U.S. Stellarator Proof-of-Principle Program

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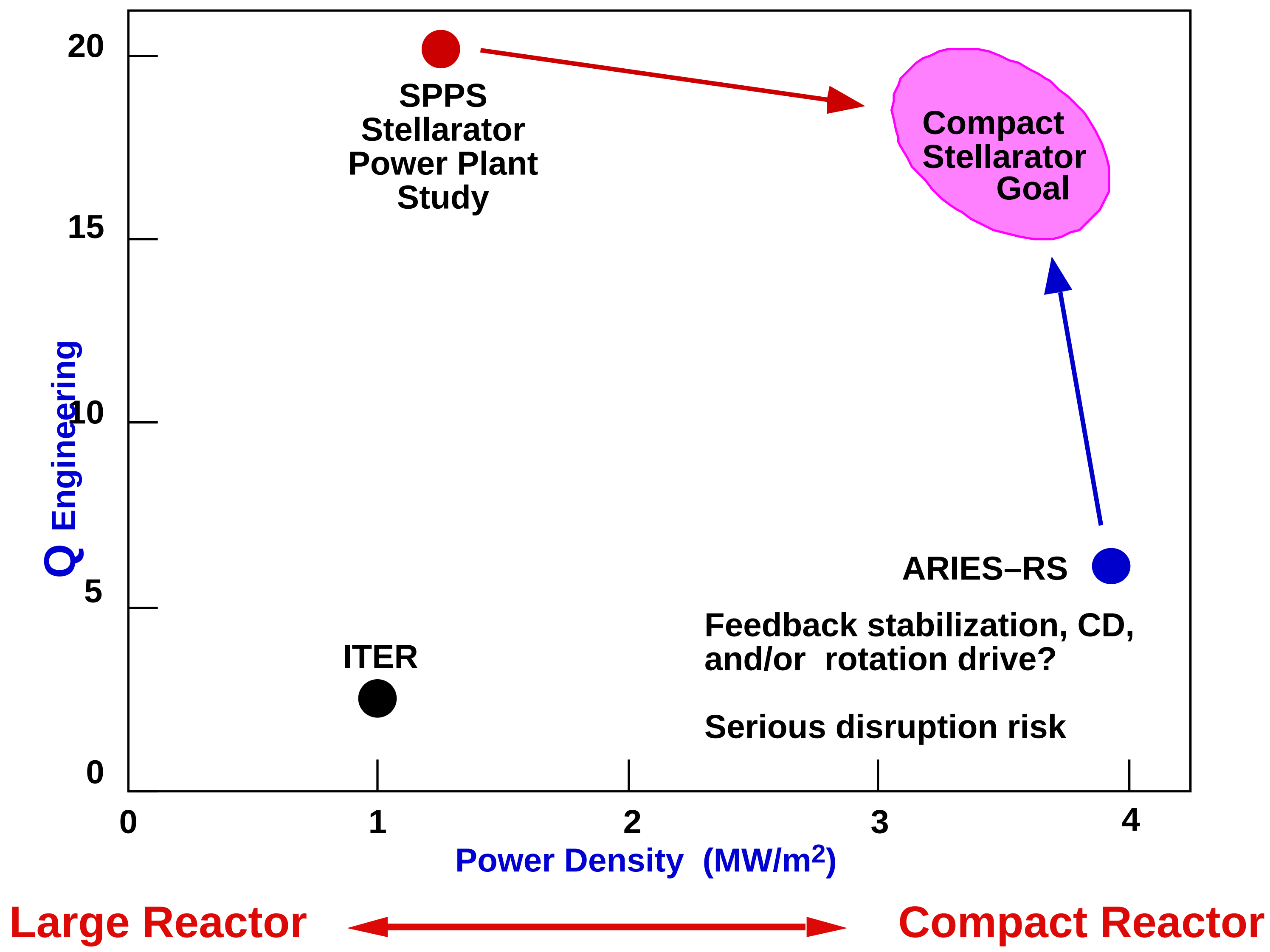
Review Panel Has Endorsed the Scientific Merit and Readiness of the Compact Stellarator PoP Program

- **The panel agreed with us that compact stellarators have great potential**
  - absence of disruptions
  - steady-state operation
  - no need for auxiliary current drive
- **The panel concludes that the stellarator community is ready for a PoP program**

A Compact Stellarator Could Combine the Best Features of Tokamaks and Stellarators!



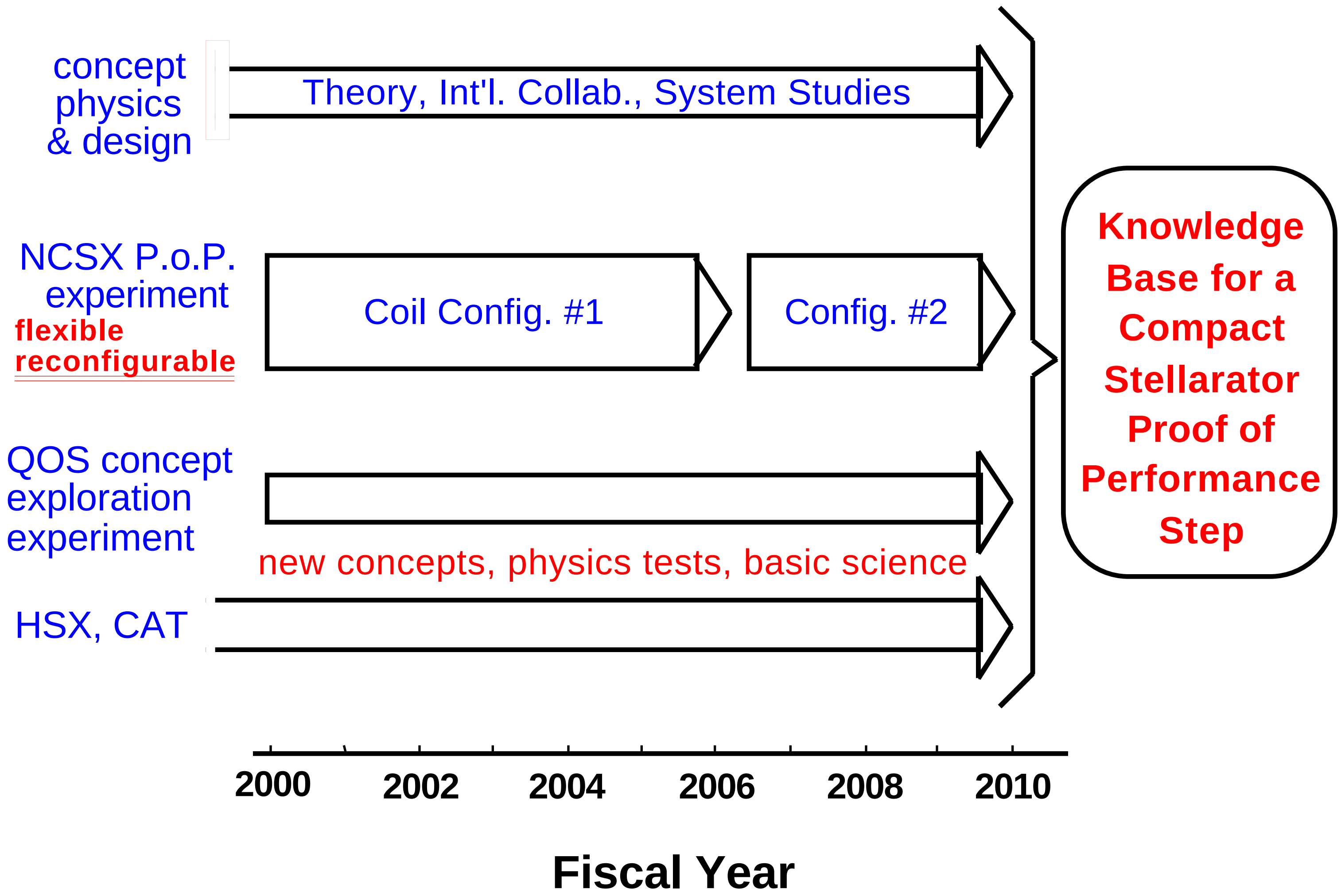
Two Different Optimization Strategies Have Been Developed for Compact Stellarators

- Both look attractive for reactors (good confinement, high beta, low recirculating power)
- Fundamentally different optimization approaches are used, each with distinct advantages
  - Quasi-axisymmetry (QA) with tokamak-like transport properties
  - Nonsymmetric quasi-omnigeneity (QO) aligns particle drift orbits with magnetic surfaces
- Both need to be pursued to determine the optimum approach

Goals of the Proposed Program

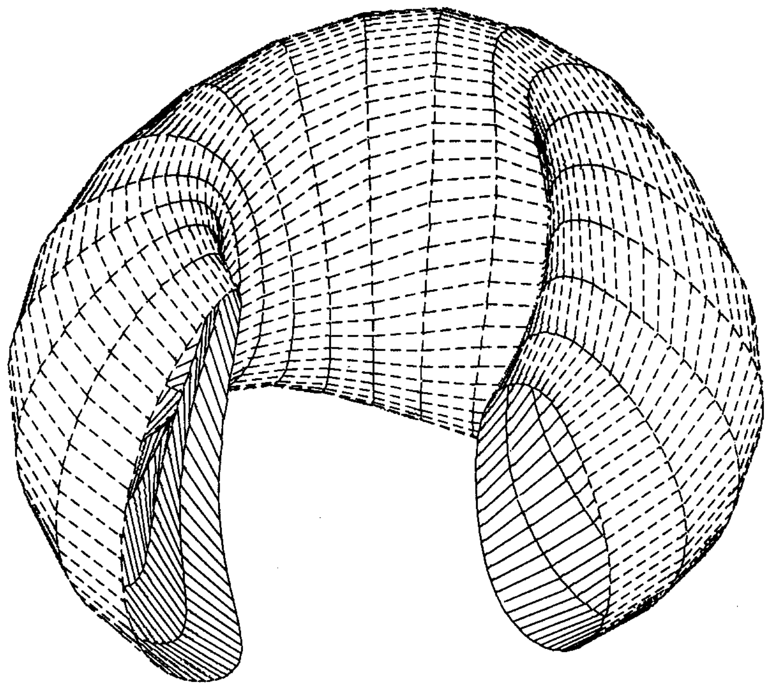
- β > 5% at low aspect ratio without disruptions
- Determine β limit and the limiting mechanism
- Reduce neoclassical transport using QA and QO optimization strategies
- Control turbulent transport to acceptable level
- Explore particle and heat exhaust schemes

Compact-Stellarator Proof-of-Principle Program



All PoP program elements are complementary, interconnected, and together provide the basis for a Proof-of-Performance decision

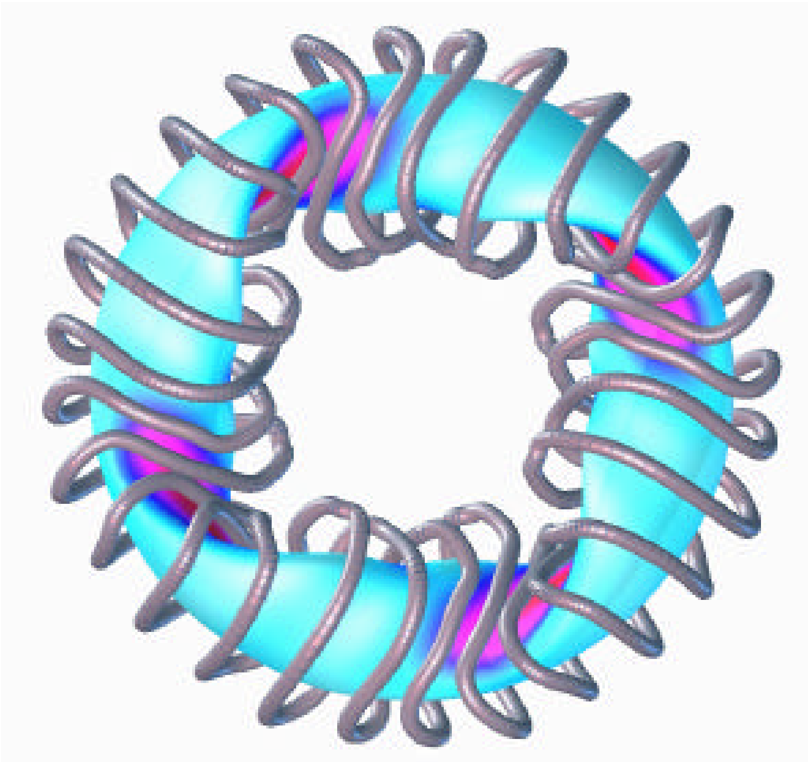
Quasi-Axisymmetric NCSX



- Major Radius 1.5 m
- Plasma Radius 45 cm
- Aspect Ratio 3.3
- Plasma Volume 6 m^3
- Magnetic Field 1 - 2 T
- Plasma Current <400 kA
- Pulse Length 3 - 5 s
- Plasma Heating
  6-12 MW; NBI+ICRF

- **NCSX provides the magnetic field, heating power, plasma size, and diagnostics needed to address key issues for compact stellarators**

Quasi-Omnigeneous Stellarator



• Major Radius	1.0 m
• Plasma Radius	28 cm
• Aspect Ratio	3.6
• Plasma Volume	1.55 m^3
• Magnetic Field	1 T
• Plasma Current	<150 kA
• Pulse length	0.2 - 1 s

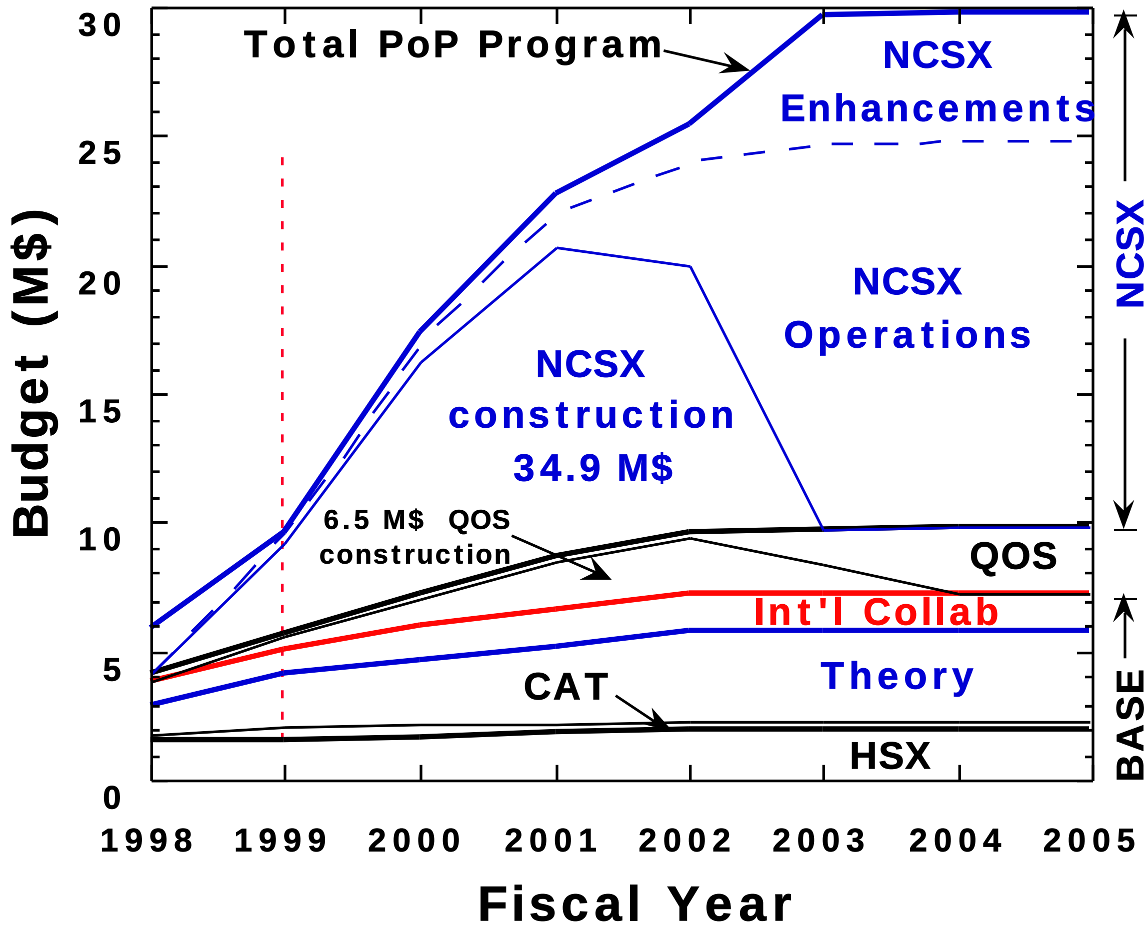
- 0.4 MW 53/60 GHz ECH
- 1 MW 6-20 MHz ICRF

- The QOS concept-exploration-level experiment addresses QO optimization issues: neoclassical transport and reduction of the bootstrap current

Each PoP Program Element Contributes Information Essential for a Later Proof-of-Performance Decision

- **Optimization approach for compactness: theory +**
  - **quasi-symmetry: NCSX**
  - **quasi-omnigeneity: QOS**
- **Bootstrap current: control (NCSX), simulation (QOS, CAT); reduction (QOS; W7-X at 3 x *R*/<*a*>); theory**
- **Disruption avoidance -- NCSX and CAT**
- **Beta limits and limiting mechanisms: theory +**
  - **NCSX at low *R*/<*a*>, W7-X and LHD at high*R*/<*a*>**
- **Reduction of orbit losses and neoclassical transport**
  - **NCSX and QOS; theory; HSX and W7-X at higher*R*/<*a*>**
- **Reduction of anomalous transport**
  - **NCSX and QOS; HSX and W7-X at higher*R*/<*a*>**
- **Particle and power control -- LHD + W7-AS/W7-X**
- **Reactor assessment -- ARIES System Studies**

We Propose a Cost-Effective Program to Investigate Compact Stellarators

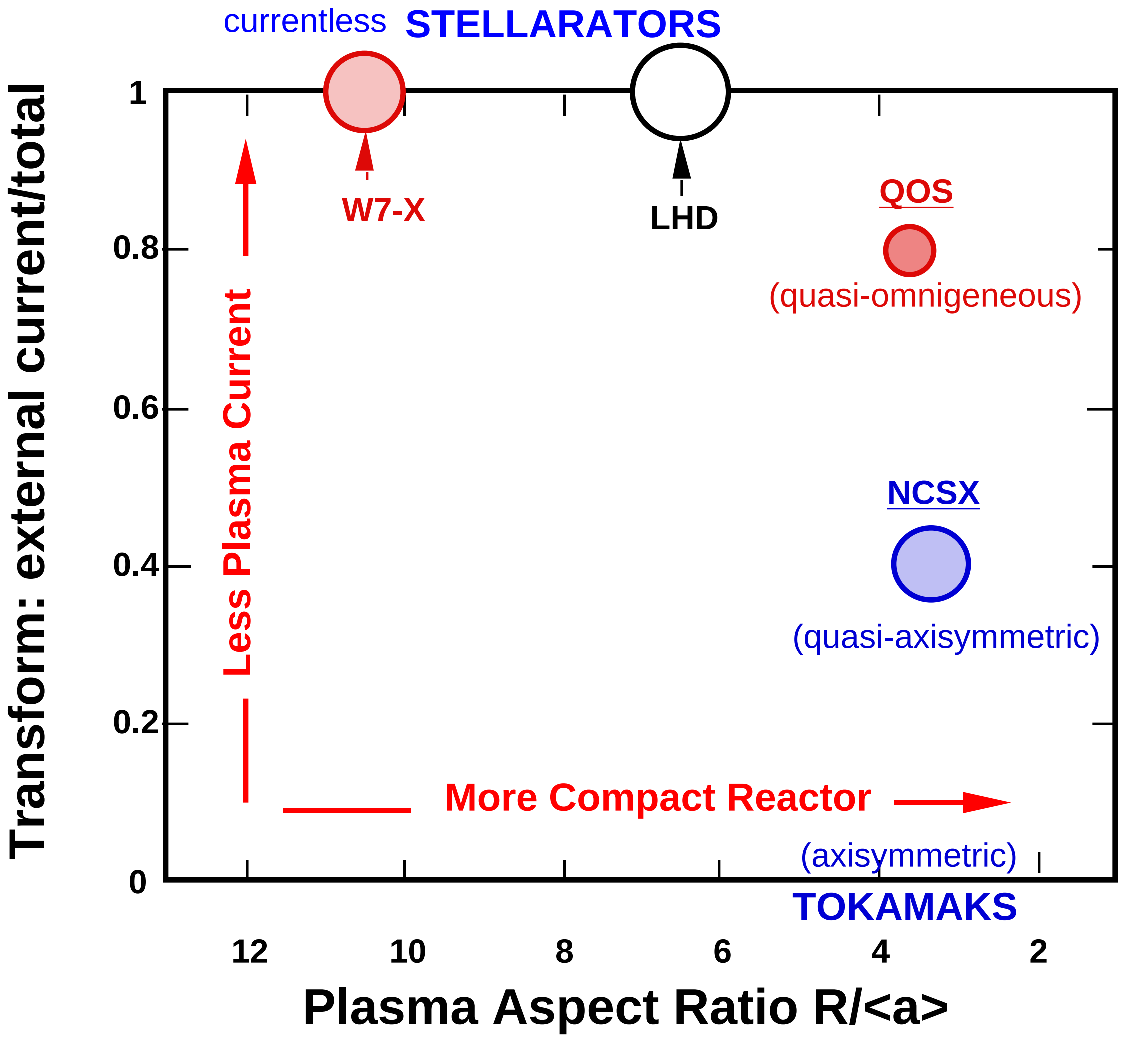


- **The review panel raised two general issues**
  - Seek ways to reduce costs and the time to obtain results
  - Some technical issues to address in the course of the program

Cost and Schedule are Important in Planning the PoP Program

- Measures taken to reduce cost and time to obtain results
  - Reuse PBX-M, a 100-M$ reconfigurable facility
  - First test the QA concept at PoP scale, and then the QO concept after its optimization in QOS
  - Take advantage of existing U.S. and foreign programs
- The total national program budget of $30M/yr compares favorably with other elements of the U.S. program (e.g., a single tokamak experiment, DIII-D, at ≈$50M/yr)
- NCSX is very cost effective
  - The project scope includes only the minimum set of equipment modifications needed to attack the most critical scientific questions
  - Later hardware improvements will be guided by progress in the program and implemented only as needed

Compact Stellarators Are Hybrid Devices



- Low aspect ratio of tokamaks
- Disruption immunity of stellarators

Summary

- Compact stellarators combine best features of stellarators and advanced tokamaks to produce a disruption-free reactor concept with low recycled power
- 2 complementary optimization strategies have been developed (QA & QO)
- US stellarator community has developed an effective, efficient program to capitalize on this exciting opportunity
- We are ready to proceed with this program!