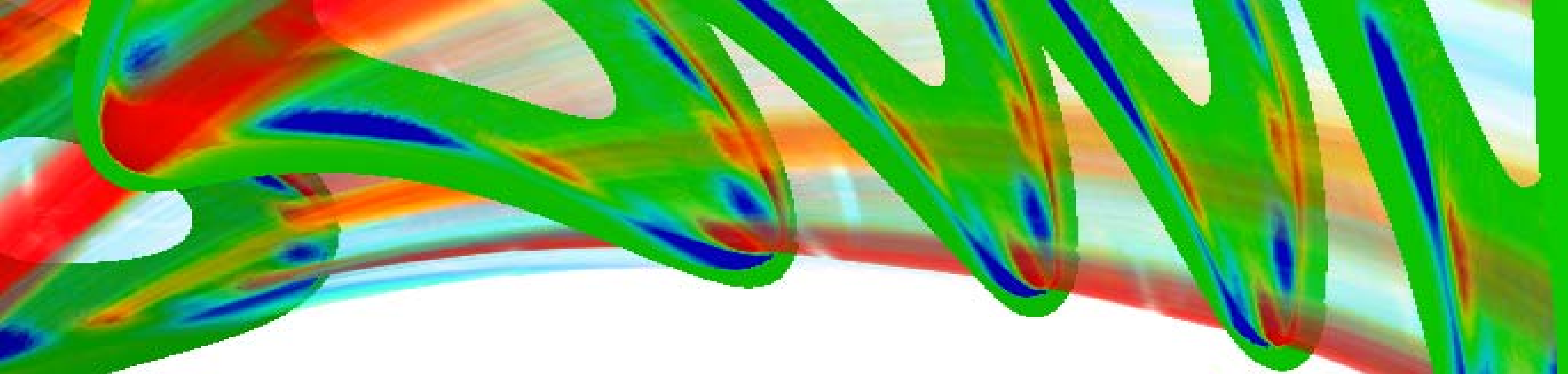

3D theory & computation

as a major driver for advances in stellarators

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3D theory & computation has the potential to close "long pulse" gaps at low cost.

3D plasmas can be intrinsically steady-state and disruption-free.

3D theory & computation is:

- A driver for experiments:
  Too many degrees of freedom in 3D to explore them all experimentally.
- A subject with historical US leadership.
- Beneficial for stellarators and tokamaks.
- Presently funded at a low level: ≤ $3M, ≤ 1% of domestic FES program

Initiative/expansion in 3D theory & computation is wise strategy.

3D theory & computation may provide transformational solutions to several crucial gaps.

3D fields can eliminate disruptions & need for current drive, solve many steady-state & control problems.

E.g. from ReNeW:

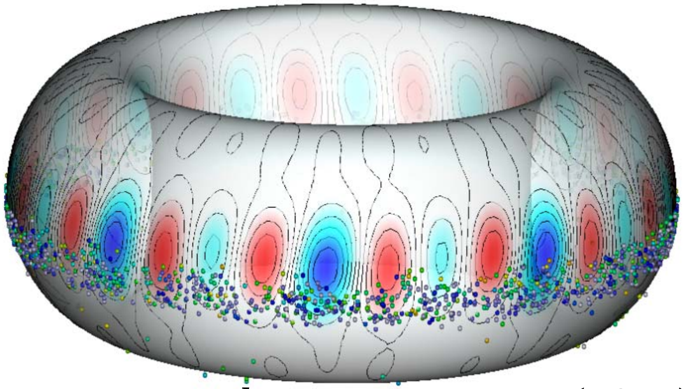
3D fields are "potential **game-changers**… Consideration should be given to the use of three-dimensional magnetic fields, based on stellarator research, to influence MHD and avoid disruptions."

"The QS (quasisymmetric) stellarator is thus a **transformational** concept, offering a timely, effective solution to the challenges of severe transient events and control in steady-state, high-pressure plasmas."

"**<u>Understanding</u> of 3-D effects is thus a core competence**, required for the success of all magnetic configurations."

An initiative in 3D theory & computation could attack many exciting & important questions.

- Fast particle confinement: How much can α losses be reduced? Focus losses on selected liquid-Li wall regions?



ITER α loss: Spong PoP (2011).

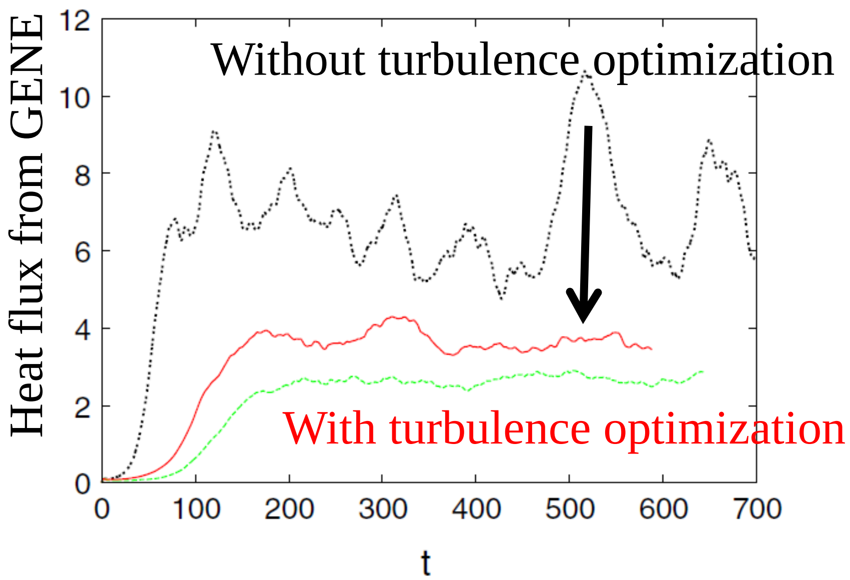
- Sensitivity: How accurately must tokamaks & stellarators be built? Precision increases cost!

- Coil design: Target only modes to which performance is sensitive & which can be efficiently produced. Include planar and/or saddle coils for improved access, flexibility, & coil shapes.

- 3D equilibrium, islands, and stochasticity: Also important for tokamak ELM suppression. Can apply SPEC, PIES, SIESTA, extended-MHD tools: HiFi, NIMROD.

An initiative in 3D theory & computation could attack many exciting & important questions.

- Shaping for reduced turbulent transport: Proof-of-principle in Mynick et al PRL (2010).



- Impurity transport: understand when impurities go in vs. out, how to transport α's out. Can use theory, gyrokinetics, extended neoclassical codes, etc.

- Edge/divertor: radiative stability, shaping to broaden heat exhaust, include in optimization. Synergy with W7-X collaboration.

A small investment in 3D theory & computation could go a long way

All these areas could be investigated for a few M$/yr:

~2 FTEs/project $\Rightarrow$ 14 FTEs, $\leq$ \$5M/yr

Now is a smart time to invest:

- US has expertise in many of these topics, for now.
- Many people retiring - need to attract more young researchers.
- 3D applications growing in tokamaks.
- W7-X results available soon.

The US has historically been a leader in 3D theory & computation.

- The stellarator was invented here.
- Analytic discovery of quasisymmetry.
- Analytic formulae for j_{bs} in 3D.
- Development of many codes used world-wide:
  - VMEC, DKES, STELLOPT, V3FIT, PENTA, PIES, SPEC, SIESTA, NSTAB, SFINCS, ...
- Optimization & design of NCSX & QPS.

Examining your 4 parameters, expanding 3D theory & computation is wise strategy.

- Priorities & science drivers: critical: directly addresses major "long pulse" gaps: steady-state, disruptions, control.

- Time scale: short: theory & computation are nimble, many well-developed codes exist.

- Size/cost scale: small: great potential rewards for ≤ $5M.

- Potential for US leadership: high: historical & present expertise.