New Ideas in Turbulence

NSF Grant # CTS-9972077

Final Report

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August 2, 2000

SUMMARY

The **New Ideas in Turbulence** workshop had two objectives: first, to develop new ideas in fluid dynamic turbulence; second, to experimentally test the performance of facilitated groups. The hypothesis is that Facilitated Collaboration can deliberately stimulate breakthrough thinking.

The workshop did produce ideas, the most significant of which was Shiyi's alpha model (§ 3.2). This idea was the result of classical small group synthesis. While Shiyi's hypothesis is worthy of further investigation and research, it does not appear to be the expected conceptual breakthrough.

Facilitated Collaboration worked quite well. A critical accomplishment was that the group dynamics were excellent. This is a gating factor; without a good climate and group dynamics, nothing else is going to work. In retrospect, however, there were a number of process deficiencies, the cumulative effect of which was probably significant.

A primary lesson is that three days did not provide enough time for both process training and for the group to identify and analyze fundamental issues. A one-time three-day workshop may not be very productive in attacking fundamental questions in science. A more productive format should be a staged sequence of workshops with a persistent group building on lessons learned from earlier workshops.

The task is incomplete. The original goal, that we can deliberately stimulate breakthrough thinking on the frontiers of science, remains intact. The recommendation is for a second workshop with the same objectives, same group, expanded from seven to ten participants.

1.0 OBJECTIVES

The proposed scientific objective is to develop new ideas explaining the dynamical origin of scaling and self-similarity in turbulence. Results to be measured against this objective are presented in § 3.0 Contributions to Fluid Dynamic Turbulence.

In their proposal analysis, sponsoring NSF program officers noted that ".. The use of facilitators represents a relatively novel approach and one, we believe, that should be subjected to 'experimental' evaluation." Further, the PI believes that Facilitated Collaboration can deliberately stimulate breakthrough thinking. Results to be measured against this objective are presented in § 4.0 Contributions to small group processes.

2.0 THE WORKSHOP

The **New Ideas in Turbulence** workshop was held January 20 - 23, 2000 at the Aspen Institute's Wye River conference centers in Maryland.[1] The workshop was scheduled to sequence with the Institute for Theoretical Physics Program on Physics of hydrodynamic Turbulence. The group decided to defer the final report for six months to provide the time for reflection on lessons learned.

The group size was deliberately targeted to seven active participants. The following scientists expressed an interest for the proposal.

Participants	*Support*
Luca Biferale, University. of Rome, Italy	Generalist: Alex Pavlak, Thales Research
Gregory Eyink, University of Arizona	Facilitator: Ginna Gemmell, GlidePath
Charles Meneveau, Johns Hopkins Univ.	Scribe: Stuart Chester, JHU
Mark Nelkin, New York University	
Evgeny Novikov, Univ. of California	
Massimo Vergassola, Observatoire de Nice, Fr	
Akiva Yaglom, MIT	

Scheduling presented an irreconcilable teaching conflict for Massimo Vergassola. At the time of the workshop, Evgeny Novikov was incapacitated by the flu. These two scientists were replaced by:

Shiyi Chen, Los Alamos National Laboratory
Ronald Myers, Army Research Laboratory

[1] The workshop was scheduled to start the evening of January 20 which coincided with a severe winter storm. The storm significantly disrupted participant arrival which was not complete until noon on the 21st.

3.0 CONTRIBUTIONS TO FLUID DYNAMIC TURBULENCE

While the **New Ideas in Turbulence** workshop did not produce obvious breakthrough ideas, the actual results are substantive and consistent with the process lessons learned. With process refinement, the deliberate stimulation of breakthrough thinking is a viable goal.

The following results are prioritized relative to their impact on workshop objectives. The results include post workshop events that were influenced by the workshop.

3.1 KEY QUESTIONS - The group compiled an excellent list of questions that were to drive the problem-solving sessions. Roughly half of these questions were brought to the workshop by the participants. The remainder were developed during the workshop.

1. Is the empirical Lagrangian formulation of Richardson's diffusion an exact relationship?

$$\left\langle R^2(t) \right\rangle \propto \langle e \rangle t^3$$

2. Can we invent new Multiscale mathematical representations (e.g. wavelets)?
3. What is the physical basis for similarity?
4. Is there a dynamical basis for multiplicative cascades?
5. What are universality classes?
6. What are the coherent structures?
7. Can we generalize energy cascades? (e.g. explain momentum transfer?)
8. How does shear, rotation, buoyancy effects influence cascade models?
9. What are the limits of isotropy in models? Is isotropy useful in complex flow?
10. How to combine high Re and low Re experiments to learn about turbulence?
11. How should scaling be done in atmospheric diurnal cycle where there is no steady state?
12. Can we find model dynamic systems where anomalous scaling can be turned on and off?
13. Why isn't renormalization group theory more successful?
14. Can inverse RG be applied (non-perturbatively) to NS, through DNS or more novel tools?
15. What are the dynamical origins of k^{-1} scaling near wall turbulence?
16. How can we better measure κ (wall stress)?
17. Is the mechanism for intermittency universal?
18. Is LES accuracy fundamentally limited by averaging inherent in subgrid models?
19. Can we recast the Navier Stokes equations into functional form?

3.2 SHIYI'S ALPHA MODEL - This was felt to be the most significant idea to come out of the workshop. The synthesis process was a classic response to question 3.1.12. Mark Nelkin said "I wish we could find a model system where we could deliberately turn anomalous scaling on and off." Shiyi Cen responded "I can do that!" This interchange led to the following concept:

The idea is to deliberately manipulate or tune intermittency in direct numerical simulations (DNS) to probe the character of turbulence. This can be accomplished in the vorticity form of the Navier

Stokes equation by using an artificial term α to change the amplitude of vortex stretching. Adjusting alpha would adjust the intensity of vorticity, filaments and intermittency under controlled flow conditions.

$$\begin{cases} \frac{D\vec{w}}{Dt} = a\vec{w}\cdot\nabla\vec{u} + n\nabla^2\vec{w} \\ \nabla^2\vec{u} = \nabla\times\vec{w} \end{cases}$$

3.3 TOY MODELS - The traditional role of Toy models (Kraichnan, Shell, Burgers') can be substantially expanded. They could serve as tools in the development of LES subgrid models, tools in the development of new multiscale mathematical representations.

3.4 COLLABORATION - Along the lines of 3.2 & 3.3, Nelkin and Biferale collaborated post workshop to write a discussion document. The focus was to “... ask if tuning a parameter in the equations of motion can reduce or even eliminate anomalous scaling.”

3.5 GENERAL CONCEPTIONS OF INTERMITTENCY - The group spent the most time, the better part of a day, on this topic. Intermittency is important because dimensional analysis breaks down, exponents are anomalous, and we do not understand why. Rare intense events are important to subgrid models, diffusion coefficients, combustion. Other than the observation that intermittency with non-universal high moments may not be universal, there were no definitive ideas. This would be a good focus for follow-on workshops.

3.6 RICHARDSON DIFFUSION - Is the empirically determined distance between two particles (Lagrangian coordinates) an exact relationship? One idea is that the equation is consistent with a random walk in velocity.

3.7 MULTISCALE MATHEMATICAL REPRESENTATIONS - The group spent several hours here without finding a decent focus. It was not clear that significant progress could be made within the time available.

3.8 SUBGRID MODELS - Combine traditional mapping closure with fractal models. More generally, there is an enormous opportunity to improve traditional LES subgrid models by incorporating more physics into the model.

3.9 MULTISCALE SIMULATION - Multiscale data can be acquired by synthesizing a complete 3D time dependent database by combining LES, HPIV and DNS. Such a database could characterize isotropy as a function of scale, diffusion coefficients, scaling coefficients, LES averaging errors. Interfacing boundary conditions would be difficult.

3.10 COLLABORATION - Meneveau visited Biferale in Rome post workshop. The discussions sparked a new research program on LES models in Rome.

3.11 COLLABORATION - Myers and Pavlak are collaborating with the idea of using Facilitated Collaboration to explore performance gains that could result from custom supercomputers. Weather prediction is a proposed baseline.

4.0 CONTRIBUTIONS TO SMALL GROUP PROCESSES[2]

The **New Ideas in Turbulence** workshop was the first facilitated workshop in fluid dynamics. While the workshop seemed to have all of the right elements - superb group dynamics, the right talent, problems, and environment, it did not hit the big breakthrough. Why? In retrospect, there were a number of process deficiencies, the cumulative effect of which was significant. The following presents process lessons learned prioritized relative to its impact on the original goal.

4.1 GROUP DYNAMICS - The turbulence group bonded quickly and reached a level of intense dialog within a few hours. In the PI's experience with technical groups this level of openness and trust is reached only after months or years of interaction. In the facilitator's experience this is nothing unusual, indeed the facilitator sees room for improvement.

The group reached the stage where they were able to play with the problems as a group, though this was limited. The group never reached a freewheeling stage (random associations). These were seven serious scientists, no obstructionist personalities.

> *LESSON - A critical accomplishment is that the group accepted the leadership of a non technical process facilitator and a content neutral generalist.*

4.2 STAGED FORMAT - In retrospect, the most prescient advice I received prior to the first workshop was: *"Your are not likely to accomplish anything truly fundamental in three days."*[1] An intense three-day workshop offers no time for reflection and incubation.[2] Indeed there is barely sufficient time to get to the core of a deep intellectual problem. For example, the group defined the problem of intermittency with an equation and moved on. To thoroughly understand the constraints we need to thoroughly define the anomaly and its effects from several points of view.

> *LESSON - A single three day workshop is not likely to get to the core of a deep intellectual problem. The logical solution is to stage the workshops, a sequence of facilitated workshops with a persistent group.*

4.3 PROCESS TOOLS - More advice not fully appreciated at the time: *"Group techniques work well in business but science is different."[3]* Science is different in that fundamental problems are intellectually deep. There is much history; it is difficult to find an idea that has not been considered many times before. In mature disciplines the problems are highly constrained. A reflective assessment of the workshop suggests that the group needs to spend more effort to analyze and define the constraints. Some of these constraints are rigid and inviolate, others are more flexible. <u>The art is to then innovate within these flexible constraints.</u>

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[2] In June, 2000, the PI facilitated another workshop in cognitive science (the PPG group). There were several important differences: the PPG group was an existing group with a mission/vision task; the Turbulence group was a new group with a problem-solving task. Where appropriate, PPG group process lessons have incorporated and noted.

A major advantage of a facilitated group problem-solving is that facilitators can implement powerful tools to simplify and stimulate the process. The optimum tools depend on the nature of the problem. These tools need to be tailored to problem, particularly with regard to the level of analytical thinking vs creative thinking that is required.

The **New Ideas in Turbulence** workshop employed Synectics® tools.[4,5,6] Synectics is particularly well suited for group building and for problems that require a high level of creativity.[7] There are other tools, such as Kepner Tregoe® that are better suited for analysis.[8]

LESSON - Facilitator support needs to include problem analysis tools.

4.4 CREATIVITY STIMULATION - A powerful technique for stimulating group creative thinking is called an excursion. The theory is to take a break from the problem, jumble the groups thinking by working on something else (perhaps a fantasy), then bring the group back to the problem. Generally, this process enables the group to be able to make new connections. The group experimented with two excursions which did not result in new insights.

Excursions are one of a number of "blockbusting" techniques. If the group encounters a mental block, these techniques can stimulate the group to break the block. In our case the group was stuck, but it was stuck in the mud, not against a well defined barrier. Factors contributing to the disappointing excursion experiment are believed to be: the group needed substantially more analysis to define the constraints; the excursion content was inappropriate for a highly abstract scientific problem; and, perhaps the group was too serious, not sufficiently relaxed, not freewheeling.

LESSON - There is a strong body of evidence showing that excursions work in a wide range of scenarios.[9] Experiments need to continue.

4.5 WILDCARD - Another powerful dimension of a facilitated group is that individuals can be introduced to achieve certain perspectives or group dynamics. This group consists of serious analytical scientists. In other environments it has been demonstrated that introducing someone who is not embedded in the problem can result in insights that would not normally be achieved by a group of experts. This individual is called a wildcard.

LESSON - Try a wildcard.

4.6 GROUP SIZE - The size of the Turbulence group was seven. Throughout the workshop the PI had a strong visceral sense that the group was on the verge of losing performance if someone should leave. The size of the PPG was ten and there was no obvious difficulties.

LESSON - Experiment with problem-solving group sizes in the range of seven to ten.

4.7 THE STARTLED FLOCK RESPONSE - Several times during springboard sessions a remarkable event occurred after someone suggested a novel idea. The suggestion sparked several minutes of intense discussion centered around who published what when. At the time it was not clear to the facilitator & generalist how to best manage this. On reflection, the group is attempting to understand the idea, to define it, to explore its boundaries and constraints. The response is natural and intense. Deferring the dialog would be frustrate the group.

> *LESSON - The facilitator should support the response, keeping it from becoming critical or judgmental.*

4.8 COORDINATION ROLES - The process facilitator plus technical generalist roles worked quite well for both the turbulence group and the PPG group. In both cases the scientists accepted process management by the non-technical facilitator without reservation. In both cases the content neutral generalist was necessary as a technical interpretator and coordinator.

> *LESSON - For good group dynamics, scientists must have confidence that the coordinators are content neutral with no hidden agenda.*

4.9 NEW GROUP VS EXISTING GROUP - While the seven scientists in the **New Ideas in Turbulence** group knew each other by reputation and a couple of them had collaborated on other research projects, they had not worked together before as a group.. In contrast, the PPG group had worked together as a group for over ten years. As a result, the PPG group has a number of interpersonal dramas that had a serious impact on group performance.

> *LESSON - New groups are easier to manage than existing groups.*

4.10 SCRIBE ROLE - Both groups employed a graduate student to keep notes. The graduate student worked at a desk in the corner with a laptop, kept a record of the headlines recorded by the facilitator on the flip charts, and added comments from the dialog. This process works well.

> *LESSON - The proposed role was validated.*

4.11 ENVIRONMENT - The "living room" environment consisting of comfortable chairs with arms centered on flip charts worked quite well. The participants sought isolation during down time and group entertainment (a piano recital) was not well attended. The isolation achieved at the Wye River Conference Center was unnecessary.

For breakout groups, the whiteboard worked, but could have been replaced by flip charts. The printing whiteboard was not needed. Faster internet connections for downloading papers and a faster printer would be useful.

> *LESSON - With the exceptions noted above, the initial planning factors were validated.*

4.12 DURATION - Three days is an endurance limit, any longer would require a day-off break.

LESSON - The initial planning estimate was validated.

4.13 AGE DIVERSITY - It was noteworthy that the younger scientists provided important input with the PPG group.

LESSON - Maintain some age diversity.

4.14 GENDER DIVERSITY - The turbulence group was all male, the PPG group was 7 male, 3 female. While gender diversity is probably important, it is too subtle to be appreciated at our current crude learning stage. Other factors are more important.

LESSON - Do not distort the group to achieve gender diversity.

4.15 OBSERVERS - An NSF sponsor observed the Turbulence group summary session, the last session of the last day. While it did not interfere with building a summary, the inhibiting effect on the group was dramatic. Everyone was concerned about saying the wrong thing.

LESSON - The initial planning guidance - no observers - was validated.

5.0 RECOMMENDATION

The **New Ideas in Turbulence** workshop generated new ideas. The process was classical small group synthesis. It was disappointing, however, that these ideas do not appear to be the expected conceptual breakthroughs. Several factors inhibited performance.

A one-time three-day workshop does not provide much time to reach fundamental issues. Considerable effort is spent on group building, training and preliminary problem assessment. A staged sequence of Facilitated Collaboration workshops with a persistent group would build and extend the results of earlier workshops and should be more productive.

The **New Ideas in Turbulence** workshop was the first Facilitated Collaboration workshop. While everyone involved viewed the experience as most extraordinary, there were a number of process deficiencies. No one of these were very serious and these startup deficiencies and they would not be repeated in subsequent workshops. However, the cumulative effect of these deficiencies inhibited performance of the first workshop.

<u>The recommendation is for a second workshop that incorporates the lessons learned and builds on the results of the first Facilitated Collaboration workshop. We have a good group, a good set of problems and a good process. The deliberate stimulation of breakthrough thinking remains a very viable goal. The task is simply incomplete.</u>

6.0 REFERENCES

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