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14. ABSTRACT The Princeton-CEFRC-CI Summer School on Combustion was held June 19-24, 2016 on the campus of Princeton University in Princeton, New Jersey. The summer school was organized by the Combustion Energy Frontier Research Center (CEFRC). The goal of the school was to expose participants to a comprehensive knowledge base on the foundations of combustion physics, combustion chemistry, experimental laser diagnostics, combustion dynamics, and turbulent combustion.					
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Report Title

Final Report: 2016 Princeton-CEFRC-CI Summer School on Combustion

ABSTRACT

The Princeton-CEFRC-CI Summer School on Combustion was held June 19-24, 2016 on the campus of Princeton University in Princeton, New Jersey. The summer school was organized by the Combustion Energy Frontier Research Center (CEFRC). The goal of the school was to expose participants to a comprehensive knowledge base on the foundations of combustion physics, combustion chemistry, experimental laser diagnostics, combustion dynamics, and turbulent combustion.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received

Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received

Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Names of Under Graduate students supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: 0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME

PERCENT SUPPORTED

FTE Equivalent:

Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Please find Final Report attached.

Technology Transfer

Report on the

2016 Princeton-CEFRC-CI Summer School on Combustion



Prepared by: **Chung K. Law**
Robert H. Goddard Professor, Princeton University
September, 2016

ACKNOWLEDGEMENT

The 2016 Princeton-CEFRC-CI Summer School on Combustion was conducted at Princeton University and attended by over 220 US and international graduate students and researchers. Five 15-hour lectures on aspects of foundational and technical combustion were delivered by five world-renowned researchers (S.M. Candel, H.J. Curran, J.D. Driscoll, C.K. Law and M.A. Linne) who are also recognized as master lecturers. This Summer School was sponsored by the US Department of Energy through the Combustion Energy Frontier Research Center (CEFRC) headquartered at Princeton University, the Combustion Institute, and Princeton University, with additional funding support from the US Army Research Office, the US National Science Foundation, and the King Abdullah University of Science and Technology (KAUST). On behalf of all the attendees, the organizers of the Summer School express their profound gratitude to the lecturers, sponsors and supporters for their participation in and contributions to this well-attended and much-needed annual event which has become an integral educational and outreach activity of the global combustion enterprise. The following is a summary of the program, feedbacks from the participants and lecturers, thoughts of the organizers, and images of the event.

PROGRAM AND SCHEDULE

2016 Princeton-CEFRC-CI Summer School on Combustion - Schedule of Events

Sunday, June 19th

- 13:00 – 17:00 Check In (Butler College)
 18:30 – 20:30 Welcome Dinner/BBQ (Frick Chemistry Building)

Monday, June 20th – Friday June 24th (see schedule below for special events)

- 08:45 – 09:45 Morning Lectures
 09:45 – 10:00 Break
 10:00 – 11:00 Morning Lectures Continues
 11:00 – 11:15 Break
 11:15 – 12:15 Morning Lectures Continues
 12:15 – 14:00 Lunch Break (Tiger Inn Eating Club*) [Tuesday(21st June): 12:15 – 13:30]
 14:00 – 15:00 Afternoon Lectures [Tuesday(21st June): 14:15 – 15:15]
 15:00 – 15:15 Break [Tuesday(21st June): 15:15 – 15:30]
 15:15 – 16:15 Afternoon Lectures Continues [Tuesday(21st June): 15:30 – 16:30]
 16:15 – 16:30 Break [Tuesday(21st June): 16:30 – 16:45]
 16:30 – 17:30 Afternoon Lectures Continues [Tuesday(21st June): 16:45 – 17:45]
 17:30 Adjourn for the day [Tuesday(21st June): 17:45]

Friday, June 24th

- 08:45 – 17:30 Check Out (Friend Center)

Lecture Schedule:

Mon 6/20	Tue 6/21	Wed 6/22	Thur 6/23	Fri 6/24
Morning Lectures: 08:45 – 12:15				
Chemical Kinetic Modeling for Combustion - Prof. Henry Curran, Comp Sci Bldg 104				
Combustion Dynamics - Prof. Sébastien M. Candel, Friend Center 101				
Afternoon Lectures: 14:00–17:30 [Tuesday(21st June): 14:15 – 17:45]				
Combustion Physics - Prof. Chung K. Law, Friend Center101				
Advanced Laser Diagnostics in Combustion Research – Prof. Mark Linne, Friend Center 006				
Turbulent Combustion: Experiments and Fundamental Models – Prof. Jim Driscoll, Comp Sci Bldg 104				

Special Events Schedule:

Sun 6/19	Mon 6/20	Tue 6/21	Wed 6/22	Thur 6/23	Fri 6/24
Welcome BBQ - Frick Chemistry Building 18:30-20:30		Career Panel – Friend Center (101) 13:30-14:15	Group Picture 12:15-12:45 Poster Session- 19:45 – 21:00 Fields Center Multipurpose Room	Group Celebration Dinner (Frick) 18:00-20:00	Program Adjourns 17:30

*Tiger Inn privileges are restricted to attendees with white name tag.

Dining Hall Hours: Breakfast: 07:00-08:30 (Wilcox Dining Hall, adjacent to Butler dorm) Lunch: 12:15 – 14:00 (Tiger Inn, Student Eating Club), Dinner: 17:30 – 19:30 (Tiger Inn, Student Eating Club)

Emergencies - Dial 911 (Call 609-258-3333 from your cell phone for on-campus emergencies)

Princeton University Public Safety - (609) 258-1000 (non-emergencies)

GEOGRAPHICAL BREAKDOWN OF ATTENDEES

<u>Country of Affiliation</u>	<u>No. of Participants</u>	<u>Continent of Affiliation</u>	<u>No. of Participants</u>
China	4	Asia	18
India	1		
Israel	1		
Japan	3		
Saudi Arabia	9		
Australia	1	Australia	1
Finland	1	Europe	8
Germany	2		
Norway	1		
Russia	1		
UK	3		
Canada	2	North America	194
USA	192		
Brazil	1	South America	2
Colombia	1		
Total	223		223

FEEDBACKS AND SUGGESTIONS

Sample Feedbacks from Participants

At the conclusion of the session, participants were asked to provide their feedback and suggestions for further improvements. The following are *representative* of the overall very positive feedbacks that were received.

- “I am studying the phenomena of flashback in stratified swirl flame (methane and hydrogen) at elevated pressure conditions. My work is experimental in nature and requires understanding of propagating flame-flow-wall interaction in turbulent conditions. During these experiments, I need to stabilize the swirl flame in a model combustor which requires me to understand the acoustic effects which the swirl flame might experience. Dr. Candel's sessions on combustion flame dynamics helped me in getting an insight for the same. On top of that, numerous interactions with him - while walking for lunch or on lunch table - made me aware of existing challenges in energy security for the world. Dr. Driscoll's sessions helped me understand the basics of turbulence-flame interactions, how the people in combustion community agree/differ (on Borghi diagram and few other issues) and how experimental and numerical research community is trying to improve the understanding of turbulent combustion.

Never, at any point during the lectures did I feel unwelcome for my questions. Interacting with these esteemed researchers is also a lesson in humility which I'd definitely like to keep in future.

I couldn't attend your lectures but interaction with you during the welcome & closing session inspires me to give back to the research community the way you are doing it.

Thanks again for giving me the opportunity to attend the summer school.”

R. Ranjan (PhD student, Univ. Texas, Austin)

- “Thank you for the very memorable and fulfilling experience during the CEFRC-CI summer school. I wanted to take a moment to share some of my thoughts regarding the summer school. In all, I thought the organization and content were excellent, both of which facilitated a positive learning experience and good breadth of coverage for combustion science disciplines.”

J. Koczak (PhD student, Univ. Michigan)

- ”This last week in Princeton had been great! All were very friendly and approachable, and I really enjoyed being part of it. Thanks for everything.”

M. Alzuabi (PhD student, Univ. Michigan)

- ”This was my first time to attend the combustion summer school and I had a great time! I want to thank you for your dedication not only to this Princeton Summer School but also to the whole combustion science society. The whole program was fantastic..... Again, your idea

to hold this combustion summer school is amazing and I really appreciate your great efforts and time to the development of this program.”

Y. Ding (PhD Student, Univ. Maryland)

- ”I am writing to thank you for all of your remarkable efforts you did for this year summer school, one the bests all round the world. It was my first experience and everything went quite well. I could add to my knowledge and network a lot and also I found great friends there. I hope you continue combustion summer schools in following years.”

N. Zamani (PhD student, West Virginia Univ.)

- ”First of all, thank you very much for organizing the CEFRC-CI summer school this year. It has been both a productive and a joyful experience for me, as I am sure it was for others!”

B. Mosevitzky (PhD student, Technion - Israel Institute of Technology, Israel)

Suggestions from Participants

Some common suggestions by the participants are summarized below, and will be considered in the formulation for the programs in subsequent sessions.

- Lab Tour: Participants suggested bringing back the “lab-tour” event. This year we did not include this event because of the crowded schedule. Next year, we will very likely reinstate the lab tour event.
- Longer Poster Session: Poster session was a new event in this year’s program and it was scheduled for three hours. To our surprise, despite the very tight schedule, most of the participants attended and visited the posters and engaged in long discussions with the presenters. We will extend the duration of this event next year.
- Longer Career Panel: The Career Panel, taking place after one of the lunches, has always been a highlight of the program, during which the lecturers and guest panelists would each make brief comments on their thoughts on career options for the participants and how they could prepare for them, and then take questions from the participants. Due to the large demand we shall consider extending the duration of this event.

Feedbacks from the Lecturers

1. Professor Sébastien M. Candel

Here are a few impressions about the Summer school organized in Princeton in June 2016 by Professor Ed Law:

- The period chosen for the school was quite good, after the classes and before July
- The number of hours allocated to each set of lectures is sizable (15h) and adequate for an in depth development of the material. School is quite effective in this way
- A remarkable number of attendees with a broad range of origins
- Excellent classroom conditions with perfect projection, many blackboards, reasonable (not too cool) ambient temperature
- Excellent lecturing conditions with class participation and many interactions during the lectures and during intermissions
- Nice welcome and banquet receptions and friendly atmosphere
- A nice session to discuss professional career building with the students, well attended and highly interactive
- Excellent accommodation arrangements

Warm and friendly reception by Professor Law, his staff (Dr. Abhishek Saha) and colleagues with every evening get together.

I should add my grateful thanks to Professor Law for taking this initiative and handling this event so well.

2. Professor Henry J. Curran

- Overall, I have a very positive impression of the Princeton Combustion Summer School. The event was mainly organized by both Dr. Abhishek Saha and Prof. Law with their team at Princeton in a most professional way. The opening and closing receptions were quite informal attended by lecturers and students alike. The opening reception was quiet compared to the closing one, where the students had a great time and by the end of the week had gotten to know the lecturers and had great fun socialising with one another and with the lecturers. I think there are many good photos available to testify to this!
- The lecture halls themselves were excellent. Their size was ideal for the number of participants and the acoustics and presentation facilities were excellent.
- I have taught at a number of combustion summer schools now over the years. However, this year the students really impressed me with their enthusiasm and already strong knowledge of the field. It was great to see so many sitting with Prof. Candel at lunch (the food was excellent and was different every day) chatting about Combustion Dynamics but in an informal environment which is so important to their professional development.

- Finally I'd like to compliment Prof. Law on being a pioneer in developing the concept of graduate student combustion summer schools. Now there are many around the world but the Princeton Summer School was the first and really paved the way for what is a most important initiative for combustion and the combustion institute.

3. Professor James F. Driscoll

My feedback to you is that I was very impressed with every aspect of the Princeton / CI summer school in 2016. My lectures addressed the area of turbulent combustion. The summer school organization was excellent, and the selection of lecturers insured that the lectures were very relevant and informative. Students told me that the lecture material was of real academic value, since the topics covered were not covered by courses at their institutions. The students displayed a serious interest in the subject areas. Their background was diverse; there were students from many different countries. My opinion is that the funding allocated by the Combustion Institute to assist in the Princeton / CI summer school was well spent.

4. Professor Mark A. Linne

- The Princeton Summer School on Combustion is one of the best short-course format educational forums I have seen. The organization of the school is flawless, with excellent facilities, well organized social events in addition to the normal classes, accommodations, meals and so forth. It works incredibly smoothly, thanks mostly to the hard work of the people at Princeton (especially Prof. Law and Dr. Saha).
- The course involves 15 lecture hours in each of four highly advanced topics that are central to combustion research. It is an incredibly ambitious undertaking when you look at the depth of coverage in the course notes. I am happy to report that the students were up to the task. In my lectures (on advanced laser diagnostics) we had students who were expert in one or two topics all the way over to students who knew nothing about diagnostics. They were all highly engaged; the experienced students often added interesting viewpoints but the novices were unafraid to ask good questions as well. They remained highly engaged throughout the entire week.
- I was encouraged to see so many new and highly talented people entering our field, and this school also offered an excellent opportunity for them to meet and get to know each other. I am sure they made connections that will last. This school is building a new generation of talent in a much more intentional and productive way than when I was a student.
- The school attracted students from all over the globe. As an example, I had a more mature student who teaches in Ecuador. We had good conversations about how he could start small and build an activity there. He promised to stay in touch. The school has an impressive reach, probably because it is based at Princeton and organized by Prof. Law.
- The financial support supplied to this school is money very well spent; it's an investment in a healthy future for our community.

Program Organizers' Experience

This year's program was attended by a record number of over 220 participants, exceeding by 40 from last year which in turn was a record year. This sustained surge in participation, while much welcomed as a solid indicator of the robustness of the discipline, posed severe logistic challenges in terms of available facilities for accommodation and dining. The problems were solved by arranging double occupancy dorm rooms, directing the senior, non-student researchers to off-campus, though equally convenient, restaurants, and moving the large-scale reception barbeque event to a larger venue. Our call for volunteers to share dorm rooms resulted in many enthusiastic responses – a rather moving and inspiring outcome.

Although it was initially a challenge, the increased number of attendees greatly enriched the summer school experience, to the attendees, lecturers and organizers, in that it provides the strongest testimony of the need and importance of the summer school. Furthermore, the increased number of attendees, especially many of them were first-timers, also conveys the importance of combustion science and technology, and that combustion remains an attractive career choice for graduate students. Finally, as organizers, perhaps the most precious reward is to see the students come, enjoy and learn from this one-week experience, and bring it back to their own research environments as a continuing source of knowledge and inspiration. Just like the lecturers, the organizers derive immense pleasure and satisfaction in facilitating the education, networking and collaboration elements of the combustion enterprise.

IMAGES



2016 PRINCETON - CEFRC - CI
Summer School on Combustion

Group Portrait: A Magnificent Sea of Blue!



Farewell Dinner



Session on Career Panel



A Lecture Session