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The Remote Classroom – Asynchronous Delivery of Engineering Courses to a Widely Dispersed Student Body

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Introduction

As the world continues to flatten (Friedman, 2005), student demand for significant overseas experiences has intensified. This demand is seen broadly across the nation, but at the United States Military Academy (USMA), it has manifested in the Dean's goal of getting 15% of all students at USMA to spend a semester studying abroad. This translates to roughly 150 students each year—all of whom study in countries corresponding to the seven foreign languages (Chinese, Russian, Arabic, French, Spanish, German, and Portuguese) taught at USMA. A quick search of almost any university's website, large or small, reveals that similar drives towards a broad, internationally-informed education for all students has overtaken the entire higher education enterprise. Additionally, since interaction in a language other than English is strongly preferred and student language proficiencies are highly unpredictable, these semesters abroad are not completely “programmable” across all majors at one university through a direct partnership with a single overseas institution. When combined with state, or in our case federal, mandates for graduation in 8 semesters, these international exchange programs present some unique challenges both in terms of curriculum and delivery of engineering course content.

At USMA, our solution has relied on a two-pronged approach. First, the curricular content of the semester abroad is focused on the liberal arts, which are arguably much better suited to delivery at many different overseas institutions. Second, by offering at least one engineering course via remote, internet-enabled means, we can keep the student on-track for timely graduation within their ABET major. We distinguish between the more traditional *distance learning* as taking place at a known facility at the receiving end and *remote learning* as a highly adaptable, asynchronous educational delivery method that is focused on effectively delivering content to a single student at an unknown location assuming only a rudimentary, intermittent internet connection. This paper will address specifically remote learning.

This paper explores results and observations based on two principal methods of delivering engineering courses via remote learning--low-overhead and high-overhead. In the low-overhead mode, we taught Mechanics of Materials to a student in central France through the use of simple internet technologies and a webcam, allowing the student to view lectures (though not live) and interact directly with the professor live over the internet through text-based chat (AIM) and live video “telephone” (Skype). The principal methods for evaluating student work were an occasional electronic submission of worked problems and a final exam administered after the student's return. In the high-overhead mode, four students took Introduction to Engineering Mechanics and Design, a combined statics and mechanics of materials course, during the same semester while in Russia, China and Brazil. This version of remote learning was enabled by extensive use of interactive Flash media content, frequent direct feedback to students based on the weekly submission of worked problems and daily responses to lesson-specific “critical

thinking questions,” ungraded midterms packaged as self-evaluations, and a final exam administered upon the student’s return from abroad. It is noteworthy that both modes, though differing significantly in their demands on faculty time, were offered at essentially zero cost in hardware and software, and with no supplemental technical support. This is possible using current technology, and it is anticipated that these technologies will only improve and become more widely available in the future. The two methods and the general challenges and some solutions to the remote learning problem are addressed, and recommendations are made concerning the use of these methods in the future.

Background

This paper draws a perhaps new distinction between two types of non-resident courses taught by a student’s home institution. The first type, distance learning, is well known. While many definitions of distance learning exist, for the purposes of this paper it will be defined as instruction provided by an institution to non-resident students who are receiving content electronically at a known location in a synchronous fashion. For example, in the most common application, they are at a remote location watching the professor live on TV, often supported by a two-way voice link (and sometimes two-way video) which allows them to ask the instructor direct questions during the presentation. Remote learning, on the other hand, involves a student taking a course asynchronously at an unknown location, relying on a catch-as-catch can internet or other connection. In the case of remote learning, the connectivity and timing of the student’s educational experience are not well-known at the outset, but the student is far less constrained in terms of showing up at a particular location on a particular day to receive the content.

While many universities have a long history of both overseas extension and distance learning, USMA had little or no experience with either prior to the beginning of this project. Some limited semester-abroad programs had been undertaken previously on an individual basis, but no engineering students were included in any of these efforts. Further, while distance learning is well known to the Army at large, with large-scale projects like Army Knowledge On-Line being fairly common, USMA had not previously offered any courses to students not present on campus. In that sense, to the best of the authors’ knowledge, the offering of CE364, Mechanics of Materials, was unique. This is strange, especially given the Army’s tradition of embracing distance learning, but doubly so when one considers that the entire engineering portion of the student’s training is compressed into 5 semesters, with a direct mandate that the students graduate in 47 months. Adding a semester onto the end is not an option. With this in mind, one would think that the demand for make-up and fill-the-gap courses via distance learning would be very strong. One can only conclude that previous experiments in distance learning had not been attempted due to matters of institutional culture rather than necessity or demand. This conclusion is supported by the fact that demand for remote courses at the institution is now very strong.

The Cheap Route – Webcams and FTP sites

The first remote course offered at USMA was in the fall of 2005 and was, surprisingly, an engineering course; CE364, Mechanics of Materials, which covers somewhat advanced engineering mechanics, failure mechanisms, an introduction to material science and combined

loading. This course is significantly different from the traditional introductory mechanics course that had been taught in the past; in fact, the course was being offered for the first time in its' new format during the semester in question. Further, since the course was being given to a single student studying at St Cyr in France, the instructor (Dr Klosky) saw little purpose in involving the entire institution in the decision process or the design of the course, and obtained direct approval from the department head to conduct what everyone saw as a teaching experiment or proof of concept.

The first key decision was "What is the objective of the educational experience we hope to provide?". This decision was driven principally by equivalency concerns, since the course was to be listed in the student's transcript as if the course were taken at USMA. Thus, it was decided that the content and workload must be similar to that of the students at the home institution. The laboratory component posed a problem, but it was judged that the lab load was relatively light, with only 4 laboratory periods (one of which was principally a demonstration), and could thus be waived. Further, the principle laboratory experience for the student within the major would come in the follow-on semesters.

The second driving decision was "How will we evaluate the student's work?". This was a particular problem at USMA, since the institutional focus on honorable behavior is considerable. After considerable deliberation, the independent-study grading model was adopted, with the modification that the student would face the same final exam as his peers, and that the score on that final would be a major factor in determining the final grade. This philosophy of evaluation can be summarized as flexible but verifiable. It was particularly important that the grading and evaluation scheme be relatively "bulletproof", given that this was a test case and might draw considerable scrutiny from unforeseen persons or organizations. The shared closely-proctored final exam administered at the home institution upon return was judged to be fair, illustrative of the student's level of achievement, and scholastically defensible.

Evaluation of the student's work was also provided throughout the semester as the student worked the same homework problems as his peers at the home institution. This key feedback mechanism provided a number of essential educational elements;

- By turning in regular homework, the student was kept on-track for timely completion of the course, and the instructor was able to track that progress.
- Sharing common submissions with the rest of the course kept the workload on the instructor at a reasonable level, and added authenticity to the efforts of the overseas student.
- Through careful evaluation and feedback, the instructor was able to give the remote student a critical check on progress; the student almost always knew where he stood compared to his peers and the instructor's expectations.
- The submission allowed the instructor to form a clear impression of the student's level of effort and the quality of the student's work; necessary elements in assigning a final grade.

Critically, by making homework submissions the backbone of the student's efforts, the timing of the student's progress was decoupled from that of the home institution, providing for the

necessarily *asynchronous* nature of the course. That is, the academic schedules and time expectations of the two participating institutions were quite different, so the content and work products could not be in-step with the main body of the course being offered at the home institution. This absolutely mandated the adoption of a remote learning approach as opposed to a distance learning approach, with the content available at any time and the submission of work products occurring according to an agreed upon but highly flexible schedule.

Mid-term exams were also used as an evaluation tool. Rather than taking these exams for a straight grade, the student was asked to take the tests (2) as a self-evaluation event. The student timed his own work and submitted the tests, and they were graded on the same basis as the mid-terms administered at the home institution. The principle difference was that the test grades were not recorded, but simply provided to the remote student to let him know where he stood in comparison to his peers.

Technologically, both the homework and the tests were provided to the student via e-mail in a pdf format. The student then completed the work either on standard green engineering paper using a pencil or using mathematical software (in this case, Mathematica, but MathCAD and MatLab would also have been suitable). Submission of electronic work was simple and accomplished via email, and submission of written work was typically in the form of either pdfs or jpegs, generated by either a scanner or hand-held digital camera. The digital camera worked well, and together with the student's laptop and the remote institution's internet connectivity formed the essential technology needed to support the remote learning experience.

The final key decision to be made was "What is the best way to teach the material to the student?". In this case, given that there was one student, a key factor was cost, both in terms of faculty time and hardware. Further, with essentially no broader institutional support for the effort, the methods had to be easy, available, and familiar to the instructor, who was carrying a full teaching load in addition to the remote course. With this in mind, the following methods and resources were employed:

1. The instructor's notes, already available as formal, well-segmented chunks, or board notes¹, were provided to the student as pdf documents on an ftp site. These documents were typically less than one megabyte each.
2. The instructor carried a laptop and simple webcam into class each lesson and, using Windows Movie Maker, captured a simple wide-angle view of the classroom with sound. No editing of any kind was done, and the video stream was saved at a resolution of about 1MB per minute. This took about 5 to 10 minutes per lesson to set up, save and upload to the ftp site.
3. The instructor was available via AOL's Instant Messenger and Skype, technologies described by Klosky and Klosky (2006)², making it possible to provide the student with instant access to the instructor for questions, clarification and guidance.
4. The student had the course textbook in-hand prior to departure.

The list above is presented in the order of importance of each resource, as judged by the student and the instructor in a post-course assessment interview. In retrospect, the list is not surprising;

student reliance on classroom notes has always been high, and being able to link these notes with the instructor's verbalization provides a key link between the written and visual. Thus, items 1 and 2 formed the backbone of the content. Further, having direct access to the instructor via live chat, voice and video not only provided the student with the many advantages of live instructor access, but also sent the student a clear message about the level of faculty commitment to the process. There are many arguments for and against the use of "instant" instructor access, and these have been addressed by the authors and others in separate papers^{3,4}, and so will not be addressed in detail here.

Though a sample of one student is probably not significant in terms of either student attitudes and learning, it is certainly worth mentioning that the student did well in the course, scoring an 88% on the final exam (about 10% ahead of the course average), and reported being highly pleased with the overall conduct of the course and both his efforts and those of the instructor. More significant, though, was the proof of concept; we now had a workable method for collecting, collating and delivering content, and a plan for evaluating student work. The work was presented as a "mission accomplished" to the administration, and won wide acclaim within the institution despite the lack of initial formal approvals.

The Gold Standard

Emboldened by Klosky's success in offering the CE364 remote learning experience to a single civil engineering major, Ressler developed and taught an introductory engineering course to four non-engineering majors who were studying abroad in three different countries during the fall semester of Academic Year 2006-7. The course was CE300, Introduction to Engineering Mechanics and Design, which covers statics, basic-level mechanics of materials, and an introduction to the engineering design process. CE300 is taken by civil and mechanical engineering majors in the spring semester of their sophomore year and by non-engineering majors in the fall semester of their junior year. The course is not varied between semesters; both student populations take the same course. In the latter case, students take the course as the first in a mandatory three-course core engineering sequence in both civil and mechanical engineering. At USMA, all non-engineering majors are required to take any one of seven such discipline-specific engineering sequences. Thus all four students who enrolled in Ressler's remote learning version of CE300 were non-engineering majors taking their very first engineering course.

These four students were all junior foreign language majors, with grade point averages ranging from 2.9 to 3.7. One of the four had taken remedial math as a freshman, as a result of inadequate mathematics background in high school. The students—two men and two women—would be studying in China (two students, one each at two different institutions), Russia (one student), and Brazil (one student). In all cases, they would be traveling abroad with their own internet-enabled laptop computers. They would be taking a full schedule of courses at their respective host institutions, and all courses would be taught exclusively in the native languages of the host countries. In all cases, the students' principal motivation for enrolling in the remote learning course was to enhance curricular flexibility for their final three semesters of study at West Point. They were, in effect, getting CE300 out of the way to avoid having a large number of mandatory core courses pushed back into their senior year. None of these students took the course because of an interest in engineering.

The development of the remote learning version of CE300 was subject to a number of significant constraints:

- The decision to teach CE300 in a distance education format occurred only two months before the start of the fall semester; thus the time available for course development was very limited.
- Because the Department of Foreign Languages (the proponent for the USMA semester abroad program) had had no previous experience with sending students to these particular institutions, the author received absolutely no reliable information about the internet connectivity, academic schedules, or time demands the students would face at their host institutions.
- The students were located in three different time zones.
- The students were at four different institutions, all of which had significantly different academic calendars and different daily schedules.
- The students had no scanning capability and had little or no proficiency in using computational and computer graphics software.

Given these constraints, the author began by assuming that all students would have internet access, but access might be sporadic and bandwidth might be limited. Thus instruction would need to be primarily asynchronous and would have to be tailored to the individual academic schedules of the four students. Instructional materials would need to be downloadable to the students' computers in a mode that was suitable for subsequent, off-line viewing. Similarly, the students would need to be able to work all homework assignments off-line but then submit the work electronically, as e-mail attachments. The author also assumed that the students would not have access to scanning technology, but that they would be able to create simple drawings using the graphics tools included in Microsoft PowerPoint—a program with which all of the students were both familiar and comfortable. Thus, all quantitative homework would have to be done with a computational software package (e.g., Mathcad or Mathematica), with PowerPoint graphics cut-and-pasted into the homework files as necessary.

With these assumptions and constraints in mind, the author created a simple course website as the principal mechanism for delivering the remote learning edition of CE300.⁵ The website consisted of one page for the course schedule (individualized for each student), one page for course administration, one for all homework assignments, one for additional course resources, and one lesson page for each of 40 lessons. The lesson pages were designed in accordance with the Model for Instructional Design used in the American Society of Civil Engineers (ASCE) ExCEED Teaching Workshops.⁶ Each individual lesson page included the following elements:

- An orientation to the lesson topic, including explanations of (1) why the topic is important and (2) how it relates to previous learning.
- Lesson objectives, formulated in accordance with Bloom's Taxonomy.
- A reading assignment from the course textbook.
- Key definitions for the lesson.
- A multi-media "e-lecture" explaining and illustrating the key concepts from the lesson.
- Worked problem solutions relevant to the lesson.
- Critical thinking questions for the lesson.

- Applications, consisting of homework problems relevant to the lesson.

In developing the e-lectures for each lesson, the author initially chose to use Macromedia Flash as the development tool. Flash is well-suited to this purpose, as it has a powerful array of graphics and animation tools; it allows for close synchronization of animation and an audio narration; and it can be used to create a stand-alone executable multi-media module of reasonably small file size. Unfortunately, creating high-quality Flash presentations is also very time-intensive, and even after attaining a high level of proficiency, the author was still taking approximately four days' discretionary time to create each new lecture. Eventually, at Lesson 8, the students caught up with the instructor, and he had no choice but to switch to a simpler, less time-intensive format for the e-lectures. The revised format consisted of scanned, handwritten "board notes," accompanied by an audio narration in .mp3 format. Board notes are one component of a comprehensive methodology for organizing and delivering classroom instruction, developed for the ASCE ExCEED Teaching Workshop.¹ A set of board notes is simply an accurate, hand-drawn graphical representation of all material—text and graphics—that the instructor plans to write on the chalkboard during a given lesson. This tool was originally developed strictly for the instructor's use—for planning tool and as a "script" to be followed while teaching. Board notes were never intended to be distributed to students. Nonetheless, when accompanied by an audio recording of the instructor's voice explaining their content, board notes proved to be highly effective as a simple instructional medium for students' use in CE300. This method compares with the initial delivery method used in CE364 rather closely, except that it is more suitable to remote education (the audio recordings are far smaller files as compared to full video) and takes slightly more time to prepare, since the audio track was recorded separately rather than as part of a class already being presented.

In addition to the instructional materials developed uniquely for the remote learning version of CE300, the author also used all of the formal graded requirements—homework assignments (problem sets), laboratory exercise, mid-term exams, and final exams—that were being used in the standard version of CE300, which was being taught concurrently to approximately 200 students in a traditional classroom setting.

With these resources available, delivery of the remote learning version of CE300 proceeded as follows:

- Every second day, according to the published course schedule, students were required to (1) study the appropriate lesson web page, (2) read the textbook reading assignment, (3) answer the critical thinking questions for the lesson, (4) send these answers to the instructor in an e-mail message, and (5) do an appropriate portion of the problem set assigned for the associated block of instruction. This procedure ensured that the students stayed engaged with the course and that the instructor would hear from them at least once every other day.
- Approximately once per week, the students were asked to submit complete solutions to an assigned problem set. They were expected to prepare their solutions using Mathcad software, with appropriate graphics (e.g., free body diagrams) created in PowerPoint and copy-pasted into the Mathcad worksheet; and then to e-mail the Mathcad file to the

instructor for grading no later than a specified date.

- The instructor established an America Online Instant Messenger (AIM) account and asked the students to do so as well. Students were encouraged to use AIM to seek help and to obtain responsive, real-time assistance on homework assignments.
- At the one-third and two-thirds points in the semester, the students were provided with the same mid-term examinations that students in the standard version of CE300 had just taken a few days prior. Because of an institutional prohibition on take-home exams, the distance education students were asked to work the exams as homework assignments, rather than as timed tests, and then to submit their work electronically to the instructor for grading.
- To fulfill the requirement for the single course laboratory exercise (a uniaxial tension test of three specimens made of different materials), the students were provided with a digital video file and a PowerPoint presentation illustrating the experimental procedure. They were also provided with an authentic set of raw experimental data and were asked to process the data (e.g., convert load to stress and deformation to strain), construct stress-strain curves, analyze the results, draw conclusions, and write a technical report.
- At the end of the semester, the students returned to West Point and were required to take the same final exam that the students in the standard version of CE300 had taken. The closed-book exam was administered under the instructor's direct supervision and was graded by the instructors from the standard CE300, using exactly the same grading scales as were used for the standard course exam. This procedure for administering the final exam provided a vital quality control check on the remote learning course.

As of this writing, the CE300 remote learning experiment was completed only one week ago, and a detailed comparative analysis of the learning outcomes of the remote learning and standard versions of the course is still underway. Nonetheless, the authors have been able to make a number of important quantitative and qualitative assessments of the experiment:

- Three of the four students completed the course successfully. The fourth student dropped the course six weeks into the semester after having made no progress at all toward course completion. He reported that the challenges of attending his host-institution classes taught entirely in Chinese were overwhelming, and he was unable to devote any significant time to CE300. Of the three successful students, one earned an A+, one earned an A, and one earned a B, according to objective, criterion-referenced grading of all their course submissions, including the final exam, using the same evaluation standards as were used in the standard version of the course.
- The three greatest challenges encountered in this experiment were connectivity, connectivity, and connectivity. None of the three successful students had adequate internet connectivity, and all of their respective challenges were unique. The student in China was able to obtain reasonably high-quality wireless internet access in her apartment; however, soon after her

arrival in China, her access to the course website was apparently blocked by the Chinese authorities. As a result, the instructor had to send her all course materials via a Yahoo e-mail account. (She was prohibited from using her USMA e-mail account because of security concerns.) The student in Russia was only able to access the internet from an internet café near his apartment. His USB “thumb drive” proved to be incompatible with all of the computers at the various internet cafés at the university and in his neighborhood, and so he obtained course materials by downloading them to the internet-connected computer, then transferring them to his iPod, and then finally transferring them from his iPod to his personal laptop computer. The student in Brazil had high-quality wireless internet access at her host institution, but the institution closed after normal business hours and on weekends—the only times when the student was able to spare sufficient time to work on CE300. The only solution to these challenges was to adapt course procedures and scheduled due dates to accommodate the connectivity problems as they developed.

The instructor’s use of Macromedia Flash for e-lectures was initially very effective and well received by the students but, as noted above, proved to be too time-intensive to be sustainable for all 40 lessons of the course.

- The instructor’s attempt to have the students use PowerPoint to create free body diagrams and other engineering graphics was a total failure. Although the students were reasonably familiar with PowerPoint as a presentation tool, they were unable to use it to create anything but the simplest graphics. As non-engineers who had taken no previous engineering courses, their “graphical literacy” was extremely limited. More important, the meticulous process of drawing complex diagrams in a software package that is independent from the computational tool severely limited their ability to understand how graphics should be integrated into engineering problem-solving. After a few unsuccessful attempts, one student asked if he could do his drawings by hand on graph paper and then photograph them with his digital camera for transmission to the instructor. The instructor readily agreed and then suggested the same procedure to the other two students. The results proved to be quite successful, though some manual image processing was usually required to enhance the quality of the students’ digital images.
- The instructor’s attempt to have students do all of their homework in Mathcad proved highly successful for one student and utterly unsuccessful for the other two. At the start of the semester, none of the three students had ever used Mathcad, and so learning the software would need to be done while abroad, in conjunction with the remote learning experience. In the single successful case, the student learned Mathcad very quickly, through the completion of a specially created tutorial, and then used the software with increasing proficiency and efficiency throughout the semester. In one case, the student was never able to complete a successful installation of the software package, as a result of an administrative problem with the software license. In the third case, the student attempted to use Mathcad but struggled with learning the software and the course material simultaneously, without an opportunity to get direct assistance from the instructor. Ultimately, the instructor determined that, in this student’s case, using Mathcad was more distracting than helpful. Both of these latter students were advised to complete their homework solutions by hand and use the newly discovered digital photography method for transmitting their work to the instructor for grading.

- AIM proved to be extraordinarily successful as a tool for facilitating instructor-student interaction, rapport, and student learning. All of the students were initially reluctant to use AIM, as they believed it to be too informal for communication with a professor. Once the instructor demonstrated his willingness to use the tool (by initiating chat sessions with the students), they quickly adopted it. Ultimately, the students conducted a total of 35 AIM conversations with the instructor during the semester. All of these conversations involved requests for assistance on homework problems. They ranged in length from two minutes to one hour. The instructor observed that, because of the real-time nature of instant messaging, some of the most productive learning in the course occurred during these chat sessions.
- Requiring the remote learning students to take the same final exam as students in the standard version of the course proved to be critically important for establishing the legitimacy of the distance education experiment. Because one common, comprehensive measure of student performance was used for both versions of CE300, it was impossible for skeptics to claim that the remote learning course was less rigorous than the standard version or that student learning outcomes would be impaired by the distance education format.
- In an exit interview at the end of the project, all three students reported a very high level of satisfaction with the course. They reported that they found it significantly more challenging than a standard course, primarily because they had no peers with whom they could discuss course material and requirements. Yet, primarily because of this isolation from their peers, all three students expressed considerable pride in having completed the course in an environment of total responsibility for their own learning.
- Ironically, two of the three students reported that they preferred the simpler e-lecture format—board notes and an accompanying audio file—to the more sophisticated Flash e-lectures. From their perspective, the decoupling of the graphical content from the verbal narration allowed them to process the information more flexibly. By having all of the board notes available simultaneously, they could quickly shift from focusing on one specific topic to a broader perspective of how that topic fit into the class as a whole. And the simpler .mp3 audio file could easily be paused, rewound, and repeated when the students did not fully grasp a concept after hearing it the first time.

All in all, the authors judged the CE300 remote learning experiment to be successful, not only because three of the four students completed the course successfully and had very strong positive feedback about the mode of instruction, but also because the authors learned so many valuable lessons from the experience. In retrospect, there is no doubt that the key to success was *adaptability* on the part of both the instructor and the students. Indeed, in a program that seeks to develop adaptability in its graduates, the experience of adapting course procedures, processes, and content to unanticipated and changing circumstances may very well have been the most important learning outcome of the course.

Lessons Learned

The following is a summary of observations and suggestions based on the remote teaching experiences of the authors:

- Remain flexible. Even if you are familiar with distance learning, recall that remote learning requires a different skill set and the ability to adapt teaching and learning methods to match available resources, timelines and student needs is essential.
- The flashiest solution isn't always the best. Methods of presentation and submission that are very familiar to students tend to succeed.
- Be ready to use a variety of communication tools, from digital cameras to chat rooms. Your students are probably very effective electronic communicators; give them room to set the rules and drive the content *delivery* methods.
- Don't compromise on content. It is possible to deliver complex, highly technical information and training to students at remote, somewhat indeterminate locations.
- If someone says "Don't do this" or "It will cost \$100k", don't believe them. It is rewarding, and done creatively can be very inexpensive.
- Know that you cannot predict all the possible barriers or conditions that the student will face in their host county. Barriers will emerge, but with guidance, persistence and determination a good student can overcome most of them.

Conclusions

The programs offered by the department and the institution were significantly enhanced through this exploration of remote learning. After offering two different courses in 4 separate countries, all to students at institutions where the conditions going in were unknown, the authors believe the experiment was a success. The department will continue offering courses in engineering to students at remote locations, and the prospects for doing that effectively and efficiently in the future are excellent.

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