Precision Ceramics

Technical ceramics for demanding environments and applications:

Precision Ceramics

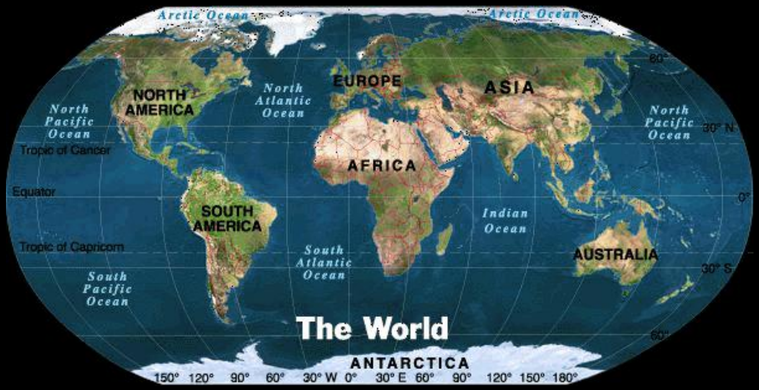
- I'm Geoff Randle
- This is a presentation of the combined experiences of my colleague Steve Lyle and me with over 80 years of working with technical ceramics.

Precision Ceramics

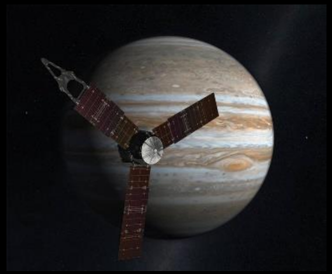
- Located in USA and Europe
- St Petersburg
  Florida
- Birmingham
  England
- Specialists in Technical Ceramics and CNC machining

PC USA Inc

- 7 continents



- 3 planets



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- Typical components

- **Ceramics are being used ever more often for space and aerospace applications.**

- Hall Effect Thrusters:-
  - And the ever increasing need for high performance technical ceramics

- **Requirements for any ceramic material:**
  - **Density**
  - Weight is a major factor for anything used in space
  - A critical factor for launch and operation
  - **High dielectric strength**
  - By necessity as high voltages are involved
  - **High thermal conductivity & High thermal shock resistance**
  - Satellites are exposed to extreme temperature fluctuations is space
  - Localised heating during firing

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- **Consistent homogenous materials**
- Critical for design and operational consistency

- **Low Thermal Expansion**
- A low CTE is imperative to maintain dimensional stability with widely fluctuating temperatures

- **Other considerations:**

- Able to withstand constant bombardment by Xenon ions

- Available in large sizes

- Machinable vs non machinable
- Able to be made into complex shapes

- Reliably achieve required tolerances

- Cost !
- The accumulation of material and processing costs

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- **Materials that have been tried in the past:**
  - Borosil
  - Macor
  - Quartz
  - Aluminum Oxide
    - All had limitations
    - **The most successful solutions involved these materials**
  - Boron Nitride & Boron Nitride composites

Comparative Properties

	Composition	Density g/cc	Hardness relative to each other 1-10	Maximum Size/ Billet Availability	Dielectric Strength	Dielectric Constant K +/-5%	Anisotropy relative to each other 1-10
HP	95%BN, 5% calcium borate glass	1.9 +/- 0.15	4	490x490x400mm	>25KV/m m	4	More - 6
M26	60%BN, 40%SiO2	2.0 +/- 0.02	8	490x490x400mm	>25KV/m m	4	Minor -2
AX05	99.7% BN	1.9 +/- 0.02	1	Very design dependent	>25KV/m m	4	Most - 10
Shapal High M Soft	70%AIN,30%BN	2.8 +/- 0.1	10	304x304x86mm	>25KV/m m	6.8	Least - 1

- **h-BN and BN-AlN composites have been the most successful in satisfying the above requirements**

- The materials are hot pressed for consistency
- Low density
- Low sputter erosion and some grades have secondary ion emission
- Low outgassing rates.
- Non-wettable by molten metals

- BN is also available in large sizes
- And is readily machined.

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- **Shapal-HiM soft is one BN-AlN composite we have particular experience with and success in using**

- Again hot pressed for consistency
- Relatively low density
- Tested and proven in space environments
- Very very low outgassing rates,
  - Zero porosity
- A very homogenous material

- Shapal is not available in sizes as big as pure BN
- But again is readily machined.

Shapal-HiM soft

- The newest material under development for HET components
- Made by Tokuyama,
- Careful control of powder microstructure yields a high density, zero-porosity product
- Still machinable but much stronger than the traditional Boron Nitrides.
- It shares the dielectric strength and very high thermal conductivity of BNs, but its lack of porosity and vacuum impermeability are unmatched.
- Shapal has the additional advantage of being much harder when the specific insulator design requires.

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- You have selected material from data sheets
- You have received a small sample of the material.
- You have possibly manufactured a small scale part to ensure everything works .
- What could possibly go wrong ?

- Don't assume the selected material is available in the sizes and geometries you require.
- You order and test a small scale part, then order the full size , assuming its from the same billet!
- You want all of the parts for a program from the same billet!
- You are familiar with ceramics, and use cleaning specs for other ceramic materials!
- Orientation is critical in h-bn

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- Crack detection of ceramics is standard using a dye penetrant, is that a good idea?
- You want to machine yourself, you order material ,please don't forget to ask for traceable material as this may not be possible in retrospect!
-   There are clone materials out there, copies of data sheets and no guarantees .
- These examples are real and have happened ,please be aware!

- Boron Nitride solids are anisotropic, so have directional properties.
- Hot pressing results in orderly alignment of the platelets , the pressing direction has the strongest bonds.
- If you are sampling / designing in BN you may want to take the press direction into account

- Can withstand the vibration of take-off

European space agency GOCE satellite.

Plasma engines

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