The case for QUASAR (NCSX)

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My starting point

I ❤ Tokamaks
Then why support QUASAR?

• Tokamaks have many advantages
  • Yada, yada, yada

• Tokamaks have challenges
  • Steady state
  • Disruptions
  • PMI (Everybody’s problem)

• A standard tokamak does not scale to a reactor!!
  • Standard = \( P_E, P_W, B_{\text{max}}, \beta_N, q^*, \text{profiles} \)
  • Needs too much current \( I \)
Possible solutions

- Advanced tokamak physics
- High field
- High power output
- Stellarators
Stellarators

• Stellarators are inherently steady state
• Low or no current makes them disruption resistant
• Good plasma performance

Why then hasn’t the stellarator overtaken the tokamak?
Stellarator Challenges

• Collisionless transport (Physics issue)

• Complicated magnets (Cost issue)

• Large size reactors (Cost issue)
Collisionless transport

Tokamak vs. stellarator neoclassical transport

Tokamak

Stellarator
Solution – No \parallel helical ripples

- Quasi-omnigenous stellarator (2 possibilities)
  - Quasi-isodynamic (W7-X)
  - Quasi-axisymmetric (QUASAR)
The Magnets

Tokamak

Stellarator

Walmart

Neiman-Marcus
The Solution

• Expensive learning curve

• Experience

• The price has been largely paid
Large Size

Compare HELIAS (W7-X) with ARIES-CS (QUASAR)
## Scaling Relation

<table>
<thead>
<tr>
<th>HELIAS</th>
<th>ARIES-CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_0(m)$</td>
<td>18</td>
</tr>
<tr>
<td>$a(m)$</td>
<td>2</td>
</tr>
<tr>
<td>$P_w(MW/m^2)_{max}$</td>
<td>1.7</td>
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</tbody>
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### Scaling

\[
P_w A = P_n
\]

\[
\begin{align*}
\text{Cost} & \propto \frac{V_i}{P_E} \\
\text{Watt} & \propto \frac{1}{P_w}
\end{align*}
\]
Why not wait for W7-X?

• A car is a car is a car – right?

• A stellarator is a stellarator is a stellarator – right?

• Both W7-X and QUASAR are stellarators

• But they are very, very different stellarators
OK – Why QUASAR?

Short term:

• Theory says both W7-X and QUASAR should work
• A good start, but
• **We need experimental proof!!**
• W7-X is nearly completed
• QUASAR is already designed and partially constructed

Long term:

• QUASAR – the more economical path forward
Suggestions for FESAC to DoE

• Stop shutting down experiments
• Start building experiments
• Make QUASAR part of the 10 year plan
• Sooner rather than later
Putting our money where our mouth is

If QUASAR is built MIT would partner with PPPL:

- Engineering
- Diagnostic development
- RF heating development
- Major part of scientific team

My new MHD book

Ideal MHD
Jeffrey P. Freidberg