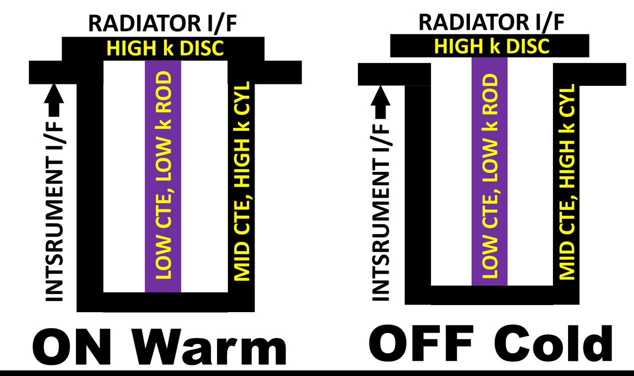
Isolator G < 0.001 W/K will require test setup with Q-meter that minimizes parasitic heat gains/leaks so that G = Q/DT is the sole governing equation.

Instrument Implementation

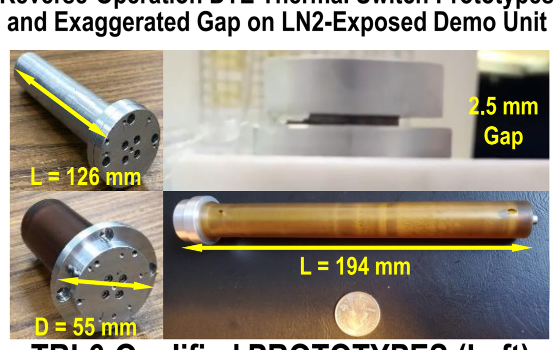
TYPE	CHALLENGES	CANDIDATES
MAGNETOMETER	External Boom Boom Deployment External Fiber Optics	SVH SI-C Others
SEISMOMETER	Rigid Link to Carrier High Data Rate High Duty Cycle	SP UMS Others
IR SPECTROMETER	High Power (Cryocooler) High Data Rate Apertures, External Gimbal	UCIS-Moon SILVIR Others

DTE Thermal Switching

At 300 K, ROD Stretched for High DISC-CYL "ON" Force
At < 273 K, CYL Differentially Contracts Causing "OFF" Gap



Reverse-Operation DTE Thermal Switch Prototypes and Exaggerated Gap on LN2-Exposed Demo Unit



TRL6-Qualified PROTOTYPES (Left)
Extended Stroke DEMO UNIT (Right)

Future Challenges

BATTERIES	→ Packaging Enough for Overnight Ops/Survival
RADIO/COMM	→ Internals + Antenna for Carrier Independence
C&DH	→ Processing Capability for Carrier Independence
GIMBAL	→ IR Spectrometers May Need 2-Axis Gimbal
INSTRUMENT SUITES	→ Multi-Instrument Capability Sought by NASA
THERMAL STORAGE	→ Use 100 K Nighttime Temps to Eliminate CCs
LOOP HEAT PIPE	→ Combo Unit with Switch for 20000:1 ON/OFF
PLANETARY USE	→ Extended Stroke Thermal Switch (see Demo Unit)

ARTEMIS

ARchitecture for Thermal Enclosure of Moon Instrument Suites

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