MAGNETIC FUSION ENERGY CONCEPTS

Raymond J. Fonck
University of Wisconsin-Madison
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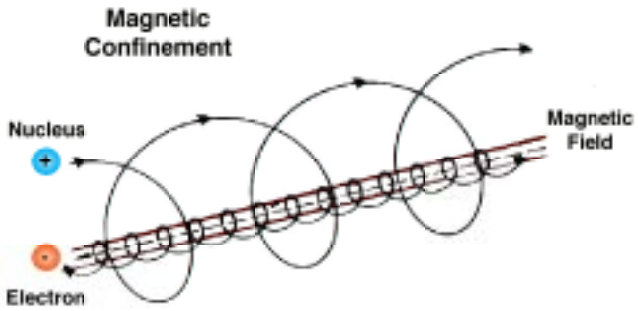
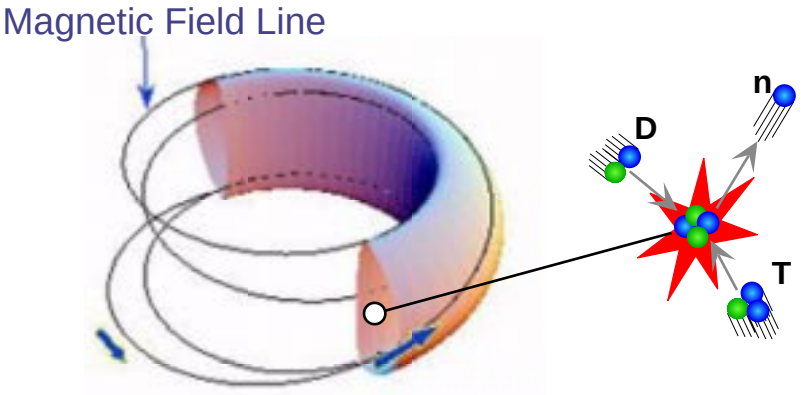
Magnetic Fusion Energy Overview

- Magnetic field confinement of hot plasma fuel for sustained nuclear burn

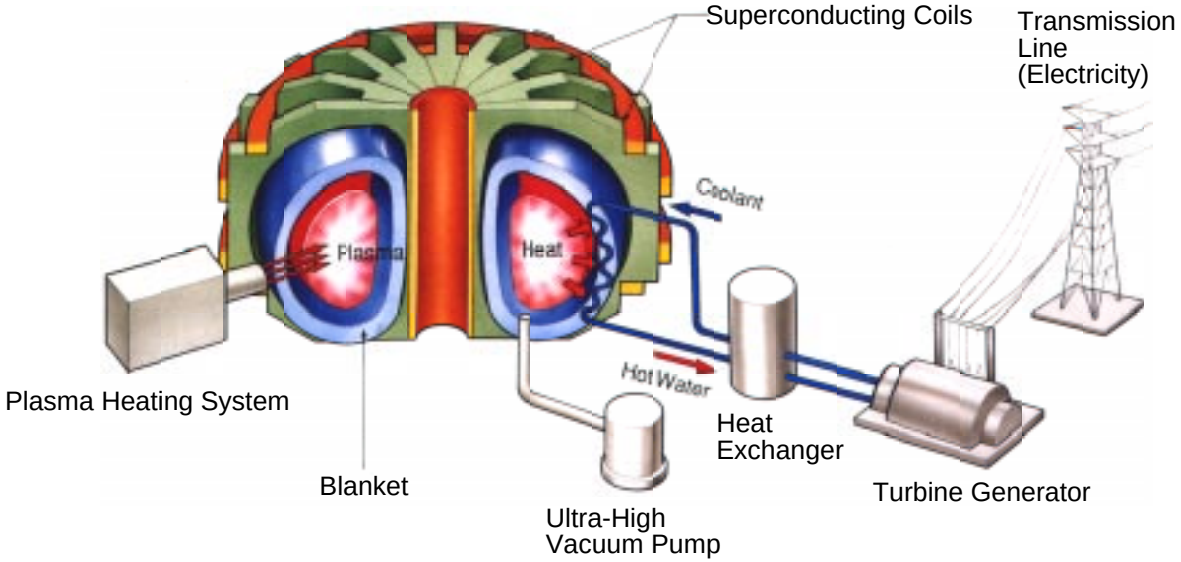
Plasma particles tied to magnetic field lines:





Use <u>toroidal</u> magnetic bottles to eliminate end losses.

Fusion Power Station



Issues for Magnetic Fusion Energy

- Several issues arise in examining the potential for fusion power production

Practical:

- Complexity
- Reliability
- Size
- Cost of development
- Development time
- Cost of final product
- Environmental attractiveness

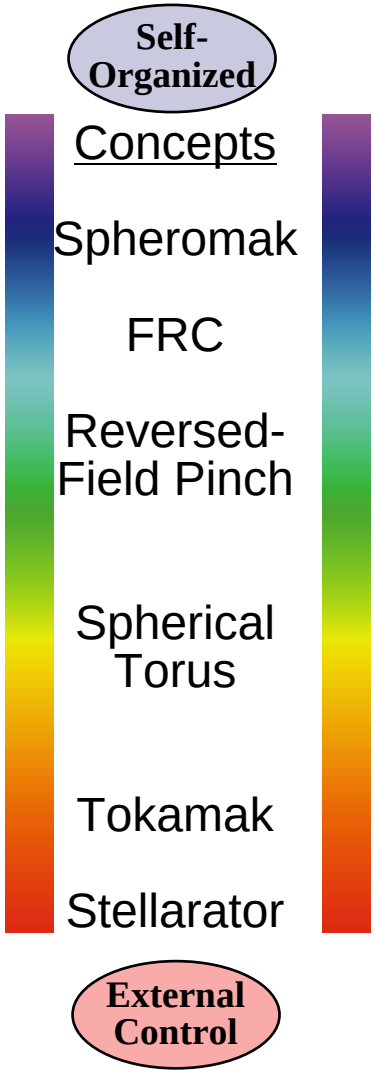
Technical:

- Confinement and stability
- Power density and efficiency
- Sustainment of plasma and burn control
- Wall damage from intense heat and radiation
- Energy exhaust and conversion
- Mechanical stresses
- Fuel Cycles
- Maintainability

- Address these issues through science and technology research portfolio

MFE Research Portfolio Targeted to Addressing Critical Issues

- Classify by degree of external magnetic control vs ability of plasma to organize itself



Figures of Merit (preferable)

External Field	*Size*	*Stability*	*Confine-ment*	*Wall Loads*	*Complexity*
Weak	Compact	Poor	Low	Higher	Lower
↑	↑	↓	↓	↓	↑
Strong	Large	Good	High	Lower	Higher

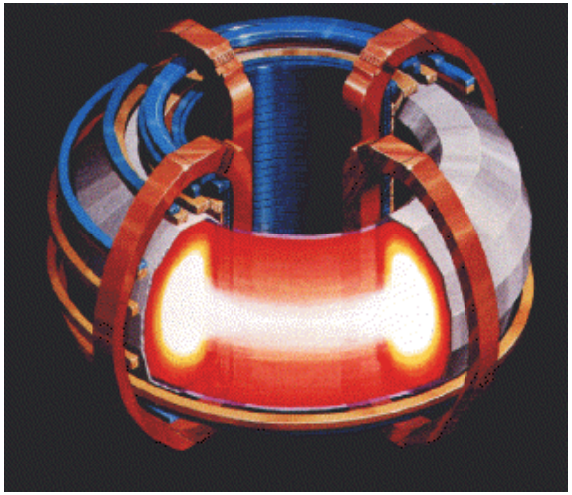
- Strong degree of unity and overlap in concepts
  - *Study of one enhances ability to develop others*

Advanced Tokamaks Lead to Smaller, Reduced-Cost Reactors

- **Advanced Tokamak**: Improved physics ⇒ smaller reactor core

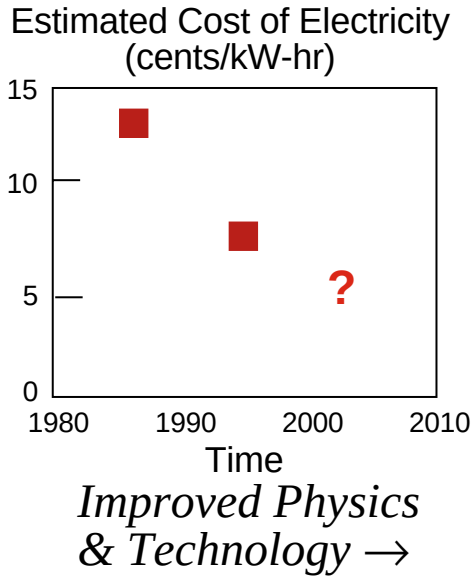
  - New physics findings build on past success
    - *Instability suppression ⇒ improved confinement*
      = fundamental fluid turbulence science!
    - *High pressure operation*
    - *Promising path to Burning Plasma experiment*

  - Critical issues:
    - *Sustaining enhanced performance*
    - *Pressure-driven current*



- U.S. is leading advanced tokamak concept development
  - Allows leveraging of international investments in tokamak facilities

- Estimated cost of electricity decreases as science and technology improves

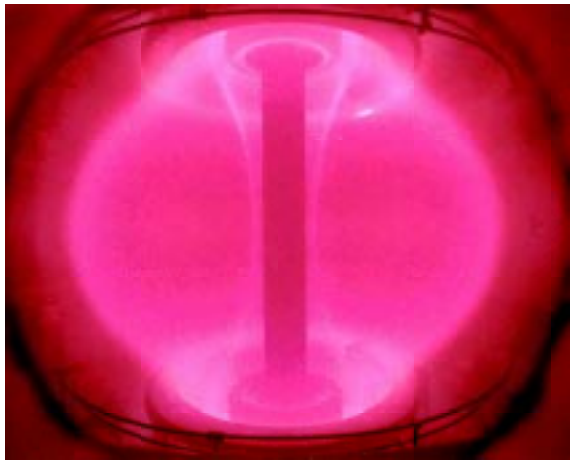


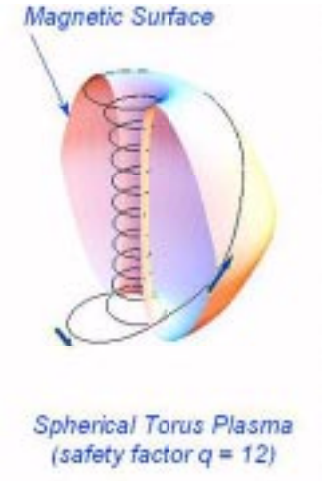
Improved Physics & Technology →

Spherical Torus Offers a Low-Cost Development Path

- Shrink "hole in the donut"
  - Gives strong-field stability in a weak-field device

Photograph of a high pressure ST plasma (START - UK)





  - Cheaper development path
    - *Low fields, copper magnets, simple configuration*
    - *Candidate for small fusion test device*

  - Critical issues:
    - *Confinement*
    - *Steady-state operation*
    - *Heat dissipation on center column*

Self-Organizing Plasmas Lead to Simplified Concepts

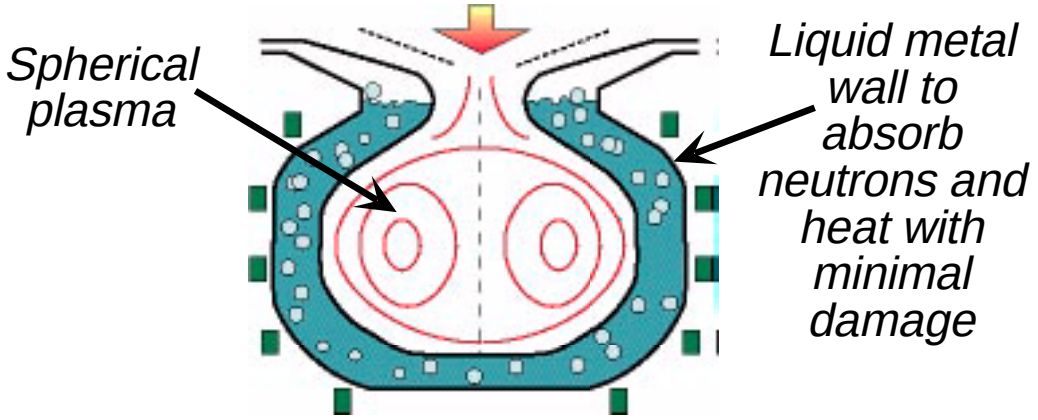
Example:

- **Spheromak**: Use self-generated magnetic field

  - Dynamo: plasma generates its own field and relaxes to a stable configuration!
    - *Physics of earth's magnetic field*

  - Simple spherical geometry: eliminate central column
    - *Opportunity for advanced reactors like liquid walls (c.f., IFE)*

  - Critical issues:
    - *Formation*
    - *Stability*
    - *Sustainment*
    - *Confinement*
    - *Pressure limits*

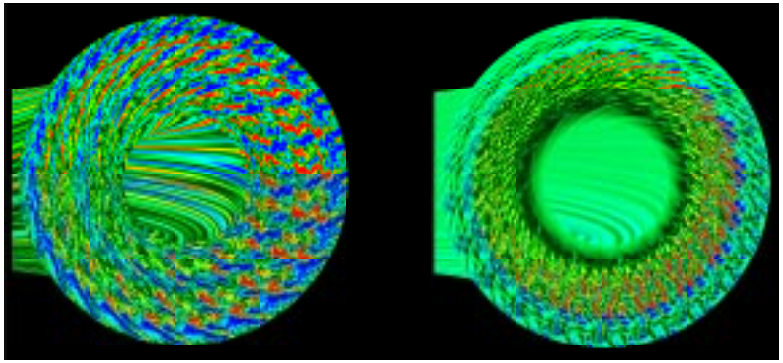


Simulations Spur Concept Development

- **Theory and Simulation:** Major progress in fundamental understanding of plasmas

  - Advancing the frontiers of basic and applied plasma science

Simulated unstable toroidal plasma

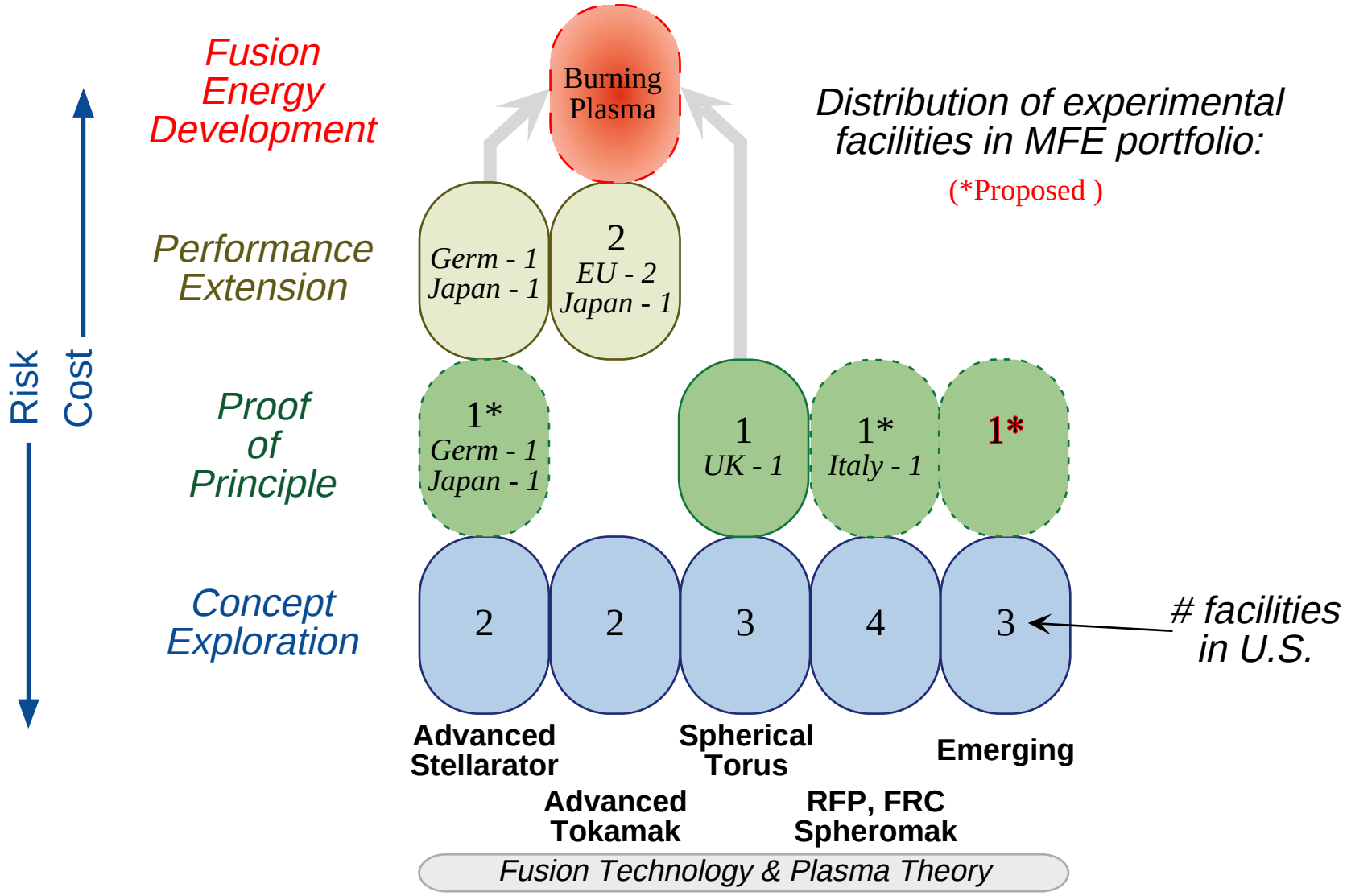


Simulated stable toroidal plasma

  - Critical issues:
    - *New parallel computers ⇒ increasingly realistic simulations*
    - *Evaluation of less-developed concepts*

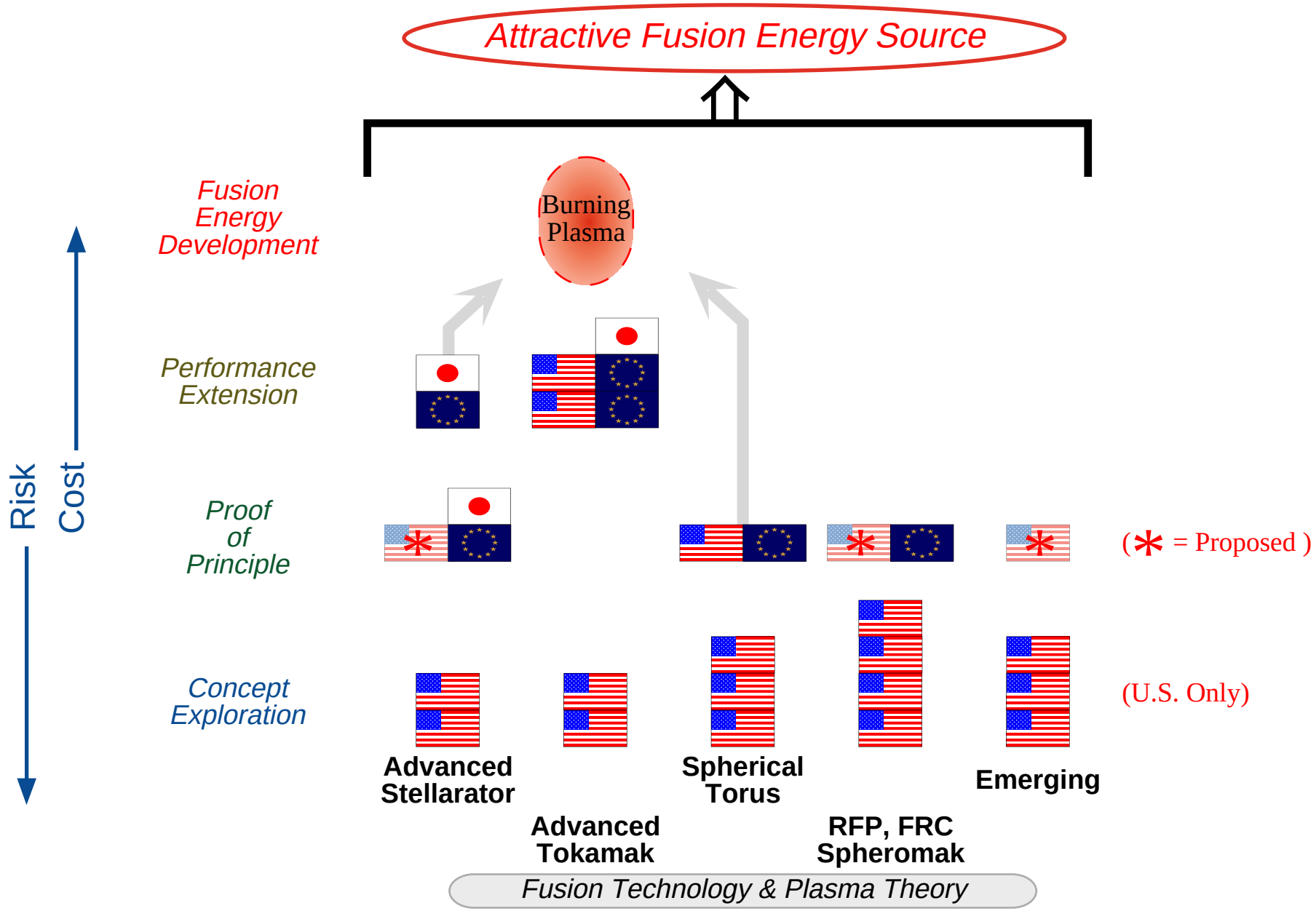
Chaos & turbulence
Self-organizing systems
Large-scale simulations

Diversified MFE Research Portfolio



- Work on entire portfolio leads to an attractive source of energy
- Development costs minimized through international collaboration

Diversified MFE Portfolio Leads to Attractive Energy Source



- Development costs minimized through international collaboration