Organization to Fast-Track Undergraduate Students into Engineering Research via Just-In-Time Learning

Matthew J. Traum*
Assistant Professor
Department of Mechanical and Energy Engineering
University of North Texas
PO Box 311089
Denton, TX 76203-1089

Sharon L. Karackattu
Research Coordinator
Planning and Advancement for Student Development
University of North Texas
PO Box 305358
Denton, TX 76203-5358

Dana Houston Jackson, PMP
Undergraduate Research Assistant

Joshua D. McNutt
Undergraduate Research Assistant
Department of Mechanical and Energy Engineering
University of North Texas
PO Box 311089
Denton, TX 76203-1089

Abstract

Meeting the need for trained researchers in the new Mechanical and Energy Engineering (MEE) Department at the University of North Texas (UNT), faculty and undergraduates are working together to develop a "researcher incubator" based on Just-In-Time learning pedagogies. The incubator's missions are to 1) train engineering undergraduates to perform research; 2) offer interdisciplinary, hands-on technical experience and training reflective of engineers' needs in the 21st Century; and 3) fast-track undergraduates into successful research experiences earlier than would be possible within conventional engineering programs. We share how we organized this research group and highlight initial successes with undergraduate research problem solving.

Summary

In a research context, an "incubator" is a place where formation and development of new skills and ideas are encouraged. To meet the need for trained researchers in the new Mechanical and Energy Engineering (MEE) Department at the University of North Texas (UNT), faculty and undergraduates are working together to develop a "researcher incubator" that integrates research into the undergraduate engineering curriculum. This group is envisioned to become a self-sustaining, self-funded, faculty-led organization whose missions are to 1) train UNT engineering undergraduates in the essentials of engineering research,

* Corresponding author. E-mail: mtraum@unt.edu, Phone: (940) 565-3446

2) offer an educational experience reflective of the engineering skills necessary for success in the 21st Century, and 3) fast-track students into successful research experiences much earlier than would be possible within conventional engineering programs. We report initial results from an in-progress pilot-level program that tests the effectiveness of merging Just-In-Time learning with Project Management Institute tools and processes to organize undergraduate research. This approach encourages ownership and active participation of undergraduates in the research enterprise and will enable students to be contributing coauthors of published technical works, as recommended by the National Research Council.[i]

Relevant Literature

According to the National Research Council, undergraduate curricula consisting solely of traditional lectures and laboratories may be inadequate for science, technology, engineering, and mathematics (STEM) education.[ii] The National Research Council identified undergraduate research as "the purest form of teaching" and an essential component for effective learning[iii]. The National Academy of Engineering acknowledges that all necessary engineering knowledge cannot be taught through traditional four-year baccalaureate degrees, and endorses research in engineering education as a valued activity for faculty as a means to enhance and personalize the connection to undergraduate students[iv]. In the new UNT MEE Department, undergraduate research is employed to compliment classroom engineering education; To continuously improve the impact of engineering research as an educational process, gauging the effectiveness of various approaches is critical to illuminating which methods are most effective.

Research is defined as the "diligent and systematic inquiry or investigation into a subject in order to discover or revise facts, theories, applications, etc."[v] The misconception that undergraduates lack the technical depth to perform research[vi] bars faculty from engaging undergraduates in serious research projects. Ironically, graduate students are welcomed to engage in research despite being equally unprepared. If graduate researchers had the knowledge to solve a research problem from the beginning, the problem could not be defined as research. To eliminate barriers to entry for undergraduate researchers, the UNT MEE Department is conducting a pilot-level study to gauge the effectiveness of "Just-In-Time" learning, a subset of Inductive Learning,[vii] as a tool for engineering research. Just-In-Time learning is modeled after manufacturing processes that deliver completed products to customers simultaneously with the moment of purchase. The hallmark of Just-In-Time learning in the context of research is that students are empowered to select and learn the specific elements necessary to solve a problem at the moment that a need for a solution arises.[viii] Although neither systematic nor formalized, the approach graduate students must undertake to solve research problems is Just-In-Time learning.

Topic and Aim of the Presentation

In this study, we test whether Just-In-Time learning methods can be formalized, packaged, and taught to undergraduate students through the Researcher Incubator to fast-track them into successful engineering research experiences. The hypothesis of UNT's Just-in-Time learning experiment is that if undergraduate students are 1) taught the skills needed to discover technical information and knowledge themselves, 2) enabled to work in collaborative groups that facilitate idea exchange, and 3) vested with responsibility to manage and execute serious research projects, they will spontaneously find or develop the theoretical and practical engineering knowledge required to successfully complete the project. We demonstrate that given the resources and formalized training in generating or finding knowledge, undergraduates are as capable as graduate students in succeeding as researchers starting from the same initial conditions.

Methodology

Organization

In addition to being a teaching pedagogy, Just-In-Time learning is also a research laboratory management tool that vests significant responsibility in the undergraduate researchers. It therefore requires well-thought-out prior organization. To assure a structured approach, we incorporated Project Management Institute tools and processes to clearly outline the incubator's goals and procedures, gain agreement of stakeholders, and effectively organize the efforts of the undergraduate students. The students created a charter, an agreement between stakeholders to obtain commitment from all affected groups and individuals within a specific project (in this case faculty advisors, and students). The charter provides a consolidated overview of the project and allows all parties involved to document the agreed-upon scope, objectives, approaches and deliverables of the project.

Student Selection and Organization

To pioneer the Researcher Incubator, undergraduate MEE student applicants were surveyed to gauge their motivation factors, ability to work independently, and level of interest for research. Of the 65 surveyed, 22 students volunteered to join a pilot-scale incubator. The volunteers self-organized into six separate project teams: five technical teams and one fundraising team. Team members democratically elected a leader from among their peers to represent the group in interactions with the faculty.

Resources, Training, and Advising

The underlying ideas for the five technical projects were developed jointly by students and faculty and were all linked to some existing research apparatus or external connection already available to UNT. For example, one team is designing a novel solar energy collector because Fresnel lenses and a small parabolic dish were available. Another team is working to develop a wireless energy monitoring network for the built environment to capitalize on a pre-existing relationship with a company with overlapping expertise. Before beginning research, all incubator researchers underwent a series of workshops conducted by UNT librarians to train them in performing literature searches. This training is critical to the Just-In-Time learning methodology of the incubator because it enables students to locate technical information on their own. To house the researcher incubator, a laboratory with benches, basic instruments, and tools was provided. Each team was allotted a start-up budget of $500.00 with the requirement that any additional expenses must be raised externally by the fundraising team.

Regular weekly meetings were set between each individual team leader and the faculty advisor. Instead of acting as a manager, the faculty member took on the role of technical advisor. For example, if specific mathematical steps were needed to develop a research model (usually multi-variable calculus or identification of an obscure engineering correlation), the professor would work through the problem with the team leader, and the leader would present the solution to the group. Because of his research experience, the faculty advisor could also identify more precise, inexpensive, or facile approaches to solve certain problems. In these cases, suggested approaches were shared with team leaders, but a specific path forward was never mandated.

Results

This presentation includes two components. First, we share the Charter for the UNT Researcher Incubator, developed using established project management techniques, as a guide for founding this type of undergraduate research organization at any engineering university. Second, to highlight the validity of our hypothesis and our methods, we provide a case study illuminating one Incubator research group's path of discovery and eventual success when confronted with a theoretical research problem beyond their collective engineering knowledge and experience.

Future Directions

If found successful, the researcher incubator's Just-In-Time learning pedagogy will be elevated from a pilot-level study to a permanent program within the UNT MEE Department. In addition to facilitating undergraduate research, internalizing Just-In-Time learning is critical to the success of UNT engineering graduates. In response to rapid evolution of the marketplace, technical professions have shifted to on-demand problem solving. Therefore, students' mastery of Just-In-Time learning is a critical component to management of real engineering projects in the 21st Century[ix].

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Conference On Being an Engineer: Cognitive Underpinnings of Engineering Education, Center for the Integration of Science Education and Research, Lubbock, TX, February 1-2, 2008.

UNIVERSITY OF NORTH TEXAS
Discover the power of ideas

Matthew J. Traum, Ph.D.[1] ; Sharon L. Karackattu, Ph.D.[2] ; Dana Houston Jackson, PMP[1]; and Joshua D. McNutt[1]

Department of Mechanical and Energy Engineering[1], Division of Student Development[2]

University of North Texas, PO Box 311089 Denton, TX 76203

Thermal Fluid Sciences Group @ UNT
A Student Centered Research Lab

Abstract

To meet the need for trained researchers in the new Mechanical and Energy Engineering (MEE) Department at the University of North Texas (UNT), MEE faculty and undergraduate students are working together to develop a "researcher incubator" based on "Just-In-Time learning" pedagogies. The incubator's missions are to:

1) Train engineering undergraduates to perform research;
2) Offer interdisciplinary, hands-on technical experience and training reflective of engineers' needs in the 21st Century; and
3) Fast-track undergrads into successful research experiences earlier than would be possible within conventional engineering programs.

We share how we organized a research group to address these missions, and we highlight initial successes with undergraduate research problem solving.

This poster includes two components. First, we share the organizational structure underlying the UNT Researcher Incubator, developed using established project management techniques, as a guide for founding this type of undergraduate research organization at any engineering university. Second, to highlight the validity of our hypothesis and our methods, we provide a case study illuminating one Incubator research group's path of discovery when confronted with a research problem beyond the group's collective engineering knowledge and experience.

Introduction and Background

In a research context, an "incubator" is a place where formation and development of new skills and ideas are encouraged. MEE faculty and undergraduate students are working together to develop a "researcher incubator" that integrates research experiences into the undergraduate engineering curriculum. This group is envisioned to become a self sustaining, self-funded, student-led, faculty-organized collective. We report initial results from an in-progress pilot-level program that tests the effectiveness of merging Just-In-Time learning with Project Management Institute tools and processes to organize undergraduate research. This approach encourages ownership and active participation of undergraduates in the research enterprise and will enable students to be contributing coauthors of published technical works as recommended by the National Research Council [1].

According to the National Research Council, undergraduate curricula consisting solely of traditional lectures and laboratories may be inadequate for science, technology, engineering, and mathematics (STEM) education [2]. The National Research Council identified undergraduate research as the "purest form of teaching" and an essential component for effective learning [3]. The National Academy of Engineering acknowledges that all necessary engineering knowledge cannot be taught through traditional four-year baccalaureate degrees, It endorses research in engineering education as a valued activity for faculty to enhance and personalize the connection to undergraduate students [4]. To continuously improve engineering research as an educational process, gauging the effectiveness of various approaches is critical to illuminating which methods are most successful.

Research is defined as the "diligent and systematic inquiry or investigation into a subject in order to discover or revise facts, theories, applications, etc." [5]. The misconception that undergraduates lack the technical depth to perform research [6] bars faculty from engaging undergraduates in serious projects. Ironically, graduate students are welcomed as researchers despite being equally unprepared. To eliminate barriers to entry for undergraduates, the UNT MEE Department is conducting a pilot-level study to gauge the effectiveness of "Just-In-Time" learning, a subset of Inductive Learning [7]. Just-In-Time learning is modeled after manufacturing processes the deliver completed products to customers simultaneously with the moment of purchase. The hallmark of Just-In-Time learning in the context of research is that students are empowered to select and learn the specific elements necessary to solve a problem at the moment that a need for a solution arises.

In this study, we test whether Just-In-Time learning methods can be formalized, packaged, and taught to undergraduate students through the Research Incubator to fast-track them into successful engineering research experiences. **The hypothesis of UNT's Just-In-Time learning experiment is that if undergraduate students are 1) taught the skills needed to discover technical information and knowledge themselves, 2) enabled to work in collaborative groups that facilitate idea exchange, and 3) vested with responsibility to manage and execute serous research projects, they will spontaneously find or develop the theoretical and practical engineering knowledge required to successfully complete the project.** We demonstrate that given the resources and formalized training in generating or finding knowledge, undergraduates are as capable as graduate students in succeeding as researchers starting from the same initial conditions. We provide a specific example of one undergraduate research group's success as a case study.

Methods

Organization

In addition to being a teaching pedagogy, Just-In-Time learning is also a research laboratory management tool that vests significant responsibility in the undergraduate researchers. It therefore requires well-thought-out prior organization. To assure a structured approach, we incorporated Project Management Institute tools and processes to clearly outline the incubator's goals and procedures, gain agreement of stakeholders, and effectively organize the efforts of the undergraduate students. The students created a charter, an agreement between stakeholders to obtain commitment from all affected groups and individuals. The charter provides a consolidated overview of the project and allows all parties involved to document the agreed-upon scope, objectives, approaches and deliverables of the project.

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Resources, Training, and Advising

The underlying ideas for the projects were developed jointly by students and faculty and were all linked to some existing research apparatus or external connection already available to UNT. For example, one team (highlighted in this poster) is designing a novel solar energy collector because Fresnel lenses and a small parabolic dish were available. Before beginning research, all incubator researchers attended a series of workshops conducted by UNT librarians to train them in performing literature searches. This training is critical to the Just-In-Time learning methodology of the incubator because it enables students to locate technical information on their own. To house the researcher incubator, a laboratory with benches, basic instruments, and tools was provided. Each team was allotted a start-up budget of $500.00 with the requirement that any additional expenses must be raised externally by the students.

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Undergraduate Research Project Case Study: Determining Best Method To Generate Electricity from Concentrated Sunlight

The group is seeking the best method to generate electricity from concentrated sunlight within a power range below one kilowatt. After performing a literature search to illuminate best practices utilized in large-scale solar energy generators, the group brainstormed three compelling options:

1) Concentrate sunlight with a highly-reflective parabolic dish. At the dish focus, a photovoltaic (PV) panel converts the solar photons directly into electrons;
2) Using the concentrator scheme in (1), place a heat exchanger at the dish focus to warm a working fluid that drives a heat engine (e.g., a Stirling engine); and
3) Concentrate sunlight with a Fresnel lens focused on the hot side of a thermoelectric generator whose cold end is exposed to a deep ground heat sink.

To select the best method, the group gathered preliminary data on solar insolation in Denton, TX to insert into textbook-based analytical models of option (1) and option (2). The literature revealed one full-scale solar-thermal power plant operating at lower efficiency than conventional PV panels [9]. A scaling analysis suggests rejecting the exact replication of the large solar-thermal power cycle (11 MW) on a smaller scale (1 kW), but it is not cause for total rejection of option (2). The inherently small collection area of a sub-1-kilowatt solar concentrator yields a lower maximum temperature and reduced Carnot efficiency compared to the full-scale plant and therefore lower efficiency than PV panels.

No textbook or literature model was located to enable evaluation of option (3). An experiment (Figure 1) is needed to determine the maximum attainable temperature on the hot side of a thermoelectric generator exposed to concentrated sunlight. Experimental determination of this temperature will yield a Carnot efficiency and facilitate comparison to option 1.

If theoretical performance of option (1) and option (3) are comparable, additional experiments must be designed to measure the solar reflectivity and long-term robustness against the elements of several different coating options for the parabolic solar concentrator (a satellite dish). The degree of surface reflectivity is the key unknown parameter needed to determines the conversion efficiency of the solar concentrator.

Future Directions

If found successful, the researcher incubator's Just-In-Time learning pedagogy will be elevated from a pilot-level study to a permanent program within the UNT MEE Department. In addition to facilitating undergraduate research, internalizing Just-In-Time learning is critical to instilling a philosophy of lifelong learning in UNT's engineering graduates. In response to rapid evolution of the marketplace, technical professions have shifted to on-demand problem solving. Therefore, students' mastery of Just-In-Time learning and lifelong learning is a critical component to management of real engineering projects in the 21st Century [10].

References

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Figure 1 and Figure 2

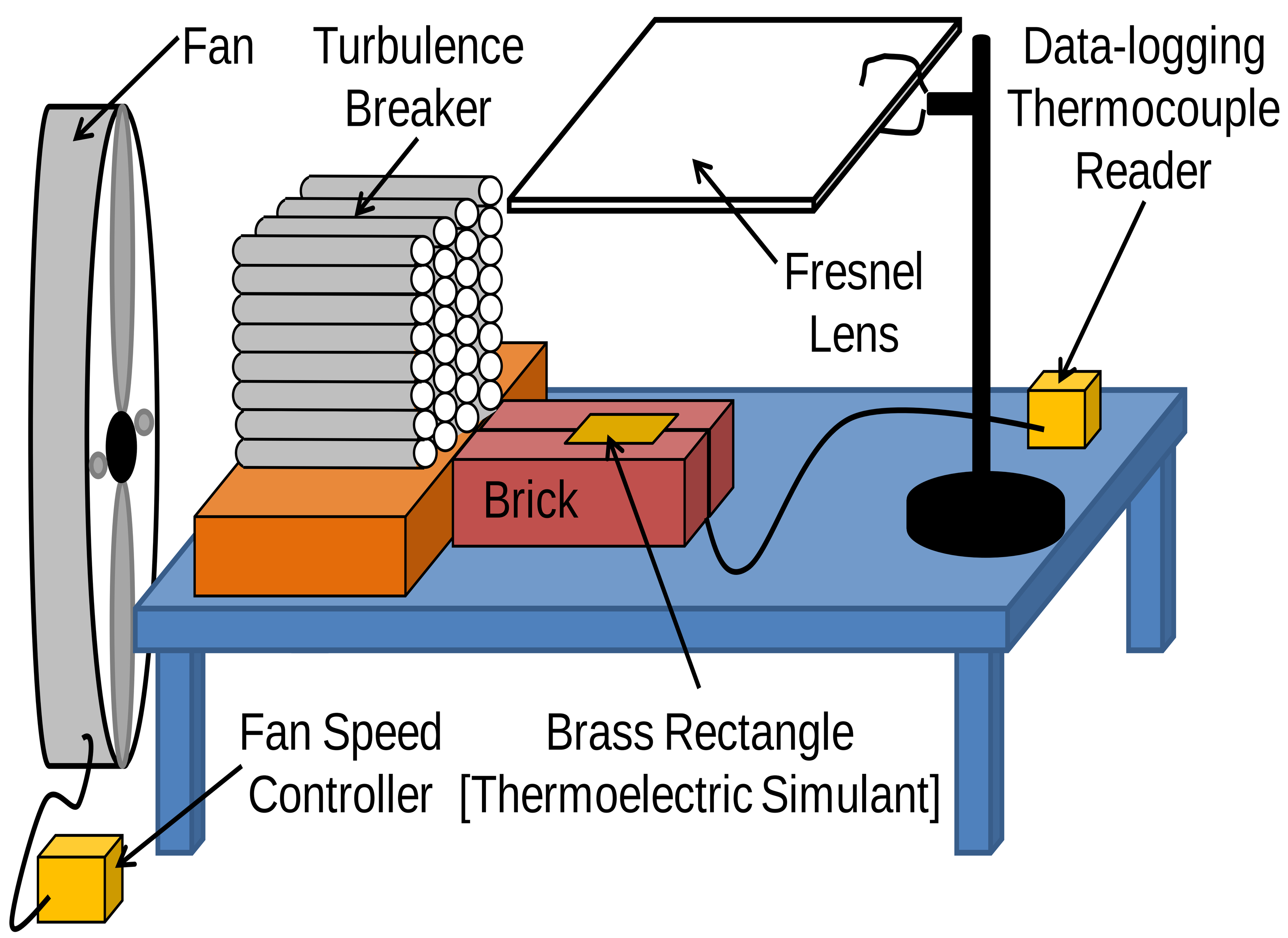

Figure 1: A schematic representation of the apparatus used to measure local solar insolation and maximum thermoelectric generator warm-end temperature.

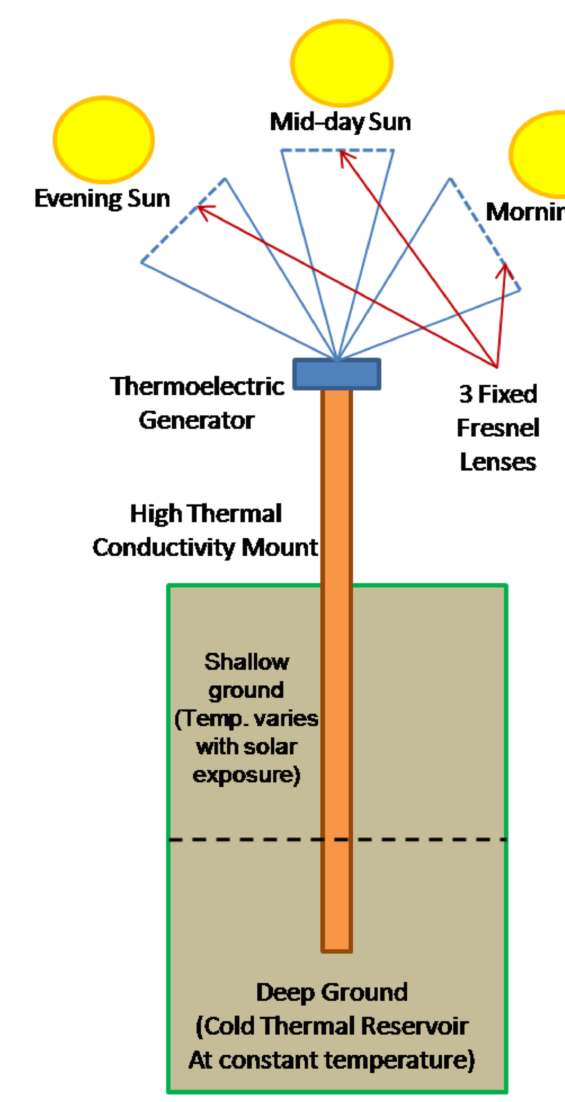

Figure 2: The conceptual design for a Fresnel-thermoelectric energy generator.

$$\dot{Q}_{solar} = hA\left(T_{brass} - T_{\infty}\right) + m \cdot C \cdot \frac{\partial T_{brass}}{\partial t}$$

Equation 1: An expression of the First Law of Thermodynamics accounts for major energy flows into and out of the brass rectangle (TE Simulant).

$$\dot{Q}_{solar} = hA\left(T_{brass} - T_{\infty}\right)$$

Equation 2: The steady-state expression of Eq. 1 gives maximum brass temperatures as a function of solar insolation and wind velocity.