Towards An Attractive Fusion Power Plant

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The ARIES Team Has Examined Several Tokamak and non-Tokamak Power Plants in the Past 10 Years

- TITAN reversed-field pinch (1988)
- ARIES-I first-stability tokamak (1990)
- ARIES-III D-^{3}He-fueled tokamak (1991)
- ARIES-II and -IV second-stability tokamaks (1992)
- Pulsar pulsed-plasma tokamak (1993)
- SPPS stellarator (1994)
- Starlite study (1995)
- ARIES-RS reversed-shear tokamak (1996)
- ARIES-ST spherical tokamak (in progress)

Top-Level Requirements for Commercial Power Plant Were Developed through Interaction with Representatives from US Electric Utilities & Industry

1) No public evacuation plan required: Total does < 1 rem at site boundary
2) No radioactive material generated with waste category greater than Class C
3) No disturbance of public's day-to-day activities
4) No exposure of workers to a higher risk than other power plants
5) Closed tritium fuel cycle
6) Ability to operate at partial load condition (50%)
7) Ability to maintain power core
8) Ability to operate reliably with < 0.1 major unscheduled shut-down/year

Our Vision of Tokamaks Has Improved Drastically in the Last Decade

	80s physics Pulsar	90s physics ARIES-I	90s physics ARIES-RS
Major radius (m)	9	7	5.5
β	2.3%	1.9%	5%
β_N	3	3.2	4.8
Plasma current (MA)	10 MA	10 (68% BS)	11 (88% BS)
COE (c/kWh)	13	9.5	7.3

Direction for Improvement of Product

- **Push the concepts to the limit**

  For example, for ARIES-RS reduce COE by about 10%: assume perfect bootstrap alignment, and operation at the maximum theoretical β.

- **This is a trade-off of credibility with performance**

More Efficient Confinement System

- No superconducting TF coils
  - Spherical tokamaks (ARIES-ST): Potential for high performance and small size devices for fusion research but requires high beta and perfect bootstrap alignment. Center-post is a challenge.
  - RFP (TITAN): Simple magnets and potential for high performance. Steady-state operation requires resolution of the conflict between current-drive and confinement.
- No current-drive:
  - Stellarators (SPPS): recent advances bring the size in-line with advanced tokamaks. Needs coils and components with complicated geometry.

High-Performance Technology

- ARIES-I design explored improved performance through higher-performance technologies:
  - Cheap, high-field magnets. Note $\beta^2 B^4$ scaling,
  - A “coal-like” fusion core, i.e., no nuclear-stamped components.

- Higher performance and/or cheaper fusion core components results in dramatic improvement in our products:

- It requires extensive fusion engineering sciences R&D.

Summary

- Fusion has an attractive product at this stage of its development.
- History of fusion research shows improvement of our product through coordinated R&D.
- **Problem:** How to communicate this to outside.
- We have to continuously strive to improve our products by
  - Pursuing “better tokamks” or alternatives
  - Pursuing higher performance and cheaper technologies.
- Detailed integrated conceptual design help define the trade-off and point to directions for high-leverage R&D.