The Nordic Wind Tunnel

A very large turbulence research facility

by

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Motivation

Old ideas ...

• Classical view of turbulence dates from 1930's and 40's: Turbulence evolves to a state independent of starting (initial) conditions

…versus new ideas

• New theories suggested turbulence might depend forever on how it started (meaning passive control might be possible)

It has never been possible to truly test these ideas since there are no large low background turbulence research facilities.

• Lack of understanding of *turbulence* has important practical effects (e.g. energy waste, limitations to innovation, weather prediction, etc.)

A Large *Turbulence Research Facility* should be:

• *large enough* to remove the effect of side walls on the energetic turbulence scales.

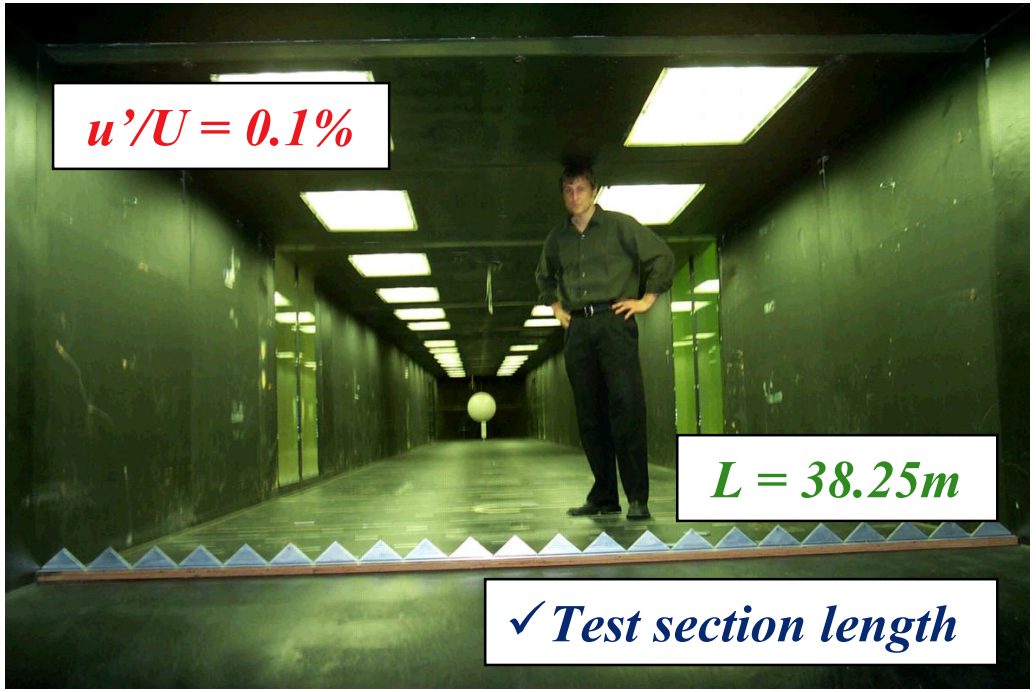
• *fast enough* and *large enough* to get the necessary high Reynolds numbers, yet still resolve the dissipative scales.

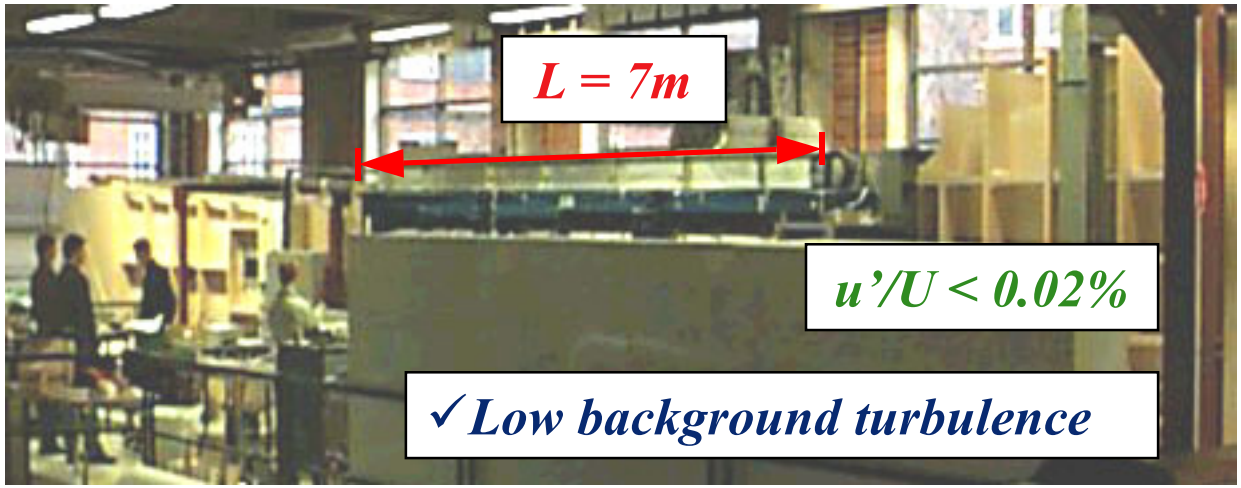
• *long enough* and with *low enough background disturbances* to obtain the necessary downstream development times.

• an experimental facility capable of resolving some of the oldest questions in turbulence while also testing conclusively new ideas.

Existing Facilities:

BLWT2 (Boundary Layer Wind Tunnel)
University of Western Ontario
London, Ontario, Canada





MTL low-speed wind tunnel
Royal Institute of Technology
Stockholm, Sweden

Overview of a selection of existing tunnels						
organization	Johns Hopkins	Colorado State	U.W.Ontario	IIT	KTH	ASU
location	Baltimore, MD	Ft. Collins, CO	London, ONT	Chicago, IL	Stockholm	Tempe, AZ
tunnel name	Corrsin tunnel	MWT	BLWT2	NDF	MTL	UWT
operational in	1950s	1963	1984	1994	1991	1987
contraction ratio	25:1	9:1	4:1	6:1	9:1	5.5:1
test section						
TS length L [m]	**10.00**	**29.3**	**38.25**	**12.19**	**7.00**	**7.40**
TS width W [m]	1.30	1.80	3.40	1.52	1.20	
TS height H [m]	1.00	1.80	2.50	1.22	0.80	
test section Uinf	32 m/s	36 m/s	30 m/s	120 m/s	69 m/s	36 m/s
turb.level u/U(%)	**0.1**	**> 0.1**	**> 0.1**	**< 0.03**	**< 0.02**	**0.01**

Design criteria:

• What length and time scales *need* to be resolved to conduct "meaningful" measurements?

• What Reynolds numbers do we need in the experiments we want to perform to resolve fundamental questions and sort competing theories? (of course length and time scale and Reynolds number criteria depend on the flow being measured!)

---> A catalog of requirements for different ***benchmark experiments*** has been developed.

• Design limitation: smallest currently available probes, 10 μm

Criteria, e.g., *turbulent boundary layers*

• Design limitation: We can resolve 10 μm (height of measuring volume of micro-LDA) this should correspond to the smallest scale occurring in a boundary layer, which is $\eta = \nu/u_*$
(alternatively: the "probe resolution" should be equal to 1 in non-dimensional viscous length units, $y^+ = y_{min} u_* /\nu = 1$.)

• Region model for wall-bounded flow of George et al.: Inertial sublayer ($y^+ > 300$ *and* $y/\delta < 0.1$) begins to emerge at $\delta^+ = \delta\, u_* /\nu > 3000$.

• We need a Reynolds number high enough to have at least one decade of inertial sublayer appear, $\delta^+ > 30{,}000$ (corresponds to: $Re_\theta > 100{,}000$)

The proposed "Nordic Wind Tunnel":

test section length:	**40 m**
cross-section*:	3 m X 3 m
max. speed (test section):	40 m/s
background disturbance level:	< 0.02% (0.01% possible)
overall dimensions:	80 m X 21 m X 7 m
total estimated cost**:	US$ 6 million

*after contraction **from design to operation excluding building

The Large Wind Tunnel Facility would:

• be the largest and longest *turbulence research tunnel* in the world with very low background disturbance level.

• be large enough for all present and foreseeable fundamental research wind tunnel experiments.

• have an estimated useful life of 50-100 years

• be suitable for eventual commercialization for a variety of atmospheric, wind engineering and sporting applications — including urban building design testing, Olympic winter sports training, and racing yacht design.

What about CFD…

Why can't a super-computer do the job *(yet)?*

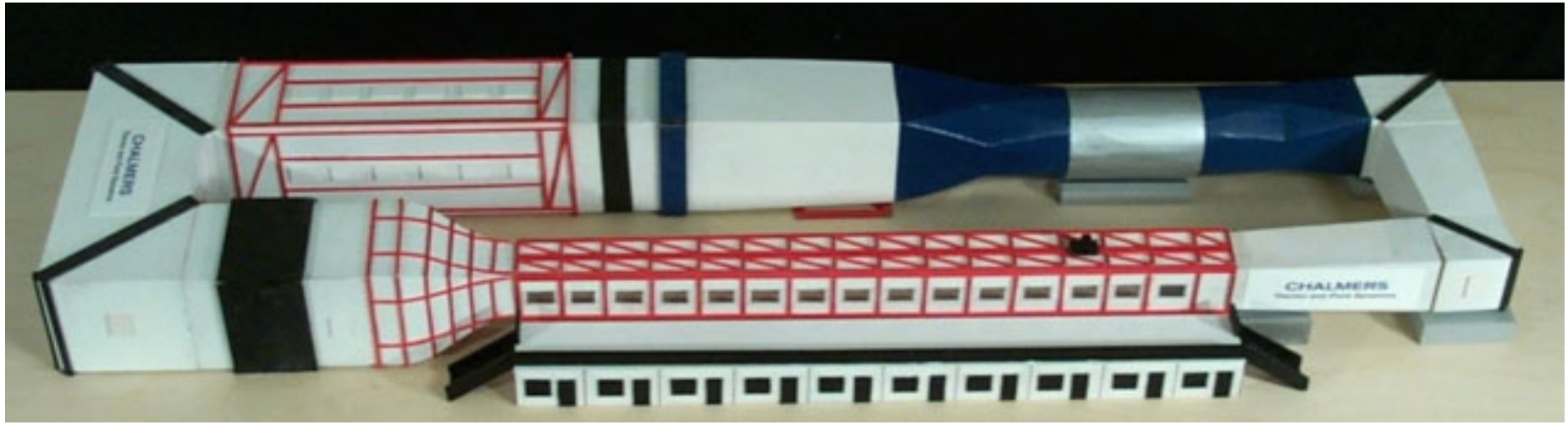
- The computational box required to duplicate the capabilities of the proposed wind tunnel is (based on test section width of 3 m):

  $(3 \text{ X } 10^5)^3 = 27 \text{ X } 10^{15}$ for each time step

- If the largest turbulence simulation (DNS) to-date is only $1024^3 \cong 10^9$, then the *simplest* computer experiment (*non-decaying* (forced) isotropic turbulence) *of this scale* can be done in 37 years!

- For effect of "box size" on DNS of turbulent flow see talk by H.Wang, APS-DFD'01, session **DC.010**, Sunday 17:47

(1:100 scale model of proposed facility)



40 m

The *"Nordic Wind Tunnel"*

Outlook

- A building to house the facility has been secured
- Formal funding request to be submitted in spring 2002

Who will use this unique research facility?

- Turbulence researchers from around the world --- *anyone* carrying out serious turbulence research is invited to participate
- We are soliciting *letters of support* / *pre-proposals* for research to be carried out in the "Nordic Wind Tunnel"