POWER CONVERSION and TURBOMACHINERY
THE UNIVERSITY OF QUEENSLAND AUSTRALIA

CENTRE FOR HYPERSONICS
THE UNIVERSITY OF QUEENSLAND

sCO2 Cycle Modelling and Low N_S Radial Inflow Turbines

by

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The Brief:

[…] In other words, the vision of the panel should be "What Universities can do (or are actually doing) to help make sCO2 a commercial reality?"

Contents:

- What universities are good at (my opinion)
- What we have done at UQ
- What else should be done.

Foundation Research

Breakthroughs cannot be scheduled.
Find the best people and challenge them.
Let them learn from false starts and errors.
Results will follow, but not on demand.

Mujeeb Malik

Applied Research

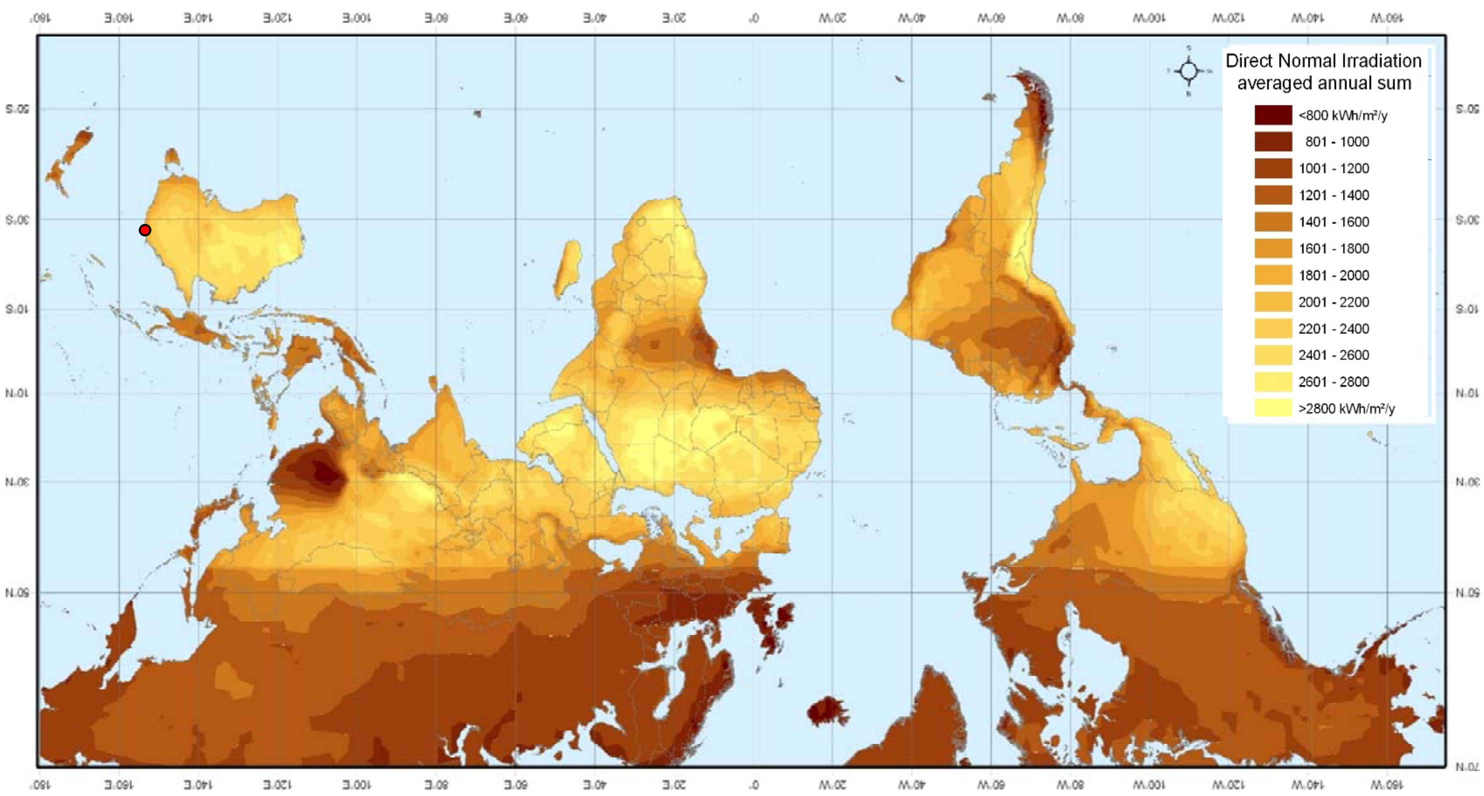
Take a proven concept and develop a system that can be commercialised. I.e. make robust, reduce cost, make more efficient.

Improved Insight

High fidelity simulations/experiments that confirm the methods and understanding and unlock further efficiency improvements.

The Australian Context

Concentrated Solar Power is a promising option for Australia, but …



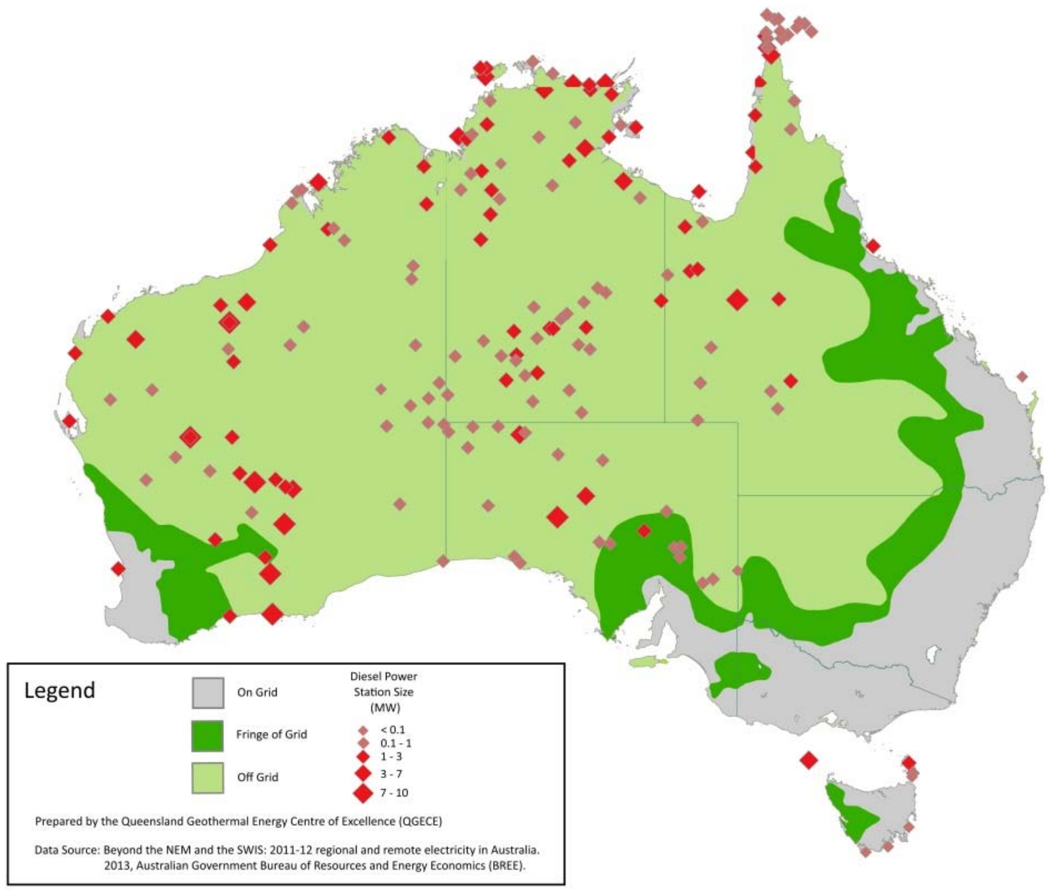
Data based on NASA SSE 6.0 dataset for a 22-year period (July 1983 - June 2005)
(http://eosweb.larc.nasa.gov/sse/)

Map created and map layout by DLR 2008
(http://www.dlr.de)

The Australian Context

Concentrated Solar Power is a promising option for Australia, but …

- Grid Infrastructure limited to densely populated regions.
- Approximately 2000MW remote diesel generation at **1-10MW** scale

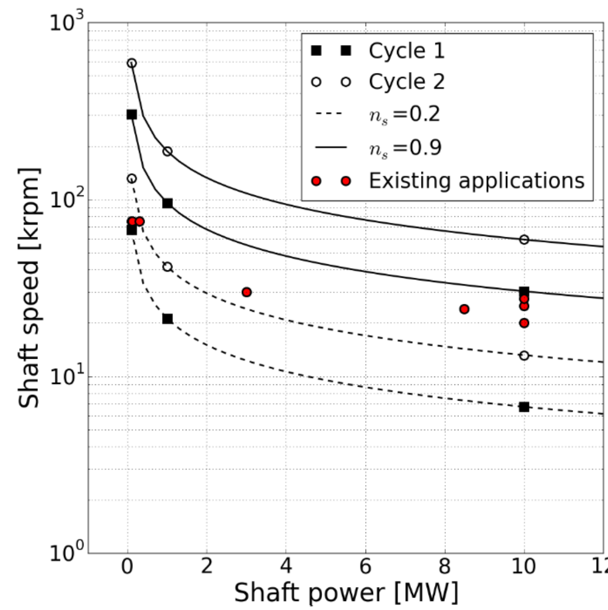


Our Challenge:

How to make a turbine that works well for a **1-5MW** system.

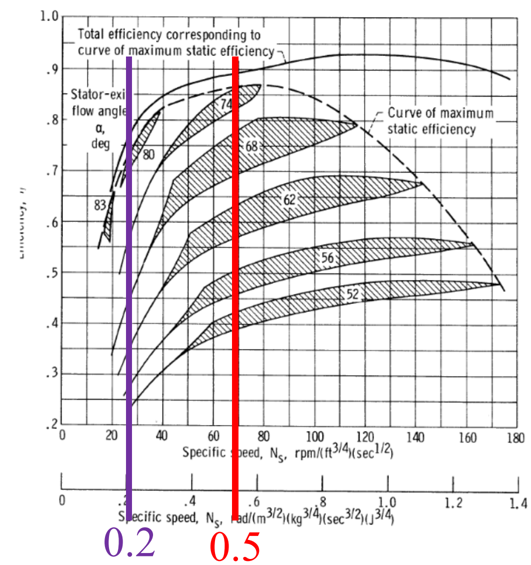
How to design a ~1MW turbine?

- Rotors are very small
- Rotors are very very very fast (based on existing wisdom Ns ~0.5)



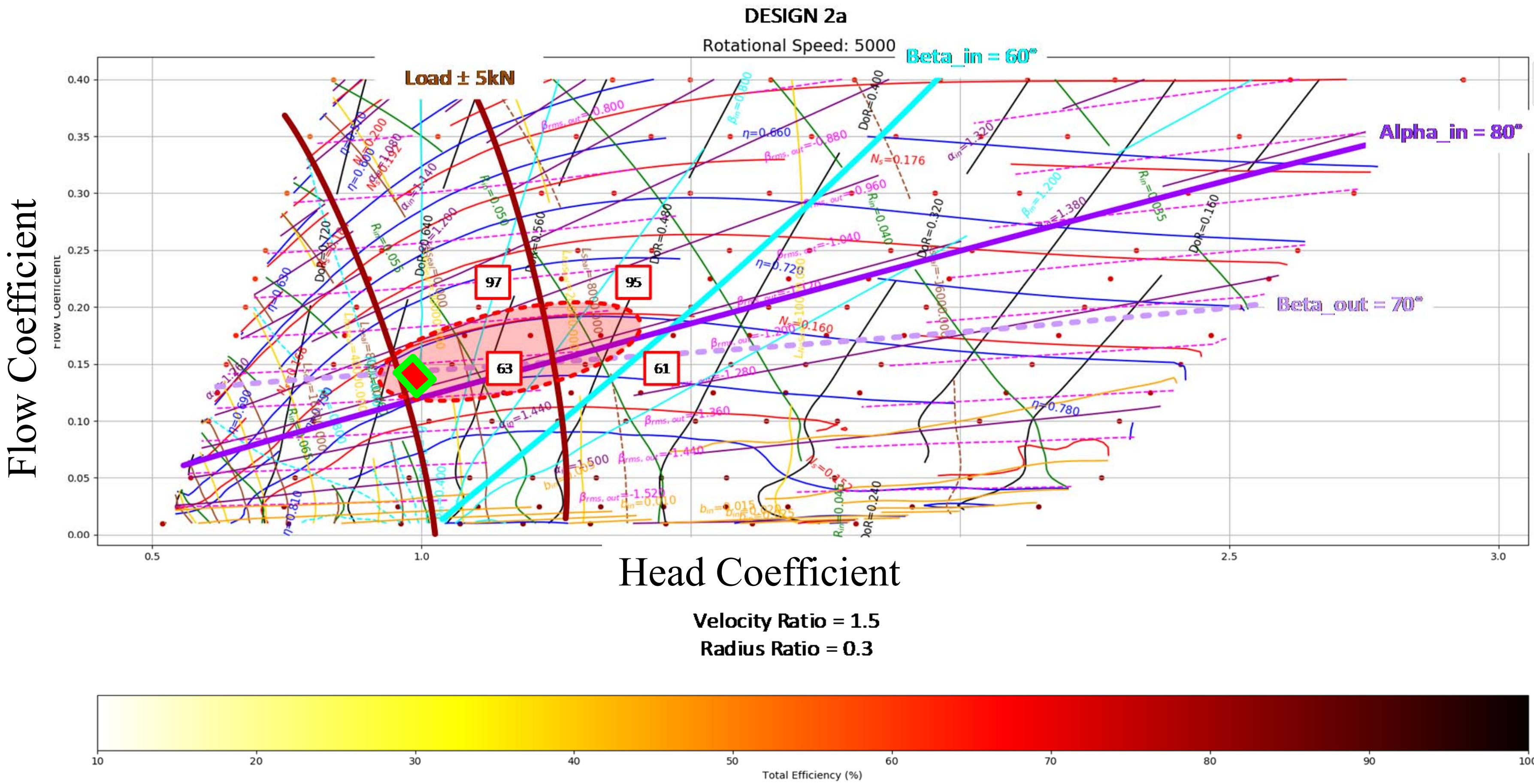
➔Can we develop a high efficiency Ns < 0.2 turbine?

- Lower rotor speed
- More gearbox options / reduced system losses, etc…



Preliminary Design (300kW)

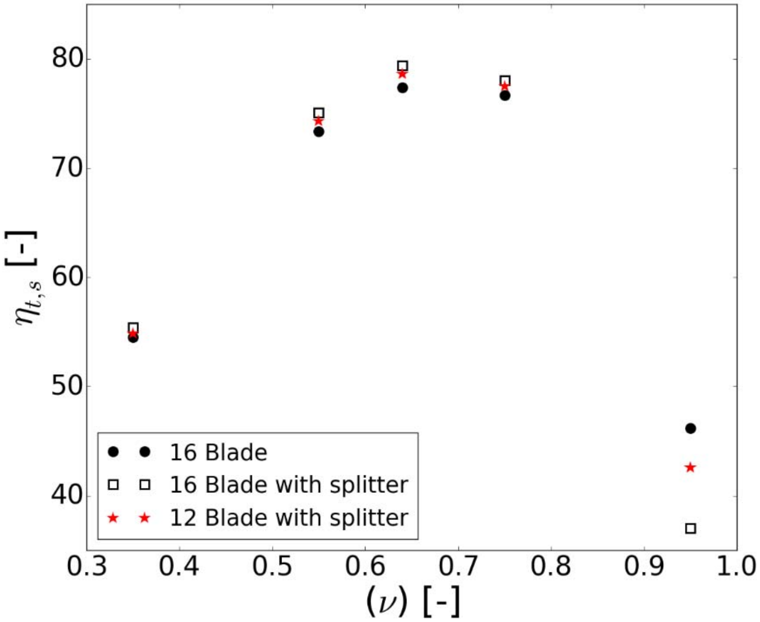
1-D design space exploration, usual empirical loss models*

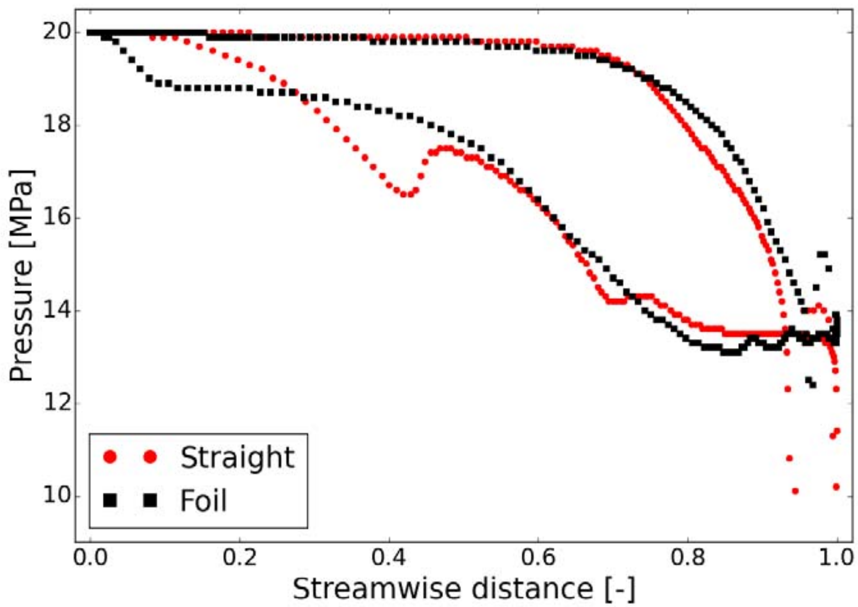


Preliminary CFD results

300kW turbine concept, direct from 1-D design $N_s = 0.14$

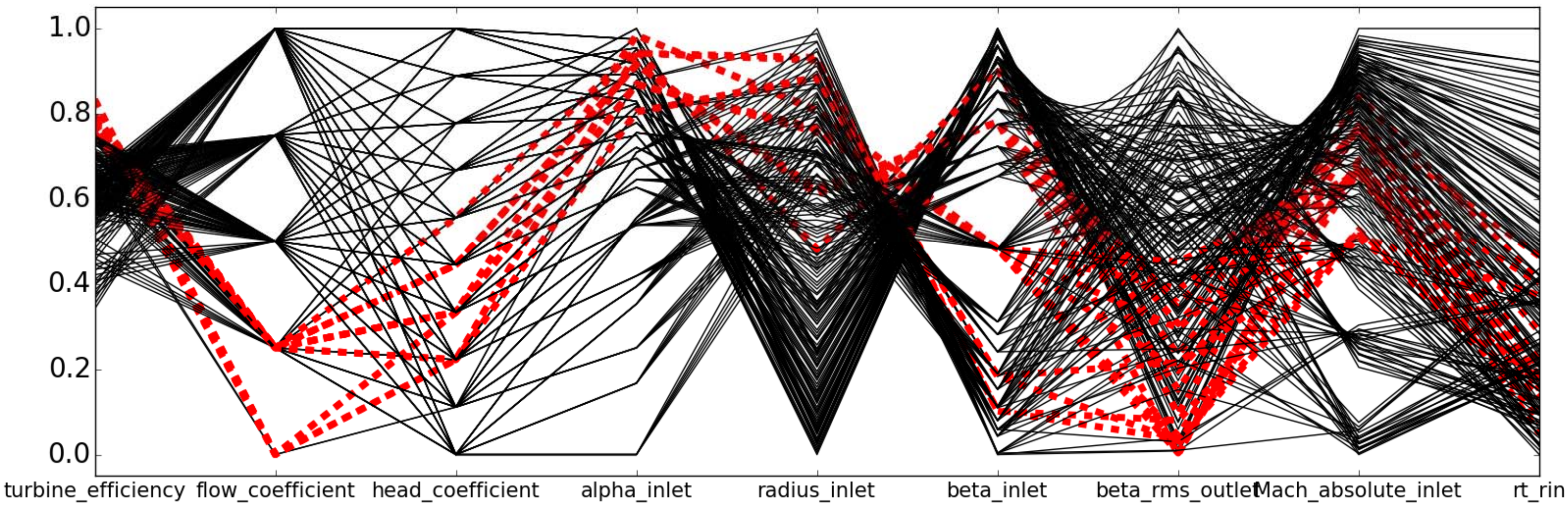
Efficiency η_{is} ~ 80% are possible.



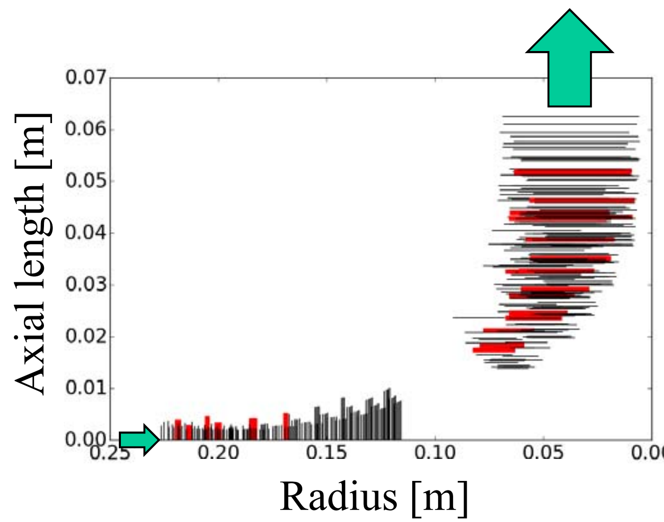


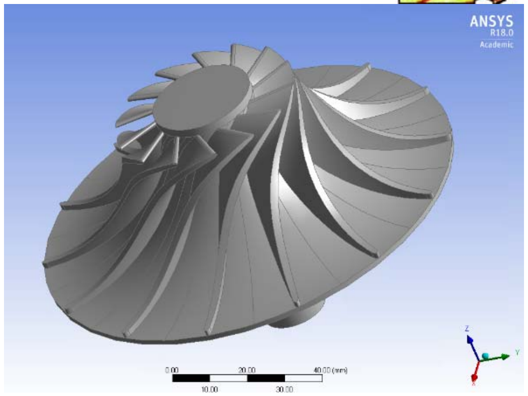
Keep, J., Jahn, I. (2018), NUMERICAL LOSS BREAKDWOWN STUDY FOR A SMALL SCALE, LOW SPECIFIC SPEED SUPERCRITICAL CO2 RADIAL INFLOW TURBINE, GPPS Conference, Montreal, 7-9th of May, 2018

Design Space Trends (1-D code for 5MW)



- F*amilies* of designs that have high efficiency at low speed specific speed have been identified
- 1-D code estimates confirmed with steady & unsteady CFD





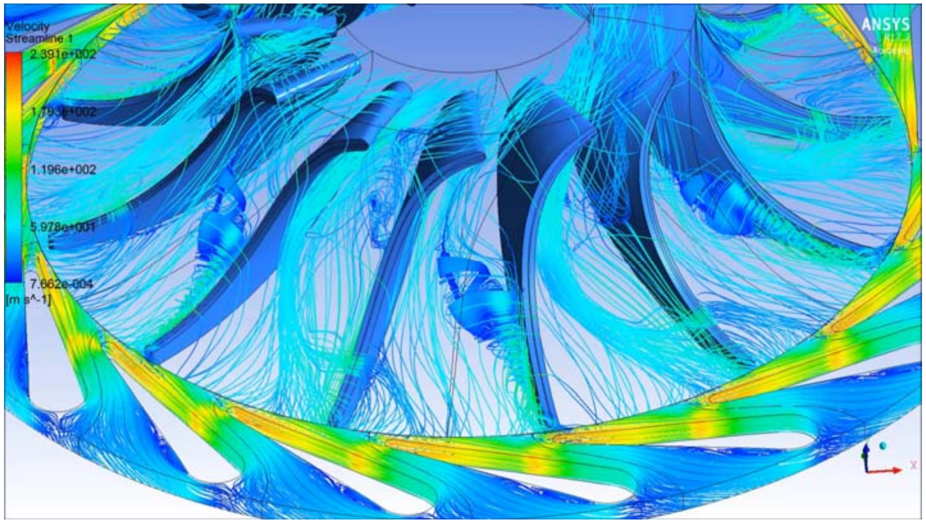
CFD based optimisation

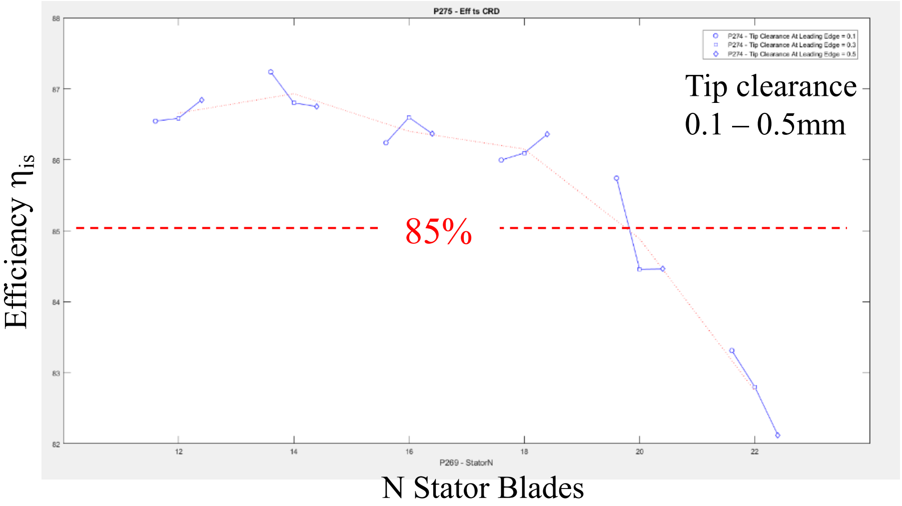
Parametric design optimisation ~ 30 parameters

Objective: Maximum Efficiency at 300kW

Sequential optimisation + structured exploration

Isentropic efficiencies > 85% possible at N_s < 0.15





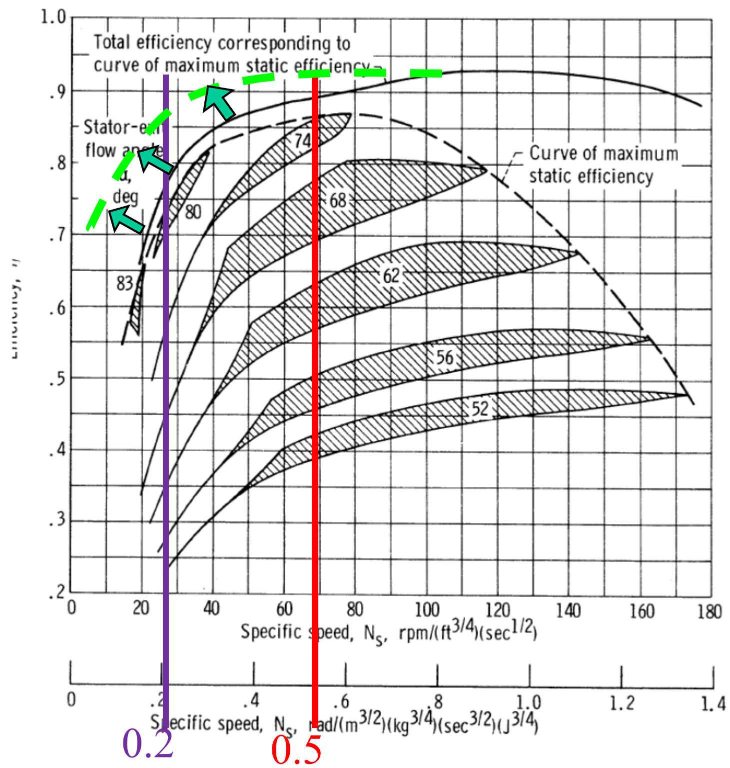
Courtesy of Mosen Modirshanechi

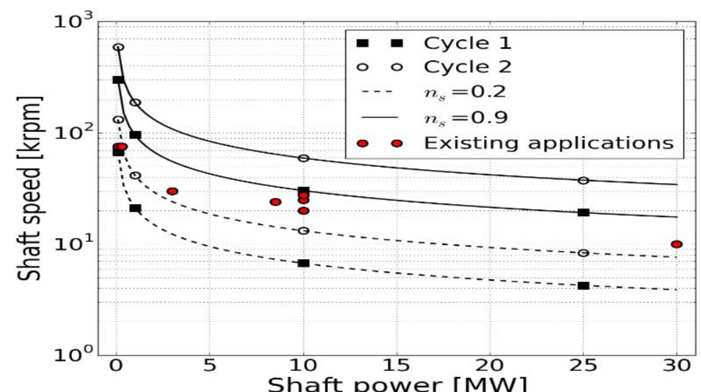
Current status

- High efficiencies possible in range $N_s \sim 0.15\text{-}0.4$
- Improvements realisable in range 300kW–25MW

Design space constraint (low η_{is} for $N_s < 0.3$) pushed outwards to enable better system designs.

System level improvements are expects to bring additional benefits.

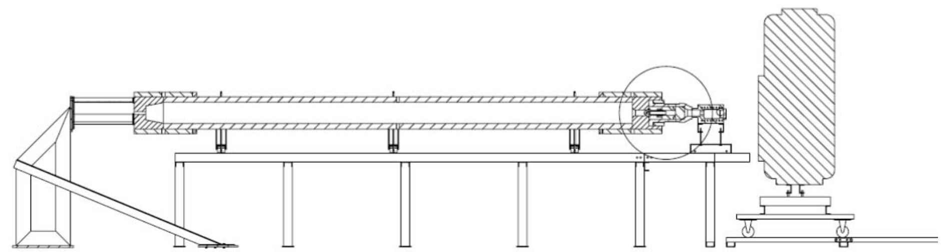




Where next?

Do we trust the CFD simulations?
Probably, but only to +/- **X%**

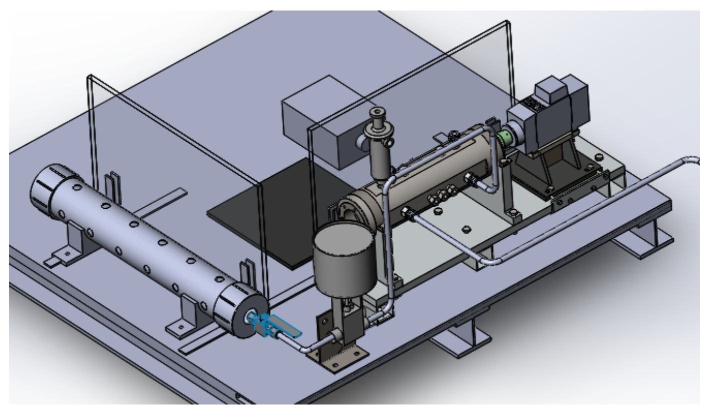
➔ We need high fidelity fluid dynamic experiments.



Transient sCO2 tunnel, ~20kg/s
(50% build, but need more funds for test section…)

What else:

- Advanced manufacturing / 3-D printing + adjoint optimisation.
  → Can we push the aerodynamics further?
- 'Autonomy' for remote systems.
  → Can we have a stand-alone autonomous power plant?



Shaft Cooling & Heat Transfer
(Tests in April 2018)

Luuk Meijboom

Yuanshen Lu

Navid Akhavan

Phil Swann

Andrew Rowlands

Berto di Pasquale

Emilie Sauret

Anand Veeraragavan

Braden Twomey

David Stevens

Viv Bone

Rowan Gollan

Peter Jacobs

Jianhui Qi (Janry)

Jason Czapla

Kamel Hooman

Stephen Gwynn-Jones

Joshua Keep

Aleks Atrens

Carlos de M. Ventura

Mostafa Odabaee

Kan Qin (Jason)

Mosen Modirshanechi

Hugh Russell

Fairuz Zakariya

Thomas Reddell

Halim Gurgenci

Ingo Jahn

Sam Duniam

Rajinesh Singh

Michael Kearney