Summary of ARIES Power Core Unit Costs

L. Waganer
The Boeing Company

4-5 September 2004
ARIES Meeting at UCSD
Background

• At the September 2004 meeting, I presented the costs for a set of materials for one of the candidate blanket/ maintenance schemes.

• Since then, I have expanded the cost basis to include the other configurations

• The cost basis is a combination of data from prior studies as well as new material quotes

• Also, I have prepared a trade study assessment tool for the proposed blanket concepts to help document the rationale for the selection into the next study phase
## Candidate Power Core Concepts

<table>
<thead>
<tr>
<th>Designation</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D1</th>
<th>D2A</th>
<th>D2B</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td><strong>Self Cooled Molten Salt</strong></td>
<td><strong>Self Cooled LiPb</strong></td>
<td><strong>Li Dual Coolant</strong></td>
<td><strong>LiPb Dual Coolant</strong></td>
<td><strong>LiPb Dual Coolant</strong></td>
<td><strong>LiPb Dual Coolant</strong></td>
<td><strong>Ceramic Breeder</strong></td>
</tr>
<tr>
<td><strong>VV location</strong></td>
<td><strong>Internal to Coils</strong></td>
<td><strong>Internal to Coils</strong></td>
<td><strong>External to Coils</strong></td>
<td><strong>Internal to Coils</strong></td>
<td><strong>External to Coils</strong></td>
<td><strong>External to Coils</strong></td>
<td><strong>Internal to Coils</strong></td>
</tr>
<tr>
<td><strong>First Wall, Blanket</strong></td>
<td>ODS FS Be Pebbles Flibe (30% Li6)</td>
<td>SiC/SiC Li17Pb83 (90%Li6)</td>
<td>ODS/RFS Li (natural) He</td>
<td>ODS/RFS Li17Pb83(90%Li6) He</td>
<td>ODS/RFS Li17Pb83(90%Li6) He</td>
<td>ODS/RFS Li17Pb83(90%Li6) He</td>
<td>ODS/RFS Li4SiO4 20-90Erchd Be Pebbles He</td>
</tr>
<tr>
<td><strong>Local Shield</strong></td>
<td>RAFS WC plates Flibe (30% Li6)</td>
<td>SiC/SiC WC Plates Li17Pb83 (90%Li6)</td>
<td>RAFS WC plates He</td>
<td>RAFS WC plates He</td>
<td>RAFS WC plates He</td>
<td>RAFS WC plates He</td>
<td>RAFS WC plates He</td>
</tr>
<tr>
<td><strong>Shield</strong></td>
<td>RAFS Borated FS Plates Flibe (30% Li6)</td>
<td>SiC/SiC Borated FS Plates Li17Pb83 (90%Li6)</td>
<td>RAFS Borated FS plates He</td>
<td>RAFS Borated FS Plates He</td>
<td>RAFS Borated FS Plates He</td>
<td>RAFS Borated FS Plates He</td>
<td>RAFS Borated FS plates He</td>
</tr>
<tr>
<td><strong>Vac Vessel</strong></td>
<td>RAFS Borated Water</td>
<td>RAFS Borated FS Plates H2O</td>
<td>RAFS He</td>
<td>RAFS Borated FS Plates H2O</td>
<td>RAFS He</td>
<td>RAFS He</td>
<td>RAFS Borated FS Plates H2O</td>
</tr>
</tbody>
</table>

**Cost data presented 9/2004**

This is the complete list of concepts the team has defined and analyzed for Phase I.
### Unit Costs Data for Systems Code

- First Three Candidate Systems -

<table>
<thead>
<tr>
<th>Designation</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td><strong>Self Cooled Molten Salt</strong></td>
<td><strong>Self Cooled LiPb</strong></td>
<td><strong>Li Dual Coolant</strong></td>
</tr>
<tr>
<td></td>
<td><strong>VV location</strong></td>
<td><strong>Internal to Coils</strong></td>
<td><strong>Internal to Coils</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>$/kg kg/m3</strong></td>
<td><strong>$/kg kg/m3</strong></td>
</tr>
<tr>
<td><strong>First Wall, Blanket</strong></td>
<td>ODS FS Be Pebbles Flibe (30% Li6)</td>
<td>$103.00</td>
<td>7800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$250.00</td>
<td>1848</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$40.88</td>
<td>1987</td>
</tr>
<tr>
<td></td>
<td><strong>Local Shield</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RAFS WC plates Flibe (30% Li6)</td>
<td>$103.00</td>
<td>7800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$30.00</td>
<td>15500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$40.88</td>
<td>1987</td>
</tr>
<tr>
<td></td>
<td><strong>Shield</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RAFS Borated FS Plates Flibe (30% Li6)</td>
<td>$78</td>
<td>7800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$31.00</td>
<td>7800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$40.88</td>
<td>1987</td>
</tr>
<tr>
<td></td>
<td><strong>Vac Vessel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RAFS Borated Water</td>
<td>$56.00</td>
<td>7800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~ $0</td>
<td>1000</td>
</tr>
</tbody>
</table>

- New ROM quote for Beryllium from Brush Wellman was provided, $220-$275/kg
- Refinement of natural Lithium cost is in work
- My prior estimate for Li17Pb83 90% enriched was in error, should be atom%. Revised number would be much lower
- Historical enriched lithium and LiPb estimates from MARS, UWTOR-M, and BCSS (circa 1980-1983) suggest $16-20/kg for 90% enriched Li17Pb83
I have a new quote for natural Lithium Orthosilicate ($44/kg) and need to convert it to 90% enriched Lithium Orthosilicate.
Unit Costs Data for Systems Code

Link to Cost Database
Blanket Evaluation and Selection Process
We Should Reach Consensus On Key Blanket Attributes For Selection and Their Importance

Key Factors in Blanket Concept Selection

<table>
<thead>
<tr>
<th>Factor</th>
<th>Discussion</th>
<th>Value 0-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tritium Breeding Ratio</td>
<td>All designed to satisfy 1.1 criteria; may need enriched lithium or beryllium</td>
<td>2</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>Determines thermal efficiency and overall plant performance</td>
<td>4</td>
</tr>
<tr>
<td>Complexity, Technical Maturity</td>
<td>Influences development risk and cost</td>
<td>3</td>
</tr>
<tr>
<td>Inherent Safety</td>
<td>All designs to be safe, but some are more inherently safe, e.g. dual coolant designs</td>
<td>2</td>
</tr>
<tr>
<td>Pumping Power</td>
<td>Higher pumping power reduces net power</td>
<td>1</td>
</tr>
<tr>
<td>Thickness of Breeding Zone</td>
<td>Influences cost of power core components</td>
<td>2</td>
</tr>
<tr>
<td>Radioactive Waste Products</td>
<td>Influences public acceptance and waste disposal costs</td>
<td>2</td>
</tr>
<tr>
<td>Service Lifetime</td>
<td>All blankets are designed for 40 FPY</td>
<td>0</td>
</tr>
<tr>
<td>Inherent Reliability</td>
<td>Too early to define data</td>
<td>0</td>
</tr>
</tbody>
</table>
This Trade Study Spreadsheet Illustrates the Evaluation Process

- Data is for illustration only -

<table>
<thead>
<tr>
<th>Evaluation Parameter</th>
<th>Option A</th>
<th>Option B</th>
<th>Option C</th>
<th>Option D1</th>
<th>Option D2A</th>
<th>Option D2B</th>
<th>Option E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Poor</td>
<td>Adequate</td>
<td>Good</td>
<td>Excellent</td>
<td>UnWtd</td>
<td>Wtd</td>
<td>UnWtd</td>
</tr>
<tr>
<td>Tritium Breeding Ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wt</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>UnWtd</td>
<td>Wtd</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Needs Be Multiplier</td>
<td>90% Enrch Lithium</td>
<td>30% Enrch Lithium</td>
<td>Natural Lithium</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Operating Temperature, °C</td>
<td>4</td>
<td>&gt;600</td>
<td>600-750</td>
<td>750-900</td>
<td>1000-1200</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Complexity, Technical Maturity</td>
<td>3</td>
<td>Very Cmpx, Immature</td>
<td>Cmpx, Low Mat</td>
<td>Cmpx, Mod Mat</td>
<td>Low Cmpx, Good Mat</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Inherent Safety</td>
<td>2</td>
<td>Poor</td>
<td>Adequate</td>
<td>Good</td>
<td>Excellent</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Pumping Power</td>
<td>1</td>
<td>High</td>
<td>Moderate</td>
<td>Mod. Low</td>
<td>Low</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Thickness of Breeding Zone, m</td>
<td>2</td>
<td>&gt;1.3</td>
<td>1.2 - 1.3</td>
<td>1.1 - 1.2</td>
<td>&lt; 1.1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Radioactive Waste Products</td>
<td>2</td>
<td>Poor</td>
<td>Adequate</td>
<td>Good</td>
<td>Excellent</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Sum</td>
<td>16</td>
<td>16</td>
<td>32</td>
<td>48</td>
<td>64</td>
<td>28</td>
<td>46</td>
</tr>
</tbody>
</table>

The closeness of the scores suggest either a) the blankets are similar in performance b) the evaluation parameters/weightings are not indicative of the true discriminators, or c) the evaluation scores are wrong.