Lessons Learned in Industrial and International Collaboration at the Integrated Media Systems Center

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Abstract *— The Integrated Media Systems Center (IMSC) is the National Science Foundation's exclusive Engineering Research Center for multimedia and Internet research. IMSC carries out a successful cross-disciplinary program of research, education, outreach, industry and international collaboration and technology transfer. IMSC's industry and international collaboration program has ranged from 20-30 members per year, who are interested in the multidisciplinary research results and technology integration projects. A key lesson learned for success in these collaborations has been the use of industry-like project organizations to integrate research results into cohesive projects. We have adapted traditional industry project management techniques for success in the university environment. Our model for group interaction emphasizes interdisciplinary collaboration and interaction. Each faculty participant must agree that there are useful benefits and new research goals to be achieved by cooperation on projects with broader, interdisciplinary goals. They must accept and share a common vision of the goals (developed in group meetings by consensus) and long-term benefit of group involvement. One of the main challenges to the project manager in academia (APM) in achieving project goals is their limited direct influence on the project team. The APM's main motivational influences are the challenge of the research, the expertise of those involved, the friendship associated with academic environment, and to a lesser extent, influence on budgets. The APM need not be one of the technical leads, and it is best if he or she is a credible (technically informed) and impartial (to depersonalize issues in the presence of conflicts) team member. Success metrics are needed to effectively manage academic projects. Based on project vision and goals, these criteria help characterize success of the research project in terms of quality, relevance, outreach and impact of the final effort. Clearly defining goals, objectives and success criteria up-front helps all parties understand their role and improve participation among team members. We ensured that (i) this simple but often overlooked step was always clearly examined and understood, and (ii) all team members, including all graduate and undergraduate students were present for discussions. The APM holds responsibility for translating goals into project specifications and requirements, and formalizing the project plan in an easily accessible central document. We use variations of a "Project Requirements Document" adapted from the traditional Product Requirements Document widely used by product managers in industry. Regular meetings of all project personnel are a must for successful projects. A review of milestones and outstanding issues leads to a highly motivational "Management by Embarrassment" approach. An additional key role for the APM is to balance the risk profile of the research against the milestones and project objectives. At IMSC, we have endeavored to create an entrepreneurial culture whereby new discoveries with commercial potential are protected by provisional patents as soon as possible so as not to impede the flow of knowledge, whether in the form of publications, presentations or even external discussions. To protect company proprietary information, pending publications are reviewed by companies only to ensure that no such information was inadvertently included.*

Index Terms *— industry programs, international programs, lessons learned, project management.*

Introduction to the Integrated Media Systems Center (IMSC)

The Integrated Media Systems Center (IMSC) is the National Science Foundation's (NSF) exclusive Engineering Research Center for multimedia and Internet research. IMSC carries out a successful cross-disciplinary program of research, education, outreach, industry and international collaboration and technology transfer. As a leader in the multimedia and Internet field, IMSC has developed unique immersive technologies, such as 3D face and body modeling, detection and animation, immersivision panoramic video technology, facial expression analysis and emotion detection, emotive speech processing, advanced information management, and multichannel immersive audio. IMSC's integrated research approach is aimed at 3D immersive environments. IMSC has 28 faculty investigators, 220 graduate research assistants, 33 undergraduate research assistants, and 15 administrative staff. IMSC's annual operating budget is approximately $10 million.

In this paper, we first present IMSC's Industry and International Collaboration Program, describe the Vision Projects that serve as the basis for research integration, and then discuss the major lessons learned in project management in an academic environment that lead to successful collaborations with industrial sponsors.

IMSC'S INDUSTRY PROGRAM

IMSC's industry program member numbers have ranged from 20-30 members per year. Current members include FX Palo Alto, Hewlett-Packard, Lockheed Martin, NCR, Northrop Grumman, and smaller entrepreneurial companies. In addition to their interest in the R&D of individual technologies, industry members are interested in IMSC's multidisciplinary technology integration projects in immersive Entertainment, Education and Communication. IMSC is also conducting two additional integration projects specifically for industry members in wireless communication for engineering collaboration, and IT in the sensor-rich oil-field of the future. A key lesson learned for success has been the use of industry-like project organizations to integrate research results into cohesive projects. These projects have adapted traditional industry project management techniques for success in the university environment. This paper discusses the specific lessons learned in merging industrial and academic environments.

Two additional key interests of industry-university collaborations are Intellectual Property, and excellent graduate students. Since its inception in 1996, IMSC has had 96 invention disclosures, 51 patents filed, six patents issued, 88 commercial licenses and technology transfers, and nine small company spin-offs established. This paper discusses lessons learned in intellectual property protection without restricting publications and free-exchange of ideas, while still safeguarding industrial commercial interests. To date, 209 students have graduated with IMSC providing funding, classes, and research aspects of their education experience, including 112 with PhD, 82 with MS, and 15 with BS. Industrial feedback has been that students with a multidisciplinary educational environment and project integration experience are more productive on the job and sooner.

IMSC'S INTERNATIONAL COLLABORATION PROGRAM

Within its Industry Program, IMSC has an active program in international collaboration, with numerous international companies among current and former members. Thrusts include research and strategic planning collaborations in Taiwan and China, Japanese entrepreneurship training, and a new multi-institute collaboration with Korean industrial and academic institutions. International companies among our current and former members include BTG (UK), EverFocus (Taiwan), FX Palo Alto Laboratories (Japan), Hitachi America, Ltd. (Japan), KDDI (Japan), LG Electronics (Korea), NTT DoCoMo (Japan), Olympus (Japan), Philips Research (Netherlands), ST Microelectronics (Italy), and Toshiba (Japan). This paper describes the success factors in managing international relationships.

IMSC'S VISION AND INTEGRATION PROJECTS

IMSC's main mission is to pursue research and technologies of immersive and other integrated media systems [1][2]. Our vision of immersive technology is the creation of a complete audio and visual environment that places people in a virtual space where they can communicate naturally even though they are in different physical locations. Three driving applications Vision Projects consistent with the mission, in entertainment, education and communication, provide challenges and requirements to the research. Research results in the various fields comprising the vision projects come from the efforts of individual faculty and students working in their individual areas of interest and expertise, shown graphically in Figure 1.

FIGURE 1
RESEARCH RESULTS FROM FACULTY AND STUDENTS AT IMSC.

The first key lesson learned in industry collaborations is that the results of the research needs to be managed, integrated and demonstrated in a format familiar to industry. The result at IMSC has been the development of a project-oriented management structure that accommodates both industry and academic needs in the Vision Projects. The integration of the research into the three Vision Projects is shown in Figure 2. Figure 2 shows the three Vision Projects' driving applications providing requirements to the research, the research from faculty and student efforts providing results addressing these requirements, and engineering and integration via traditional project milestones resulting in Vision Project demonstrations.

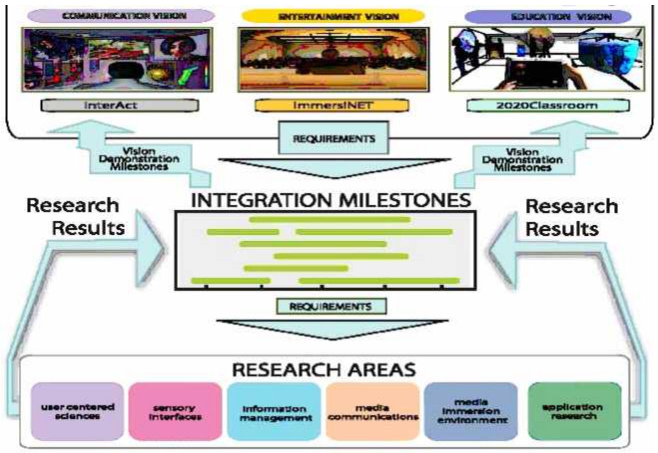

FIGURE 2
INTEGRATION OF RESEARCH RESULTS INTO VISION PROJECTS.

Distributed Immersive Performance

Our first Vision Project a real-time, multi-site, interactive and collaborative environment called Distributed Immersive Performance (DIP). The objective of DIP is to develop the technology for live, interactive musical performances in which the participants - subsets of musicians, the conductor and the audience - are in different physical locations and are interconnected by very high fidelity multichannel audio and video links. DIP is a specific realization of broader immersive technology - the creation of the complete aural and visual ambience that places a person or a group of people in a virtual space where they can experience events occurring at a remote site or communicate naturally regardless of their location. The DIP experimental system has interaction sites and servers in different locations on the USC campus and at several partners, including the New World Symphony of Miami Beach, FL. The sites have different types of equipment to test the effects of video and audio fidelity on the ease of use and functionality for different applications. Many sites have high-definition (HD) video or digital video (DV) quality images projected onto wide screen wall displays completely integrated with an immersive audio reproduction system for a seamless, fully three-dimensional aural environment with the correct spatial sound localization for participants. DIP involves a large project team, as shown in Table 1.

Faculty	Staff and PostDoctoral Fellows	PhD Students	Master Students	Industry Collaborators	Total
6	3	3	2	3	17

TABLE 1
DISTRIBUTED IMMERSIVE PERFORMANCE PROJECT PERSONNEL DISTRIBUTION

2020 Classroom

The 2020Classroom is a multidisciplinary research project with the vision to define the application of immersive technologies to learning. More specifically the research focuses on the three main interrelated goals: (i) create a prototype of *immersive distributed learning environment* geared towards high fidelity presence, (ii) create *novel curriculum* material that is specifically designed for such an environment, and (iii) develop new methods for *objective and subjective evaluation of learning* in such environments and *identify the role of immersive presence*. The project counts 14 members (see Table 2) from the following research laboratories: BioSight Lab, Audio Lab, Info Lab and the User-Centered Sciences Lab [3].

Faculty	Staff and PostDoctoral Fellows	PhD Students	Master Students	Industry Collaborators	Total
4	4	1	3	2	14

TABLE 2
2020 CLASSROOM PROJECT PERSONNEL DISTRIBUTION

CommVision

The Communication Vision research project investigates remote, distributed collaborative environments. The main focus of the project is natural multimodal interactions that facilitate both engagement and efficiency regardless of location and communication device. The primary challenge is developing technologies that aid in people's interactions with one another and with information systems by minimizing the communication gap between participants. Although our focus is on novel communications issues research, we also demonstrate systems research through the challenging task of integration of multidisciplinary research results into functional prototypes.

The Communication Vision project research is conducted mainly in the Speech Analysis and Interpretation Lab (SAIL) [4]. SAIL is also involved in the Transonics Speech to Speech (S2S) Translation project. In S2S the task is to aid in people's interaction by minimizing the communication gap due to the language barrier. The work in the S2S project is closely related to that of the Communication Vision, and in some respects can be considered an element of the overall goal. This project is further along in the integration process and a robust system is already in use. We are currently in the evaluation phase of the first generation system, and we are designing human factors experiments to both evaluate the usability of the system and provide feedback on its future development, as well as design robust evaluation metrics for such a complicated task. The participants in these projects are shown in Table 3.

Project	Faculty	PhD Students	Industry Collaborators	Total
CommVision	5	9	0	14
Transonics	5	6	4	15

TABLE 3
COMMVISION AND TRANSONICS PROJECTS PERSONNEL DISTRIBUTION

International Projects

The major international programs in recent years at IMSC have been the preparation of strategic plans and technology roadmaps in advanced digital technologies for Taiwan's Institute for Information Industries, research collaborations in UltraWideBand wireless, and application of IMSC's advanced Remote Media Immersion (RMI) video and audio technology to develop a cutting-edge wireless Internet communications system for use in engine maintenance for Korean Air and Pratt & Whitney. Keys to success in these collaborations have included enabling Taiwanese-US company collaboration opportunities by setting up visits and personnel exchanges, sponsoring an International Networking Conference and Meetings, exchanging data and input extensively, and mutual travel for face-to-face meetings.

ACADEMIC PROJECT MANAGEMENT

The traditional model for university graduate research is that a group of graduate students works under the direction of an individual faculty investigator on a single, well-defined area of research as determined by the faculty members and the project funding available. Each faculty member usually works alone, although there are many common lab or experimental facilities that are shared with other faculty. The faculty member and his/her student group often have little interest or involvement in the work of other faculty groups. This is reflected in Figure 1.

Our model for group interaction emphasizes interdisciplinary collaboration and interaction, as shown in Figure 2. Each faculty participant must agree that there are useful benefits and new research goals that can be achieved by cooperation on projects that have broader, interdisciplinary goals. In short, they must accept and share a common ***vision*** of the goals and the long-term benefit of their group involvement. The long term goals for these projects (extending more than six months) are set by the group members in a series of intense planning meeting series that are generally held once or twice a year. These series of meetings are each scheduled for 1 to 1.5 hours, and result in the agreed milestones for the project. Participation in these group projects is voluntary, although faculty members in the group may expect additional funding for part of their time and for graduate students depending on their level of effort and participation in various phases of the work. This additional funding is generally determined by the project leader. Each faculty member must agree to bring some useful piece of relevant technology and a commitment to collaborate with other faculty and students to achieve the defined objectives.

The project participants themselves define the project in detail, although some high-level goals and motivation may come from the one or two people designated as project leaders. People participate because: they like doing something new and different that represents a broadening of their own research and/or an application of it to a new area; they like the social interaction and recognition from other group members, from other faculty in their academic department, and from their research peers; they like presenting papers at conferences and publishing in journals that represent different disciplines from their past work.

The Academic Research Project Manager

The single-most important factor in the success of project-based efforts is the Project/Program Manager (PM). High quality research results are a necessary ingredient, but by themselves do not guarantee that an industry collaboration will succeed. It is well known in the industry [5] that to improve chances of success (i) a PM is needed for medium to large size projects, and (ii) that the skills of the PM have an important effect on the project's success. Academic projects are no exception and much of the same management techniques can be used for improving the chances of success.

One of the main challenges to the research PM in academia (APM) is that, of the nine traditional influences [6] available to an industrial PM, only three and one-half really work in academia. These are listed in decreasing power of influence in Table 4. The APM's main motivational influences are the challenge of the research, the expertise of those involved, and the friendship associated with academic environments. To a lesser extent, the APM has limited influence on the budgets as a motivator.

Influence	Available to Academic Project Managers
Authority	Not usually
Assignment	No
Budget	Limited
Promotion	No
Money	No
Penalty	No
Challenge	Yes, major motivator
Expertise	Yes, recognition of level of knowledge
Friendship	Yes, collaborative environment

TABLE 4
INFLUENCES AVAILABLE TO ACADEMIC PROJECT MANAGERS

Academics are generally self-motivated to work on their topic of scholarly interest for which they can get research support. It is important that the project director(s) and APM make each participant feel that they are part of a team and that their contribution is critical and worthwhile. Then each participant feels like they have a big investment in the success of the project and a real effect on its outcome. In the academic environment, project managers cannot issue orders such as: "I need a 5 page report on topic X by next Friday," but rather must motivate by embarrassment in the sense that other members of the team will be disappointed by their failure to do what they promised at a specified time.

In practice, the academic environment has the characteristic that the project is often led by senior faculty. The APM need not necessarily be one of the technical leads of the project. In fact, we would argue that it is best if he or she is a credible (technically informed) and impartial (to depersonalize issues in the presence of conflicts) member of the team with the assignment and responsibility to respond to team needs. The role of an APM is similar to the role of a traditional industrial R&D PM with some differences:

- Academic R&D projects are difficult to manage, as the level of risk is high [7]. The APM can count on faculty to help mitigate risks as faculty are among the leading domain experts in their field and can therefore provide the best information. In addition, there is little need for the APM to actively survey technical advances in the field(s) related to the project, as this input is readily available from the faculty.
- Research funds in academia are usually managed in a very effective way on a per-grant basis, grandly facilitating the PM's traditional concerns over budgets. Since the budget is usually fixed by the grant or industry support, and the time

scales for milestones are (flexibly) set by academic calendars and/or grant deadlines, the APM must then focus on the quality-risk profile.

- Most members in academic projects are only involved on a part-time basis and face frequent external (non-project) deadlines that can severely impact the project plan.
- In academia, motivation depends for the most part on the perceived scientific relevance of the project: individuals tend to balance their involvement by comparing the relevance of the work they do for the project to the work they do outside of the project.
- In academia there is a balance to strike between publishing research results and promoting technology transfer.

The academic environment places unique communications challenges among the senior faculty leading the effort, the APM, other faculty, Postdoctoral Researchers and senior students coordinating day-to-day activities. As an example, Figure 3 shows a typical reporting relationship. Please note that not all possible communications lines are shown or always present, and that all projects are managed slightly different.

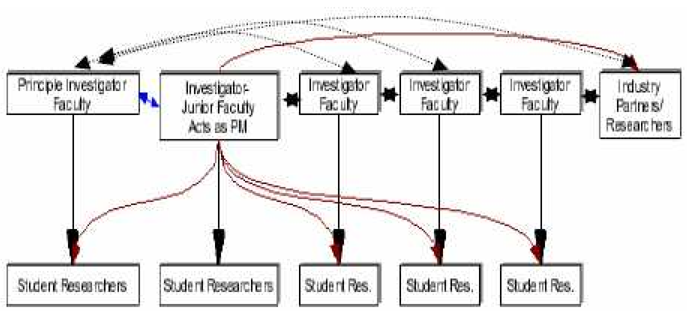

FIGURE 3
REPORTING RELATIONSHIP OF PARTICIPANTS IN TYPICAL PROJECT.

Clearly, the role of the PM in the academic environment is different in several respects.

- In this example, the APM's role is that of central supervision of the student researchers on progress and interface issues, without having to consult individual faculty on routine matters. To a certain degree, this is similar to the industry paradigm with the significant distinction that the APM has no academic authority over the student researchers.
- Most significant is that for the APM to be able to supervise the team members, there is a need for very good interpersonal relationship among the APM and the participants, especially the PI and the students. The supervision of the students from their own advisor and the APM only works if the two are in close contact and in synchrony in their requirements and tasks assigned to the students, especially if the APM has very good relationship with the students.
- The authority in the guiding vision of the project lies with the PI, whereas the actual project work is coordinated through the APM; it is thus significant that the APM and PI (and Co-PIs) are in very close contact for the management layer and the development layer to be in synchrony in their goals.
- Another significant difference in the academia as opposed to industry is that each of the participants has their own personal goals that are related to their own research interests. The APM in these cases has to be careful in assigning tasks that parallel the researchers' personal goals, and as such bank on the self-motivation of the researchers. A request for a certain task to be completed will likely be met enthusiastically if the students can use the same material in their own publications and thesis.

Defining Success in Academic Research Projects

To effectively manage academic projects metrics to measure success are needed. Based on the project vision and goals, one can define criteria to help characterize the success of a research project [5]. Those criteria generally include:

- Quality: reach and scale of the prototype and how well it showcases a promising technology
- Relevance: scientific and practical importance (publications, commercial and scientific implications, etc.)
- Outreach: relationships with industry and academia, technology transfer and licensing potential
- Impact: including productivity increase, collaborations between team members, effect on parallel research projects, etc.

We have found that clearly defining the goals, objectives and success criteria of the project up-front helped all parties involved better understand their role and improved participation among team members. We have ensured that (i) this simple but often overlooked step is always clearly examined and understood, and (ii) all team members, including all graduate and undergraduate students are present for the discussions.

University-Applicable Methods and Tools

The PM holds the responsibility of formalizing the project plan for the team in a central document that is generally available. We have used variations of a document called a "Project Requirements Document" or PRD as outlined in Table 5. The "Project Requirement Document" is adapted from the traditional Product Requirements Document widely used by product managers in industry.

Overview	Document Conventions	Explain terms and definitions
	Vision and Opportunity	Presents the vision and relevance
	User Definition	Defines who are the users of the system
	Related Projects and Products	Presents all relevant related systems
System Plan	System Definition	System definition (include use case diagrams)
	System Architecture	Optional for reference for developers
	Deployment Strategy	Deployment details (include deployment diagrams)
	Promotion Strategy	References to conferences, publications, demos, etc.
Requirements	Schedule and Milestones	High-level schedule and major milestones
	System-Level Requirements	Hardware and Software requirements, features and risks
Appendix	Miscellaneous information.	Optional

TABLE 5
OUTLINE OF THE PROJECT REQUIREMENTS DOCUMENT

The PRD needs to be reviewed and updated regularly. The PRD can help as follows:

- Academic teams tend to have relatively high turnover. Having a PRD provides a tool for quickly and effectively informing newcomers.
- The PRD provides an "official" document stating the terms agreed upon by the team members: it is developed by consensus [8] with all the stakeholders. To legitimize the PRD one can seek approval by an overseeing authority.
- The PRD provides schedule and milestones for reference. We have found that milestones need to be set carefully and sparingly as too many milestones interfere with the development of creative solutions.
- Simple diagrams in the PRD help the team better understand what is developed and how their work fits into the picture.

This central document captures the teams' integrated plan, formulated by the APM from input from the PI's during regular meetings. Changes are reflected back in the weekly working meetings with the student researchers and the APM. In some cases, there will be unplanned events to which researchers will need to make decisions that affect the PRD. These need to be examined from a system perspective to that the impact is reflected back to (and input obtained from) other investigators as appropriate.

In establishing the overall milestones and time-related goals of a project, we have found that general/global/system milestones are better set by the investigators as a result of coordination discussions, and more specific milestones related to subcomponents and individual technologies developed by the APM in consult with the developers. In IMSC's typical environment, milestones are driven by the academic calendar (Fall and Spring Semesters, Summer months), student graduations, sponsor-specified reviews (e.g., NSF or sponsor companies), advisory board meetings, and similar. It is also often the case that the specific milestones set by the APM will result in voluntary marathon working meetings. Participation in these meetings demonstrates the large degree of motivation of the whole team and the pride in their work. The schedule granularity is controlled by the APM.

For example, goals and milestones for the DIP project have been set by such external deadlines as submitting a paper to a relevant conference; a feature issue of a major archival journal whose topic is related to DIP; meetings of IMSC with many outside attendees and observers, such as the semi-annual Scientific Advisory Board (SAB) and Board of Councilors (BOC), and by external reviews such as the annual review by a major funding agency such as the National Science Foundation.

IMSC's project groups generally have regular meetings of all participants, more often as critical deadlines approach. Smaller meetings of sub-groups many be held even more often and are arranged as necessary. Much of the actual integration and interaction occurs in small meetings of graduate students who perform the real hands-on low-level hardware and software work. Faculty advisors may or may not be present at such meetings.

The PI or APM generally call the progress meetings and distribute a carefully defined agenda listing past topical action items, milestones, responsible people and critical decision items. Action items and goals for the following meeting are listed and people responsible for achieving them are listed. An important aspect of these projects is buying special purpose research equipment, network hardware and software that is necessary for the project. This equipment is often very expensive, so much of the discussion time is concerned with making sure that it is compatible with all other pieces of equipment to which it interfaces.

At times, mandatory regular meetings are important as well: ½ to 1 hour of weekly meetings is sufficient in practice. During the meetings, he APM should keep in-depth discussions to a minimum (as they are not of interest to everyone in the team). To help guide the meeting an agenda e-mailed to the team in advance can be used. Problems that can't be resolved in the allocated time (usually 5 to 10 minutes) should be discussed by a focus group (2 to 3 persons) that reports the results to the APM. If brainstorming sessions are required they should not take place during these meetings, but scheduled separately. A list of action items should be defined when appropriate as the outcome of the meeting. In practice meetings start with a short progress report from everyone including updates on the action items. Such practices help keep track of progress and motivate the team as members compare their accomplishments.

A sample listing of the PM tools used in a university environment are provided in Table 6. For example, all participants have fairly distinct tasks and thus they are responsible for their own internal version control; however, they are responsible for ensuring that their work integrates seamlessly at the system level with other work that is also being revised. The APM confirms and coordinates such work before accepting new versions into the approved system-level version. Most students employ Concurrent Versions System (CVS). This is supplemented at the system level with continuous integration and system level backups.

Tool	Purpose	Software Used
Version Control Tool	Store versions of source code and documentation	CVS
UML Design Tool	Create use case and deployment diagrams	Enterprise Architect from Sparx Systems
FTP, sftp, rsync	Store documents and third party software (drivers, sdk, etc.)	Various and platform dependant
Defect database	Track issues for the prototype	Teamatic
Message Board	Discussions, programming tips, etc.	Yahoo Groups or TWiki
Instant Messaging	Enhance remote communications	Various Messenger

TABLE 6
SOME OF THE TOOLS USED TO HELP IMPROVE PRODUCTIVITY

For sharing text data such as the PRD, the team has a TWiki site set-up for access by all participants. Some small text documents that need to be shared and frequently updated (such as module intercommunication protocols) are also on the twiki. In addition, we have a shared sftp/rsync server for members to easily exchange data. The intercommunication of the participants mostly takes place either in person or by email but also, due to the excellent working relationship of the participants, very often, at any time, and most likely through mobile phones. This is one element that needs to be emphasized in the operation of university projects -- the excellent working relationship between participants. The willingness to help each other and the excellent communication between the members is a dominant factor that sets the stage for success.

Some of the integration work done in demonstration projects has lower interest from a scientific perspective: it is the responsibility of the APM to ensure that this sort of development is kept to a minimum, yet the demonstration meets its goals. This is a careful balancing act that can be accomplished reusing available technology and the appropriate tools. Among the most useful tools used, a version control tool and an instant messaging solution where most useful, allowing team members to accommodate tight work schedules. Academic research projects refrain from implementing good development practices with the rationale that the benefits do not offset the deployment effort. Our experience is unanimous in acknowledging that the benefits are in fact well worth the effort.

Evaluation Metrics

As part of day-to-day activities in the above projects, we perform regular sub-component/technology evaluation, quality assurance reviews, and regular system integration milestones. We aim to ensure that developing systems exceed the performance of alternative systems, and approach human emulation. For example, in the Transonics project, the Automatic Speech Recognition system is regularly re-trained as data is collected and algorithms refined and compared against two test sets: a test near the systems abilities and an extremely challenging one to motivate further development. One of our observations in the work of these projects is that the researchers involved have significantly more motivation when milestones are met successfully. We aim to set both long term, and short term goals that are challenging but achievable objectives, evaluating against the project's established measures of success.

In general, we use criteria of success such as:

- How much are we pushing the envelope in the subcomponent technologies' measures of performance (MOP)? These are our short term objectives of making the system perform better than the previous best, and these MOP's are continuously shifting towards the measures of effectiveness (MOE).
- What is the potential impact of our research in making collaborations more effective? We use MOE's as measures of comparisons against the best imaginable scenario. For example in S2S, the comparison is made against a very skilled and fast human translator, who is also knowledgeable in the subject matter of the interaction.
- Human factors usability (effectiveness, efficiency, enjoyment, safety)
- Publications in both the purely research subcomponent technologies as well as at the system level.
- How are we addressing needs of the various funding sources (industry & government) and how can we attract more funding and involvement from these sources?

INTELLECTUAL PROPERTY PROTECTION

The final lesson learned discussed in the paper is the handling of the intellectual property (IP) and confidential information in a university environment. The specific challenges in university-industry collaborations are [9]:

- Handling intellectual property: A difficult part of the collaboration is the ownership, value, and use of the intellectual property arising from the sponsored project. In the U.S., when federal funds are involved, the ownership usually goes to the university. If the project is funded (or even partially) by a company, it might want ownership to develop products that come from the research. However, universities also might want ownership, for example, to stimulate local economic growth.
- Maintaining Confidentiality: The ability of faculty researchers to discuss their work with colleagues and to publish their results is an intrinsic part of academia and is fiercely defended as the basis of the way new scientific knowledge is created. However, companies have to protect the value of their investments.

At IMSC, we have endeavored to create an entrepreneurial culture whereby new discoveries are protected by provisional patents as soon as possible so as not to impede the flow of knowledge, whether in the form of publications, presentations or even external discussions. In this process, university personnel disclose their ideas and inventions to the university before any public disclosure because they understand their economic value to industry. Once protected by patent, the researchers are free to discuss publicly without having given up any rights. Publications are reviewed by companies only to ensure that no Proprietary Information was inadvertently included.

CONCLUSIONS

For successful industry collaborations, university research efforts need to be organized and integrated into cohesive demonstration projects managed like traditional industry projects, with adaptation to the academic environment. The system-level project results allow for validation of scientific, engineering or technological ideas in a system environment that demonstrates candidate industrial application. The approach also allows for the examination of interface, integration and systems issues.

The single-most important factor in the success of a university project is then the adaptation of project management techniques to the university environment. Our model for project interaction emphasizes interdisciplinary collaboration and interaction. Each faculty participant must agree that there are useful benefits and new research goals to be achieved by cooperation on projects with broader, interdisciplinary goals. They must accept and share a common vision of the goals (developed in group meetings by consensus) and long-term benefit of group involvement.

One of the main challenges to the project manager in academia (APM) in achieving project goals is their limited direct influence on the project team. The APM's main motivational influences are the challenge of the research, the expertise of those involved, the friendship associated with academic environment, and to a lesser extent, influence on budgets. The APM need not be one of the technical leads, and it is best if he or she is a credible (technically informed) and impartial (to depersonalize issues in the presence of conflicts) team member.

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The APM holds responsibility for translating goals into project specifications and requirements, and formalizing the project plan in an easily accessible central document. We use variations of a "Project Requirements Document" adapted from the traditional Product Requirements Document widely used by product managers in industry.

Regular meetings of all project personnel are a must for successful projects. A review of milestones and outstanding issues leads to a highly motivational "Management by Embarrassment" approach.

An additional key role for the APM is to balance the risk profile of the research against the milestones and project objectives. The APM can rely on the expertise of the project team to provide the necessary input for the decision-making process. The APM then presents the balance to the PIs who must make the final decisions.

At IMSC, we have endeavored to create an entrepreneurial culture whereby new discoveries with commercial potential are protected by provisional patents as soon as possible so as not to impede the flow of knowledge, whether in the form of publications, presentations or even external discussions. To protect company proprietary information, pending publications are reviewed by companies only to ensure that no such information was inadvertently included.

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