T300/SiC HoneySiC for Mirrors

Prepared by: Dr. Bill Goodman; 858-437-3899 bgoodman@trexenterprises.com

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NASA MSFC COTR: Ron Eng

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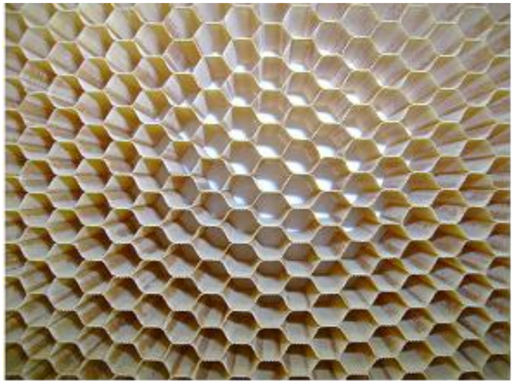
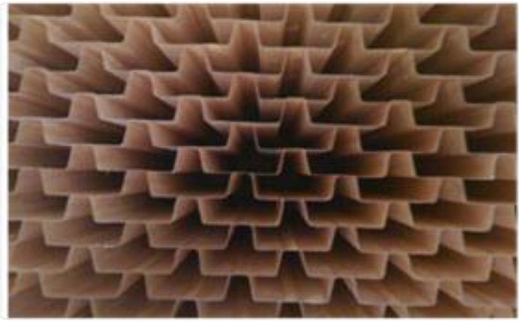
Understanding HoneySiC

- **HoneySiC is a molded ceramic matrix composite material composed of a honeycomb core sandwiched by facesheets.**
  - Starting materials are prepreg plies. Matrix is carbon based resin, epoxy or preceramic polymers.
  - Reinforcement can be either discontinuous or continuous fibers.
  - In latter case the fibers can be uniaxial or woven.
- **Prepreg materials are highly compliant with no ability to hold their shape, but they are readily molded.**
- **Ultracor Inc. molds our honeycomb.**

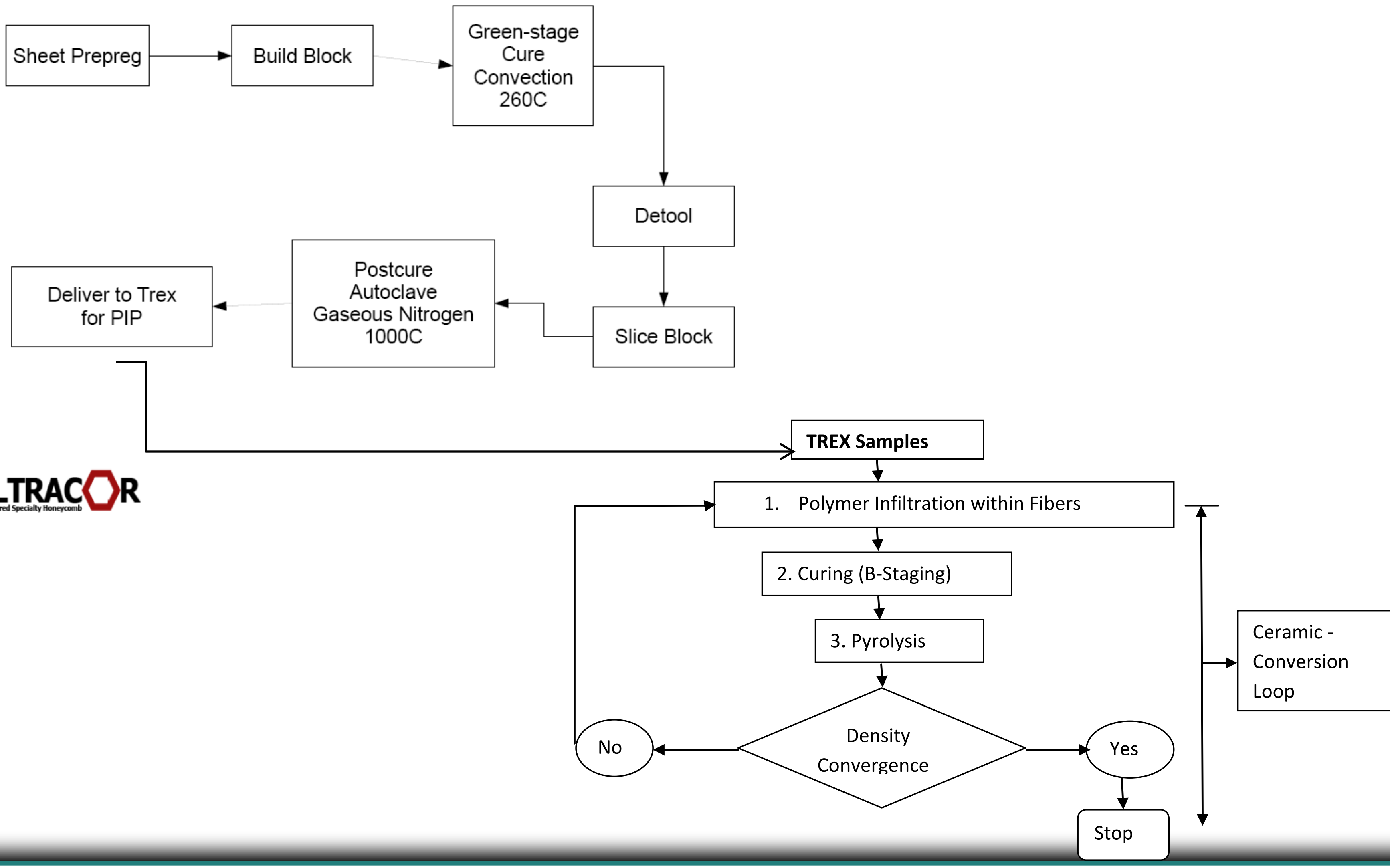




Sizes, Shapes and Densities of Composite Honeycomb: By varying the size of the mandrels within the layup, varying degrees of density can be achieved. Typical sizes are 3/8" and 3/16". Cell sizes up to 1" have been manufactured. Similarly, the shape of the core can be altered.

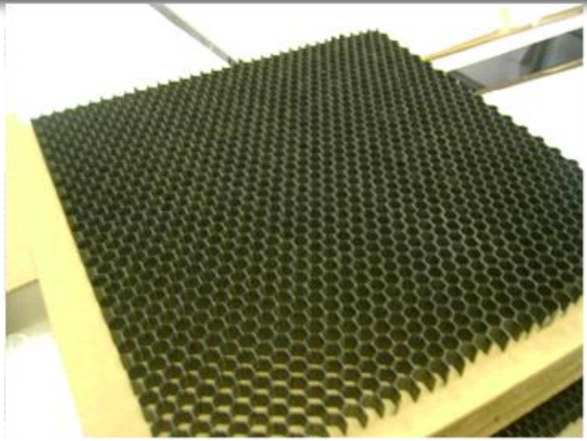
Process Flow Example for One Set of Fiber/Matrix

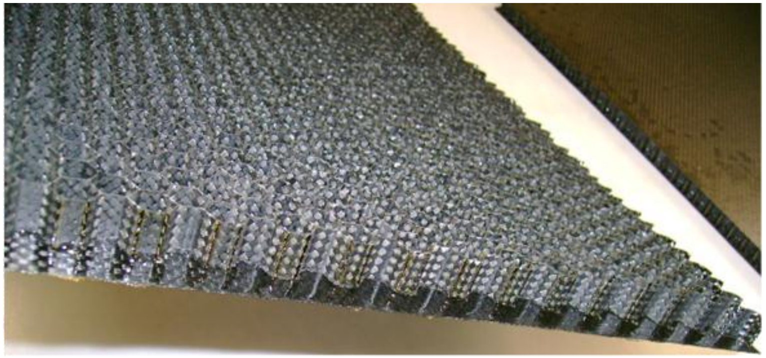
Process Flow Chart for HoneySic Manufacture

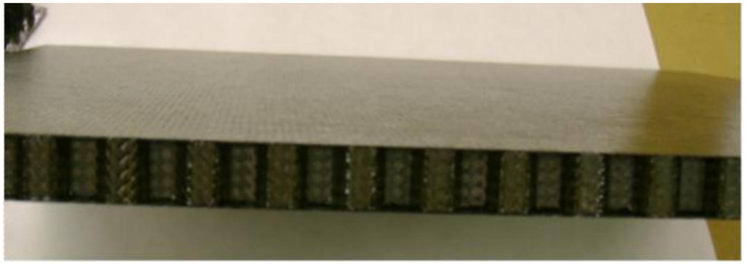


Phase I: Raw Materials Are Inexpensive

- Limitations of Phase I SBIR are 66% funding to Small Business
- LOW AREAL COST: We made a 1 cubic foot honeycomb block of phenolic reinforced T-300 polyacrylonitrile (PAN) carbon fiber.
- We cured it and sliced it into 0.5-inch sheets.
- We made laminate panels for facesheets.
  - Layer 1: 0/90 degrees;
  - Layer 2: ±45 degrees;
  - Layer 3: 90/0 degrees;
  - Layer 4: ±45 degrees;
  - 2 fiber layers pointed to the degree points 0, 45, 90, 135, and 180.
- One panel was open-backed, and one was closed-back.
- NOTE: There are no limitations to scale – think Boeing 787 DreamLiner aircraft







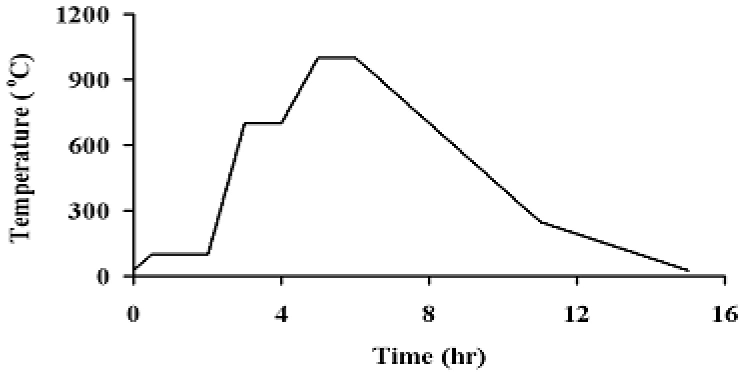
Unclassified

Phase I: Carbon-Carbon Honeycomb (CCH)

- **Next we cut coupons and made Carbon-Carbon Honeycomb (CCH)**
  - Char for ~11 hours at Temperature up to 815 ^{o}C.

Polymer Infiltration Pyrolysis (PIP)

- **Polymer Infiltration Pyrolysis (PIP) performed by University of Hawaii**
- **Polymer Infiltration (Re-infiltration)**
  - **Environment**: samples dipped in Pre-ceramic polymer (KION CERASET) in vacuum environment.
  - **Temperature**: Room temperature.
  - **Duration**: 30 minutes.
- **Curing (B-Staging)**
  - **Environment**: Atmospheric conditions
  - **Temperature**: 200 °C
  - **Duration**: 2 hours.
- **Pyrolysis in Argon Inert Environment**

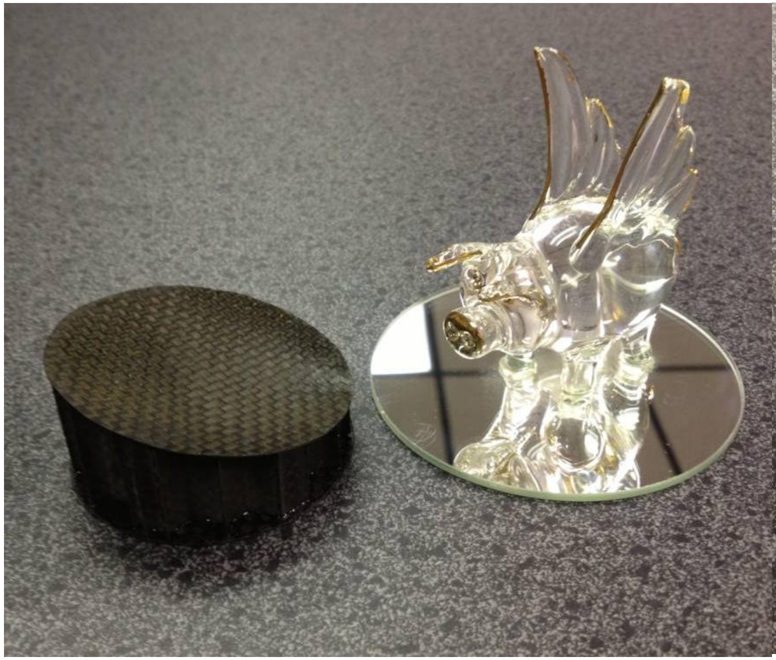


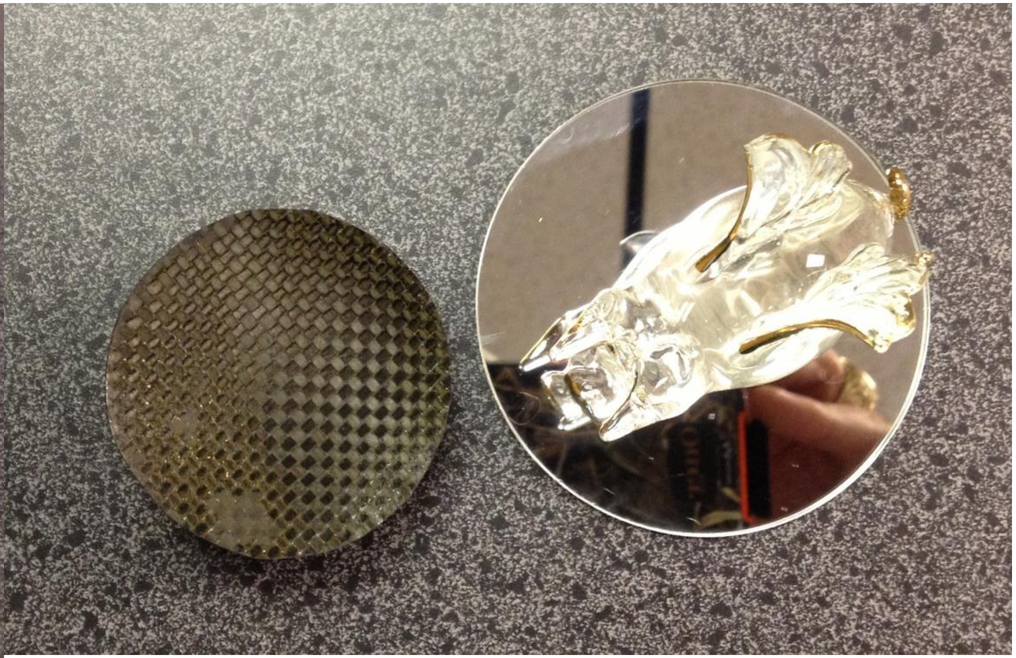
- **Duration: 15 hours per cycle, 7 – 10 cycles: 7-10 PIP cycles are performed, to achieve weight gain convergence, based on carbon char yield and weight gain of samples. PIP iterations are stopped according to weight gain convergence criterion. The criterion for weight gain convergence was that the last sequential weight gains of the samples should be less than 1%.**
- **C/C dual-skin composite panel has a density of 0.16 g/cm^3, and C/C-SiC increases density to 0.25 g/cm^3, about the same as 85% lightweighted Beryllium.**

TREX ENTERPRISES HAWAIIAN OPERATIONS

Can you make mirrors?

- I do not know, let's ask the Flying Pig?
- He says we need a polishable cladding with a matching CTE.
- He's super impressed by how light it is. And these can be massed produced from Master Molds – sweeeeeeeeet!

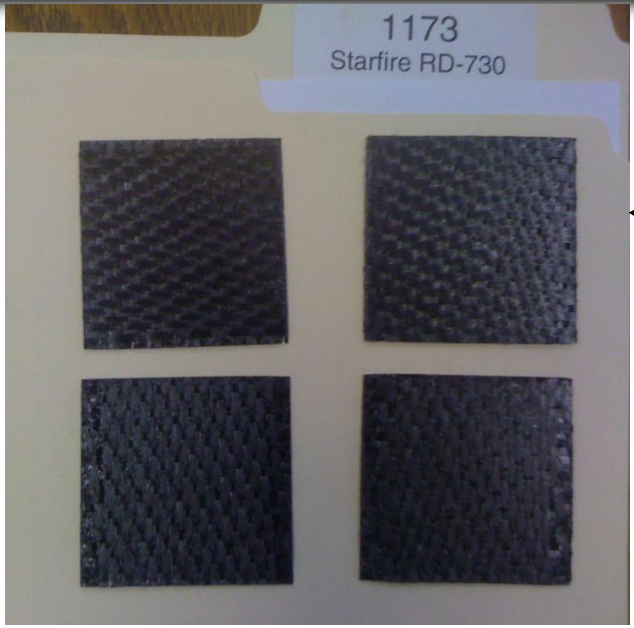




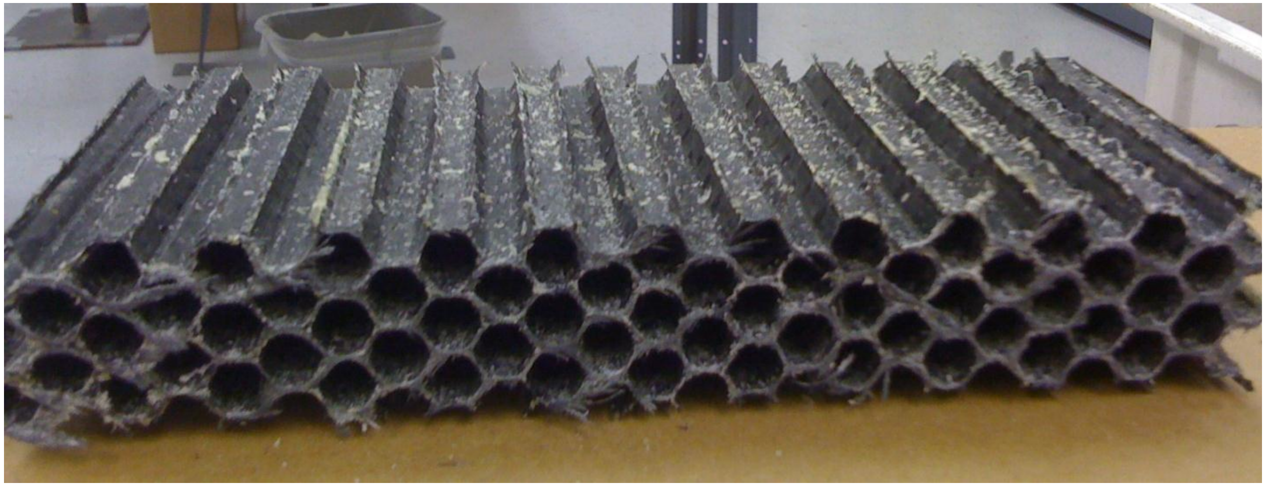
Phase II: A New Matrix Materials - Starfire® RD-730

- **A better CTE match should be obtained by replacing the carbon matrix with a SiC matrix and making a C/SiC part.**
- **Starfire® RD-730 is a polycarbosilane**
  - Converts to thermally stable silicon carbide by direct pyrolysis.
  - Solid at room temperature, flows at temperatures to 100 ^{o}C.
  - Using melt processing, T-300 cloth fabrics can be infiltrated with RD-730, which then solidifies and becomes a hard, machinable, thermoplastic.
  - Thermoplastic form is our new prepreg material.
  - The prepreg in block form can be machined to near-net shape, put in a mold and re-flowed (re-melted). The molded parts can then be cured (curable above 150 ^{o}C) to render a thermoset, which is again machinable.
  - The cured polymer matrix composite can then be fired to form a high temperature, oxidation resistant, amorphous silicon carbide material. Pyrolysis at 1^{o}C/minute to 1000 ^{o}C results in a black glassy material with a silicon carbide yield of 65-67%. This material is then ready for additional polymer infiltration pyrolysis to fully densify the part.

Pathfinder Tests with RD-730



First prepregs and laminates made with Thornel plain weave

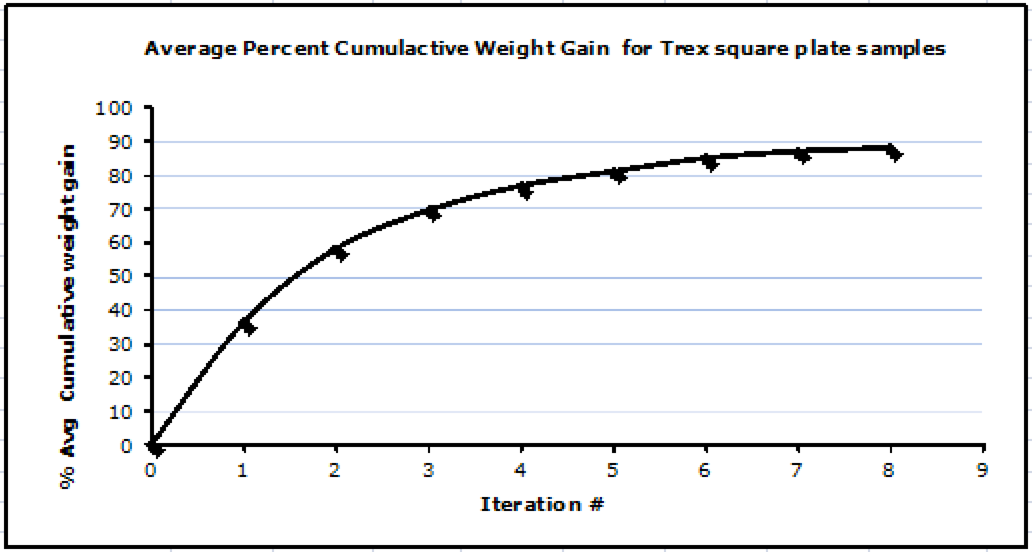


The fiber system selected was T300, 1k tows, plain weave fabric with an areal mass of 86 grams per square meter (86 gsm)

Thornel Pathfinder PIP Results

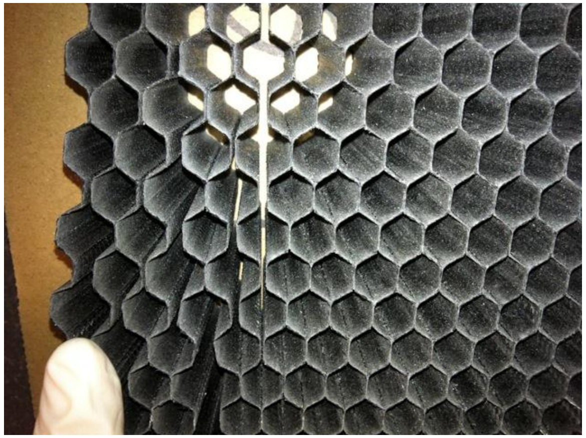
- "Vacuum after Vacuumed Infiltration" with low viscosity preceramic polymer KION Ceraset.
- New process required 8 cycles of PIP. U of H obtained a very good convergence with consistency among all four coupons with a very low standard deviation (i.e., less than 3.6%), resulting in very high quality samples.

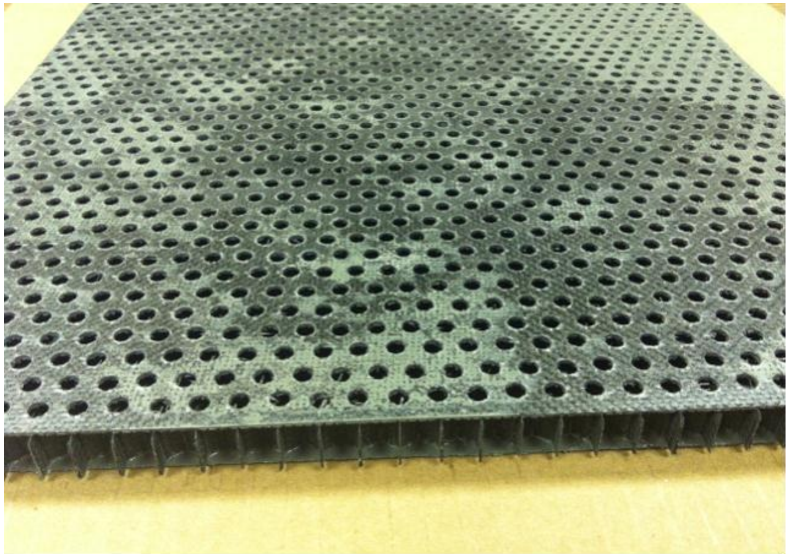
Averages for 4 samples									
	base	#1	#2	#3	#4	#5	#6	#7	#8
%Avg total wt. gain	0	36.35	58.26	69.67	76.97	81.23	85.17	87.26	88.16
Iteration #	0	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00
Standard Deviation	0	1.29	1.54	2.03	1.42	1.33	1.34	1.34	1.42
% Standard Deviation	0	3.56	2.65	2.92	1.84	1.63	1.58	1.54	1.61



Full Scale 2nd Generation T300/SMP-730 Panel

- Victimized by Murphy's law.
- First full scale honeycomb block delaminated during slicing. No issues with laminate facesheets.
- Second block made using revised temperature and pressure cure. That block successfully sliced and made into panels.





1st Pyrolysis

- Ist Pyrolysis step completed. Material too porous to conventionally machine and requires further PIP to strengthen it.
- Edges fray and delaminate.
- Too porous to vacuum chuck.

Technology Development Can Be Sporting

- Process development crossroad.
- As-cured HoneySiC panel is very fragile; coupons have displayed fraying at the edges.
- Machining best accomplished while the part still has some porosity. This means that several PIP cycles will be performed prior to machining; how many is yet to be determined.
- Have not established final preceramic polymer and final pyrolysis temperature.
- THE END. I HOPE YOU ENJOYED THIS. QUESTIONS?