Plasma Facing Components

(The Path to DEMO)

Michael Ulrickson
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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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Outline

- Solid Surface PFCs
  - Plasma Facing Materials Development
  - Heat Sink Development
  - Joining Technology
  - Manufacturing and Reliability
- Liquid Surface PFCs
  - Electromagnetic Forces
  - Plumbing Issues (corrosion, supply and return)
  - Interfaces (diagnostics, heating, pumping, …)
- Common Themes and Conclusions

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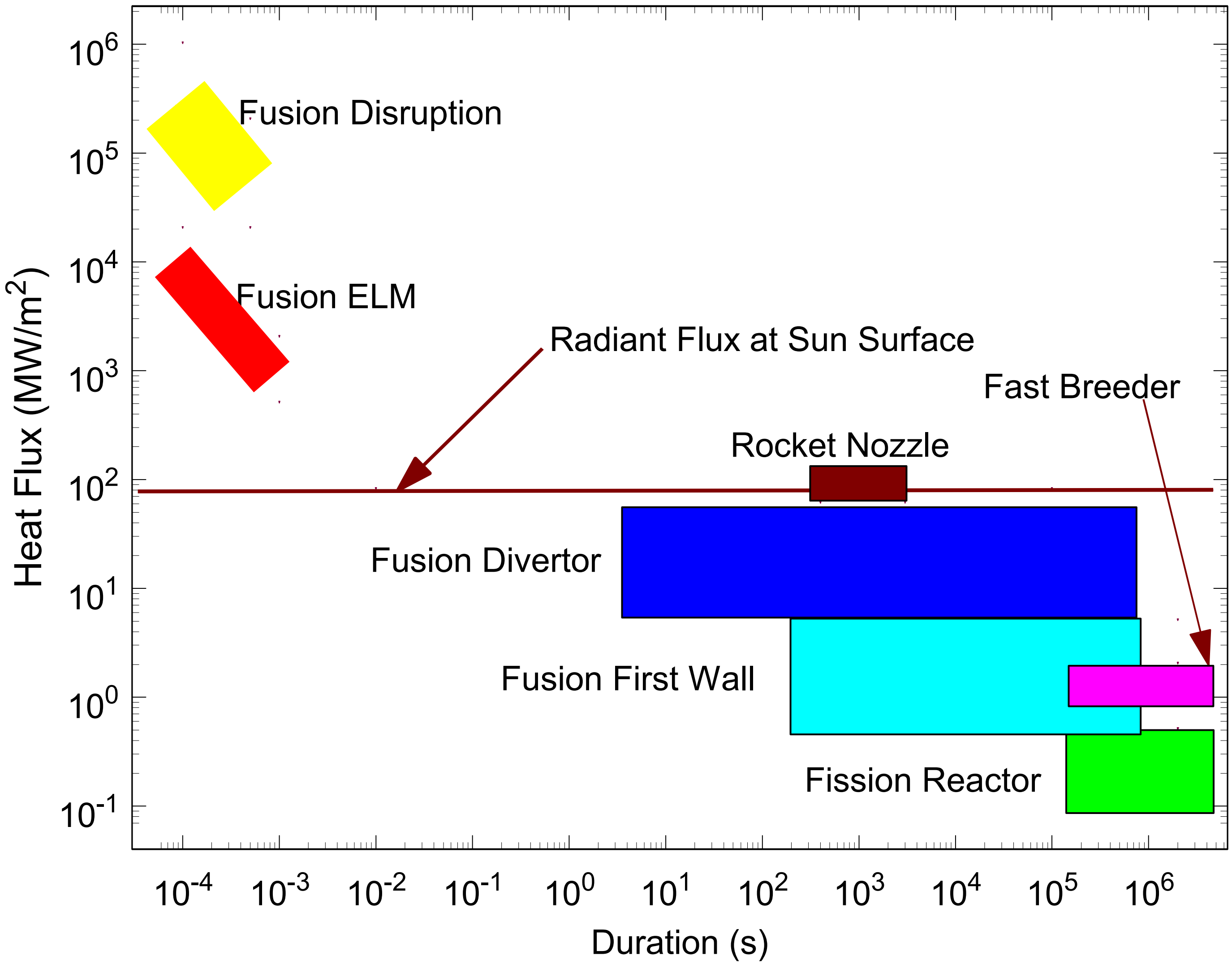
Solid Surface PFCs

Plasma Facing Materials Development

- Required Characteristics
  - High thermal conductivity
  - Reasonable activation
  - Thermal fatigue and creep resistance
  - Low erosion under edge plasma conditions
  - Low tritium retention
- Candidate Materials
  - Carbon, Copper, Molybdenum, Tantalum, Tungsten
  - Copper is not a good choice because of sputtering
  - Carbon is not a good choice because of T retention (?)

Magnetic Fusion Energy Heat Fluxes



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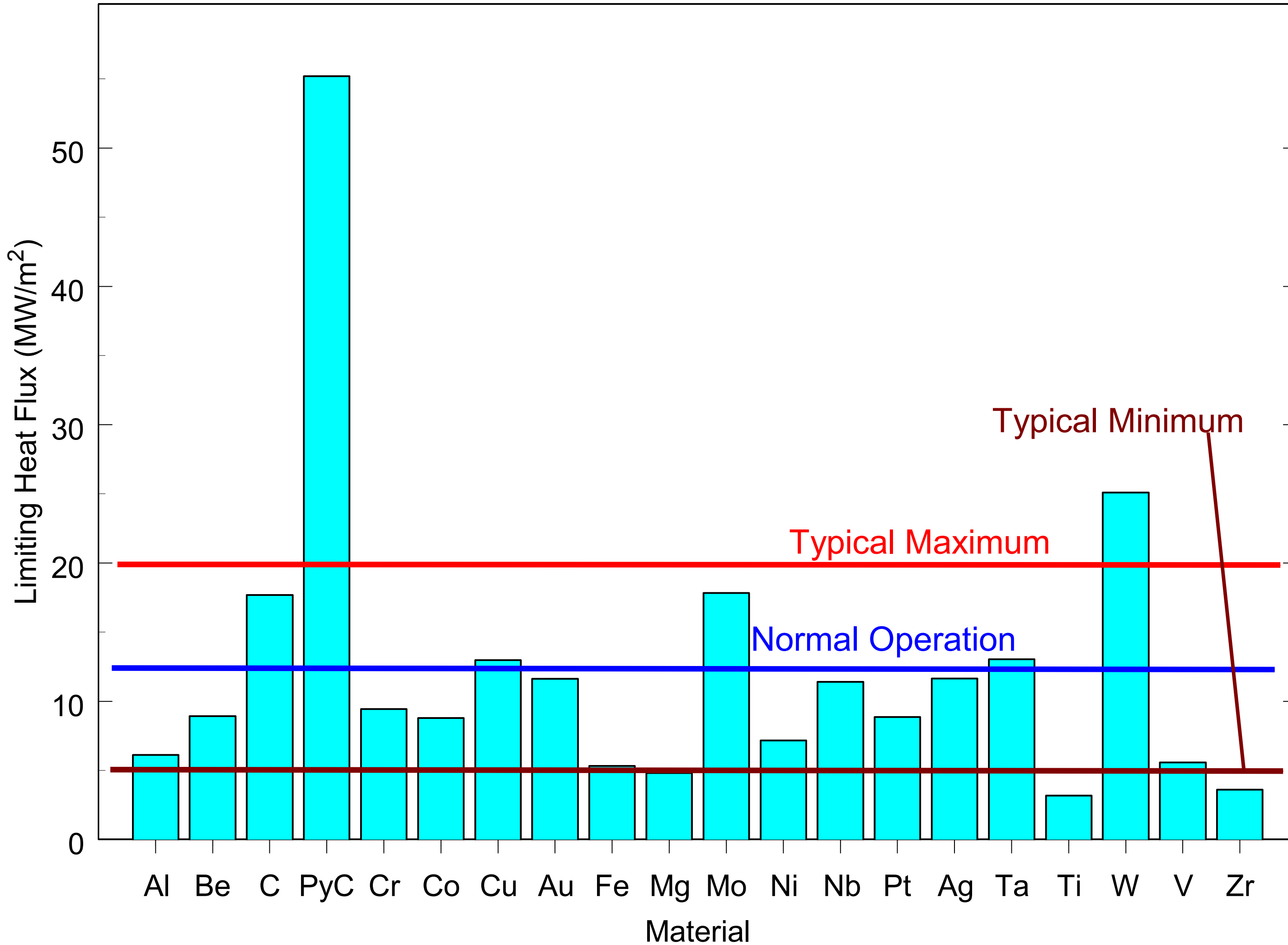
Heat Flux Capability



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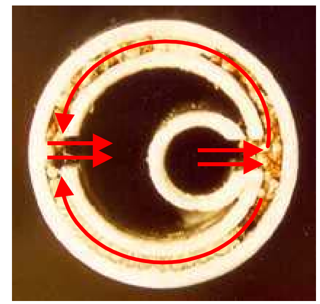
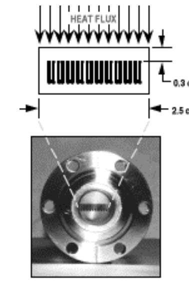
Heat Sink Development

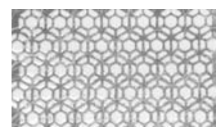
- Coolant Choices
  - Water is primary now but has issues of steam interactions with hot activated refractory metals
  - Helium gas is the prime candidate in the future
- Heat sink designs
  - For water swirl tapes, hypervapotron, screw tube, … are all well established
  - Porous metal heat sinks are in the initial stages of development for He gas cooling (Cu alloys now)

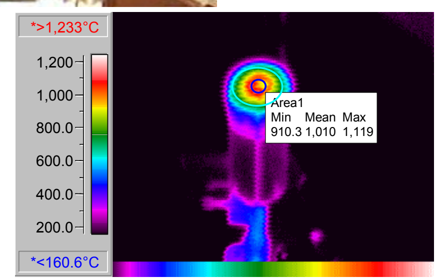
Porous Metal Heat Sinks (He)

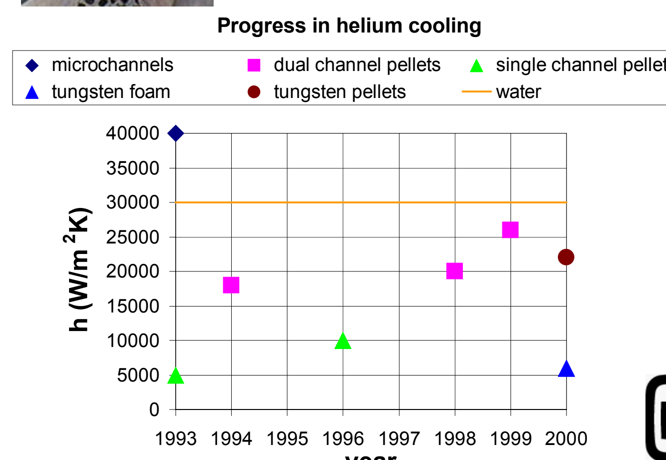
- Promising designs have been found for Cu alloys
- Heat removal is approaching water values
- Pressure drop is ok.
- Refractory metal research just starting.
- Helium gas purity is a key issue but there appear to be solutions.
- Refractory alloy development is needed.











Joining Technology

- Joining of W PFM to Cu heat sinks is well developed because of ITER R&D
- Refractory to Refractory joining
  - Initial scoping studies conducted jointly with Russians using Zr and Nb alloys.
  - Work terminated by the technology budget cuts in 1998-99
- This is a key issue that is not being addressed.

Manufacturing and Reliability

- PFC R&D is conducted on relatively small samples (~100 cm^2)
- Thousands of such parts must be reproducibly produced for a fusion device like ITER or CTF
- Tore Supra has fabricated the largest actively cooled PFC but had great difficulty with production because of repeatability, QC
- Involvement of large high-technology industries is essential to achieving practical PFCs for such machines.

Liquid Surface PFCs

Benefits of Liquid Surfaces

- High heat flux removal capability (up to 50 MW/m^2)
- No thermal stresses, no radiation damage
- Some liquids have strong hydrogen pumping and will radically alter divertor recycling
- No erosion or neutron flux limits on component lifetime
- Prime candidates for PFC applications are Li, Ga, Sn, In, and perhaps ($LiFBeF_2NaF$)

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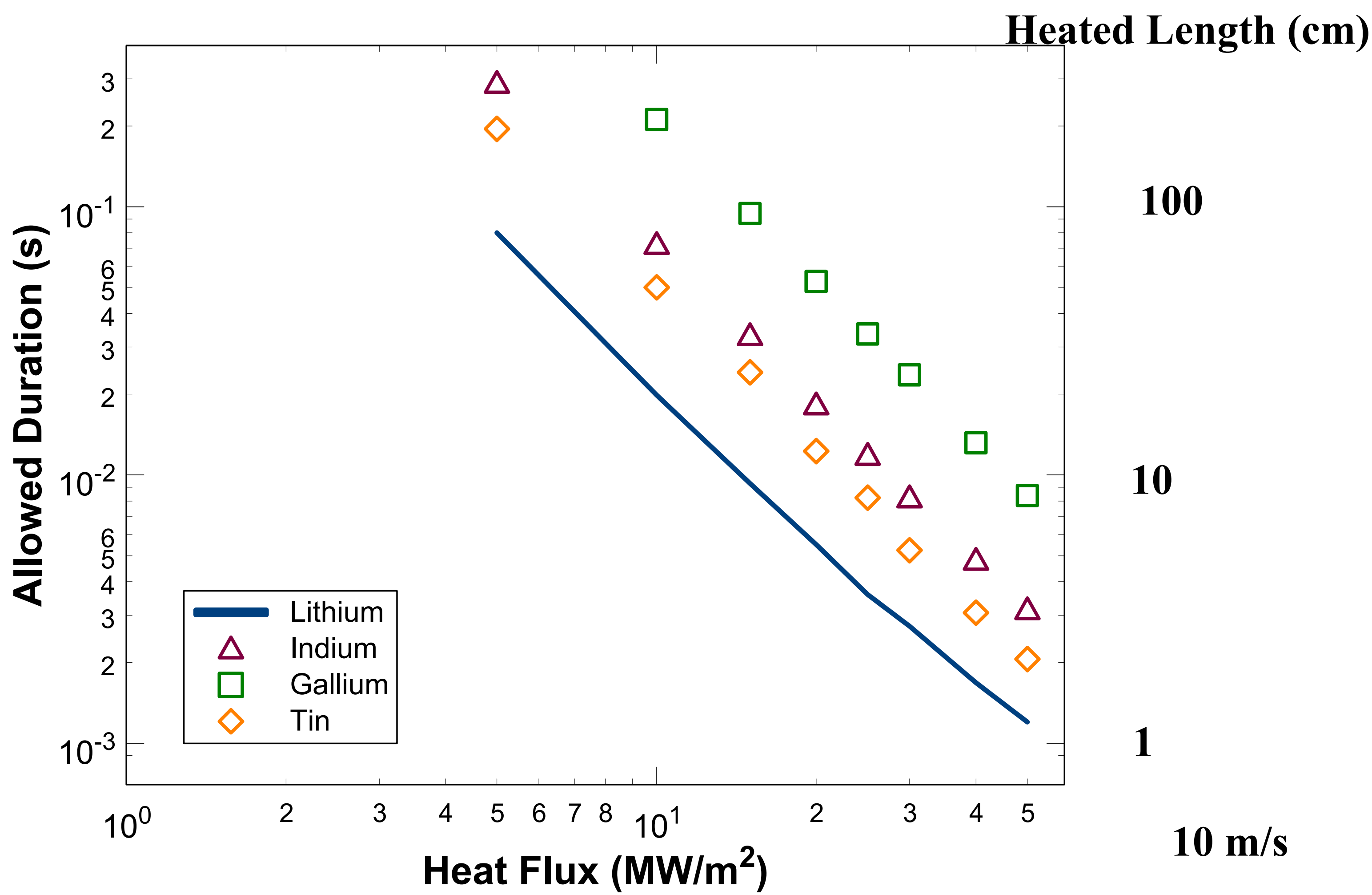
Allowed Duration for High T Limit



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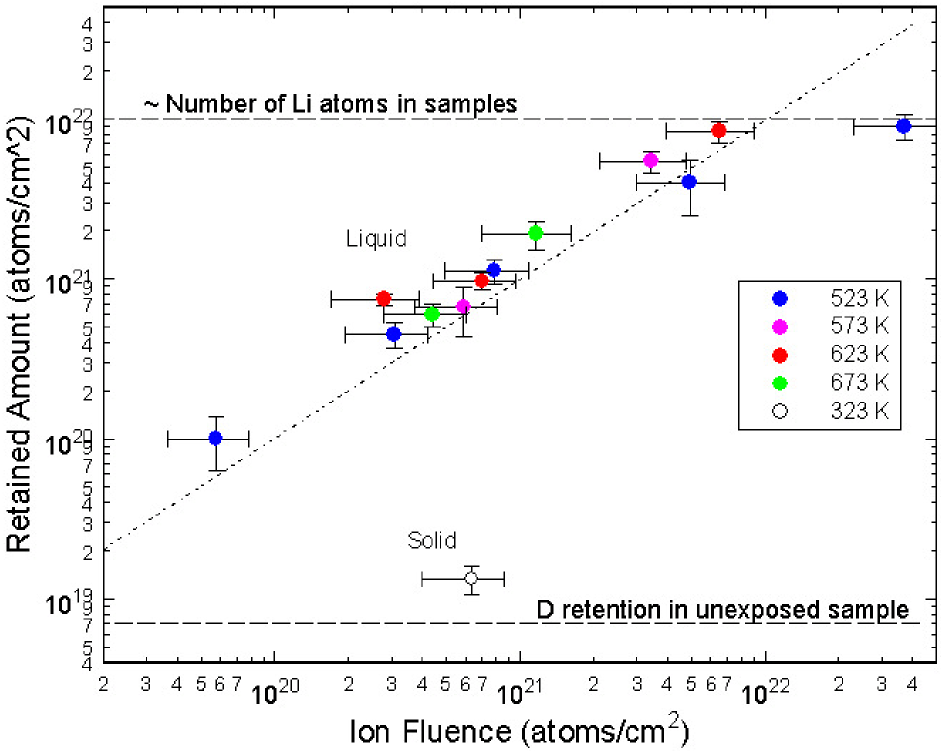
Measurement of H Retention in Li

- **High flux exposure on PISCES**
- **Retention is 100% up to complete formation of LiH over two orders of magnitude in fluence.**
- **These data have been used to determine the surface recombination rate.**
- **This means a flowing lithium surface will be an excellent pump.**



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Electromagnetic Forces

- Currents are created in flowing conducting liquids by
  - Plasma thermoelectric effect (temperature differences)
  - Halo currents
  - Spatially varying magnetic fields
  - Temporally varying magnetic fields
- Codes for computation of the effect of such currents is in progress (UCLA, Hypercomp, …)
- This is a fundamental issue for liquid surface PFC

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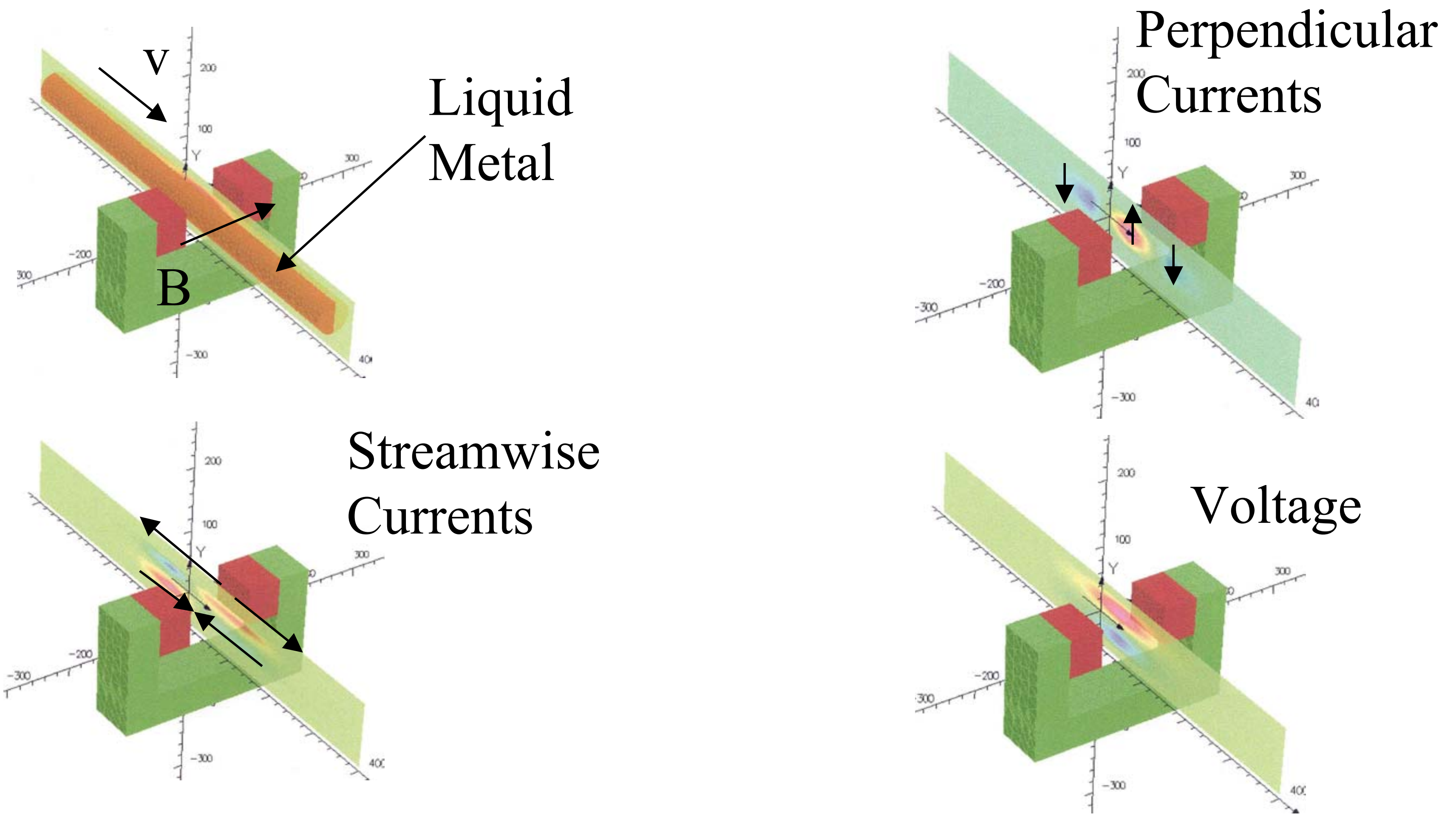
Motion Induced Currents



Other Issues

- Nozzle designs with smooth exit flow have to be designed
- Liquid metals are highly corrosive (T limits)
- External liquid metal loops are highly conducting and may have B-dot issues during current ramps.
- Electromagnetic restraint could be used to counteract EM forces
- Non-conducting liquids require special turbulence promoters
- Diversion of flow (antennas, diagnostics)

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Common Themes and Conclusions

- A long term relationship with a high technology manufacturing company will have to be matured to successfully deploy PFCs on DEMO or CTF
- Scaling R&D size prototypes to the large sizes needed is a key issue
- Materials development is needed on both paths
- The solid surface path is well defined but second priority now
- Liquid surfaces will be a cheaper development path if fundamental issues are favorably resolved