PROJECT DESCRIPTION
Vision and Goals

We propose to demonstrate a new approach to education and research in a traditional discipline of science and engineering, leveraging existing and emerging cyberinfrastructure. Specifically, we will develop a prototype of an online platform, with the mission to evolve all knowledge in a traditional discipline. The platform will not only preserve knowledge in the discipline, but also influence its future development. In steady state, the discipline and its online platform will co-evolve.

For any discipline of depth and breadth, the mission to evolve all its knowledge will require many individuals to participate. Our approach will enable a large community of academics, students, and practitioners in industries to collaborate at the forefront of research and education. Furthermore, the approach will turn the traditional model of public outreach upside down, enabling K-12 teachers and students to contribute to projects that have kindled their interests in science and engineering, and opening channels for experts to give feedback.

The goals of this approach are to (1) substantially expand the scope of education and research by providing a live environment embodying all knowledge of a discipline – from phenomena and explanations of interest to the general public, to textbooks and demonstrations for students, to data and tools used by practitioners in industries, and to theories and experiments pursued by academics; (2) prepare a new generation of experts capable of using cyberinfrastructure throughout their lives to learn and teach; and (3) enable the general public to actively participate in engineering and science.

A problem common to all traditional disciplines

To be recognized as traditional, a discipline must have accumulated a large stock of knowledge that has immense value to many human activities today and to our posterity. Furthermore, new applications constantly emerge that require ingenious use of existing knowledge, or fundamental progress in the discipline.

For centuries, knowledge has evolved by words of mouth, journals and books. This approach, however, is not scalable when a discipline grows up. Words of mouth are effective in communicating new ideas, but only among people who talk to each other. Journals and books reach far, but take long time to produce. When the number of journals and books in a discipline becomes large, we divide the discipline into subdisciplines, or declare that the discipline is mature, only to be surprised by yet another breakthrough drawing upon several subdisciplines. When a subdiscipline is no longer active as a research area, but has found a large user base, incremental insights gained in active use are mostly in the form of words of mouth and unpublished notes. The state of the art evolves among its practitioners, but the published knowledge in the subdiscipline remains static.

The sheer quantity of knowledge in a traditional discipline, as well as the way we evolve knowledge, makes it hard for any individual person to master (and to add to) the discipline, a fact at least partially responsible for turning many young people away from traditional disciplines of science and engineering. Thus, a problem common to all traditional disciplines is, Given the large stock of existing knowledge, how do we make the labor of discovering and learning more efficient and meaningful?

Abundance in resources and scarcity in time

Recent advances in cyberinfrastructure provide an opportunity to reconsider how we evolve knowledge. Building on the base technology of computation, storage and

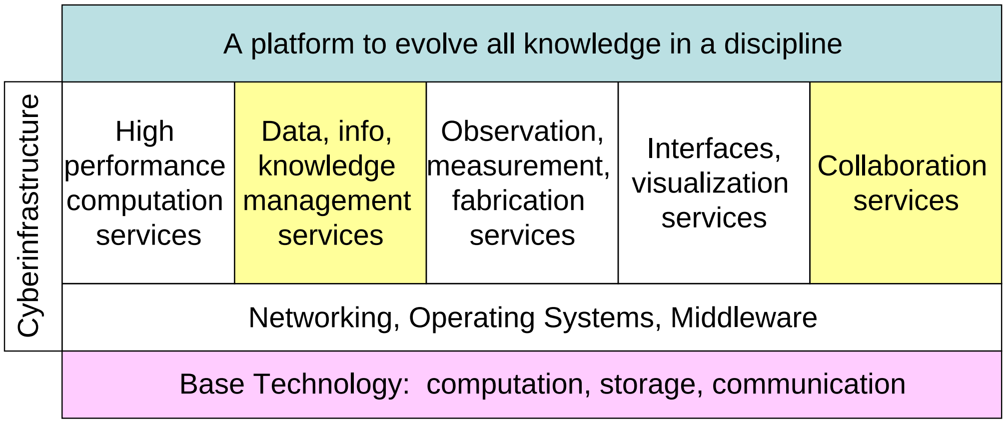

Fig. 1. Resting on the base technology of computation, storage and communication, various components of cyberinfrastructure are under development (Atkins et al., 2003). A platform to evolve all knowledge of a traditional discipline will ultimately draw upon all components of cyberinfrastructure. This Project will in particular leverage recent advances in knowledge management and collaboration services.

communication, various components of cyberinfrastructure are under development; see a NSF blue-panel report (Atkins et al., 2003; **Fig. 1**). Examples include digital libraries, collaboratories (Wulf, 1993; Finholt, 2002), grid computing (Foster and Kesselman, 2003), federated data archives (Szalay and Gary, 2006; Djorgovski, 2005), and distributed sensors (Butler, 2006). The new cyberinfrastructure will enable remote operable instruments and simulation-based engineering science (Oden et al., 2006).

As the new cyberinfrastructure links people, information, and the physical world, it is natural to contemplate an online platform to evolve all knowledge of a traditional discipline. Such a platform will draw upon abundant resources:

- *Storage.* Hard drives are cheap. It makes no sense to be stingy about storage space.
- *Bandwidth.* The Internet bandwidth is cheap. Nobody needs to own a copy of an encyclopedia, but all knowledge can be made accessible to everyone. Also, hyperlinks are far more effective than traditional references.
- *Computers.* Computers are cheap. They can generate useful information as needed.
- *Search.* Search engines are fast. Information explosion is no longer a threat to humanity, but a manageable chronic problem.
- *Collaboration services*. Services like email, videophone and content management are changing how people collaborate.

Such a platform must also treasure scarce time that people have. The first wave of the Internet has solved one problem: it has made knowledge rapidly available (nearly) worldwide. The solution, however, has made another problem more evident. The bottleneck is no longer accessing knowledge, but the scarcity of time: the speed at which our brains process information has not changed.

Then came the second wave of the Internet, known in popular media as Web 2.0 (O'Reilly, 2005). Millions of bloggers, wikians, social bookmarkers, and podcasters are creating, editing, annotating and voting on the content on the Internet by using new tools, tools that are created for the Internet, not merely clones of old tools. The new Internet tools have fundamentally changed who can collaborate, as well as how and why they collaborate.

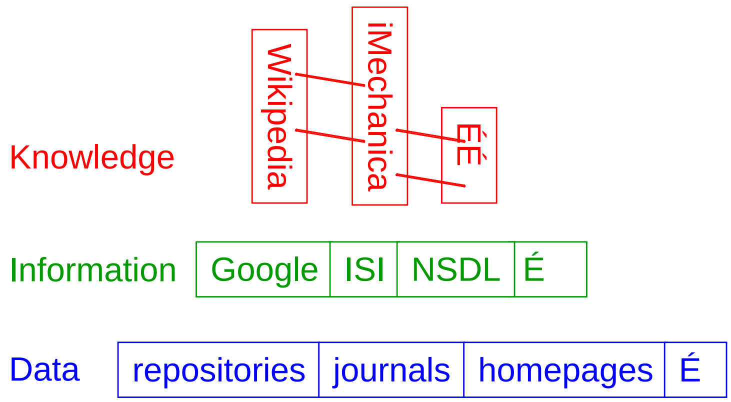

Fig. 2. A hierarchical structure of an online knowledge environment, consisting of three levels: data, information and knowledge (modified from Ginsparg, 2001). As individual disciplines organize their own knowledge, the platforms of different disciplines will be hyperlinked, growing into an organic structure, feeding on data and information.

Replicability and scalability

To demonstrate our approach, we will focus on a specific discipline, Applied Mechanics, an engineering science discipline with deep roots in academia and a broad user base in industries. Specifically, we will build a prototype, called iMechanica.Org (or iMech for short), with the mission to evolve all knowledge within Applied Mechanics.

The need to leverage the emerging cyberinfrastructure to evolve knowledge exists in all traditional disciplines. The platform developed for Applied Mechanics and experience gained should be replicable for other disciplines. iMech will draw on approaches of successful online communities that have scaled to many users and diverse topics.

More broadly, in a time when nearly everyone subscribes to interdisciplinary research and education, it has become increasingly important to evolve each individual discipline online, in all its intricacy, depth and breadth, making specialized knowledge generally accessible and useful. **Fig. 2** illustrates a possible hierarchical structure of an online knowledge environment, consisting of three levels: data, information and knowledge. The data level includes data sets, images and papers found in repositories, journals and homepages of individuals. The information level includes services such as a search engine (Google), an indexer (ISI, or Institute for Scientific Information), and a digital library (NSDL, or National Science Digital Library). The knowledge level includes an encyclopedia (Wikipedia) and discipline-specific platforms. As individual disciplines evolve their own knowledge, platforms of different disciplines will be hyperlinked, growing into an organic structure.

Deliverables of this Demonstration Project

While sophisticated cyberinfrastructure is tantalizing, evolving all knowledge in a traditional discipline requires that individual people in the discipline be the primary contributors. Between the rapidly developing Internet and mainstream researchers and educators lie two hurdles: the unfamiliar software and the unfamiliar culture. We send e-mails and download research papers, but few of us know much about blogs, wikis, RSS feeds, and social bookmarks, not to mention more sophisticated components of emerging cyberinfrastructure. Many of our colleagues have never used Wikipedia, and are shocked to learn that it is created by volunteers.

iMechanica: a platform to evolve all knowledge in Applied Mechanics	
Community building	**Knowledge processing**
?Applied Mechanics News (Fall 06)	?Applied Mechanics Archive (Fall 06)
?Web of Mechanicians (Fall 06)	?WikiMechanica (Spring 07)
?Applied Mechanics Outreach (Spring 07)	?Applied Mechanics Research (Fall 07)

Fig. 3. Deliverables and timetable of this Demonstration Project.

What motivates so many people to contribute? How are credits assigned? A few of us have heard of Slashdot, Facebook and Last.fm, but are not sure why they are successful, or how they relate to research and education.

Students understand and use the latest technology, but faculty and practitioners are mired in a set of tools that were "hot" when they were in school. To motivate many people to participate, we need to make the transition gentle but meaningful. To this end, this Demonstration Project will focus on the following deliverables, as listed in **Fig. 3**, along with approximate starting times. As will become evident, these deliverables integrate functions that are crucial to rallying people to accomplish the iMech mission.

Community building

The mission to evolve all knowledge in Applied Mechanics requires many people to participate. Applied Mechanics is practiced in many organizations and all over the world. Few issues are confined within a single organization or a single country. To build iMech as an inter-organizational and international online community, we will develop

- Applied Mechanics News (AMN), a weblog of news and views maintained for and by everyone interested in Applied Mechanics;
- The Web of Mechanicians (WOM), a combined genealogy and social network that aims to link all past and living mechanicians; and
- Applied Mechanics Outreach (AMO), an interactive website for projects involving mechanical principles designed for and by K-12 teachers and students.

If successful, AMN, WOM and AMO will serve as a visible reminder of the power of the Internet as a tool not only for disseminating information, but also for active participation.

Knowledge processing

By knowledge processing we mean all modes of interaction between humans and knowledge, including discovery, synthesis, dissemination, acquisition, and application of knowledge. To demonstrate iMech as a platform to evolve knowledge, we will develop

- Applied Mechanics Archive (AMA), an archive that allows users to upload, annotate and hyperlink data, images and notes;
- Wikimechanica, a wiki that enables collaborative synthesis of knowledge in depth; and
- Applied Mechanics Research (AMR), a new kind of journal that enhances conventional functions of journals such as archiving, filtering and commenting, and enables new functions such as wikiediting and social bookmarking.

These deliverables are crucial for iMech to aggregate insights of many users, as well as to recognize exceptional contributions of individuals. To demonstrate the use of Wikimechanica, we will teach a graduate course on Thin Film Fracture Mechanics at Harvard, with webcast to the University of Nebraska where students will also take the course for credit, and we will involve students and engineers from industries to write a wikibook on this subject.

Background

The discipline of Applied Mechanics

Applied Mechanics is a discipline that studies the response of matter to external forces, such as flow of a liquid, fracture of a solid, sound in the air, and vibration of a string. The discipline bridges the gap between fundamental physical sciences and wide-ranging applications. Representative questions are how a gecko climbs, how an earthquake occurs, how a computer chip fails, how a safe and efficient machine is designed, or how an airplane flies. Major approaches include formulating concepts and theories, discovering and interpreting phenomena, as well as developing experimental and computational tools. For well over a century, Applied Mechanics has been a flagship discipline in the innovation of research, education, and community building in many branches of engineering, including Mechanical, Civil, Aerospace, Materials, and Biological Engineering.

Despite the intellectual depth and broad user base, the discipline of Applied Mechanics is in a state of crisis, largely due to its own success. Like many traditional disciplines of science and engineering, Applied Mechanics has accumulated a large stock of knowledge over centuries. The question is, How do we educate individuals within a reasonable amount of time, so that they still have time left to innovate?

A classical answer to this question dates back at least to Stephen P. Timoshenko (1968), considered by many the father of modern Applied Mechanics. Starting early last century, Timoshenko and his followers divided the field of Applied Mechanics into subfields (such as strength of materials, theory of elasticity, theory of vibration, plates and shells, structural instabilities), and then summarized the "essential knowledge" in each subfield in a textbook. The success of this divide-and-conquer approach is immense, as attested by the rising importance of Applied Mechanics in engineering curriculum, by the fundamental progress (e.g., in fracture mechanics, in nonlinear continuum mechanics, and in the mechanics of materials and small structures), and by pervasive use of Applied Mechanics in engineering practice.

This approach, however, is not scalable. As more results accumulate in a subfield, its textbook becomes thicker and more abstruse. As new subfields emerge, new textbooks are added to the pile. Furthermore, what is considered essential knowledge for a practicing engineer is very different from that for an undergraduate student. This and other idiosyncrasies of people lead to more textbooks, each with smaller audience. Individuals agonize over which cherries to pick, leaving most untasted. Sadly, few mechanicians today consider writing textbooks professionally rewarding. Sadder still, the approach has led the discipline to fragment.

The fragmentation has been partially mitigated by the rise of computational mechanics. Over the last half-century or so, the use of computers to solve complex, nonlinear boundary-value problems in the field of Applied Mechanics has flourished, leading to commercial software like ABAQUS. Using such software, an electrical engineer, say, with a rudimentary understanding of mechanics, can analyze the strain field in the channel of a transistor. While computational mechanics has begun to unify Applied Mechanics, this unification is incomplete. Not all problems are suitable for numerical computation; many problems are solved by experiments combined with scaling laws, and by relating to previously solved problems. Some problems are solved more sensibly by trial and error. (Nobody learns to ride a bicycle by numerical simulation.) Also, to make a fundamental contribution to Applied Mechanics, one has to go beneath the software and acquire a holistic understanding of the discipline.

We believe that the Internet will further unify Applied Mechanics by going beyond numerical and computational aspects of Applied Mechanics, by making the labor of discovering and synthesizing knowledge more efficient and meaningful, by making Applied Mechanics useful to more people, and by continuously aggregating insights of many practitioners.

Knowledge processing and the Internet

To describe the best practice of knowledge processing, we quote Ziman (1964).

"The process of advancing the line of settlements, and cultivating and civilizing the new territory, takes place in stages. The original papers are published, to the delight of their authors, and to the critical eyes of their readers. Review articles then provide crude sketch plans, elementary guides through the forests of the literature. Then come the monographs, exact surveys, mapping out the ground that has been won, adjusting claims for priority, putting each fact or theory into its place.

"Finally we need textbooks. There is a profound distinction between a treatise and a textbook. A treatise expounds; a textbook explains. It has never been supposed that a student could get into his head the whole of physics, nor even the whole of any branch of physics. He does not need to remember what he can easily discover by reference to monographs, review articles and original papers. But he must learn to read those references: he must learn the language in which they are written: he must know the basic experimental facts, and general theoretical principles, upon which his science is founded."

To update on the changes in the last forty some years, we might note the following. We email a preprint to interested colleagues the moment it is written. Soon we will be able to download anything existing in any media. The Massachusetts Institute of Technology has made course content online. We all Google.

The Internet has also led to new approaches to knowledge processing. Wikipedia, for example, is a free Internet encyclopedia founded in 2001 by a one time financier, Jimmy Wales, with a radical approach: anybody can create and modify (almost) any entry. A user of Wikipedia can be simultaneously a writer, reviewer, reader, editor and publisher. Although most researchers have long played such multiple roles, Wikipedia has automated the process, vastly increasing efficiency and reducing cost. In just a few years, and with a modest budget, Wikipedia has come close to Britannica in terms of the accuracy of its science entries (Giles, 2005). The size of Wikipedia has long surpassed Britannica. Far more people today use Wikipedia than Britannica, even though the latter is also online at most universities.

As another example, Slashdot, founded by Rob Malda in 1997 when he was a college student, is an aggregator of news (chromatic et al., 2002). Anybody can submit news from any source, and each submission is reviewed by editors before promotion to the front page. Once an item appears in Slashdot, hundreds of readers visit the original source, and many return to Slashdot to leave comments, which are often more informative than the original article. It is not uncommon that news published in venerable sources are found to be false by the users of Slashdot within hours. A user can be a student, teacher, practitioner, researcher, and scholar, all at the same time. A Microsoft engineer becomes a teacher to thousands of fellow users of Slashdot when he or she posts a critique on a Google service.

Taking advantage of contributions from users has been demonstrated by, e.g., Amazon for books, Newegg for computer parts, and Last.fm for music. The website Science of Collaboratories lists many collaboratories that link people, information and instruments through the Internet. Websites like Connexions and Merlot are providing web tools to create and aggregate teaching materials, and so does Nanohub for simulation tools. Many companies have been developing knowledge management systems (Awad and Ghaziri, 2003). Progressive educators are experimenting with tools like blogs, wikis, RSS feeds and podcasts to enhance teaching (Richardson, 2006).

In hindsight, perhaps the approaches of Wikipedia and Slashdot are not so radical after all. All humans since the dawn of civilization have participated in distant, asynchronous collaboration. In particular, one scientist can always comment on a paper of another, or completely rewrite the paper by publishing another paper, sometimes centuries later. Enabling collaborative knowledge processing has been a quintessential hallmark of many great inventions, including the written word, paper, the printing press, the computer, and the Internet. On this long time scale, the Internet has been with us very recently and is in a state of flux; harnessing its power to evolve knowledge will require the same ingenuity and perseverance as innovation in any field of engineering. Indeed, we might as well think of knowledge processing as a field of engineering by itself, whose time is ripe for a revolution, largely due to ubiquity of the Internet.

Implementation Plan

This Project will focus on two essential functions of the prototype: community building and knowledge processing. We next describe deliverables (**Fig. 3**) in some detail.

Community building

To build iMech as an online learning community, we will benefit from several kinds of experience. First, disciplines in science and engineering have long organized around conferences, journals and learned societies; these components of the traditional infrastructure have found online presence. Second, online communities such as email lists and forums have existed since the inception of the Internet; for example, NSF founded the Electronic Information Exchange System (EIES) to explore communication by geographically dispersed research communities (Turoff and Starr, 1977). Such online communities have flourished among hobbyists (Anderson et al., 2006), open-source software developers (Weber, 2004; DiBona et al., 2006), as well as employees in corporations (Figallo and Rhine, 2002; Awad and Ghaziri, 2003). Third, in more recent years, new Web tools such as blogs, wikis and content management systems (Ebersbach et al., 2006; Douglass et al., 2006; Richardson, 2006) have opened new ways to collaborate. To rally individual people to accomplish the mission of iMech, this Demonstration Project will integrate several community-building tools, as described below.

Applied Mechanics News

The Applied Mechanics Division (AMD) of ASME has over 5000 paying members. There are several other large organizations of mechanicians in the US, including the American Academy of Mechanics, Society of Engineering Science, Engineering Mechanics Division of ASCE, Fluid Dynamics Division of APS, and many technical committees in American Institute of Aeronautics and Astronautics. The list goes on. Applied Mechanics is also a discipline practiced world wide. All leading journals in Applied Mechanics and most international conferences are in English.

The number of mechanicians is too large for all individuals to interact with one another directly, but too small for CNN to cover us. The existing infrastructure does not serve us well. Applied Mechanics conferences are too expensive for students to attend frequently, and too academic to interest practicing engineers. The latter mostly go to industrial conferences, where academics are absent. We are unaware of any community-wide effort for public outreach.

Since the 1960s, AMD has been publishing an annual Newsletter. At any given time, the Newsletter is edited by a single person, typically a volunteering professor. The Newsletters were mailed to members for many years, but the mailing has been discontinued recently to cut cost. The Newsletters are still produced annually but they are placed on the AMD website. Like most websites created in 1990s, the AMD website is static. The bottleneck is the webmaster, who gets a request each time someone wants to post anything, and only a few people are authorized to make such requests. The same webmaster also serves other divisions of ASME. Thus, a static website is few-to-many communication in a limiting form, bottlenecked by a single webmaster, with a small fraction of his or her time.

In January 2006, with the encouragement of the Executive Committee of AMD, but with no funding, a new member of the Executive Committee, Suo, initiated Applied Mechanics News (AMN), a weblog of news and views of interest to the community of Applied Mechanics, accompanied by three sister blogs covering research and researchers, conferences and jobs. The four sister blogs are maintained by large teams of volunteers. Within weeks, AMN topped the list on Google, Yahoo and MSN for the query of applied mechanics news. By late May 2006, the four blogs had a total of over 38,000 page loads, and on average over hundred unique visitors every day, from all over the world. The Internet has enabled AMN to be international and inter-organizational, updated continuously, rather than annually.

AMN is hosted by a free service, Blogger. The service enables few-to-many communication, but still does not serve our needs well. For example, people cannot become contributors by themselves, and Blogger offers inadequate means for search, and offers no keyword tagging. The software is proprietary and allows limited customization. Also, the websites hosted by Blogger.com are not accessible in China, a country that has perhaps more mechanicians than the US and Europe combined. The platform of Blogger has severely restricted the growth of AMN.

In this Demonstration Project, we will migrate AMN to a far more effective many-to-many communication platform. Our prototype is being constructed on iMechanica.Org, with the following features:

- Without signing in, everyone can read and comment on every entry.
- Everyone can sign in.
- Upon signing in, each user has a blog and can contribute content.
- Moderators may promote new entries to the front page of iMech.
- A user can subscribe to the RSS feeds of iMech, or blogs, or keywords.

These and other features can be customized. We will experiment with various options of moderation. The new platform will more readily recruit users and attract quality entries. While the online community will never replace conferences, it will enable people who do not go to the same conferences to communicate with each other. In particular, we will make a special effort to bring industrial practitioners and students into this online community.

The Web of Mechanicians

At present, there is no open-access directory of mechanicians. AMD maintains an online record of its members, but the record only contains names, addresses and phone numbers, and is not open to the public. Most professors and some students have homepages that contains professional information. Engineers in industries have their webpages on the intranets of their companies, but these are invisible on the Internet. It is easy to Google an academic, but difficult to Google an industrial engineer. Even if the homepage of a person is found, it is not easy to decipher the connection between the person and other mechanicians.

The Internet can do far more than making the membership record online. We will initiate the Web of Mechanicians (WOM), borrowing features of The Mathematics Genealogy Project and social networking services such as Facebook and Last.fm. WOM aims to create a page for every past and living mechanician, and list, among other items, his or her thesis advisors, students, colleagues and collaborators, subjects of expertise, and intellectual contributions. By listing advisors and students, WOM will trace the genealogy of mechanicians. By listing collaborators and colleagues, WOM will provide a professional networking service. As a distinguishing feature, WOM is enabled by wiki so that information can be quickly updated by the entire community.

WOM will become a useful tool only if it contains pages of most mechanicians. We will put in as much content as available to us, and urge our colleagues in the community to participate. WOM will popularize wiki among mechanicians, and demonstrate the power of a useful and free service made possible by the Internet and mass participation.

Applied Mechanics Outreach

NSF has long been urging researchers to reach out to the public. The cause is noble and important, and most researchers love to share knowledge with others. However, developing successful modules takes time, which few people can afford if the modules are only used once or twice, with nothing to follow up. As a result, many outreach efforts do not reach very far, if not outright perfunctory. This apparent problem suggests an opportunity for iMech.

iMech will attempt to reach out to children as early as their elementary school years to get them excited about topics drawn from Applied Mechanics. One approach to this goal takes inspiration from the successful "Le main à la pâte", or "hands-in-dough", program in France, but extends the idea of hands-on science to take advantage of the Internet.

Initially, we will gather ideas from the iMech community for inexpensive and spectacular hands-on explorations of mechanical principles that will be safe and fun for children to carry out in their first science-oriented classes. Then we will use various means (see below) to encourage schoolteachers to choose projects, try them in real classrooms, and post accounts of their successes and difficulties for everyone in the Applied Mechanics community to see and comment. We will encourage teachers and students produce short videos of the crucial moments of their experiments, and these videos can be shared online and ranked by viewers around the world such that the best ones will rise to the top.

Ideally, the system will become self-sustaining: teachers can invent new projects themselves, ask local mechanicians (possibly found in WOM) for help, and follow the best examples set by other teachers in their own classrooms. The children will learn how exciting Applied Mechanics can be at an early age, they will proudly show their parents their best experiments in action on any computer at home, and they will be more likely engaged by science classes later in their education.

We will present these approaches to RET (Research Experience for Teachers) summer program participants, and at the Current Science and Technology Center (CS&T) at the Museum of Science, Boston. The museum has over 1.7 million visitors per year, including 270,000 students on school field trips. Additionally, presentations will be posted on the CS&T website, which receives over 170,000 hits per week.

Knowledge processing

To demonstrate the use of the new Internet tools to evolve knowledge in a discipline, this

Project will focus on the following deliverables.

Applied Mechanics Archive

It is essential that iMech can capture data and image, providing access to more than what is available through journals and books. The information will be useful for synthesis of knowledge, and in classroom to expose students to real experimental and simulated data in a virtual environment.

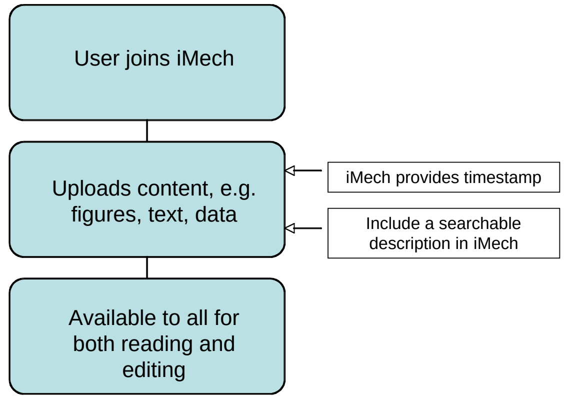

Fig. 4. Procedure for adding data and images to iMech. Contributing to iMech is a simple procedure for the average user.

Upon joining iMech, a user can upload any type of content (text, videos, graphs, photos) related to Applied Mechanics (**Fig. 4**), along with a brief description that makes the information searchable. Examples of information include stress-strain curves for various materials, images of deformation localization, dislocations, and fracture phenomena, video clips of structural response, failure phenomena, and animations of simulated response.

iMech will provide functions more than those of a passive depository. Each unit of content, called a node, has a unique URL, and can be shared by all users, who can leave comments, and make hyperlinks to other nodes. The concept is similar to that of Flickr, an online photo gallery. In the future iMech will add modules to organize information in useful ways. As an example inspired by the work of Ashby (1999), users may want to collect certain kinds of data in a uniform format, and plot them to compare different materials. Once data for many materials are plotted in some parameter space, one can classify materials. If in the space a hole appears, one may ask why the hole exists, how to create materials to fill the hole, and if such materials are indeed created, what applications they might serve. These capabilities are being explored by commercial companies (e.g., Granta Design). No open-access archive in the field of Applied Mechanics currently exists.

As in all traditional disciplines in science and engineering, many subjects in Applied Mechanics are no longer active areas of research, but have found many users. A likely function of iMech is to compile existing solutions of boundary value problems, such as solutions for deflections of thin structures (beams, plates and shells), conditions for bifurcation, and stress intensity factors of cracks. Such compilations will also aggregate new results produced by the users. As this function becomes promising among users, some form of moderation will emerge to ensure quality.

WikiMechanica

Despite its enormous popularity, Wikipedia today does not have much useful content on Applied Mechanics. One possible reason is that Wikipedia is an encyclopedia, a work for general reference. Another possible reason is the lack of incentive for experts to participate. To demonstrate that wiki can synthesize knowledge at a more advanced level than usually found in Wikipedia, we will write a wikibook on Thin Film Fracture Mechanics, involving faculty members, students, and industrial practitioners, and use the writing process as a teaching tool in a course on thin film mechanics, which we will teach at Harvard in Spring 2007 with webcast to the University of Nebraska.

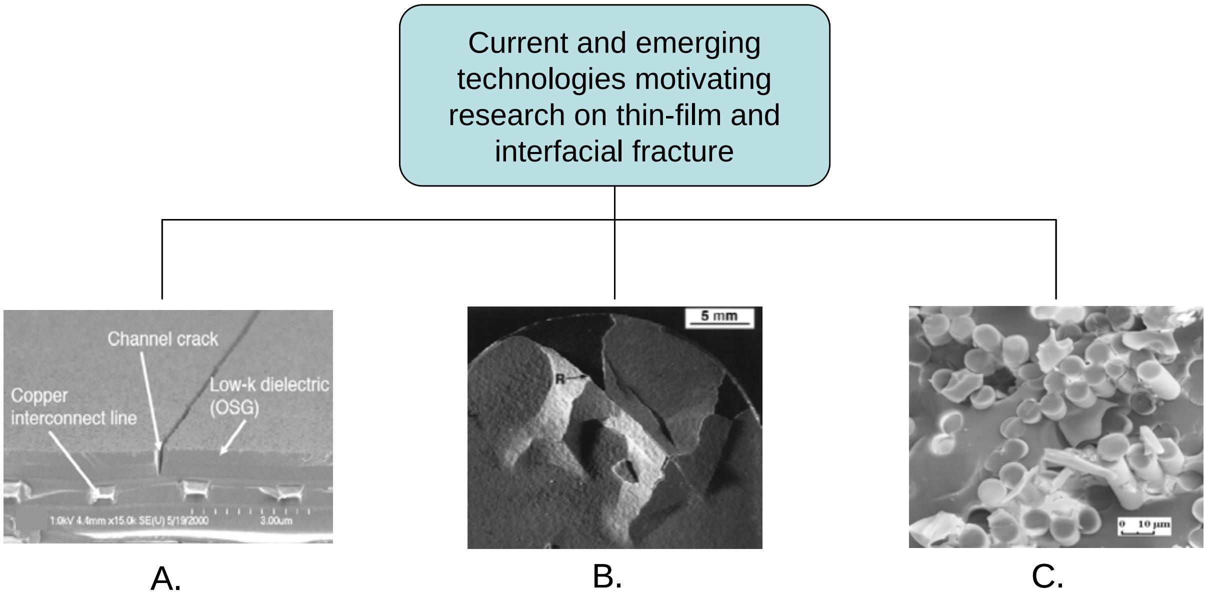

Fig. 5. Illustrations of technological problems driving research on fracture in complex systems. A. Channel cracking in an advanced low-k dielectric used in integrated circuits (Tsui et al., 2005). B. Buckle-driven delamination of a thermal barrier coating used for jet engine turbine blades (Sergo and Clarke, 1998), C. Fracture surface of a BN-coated glass fiber composite showing fiber pull-out (Mueller, 2006).

We (Hutchinson, Suo, Vlassak) have been active in this area of research since its inception. Several technological problems have motivated us to study cracking and debonding in complex material systems (**Fig. 5**). One problem is durability of electronic devices. An electronic device integrates diverse materials (semiconductors, dielectrics, conductors, etc.). Stresses arise in these materials for many reasons, such as temperature change and material transport. These stresses can cause cracking in individual materials, and debonding between dissimilar materials. In more recent years, similar problems have appeared in the nascent technology of flexible electronics. A second problem is thermal barrier coatings for turbine blades. To enhance fuel efficiency, the aerospace engine industry is always finding new ways to increase the operating temperature of turbines, by using superalloy blades, by passing cooling liquids inside the blades, and by coating a ceramic layer on the surface of the blades. A major technical challenge is that the ceramic coatings may spall off, exposing the superalloy to excessive heat. A third problem is the design of all-ceramic composites for high temperature applications, such as jet engines. Ceramics can sustain high temperature, but are susceptible to fracture. One strategy to toughen ceramics, quite ironically, is to introduce some weakness into them. For example, in a two-ceramic composite, with one ceramic being the matrix and the other the fibers, the composite becomes tough if the interfaces between the fibers and the matrix are weak.

We have taught graduate courses and industrial tutorials on the subject, drawing heavily upon our review articles (Hutchinson and Suo, 1992; Vinci and Vlassak, 1996; Suo, 2003), which in turn have been incorporated into a recent textbook (Freund and Suresh, 2003). This textbook provides excellent coverage of the fundamentals, and contains much advanced material up to late 2002. However, the field is still an active area of research. One conspicuous hole in these courses and the textbook is the lack of a substantive coverage of organic materials and their hybrids with inorganic materials. The new applications in flexible electronics are hardly mentioned. Also missing is the recent work on low-permittivity dielectrics used in microprocessors, where cracking is a significant technological concern. There are also other limitations intrinsic to books printed on paper: Typically most books have too many results for beginning learners, but not enough for experts. Moreover, human nature being what it is, perhaps no textbook will ever please all instructors. In all our years of teaching, seldom have we taught any course from a single textbook.

One possible solution is the Connexions Project (Rice University, 2006). The Project has been funded by the National Science Foundation and private donors, and has produced a system of software to enable anyone to author parts of knowledge (called modules). It also enables anyone to assemble parts into courses. In principle, Connexions is scalable to any discipline. At present, however, a search of "mechanics" returns almost no useful results.

We feel that the Connexions approach is more suitable for mature subjects, where standards are more or less established, so that parts produced by different people fit together. On the other hand, parts of the subject of Thin Film Fracture Mechanics are still developing, and it is premature to enforce such a standard. We believe that wiki is a more flexible way to organize this branch of knowledge at this time. We anticipate that the main users of this wikibook will be graduate students and practitioners in industries. By accessing different links, one can tailor the material as a textbook for a graduate course, or as a reference for general applications.

In Spring 2007, we will teach this course at Harvard University, with webcast to the University of Nebraska where graduate students will also be taking the course for credit (**Fig. 6**). A few graduate students from MIT are also expected to enroll in the course by taking advantage of the Harvard/MIT enrollment exchange policy. The course will start with a tutorial on basic fracture mechanics and then transition to specific developments on thin films and multilayers.

We will upload our course notes on Applied Mechanics Archive. Students will be divided in groups to work these notes into chapters of the wikibook, and add reviews of recent literature. They will also present their chapters and be evaluated by their peers. We will request up-to-date materials from our colleagues in universities and industries, and we will participate in editing the wikibook. Phenomena of thin film mechanics are visible in everyday life, such as paint peeling and mud cracking. Some of the introductory materials will appeal to the general public. It is also conceivable that a school kid or a traveler will like to share their own photos and videos of remarkable fracture phenomena. Such a wikibook will not be a clone of a book printed on paper, but an evolving learning environment.

Wikis have caused extensive technical and social debates; see Ebersbach et al. (2006) for references. We also anticipate some compromises. Inline hyperlinks are particularly

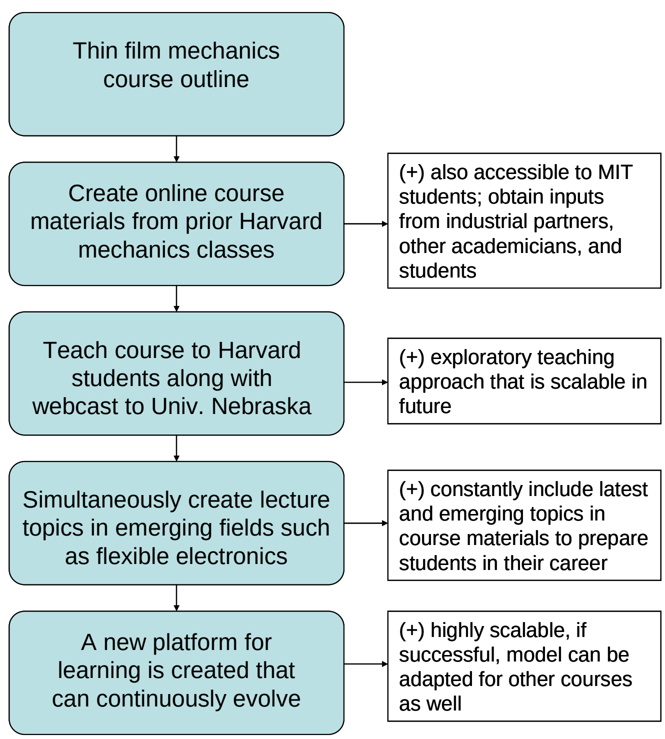

Fig. 6. A course on Thin Film Mechanics.

effective for learning. However, we expect that most people will want to read a long text on paper. Thus, we will use wiki as a tool to evolve the text, but will make sure that the text is readable on paper. This will in turn require that we refrain from using too many hyperlinks. As the reading habits of people change, and as the paper-like display technology develops (Crawford, 2005), it is conceivable that printed books will become historic artifacts in the future.

We will also experiment with the tradeoff between openness and quality control. During the period that we teach this course, we will only allow the faculty and students registered for the course to edit the text. Afterwards, we may open the text for the public to edit. A method used by Wikipedia is that many people volunteer to monitor changes. This method works for entries on poplar topics, but may not be suitable for those of specialized topics. Alternatively, we may ensure quality by using a combination of wiki and static pages. For example, at all times, wiki records all versions of an entry. We can simply link a static page in iMech to the latest version approved by experts, while letting everyone edit the current version. A static page will also allow an instructor to tailor a particular sequence of topics and versions.

Applied Mechanics Research

We will create a new kind of research journal by integrating certain features from Slashdot and Wikipedia. Our goal is to significantly enhance conventional functions of journals such as archiving, filtering and commenting, and to create new functions such as wikiediting and social bookmarking.

The question as to how to make scholarly research accessible has been extensively debated (e.g., Nature, 2004; The National Academies, 2004; Ginsparg, 2001; Odlyzko, 1999; Turoff and Satrr, 1982; Smith, 1999). However, this question does not seem to concern most researchers, despite the phenomenal success of open-access journals such as PLoS Biology (Eysenbach, 2006). Nearly all journals in science and engineering are online, accessible to researchers if their institutions subscribe to them. The pressing issue is not accessibility, but precious time of researchers. For example, Li (2006) listed 130 journals of interest to mechanicians. We may estimate that over a thousand papers per month are published in Applied Mechanics, if we assume that on average each journal publishes 10 per month.

Instead of asking how to make scholarly papers accessible, it seems more useful to ask, what should we do if all scholarly papers are already accessible, open access or otherwise?

As a form of many-to-many communication, scholarly publishing shares enough common features with news publishing that a glance at the latter provides some perspective. Nearly all news is openly accessible today. Sources include traditional ones such as the New York Times and BBC News, as well as millions of blogs. As mentioned before, Slashdot is a leading aggregator of technology news. Although anybody can submit news, usually an item from an existing source, each submission must be reviewed by editors before inclusion. Other websites, such as Reddit and Digg, take a more democratic approach, allowing anybody to post anything and relying on the community to vote for the most interesting stories. Newsvine, on the other hand, is a combination of many ideas, ranging from Digg's voting mechanism to receiving newsfeeds from the Associated Press to allowing users to have their own columns.

We will adapt some of these features for scholarly publishing, but with several important modifications (**Fig. 7**). A user of iMech can recommend any research paper from any source (e.g., a traditional journal, a self-publishing repository, or conference proceedings), so long as the paper is relevant to Applied Mechanics. The recommendation can be in a form of a citation, a URL, or the paper itself, depending on copyright permissions. The recommendation will appear in iMech automatically, accompanied by a discussion written in wiki, which can be edited by everyone. All users can comment on the paper, and tag the paper by social bookmarking. Copyright permitting, users can even evolve the entire paper in wiki, adding new materials and hyperlinking to other papers. A potent paper can evolve into a monograph. The wiki will automatically record contributions from all users, and the users will evolve the discussion page to record the history of how ideas come together, and to assign credits among themselves.

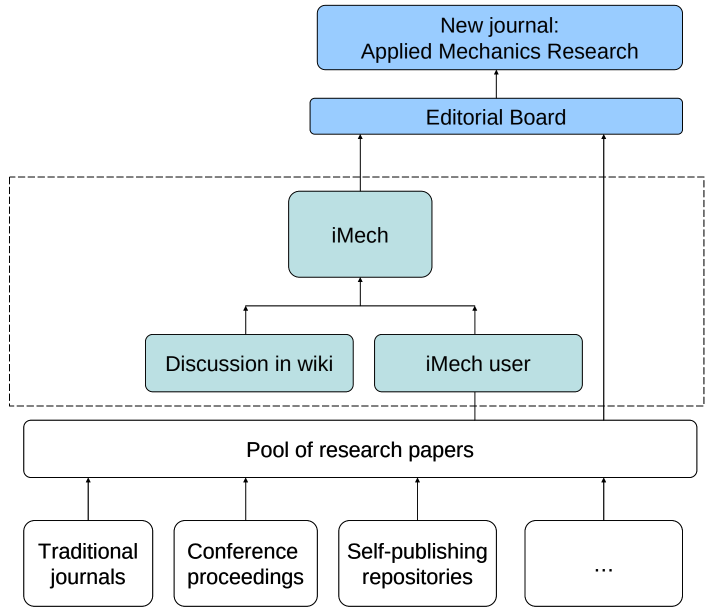

Fig. 7. Flow chart for a new kind of journal.

iMech will establish a new kind of journal, called Applied Mechanics Research (AMR), which will simply list a few (say five) papers per month, selected from all sources (including iMech), by an editorial board of recognized experts. For example, initially we may recruit 50 recognized experts. Each expert nominates a single paper at the beginning of the month. All fifty nominated papers are announced. At the end of the month, each expert votes on however many papers he or she has time to read and thinks worthy. The top five papers are then included in AMR. By restricting to a small number of papers, AMR will serve as a more selective filter, help to define future research directions in Applied Mechanics and unite the discipline. Slashdot has evolved means to reward participation and facilitate moderation (chromatic et al., 2002). We will use iMech to experiment with voting processes for the users to elect board members, as well as for the board members to select papers.

In future, when more people participate in iMech, we will implement a module to recommend papers to individuals on the basis of their own reading interest and papers that other people are reading. The idea is similar to what has been done by Amazon for books, and Last.fm for music.

Hardware and software

We have registered a domain name, iMechanica.Org, hosted on a server of Division of Engineering and Applied Sciences (DEAS) at Harvard University. Storage space will be provided and managed by the Information Technology Service of DEAS, at no cost to NSF.

A large number of open-source content management systems exits, but none fulfill all the functions described above. We will build iMech by drawing on several systems, two of which are briefly described here. Drupal is a content management system (CMS) that enables many people to create, edit, and publish multimedia content on the Internet, while being constrained by a set of rules set by the administrator of the system (Dougless et al., 2006). We have experimented with other platforms of CMS, such as Plone (McKay, 2004) and Slash (chramatic et al., 2002), and found that Drupal satisfies our needs without making excessive demands on our users. To lower the barrier of entry for users, we have kept the interface simple and disabled many modules of Drupal. We will add modules gradually as our users become comfortable with iMech. Drupal also has a large number of user-contributed modules, which we will select and install. We also expect to write our own modules.

Mediawiki is the same wiki engine that powers Wikipedia (Ebersbach et al., 2006). Although Mediawiki is not necessarily the most powerful wiki engine, the overwhelming popularity of Wikipedia has made Mediawiki almost a de facto standard. By installing Mediawiki on our own server, we will not limit iMech to be an encyclopedia, but will enable a learning community to exploit the potential of wikis, without being constrained by the conventional wisdom already formed around the Wikipedia community.

Using existing software systems as our starting point, we can focus on community building and knowledge processing without duplicating ongoing effort in Information Technology. Both Drupal and Mediawiki are open source, which will allow us to modify as our project proceeds.

Management Plan

Team members of this Demonstration Project will include mechanicians and computer scientists. Suo and Seltzer will be in charge of the architecture of iMech. They will be aided by Sircar, the Director of Information Technology at the Division of Engineering of Applied Sciences. Hutchinson will be in charge of designing the wikibook on Thin Film Fracture Mechanics. Suo, Vlassak, Ravi-Chandar (UT Austin) will be contributing authors, along with graduate students who will take the course for credit. Ramanathan will lead Applied Mechanics Outreach, and Ravi-Chandar will lead Applied Mechanics Archive. All of us, as well as our willing graduate students and colleagues, will be the initial moderators and contributors.

Evaluation Plan

The Demonstration Project should be evaluated on the basis of how well it enables iMech to achieve its mission: to evolve all knowledge in Applied Mechanics. We will collect statistics of users and items posted.

Dissemination Plan

In the Fall of 2006, we will migrate Applied Mechanics News from Blogger to iMech. This will allow us to bring readers of AMN to iMech. Because iMech will leverage the existing offline community of Applied Mechanics, we will contact our colleagues by email and make demonstrations at various conferences. Both Ravi-Chandar and Suo are members of the Executive Committees of the ASME Applied Mechanics Division, and have access to the email list of the members of the Division. We will also recruit K-12 teachers and students to participate in outreach activities, as described on p. 9 of this proposal. Material published in iMech will follow the open-content licenses, as specified on the website of Creative Commons.

Budget

We anticipate that successful completion of the demonstration project will require three graduate students at Harvard University (50% time) and one at UT Austin (50% time) for the duration of the project. These students will be instrumental in implementing the architecture of iMech, as well as in editing and uploading content. Funding is also requested for travel of one of the PIs to the grantees meeting in Washington DC and for computer supplies.