

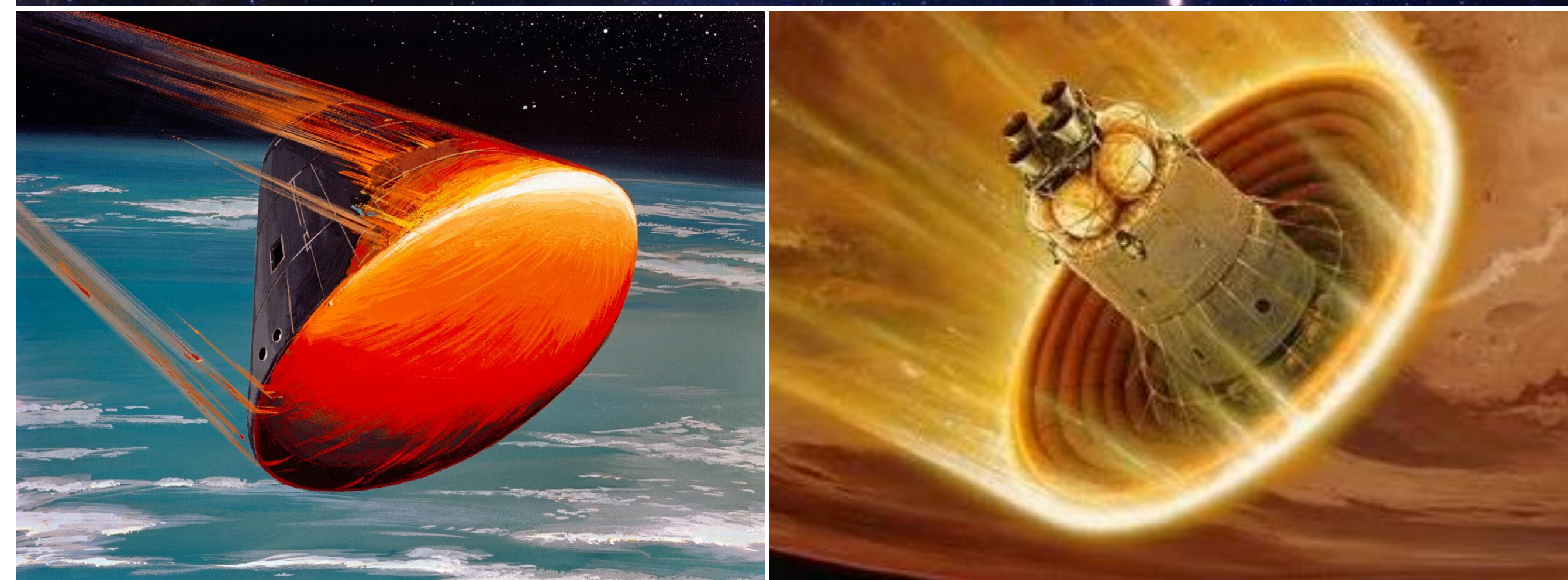
CNT Yarn Z-Stitching in Carbon Fiber for Thermal Isotropy



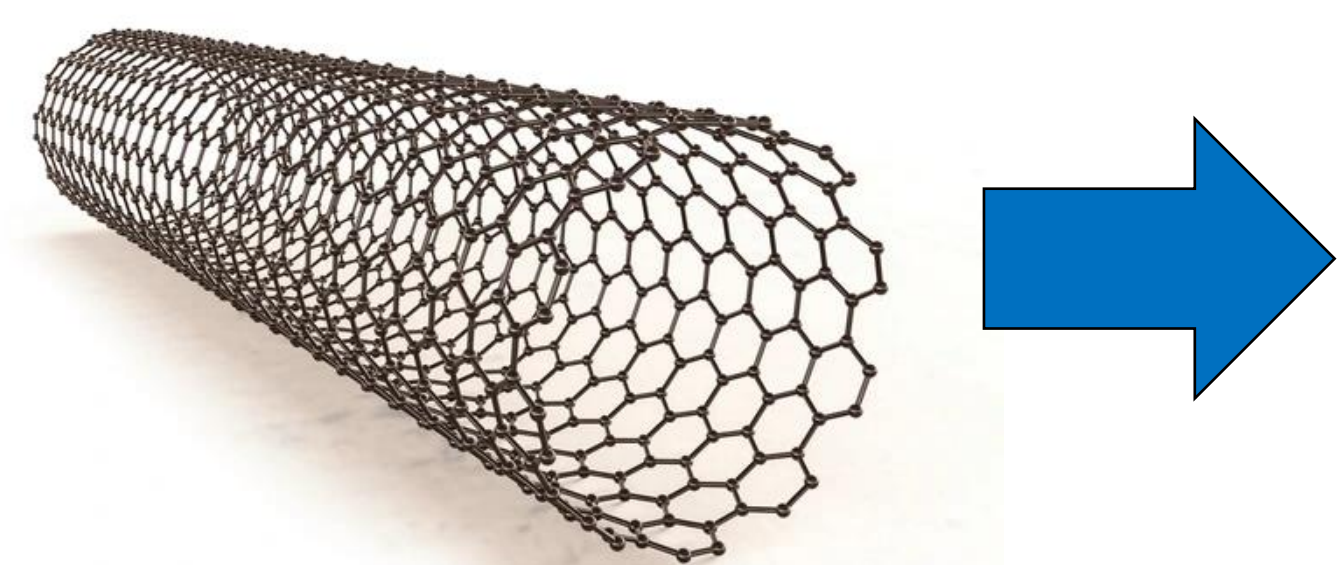
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Introduction



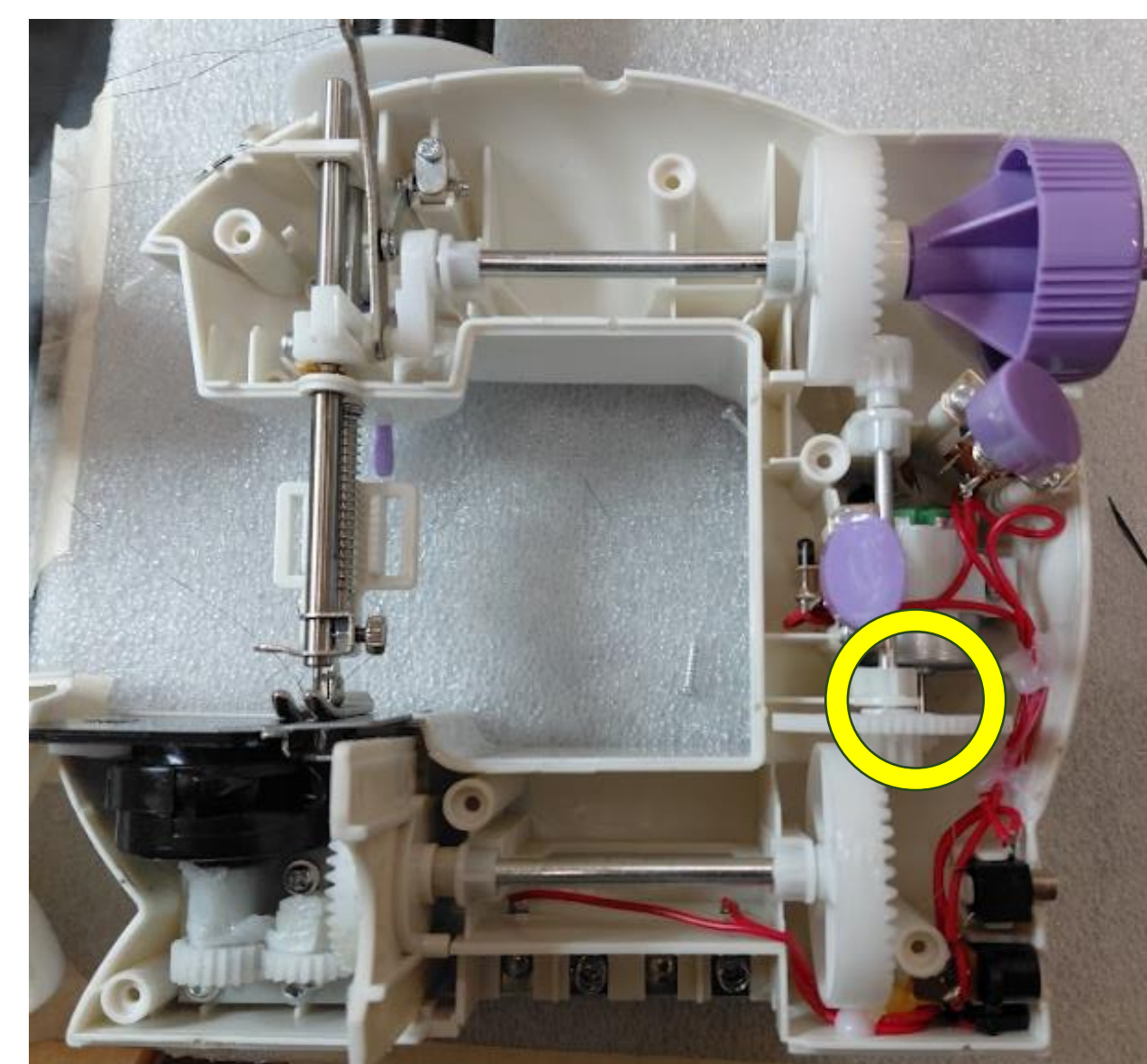
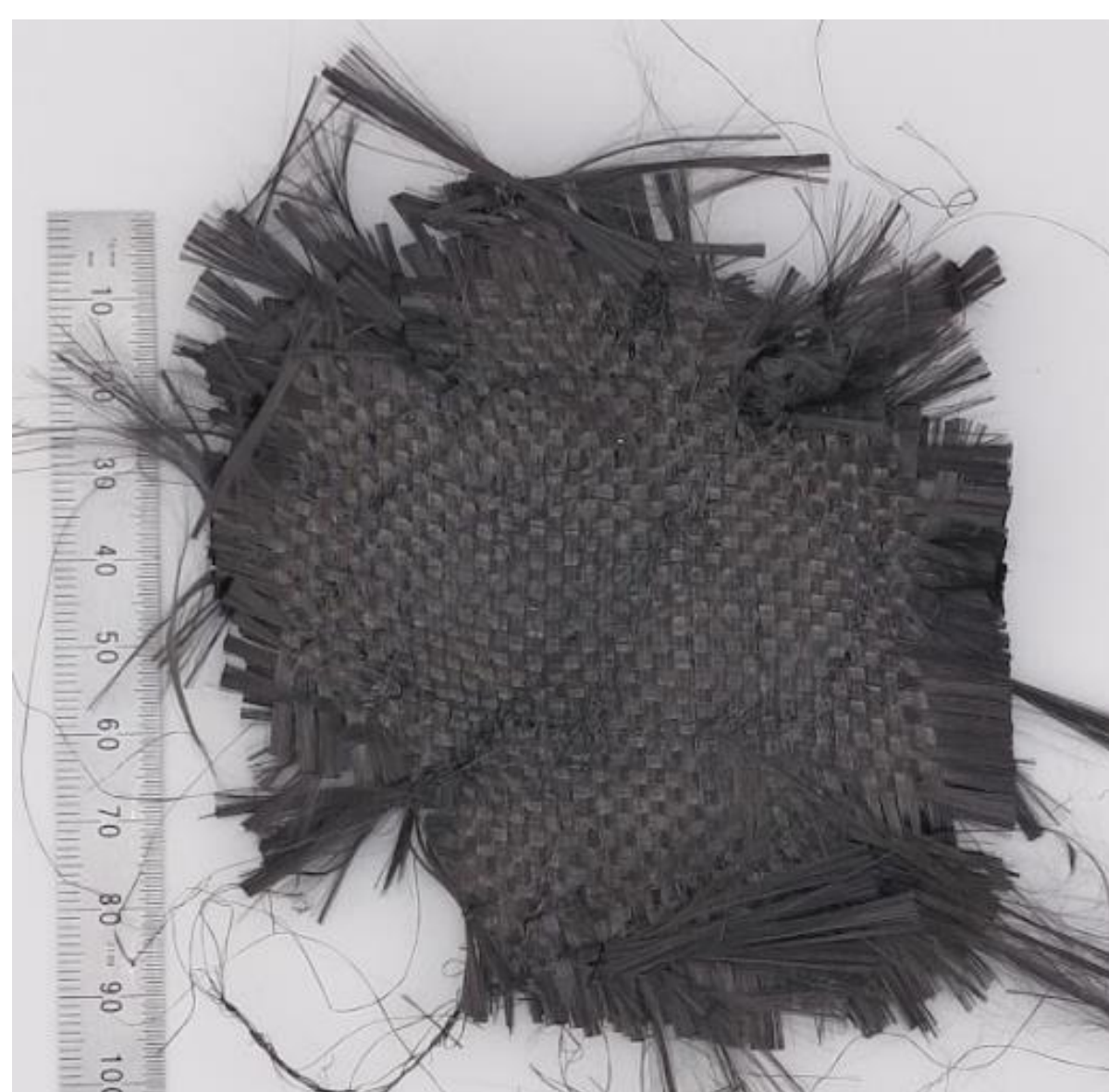
- Spacecraft materials need thermal management
- Engine exhaust, solar radiation, breaking atmosphere
- Pursuing Carbon Fiber Laminate Composites for Heat Shield



Carbon Nanotube Molecular Structure Wound into yarn (CNTy)

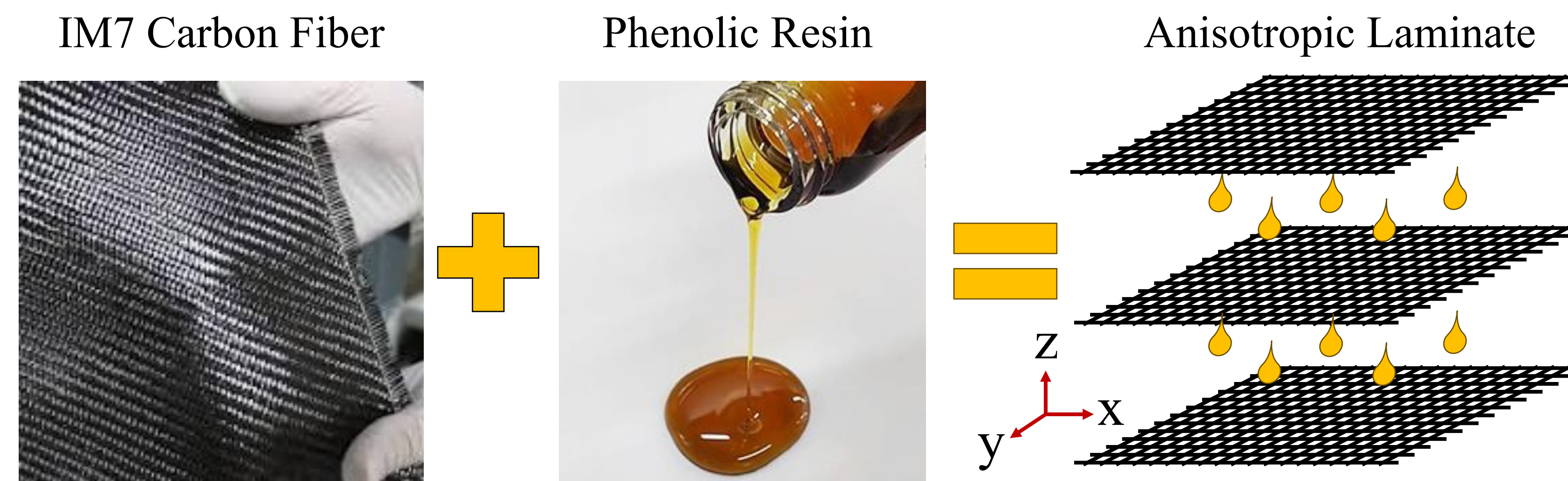
- CNTy has high thermal conductivity, strength, and flexibility
- These properties come from CNT's strong graphitic bonds
- This work stitches CNTy in Carbon Fiber for heat control

Sewing Challenges



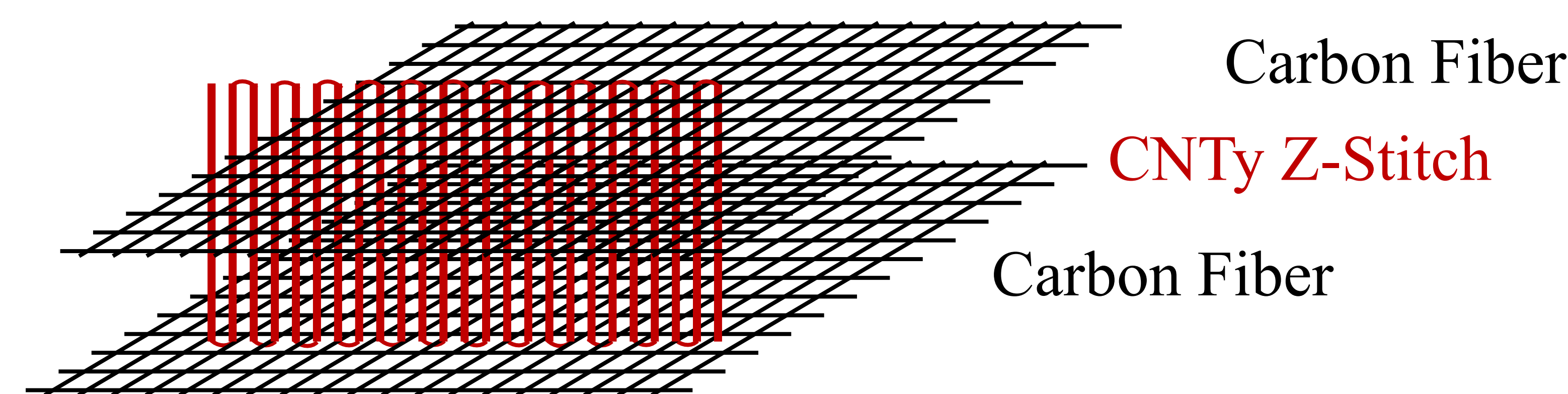
- Hand sewn first for proof of concept
- Sewing machine for second iterations
- CNTy bobbin tangling stalled motor
- ~1000 stitches (4 laminates) before breaking
- Fracture & decoupling at motor shaft gear

Laminate Status Quo



- Laminate will resist heat transfer between x-y plies
- Anisotropy in relatively low bond strength & conductivity between plies
- Heat shield will degrade layer by layer without intralayer heat transfer

Results

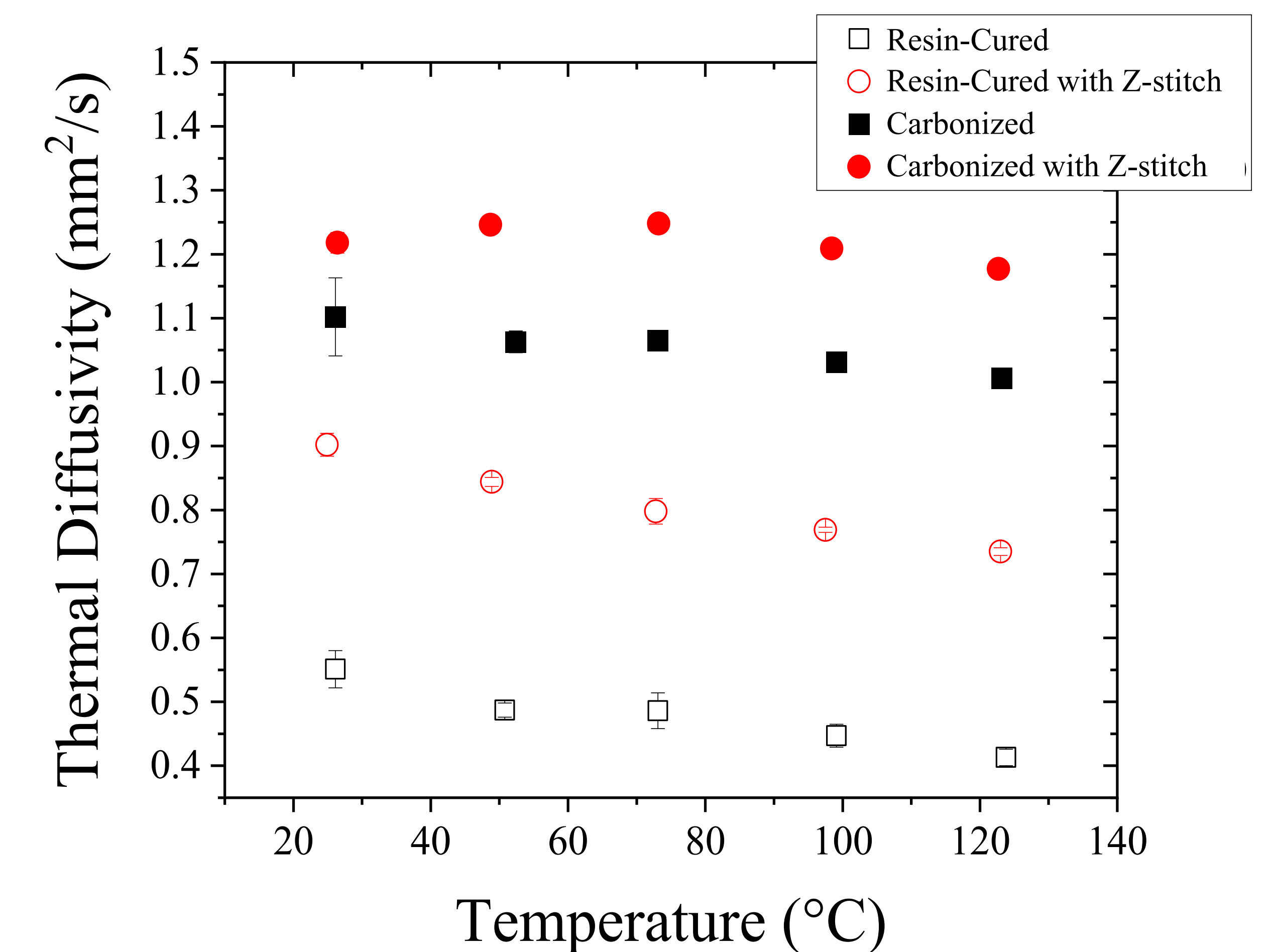


12-ply IM7 Carbon Fiber Z-stitched



- Interstices aligned by stacking carbon fiber plies on a pin cushion
- Carbon fiber fabric begins to fray and destabilize after second ply

Laser Flash Analysis (LFA)



Conclusions

- 60% gain of 0.4 mm²/s in resin-cured from Z-stitch
- Carbonization **doubles** thermal diffusivity and burns off resin
- 14% gain of 0.2 mm²/s in Carbonized from Z-stitch
- Graphitization chemically bonds carbon fibers together
- Expecting diminishing returns from Z-stitch for graphitized
- Spacecraft applications are graphitized

Future Work

- Epoxy spray adhesive + 20-min rest to stabilize carbon fiber plies
- Test different tow sizes of carbon fiber weave/interstitial densities
- Examine if load bearing capability decreases with Z-stitching
- Pursue precise interstitial stitching to preserve strength
- Mechanized embroidery for precise stitch pattern & density tests

