5 MEASURING EARTHQUAKES LIKE ENGINEERS

The technoscientists whose work I describe in this book share broad understandings of Mexican seismic phenomena. Their descriptions of where seismicity originates, why Mexico City is so sensitive to it, and how earthquakes endanger human beings are generally very similar. Some people with whom I worked most closely, however, took care to articulate significant distinctions between different technoscientific approaches to intervening in life with earthquakes. Dr. Edmundo López, a senior member of the CIRES community who was responsible for many day-to-day operations, made this very clear when I asked him to explain the system. The important thing, he said, pushing his big glasses up his nose, was that engineers had developed Mexico's public earthquake early warning system, not scientists.

López did not constrain himself to communicating with words. Instead, he pressed his hands to the wall of a CIRES office theatrically to show me what he meant. "Look," he said, "I'm measuring like an engineer now."[1] He walked his hands along the wall, lining them up thumb to thumb, little finger to little finger, until he had moved along the whole length of the wall between an overcrowded pasteboard bookshelf and the copier, miming measurement with his hands alone. "And now," he said, "I'm measuring like a scientist."[2] On the word "scientist," he changed his whole bodily orientation toward the space, getting up close to the wall to mime micro-measurements, now referencing an imaginary ruler instead of a handspan.

López had traveled a great deal in his life, earning one of his degrees in Mexico and another in Canada before returning to a long career in various projects around Mexico. He knew a few things about communication and put effort into making this point clear. His voice filled up the small space, drowning out the ordinary office sounds. “Engineers do not want magnitude data,” López told me. “They want to know if people should run.” These professional interests had consequences for how the engineers at CIRES designed Mexico’s earthquake early warning system, and the new ways they made it possible to experience earthquakes. Scientists want to know the size of an earthquake; they want devices to produce the most accurate and detailed information as possible, he explained. But that was not the kind of work that López and the rest of the CIRES team thought an earthquake early warning system should be doing.

López’s way of thinking about all the choices that went into designing and maintaining an earthquake early warning system suggested how disciplinary strategies might shape the approaches to risk mitigation. The way he explained it, engineers measure earthquakes and communicate about them to people at risk in a very distinctive way—reflecting values and priorities related to their profession. In CIRES’s headquarters, he was not the only person who told me about what it meant to be an engineer.

What happened at CIRES was engineering, I learned, in orientation as well as activity.[3] Certainly, some people working at the NGO designed and crafted circuit boards in carefully maintained spaces. Some visited equipment in the field and brought back damaged material for their colleagues to fix. These kinds of tasks are often associated with engineering—hands-on, mathematics-heavy work. Other people at CIRES did the kind of project management and communication work that is a necessary part of engineering but often considered a little less technical in nature.[4] So far, so ordinary. But people at CIRES also developed novel approaches to earthquake assessment that in other places might be considered scientific research. I understood from López that this was engineering, too, because of the kinds of priorities and commitments that people involved demonstrated. Further, while many people employed by CIRES had some training in electrical or communications engineering, others who were necessary to the organization’s engineering endeavors held degrees in mathematics, law, graphic design, computer science, and geophysics. Some were called technicians, administrators, or designers. They may or may not have been doing engineering themselves, but they were all part of an engineering project.

The distinctive aspects of engineering projects stood out when they were contrasted to other kinds of work—specifically, to scientific undertakings. López's colleague Antonio Duran explained that members of the CIRES team were not the only people who thought that the difference between their engineering work and science was meaningful. Duran told me that the difference mattered when CIRES insights and projects were presented to the broader community interested in seismology and risk mitigation technology. He thought that the CIRES team's work was significantly undervalued precisely because of its use of engineering approaches. He compared CIRES to a donkey playing the flute. "No one notices that he plays very well," he told me. "They're surprised that he does it at all."[5] Duran's reflections complicated López's points. While CIRES engineers did sophisticated analysis and developed novel technologies to encourage people to run, Duran explained that this meant that their work was not as appreciated as it might be if they were developing scientific theory.

The fact that the CIRES team saw SASMEX as an engineering project and not a scientific endeavor played out in how they talked about earthquakes, communities at risk, and the particular possibilities that people discussed in relation to the earthquake early warning system. This was not merely a matter of focusing primarily on building and operating instruments rather than performing elaborate analyses on the data that this technology produced. It was also a matter of working with people who did not share their engineering orientation and thought about risk mitigation very differently than they did. López, Duran, and others taught me to see SASMEX as an engineer's technology. They showed me how engineering worked as an important conceptual resource both within CIRES and in relation to competing perspectives in the wider world.

In this chapter, I show how the CIRES team has relied on disciplinary strategies of engineering to frame how they address not just technology, but also environmental and social conditions.[6] When they work on SASMEX, they encounter, explore, and reflect on the physical threat of earthquakes for Mexicans.[7] They use engineering ideas to take on opportunities for technoscientific risk mitigation. I follow the CIRES team's lead to show how engineering approaches happen in context. This means exploring how the CIRES team's engineering approaches to earthquake risk mitigation should be understood in relation to earthquake hazards and scientific approaches to the same issues.

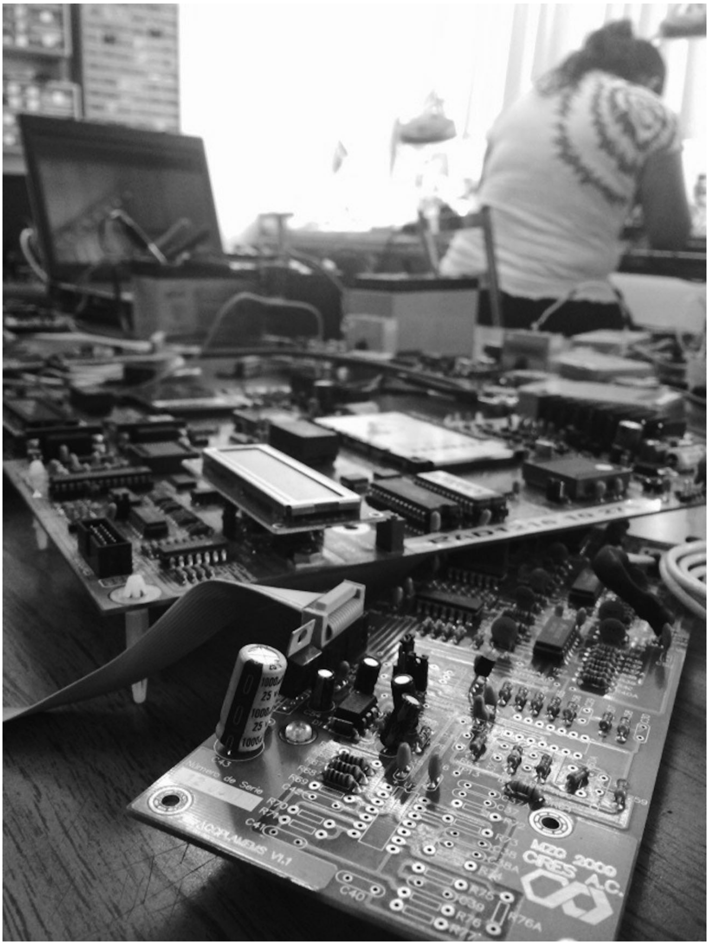

FIGURE 5.1
A technician at work in CIRES's offices. *Source*: Author (2014).

I describe how form of expertise matters for technical choices and goals related to SASMEX. I use López's explanations of what it means to measure "like an engineer" and "like a scientist," and Duran's reflections about the respect that engineering excellence fails to garner as jumping-off points to consider engineering in the context of what engineering studies scholar Atsushi Akera has called an ecology of knowledge.[8] Starting here, I can consider how engineering identity has implications for the way the CIRES team consider hazardous environments and people at risk when they make technical decisions.

ENGINEERING IDENTITIES IN PLACE

It is unsurprising that engineering logics inform SASMEX when so many of CIRES's leaders hold engineering degrees.[9] However, when I visited in 2013 and 2014, only some of the seventy-four people working at CIRES had completed training as engineers, primarily in electrical engineering or communications-related fields.[10] Of those who were not engineers, many were designated technicians and were in the process of pursuing an engineering degree. Others, including several senior consultants, had the kind of advanced degrees and academic appointments in sciences that they could have drawn on to identify as scientists, if they chose to. López was one of these. His first degree was in civil engineering and then he pursued a PhD in seismology in the United States during the mid-1980s. After a career in the petroleum industry, López had returned to work with old friends and colleagues at CIRES, where he described his work definitively as engineering.

When López and his colleagues spoke about SASMEX as an engineering project, they showcased the importance of engineering perspectives on hazardous environments, people at risk, and technologies for risk mitigation efforts. As common as the term "engineering" may be, however, what they meant by it is not necessarily obvious. Engineering identities have been a topic of some interest in engineering studies scholarship. Identities are both deeply personal and social things; and while the ways people feel and perform a given identity may vary tremendously, they are also patterned by shared experiences, circumstances, and histories.[11] Considering engineering identity in national context helps surface the particular elements of professional identity at play in López and his colleagues' risk mitigation efforts. Doing so frames their work in relation to relevant historic and contemporary politics of technoscientific practice, which may be different than those that readers assume.[12] For example, while historians have shown how engineering disciplines have developed in relation to configurations of capital and militarism in the United States,[13] drivers have taken different forms in Mexico. Historians of Mexican engineering and science instead highlight the ways that colonial interests, followed by the needs of an independent state in formation, have shaped engineering and science disciplines with attention to mining and petroleum industries as well as national development programs.[14]

As I emphasize this, I echo the many people I interviewed for this research who would not let me forget the differences between Mexico and the United States, the nation in which I was born and educated. It is true that schools in Mexico City were granting degrees while wild animals were still roaming the grounds that Harvard would be built upon. Mexico City was already an important site in New Spanish intellectual geography just decades after conquest. The European-style institutions of higher education founded under colonial rule were among the first in New Spain, cropping up as early as the mid-sixteenth century. The schools trained students in Catholic values and "useful arts,"[15] both strongly determined by the priorities of colonial elites.

The technical training fostered in New Spain focused on mining to support the extension of the Spanish empire and pay for its wars. The interests of the mining industry were more integrated into programs of higher education in New Spain than they were in much of Europe. Historians note, however, that the pedagogy that engineers and scientists of New Spain received in these programs was considered cutting-edge—simply applied, usually to mining.[16] This interest in certain particular "useful arts" that informed early Mexican engineering and science education left its mark on institutions, even as the nature of technical education changed. Technical education remained a national priority, though it was consolidated and funded in new ways after Mexican independence. During Porfirio Díaz's rule (1876–1880 and 1884–1911), industrialization started in earnest, and engineers remained in high demand. Simultaneously, because of resources mobilized by the state, education had more independence from industry. Development efforts involved engineers in post-revolutionary projects to build a modernized, independent nation.[17] In the nineteenth century, education became more accessible to the Mexican public at large. An 1857 reform made primary education both free and mandatory. The first university in North America and one of the first in New Spain was given the explicit charge of supporting both research and lay knowledge at the university level, changing its name from the Royal and Pontifical University to the National Autonomous University of Mexico, or UNAM. Founders prioritized developing a school of engineering, making it among the first offerings available in Mexican public higher education. While UNAM valued research, they housed faculty who undertook it in different university organizations (and sometimes different buildings) than those who taught professionals-to-be. There was also markedly less recognition and fewer resources available for careers in disciplines identified as science rather than engineering.[18]

While state priorities have shaped engineering training and professional practice, Mexican engineers have also had a tremendous influence on Mexican policy and research programs. Engineers from elite families like Nabor Carrillo Flores[19] and Emilio Rosenblueth[20] took on prominent roles in national and international policy in the twentieth century, as well as in their own engineering projects. They facilitated development of new institutions and fields of research in Mexico, commented on public life, and represented the nation on the international stage.

Today, engineering offers a pathway to reliable professional success, with a respectable income, for Mexico's growing middle class.[21] Perhaps this explains why engineering disciplines are attracting attention from students, capturing nearly 30 percent of those entering professional degree programs in 2011, the year I began my fieldwork in Mexico in earnest.[22] Although the career is growing, there is some concern in places like Mexico's National Engineering Institute about the quality of education being provided as training options proliferate in popular schools.[23] Even as the ranks of engineers grow, the profession retains some elite standing. It is not uncommon for Mexican politicians to earn an engineering degree before pursuing elected office.[24] The story of López's professional life—his early training in Mexico that focused on engineering, his studies abroad during Mexico's economic crisis, his subsequent work in the petroleum industry, and his return to collaborate with former classmates in his role at CIRES—all happened in the context of Mexican history. He and his colleagues did not explicitly describe engineering as the product of large-scale historical forces, however. Instead, they told me about everyday work, particularly related to designing technologies in relation to predetermined goals.

When López told me that engineers "want to know if people should run" instead of collecting information about earthquake magnitude, he was talking about engineering as a practice that concerns itself with solving urgent problems rather than producing new, theoretically robust ideas to contribute to a body of scientific knowledge. He was talking, further, about a profession that emerged in Mexico with a long-term emphasis on direct utility for addressing a given problem, for developing the nation, and for the well-being of engineers themselves. López's proud emphasis on the basic importance of determining what people should do in the seconds before an earthquake had implications for more than the application of his work, though. It influenced the way he and his colleagues understood hazardous environments, with the consequences of this information built into both the design and function of CIRES's earthquake early warning system.

HOW ENGINEERS MEASURE

Throughout this book, I have used "technoscience" and "technoscientific expert" to describe a variety of practices and people. These terms remind us that engineering and scientific objects and activities, diverse as they may be, have a great deal in common, particularly because they are inextricably embedded in the broader social and material systems in which they are produced, practiced, invented, or used.[25] While analyzing "technoscience" as a single set of ideas and practices can offer powerful insights about the world we live in and how we understand it, there is also a lot to be gained from considering how technoscientific practices form in relationship to each other. In this case, that means grappling with the implications of engineering identity and practice at CIRES, where people told me in no uncertain terms that there is more than one correct technoscientific way of understanding earthquakes, and that while the way you choose to do so is related to your disciplinary identity, your training does not alone determine how you approach a problem like earthquake early warning.

Although López holds a PhD in the science of seismology, for example, he was quite clear that in his work at CIRES his orientation toward practical knowledge and a certain form of problem-solving meant that he was working on an engineering project. Others at CIRES told me similar things—that their work was engineering, developed in light of engineering priorities, regardless of the degrees held by those involved. The identification-by-behavior went both ways. They were also comfortable telling me that people with degrees in engineering, or even in positions as engineering professors, were acting like scientists rather than engineers.

CIRES made it evident that López and his colleagues were using the same kind of careful calculation—and sometimes the same kinds of tools—that I might find in a scientific lab. SASMEX relied on equipment that they carefully maintained and updated with well-thought-out expansions. The distinctions they were making between engineering and science had to do not with tools or techniques, but with orientations toward their work and toward earthquakes themselves. I had certainly encountered efforts to distinguish between engineering and science that painted the former as a straightforward outgrowth or implementation of the latter's principles.[26] Such descriptions are reductionist and do not take engineers and engineering practice itself seriously. Engineering and scientific practices may adhere to their own social and epistemic frameworks—defining what is appropriate to do and know in distinct ways—in relation to disciplinarily relevant projects. They have their own histories and ongoing relationships within systems of industrial, state, and academic power. They feature differently in public imaginaries. Engineers and scientists in Mexico's earthquake risk mitigation community, however, also share tools, ideas, and experiences, necessarily affecting each other's work practices in the process. The distinction that López was making was happening not in the context of siloed disciplines but instead in relation to work in which both engineers and scientists were deeply involved.

In an attempt to understand this relationship better, I asked Mexican technoscientists in risk mitigation spaces—that is, scientists and engineers both—about the two fields. A technician in CIRES walked me through distinctions as we sat at a bench strewn with colorful wires where he repaired circuit boards that had been brought back broken from seismic field stations across Mexico. His colleagues moved in the background, going about their own tasks, while he explained a sort of intellectual hierarchy. Engineers were not on top; scientists were. Scientists, he explained, were intellectually powerful. They developed innovations and theories to help us understand the world in new ways. "Einstein," he remarked, "was a scientist." Engineers, on the other hand, developed practical tools. Technicians, he added, are the people who do the work. As Jacqueline Fortes and Larissa Adler Lomnitz pointed out in their study on the formation of Mexican scientific identities in the 1970s, Latin American institutions have been slow to develop scientific training compared to engineering. While science is respected, it may still be easier for some to think of it as a foreign project rather than a Mexican one.[27] Many of the engineers and scientists I spoke with were more comfortable with a definition of "scientist" that could be an ordinary job undertaken by Mexicans. They did, however, emphasize the difference between making work relevant in terms of explanatory theory or direct practice. Some went so far as to compare the two approaches with jokes that illuminated, if nothing else, more of the key ideas that people used to understand engineering and science.[28] One engineer wrote an explanation out for me on a napkin over lunch that a scientist echoed in his office during an interview—engineering was science plus common sense. It became a simple addition problem: E= S+CS. Alternately, engineering, without common sense, was science: E-CS=S.

Here, "common sense" referred to trained orientations toward the practical—certain ways of understanding how work relates to, and fits within, other systems and conditions. While scientists might develop new knowledge about vast geological systems, their theories were without "common sense" if they could not be directly applied in practice (ideally at low cost). Scientists were interested in making the best possible choices in accordance with current scientific knowledge, with little interest in the practical limitations or choices that would deliver "good enough" results. Meanwhile, while engineers might work in technologies, they did not focus their energies on conceptual exploration. The "common sense" of engineering is often integrated into social and economic systems in highly conservative ways that have inspired significant critique. STS scholar Gary Downey has described the production of this common sense as a matter of defining issues into, and out of, engineering problems. Through this process, certain forces or circumstances become available for potential intervention and transformation, and others are simply taken as given conditions in the world.[29]

DEVELOPING AN EARTHQUAKE EARLY WARNING SYSTEM LIKE ENGINEERS

López explained that measuring "like engineers" informed the whole earthquake early warning system, and this approach had been integral to the technology's design since its inception. It was an engineering system from algorithm development processes to the choices to prioritize speedy processing over accuracy. López's explanations put the descriptions of measurement and analysis that I had encountered in text, meetings, and laboratory tours in context. His comments helped me understand debates between CIRES engineers and other technoscientists over how seismicity should be measured.

Earthquakes and their effects for humans and environments may be rendered in many ways. I have described some in the preceding chapters: earthquake intensity, which describes effects experienced on a given site; acceleration, which is related to how an earthquake moves a building or the ground; and earthquake magnitude, which calculates the total energy that a rupture releases. All of these measures differ significantly with respect to what they assess and communicate. The distinction that CIRES team members like López made around measurement is a bit more nuanced. They were not drawing attention to what was measured, but instead to how that measurement was treated. Whether the seismic measurements in question are produced by observation, accelerometers, or seismometers, data can be parsed and used with more or less detail. What López calls "measuring like an engineer" is a matter of making assessments about what data should be used for, and decisions about tools and analysis processes in light of those assessments.

Anthropological work on quantification helps make sense of what López and his colleagues are doing when they associate their data decisions with their disciplinary identities. When anthropologist Helen Verran writes about quantification as a matter of "materialized relations," she draws attention to exactly the kind of situation that López and other engineers outline. Strategies for measuring and making sense of the world affirm certain priorities or commitments.[30] López's distinction between engineer and scientist was exactly this: a matter of orientation toward a problem related to how knowledge about seismicity might be used. The ways that they chose to measure earthquakes, and how they assess approaches for doing so, are related to how they understand their work in relation to the environment, society, and technology—and, at this particular moment in Mexican history, to science and scientists.[31]

Engineers designed SASMEX to collect data from accelerometers in field stations. They have often chosen accelerometers with as low resolution as is practical for the sites in which they measure seismicity. This is a cost reduction strategy sometimes, but more importantly, it is a means of limiting data processing time by collecting no more data than necessary. They analyze these data with algorithms built into computers at field stations. Based on the data collected in the first seconds of an earthquake, the algorithm distinguishes between earthquakes that are likely to be insignificant to user communities and those likely to be felt. If multiple stations detect an earthquake they deem likely to be meaningful to a user community, they transmit a message by radio relay network to a central server, which triggers broadcast warnings that then go out to dedicated radios, public radio and television stations, and, in recent years, by loudspeakers and smartphone apps.

No part of this system prioritizes producing or communicating data that local geophysicists would find useful in their own careful research. CIRES engineers preferred low-resolution accelerometric sensors that do not pick up more than the seismic information in which they are interested. The algorithms that they developed prioritize speed in data analysis over detail, and the system's public communication is a matter of simple howling alerts that convey the bare minimum information to those who might hear it—enough to indicate that an earthquake was approaching but no detail about its likely source or magnitude. Throughout the system, the engineers who designed it chose to prioritize speed of transmission (giving people more time to run, in López's words) over all other concerns, including producing detailed analyses of the earthquakes that their instruments detected. This at once provides an orienting principle to build around and demonstrates CIRES engineers' approach to making knowledge about earthquakes for publics at risk. For them, information about what the experience of the earthquake will be like is not as important to communicate as the simple fact of an oncoming quake.

This engineering approach started with SAS's very first algorithm, which allowed engineers to use accelerometric data from the first few seconds of earthquakes to distinguish between those likely to be small, of moderate size, or quite large. The algorithm was developed in the late 1980s by director Juan Manuel Espinosa Aranda (not insignificantly referred to by his employees as *El Ingeniero*, "the Engineer"). The method he used to create and refine it was unlike any kind of operation scientists might have used. Not only did the algorithm not produce detailed data about the size of the quake to come, but it was made without investment in a key scientific pursuit. This first algorithm, López told me, was developed without any explicit reference to theory. As he explained, "theory" means attempts at explanation in light of generalizable laws. Theories account for why a phenomenon happens, or a relationship emerges, in the broader context of an ordered universe that scientists are working to understand better. López, with a long career behind him, understood theory to be essential to good science.[32] Scientists might have developed algorithms based on significant amounts of data and made efforts to explain why the trends that they were identifying emerged. Engineers, on the other hand, could work with much less. The algorithm designed by engineers distinguished between earthquakes based only on data from their first seconds and included no reference to universal rules.

Espinosa Aranda began to play with these data in the late 1980s. He had a degree in electrical engineering and experience working with an earthquake sensory system for UNAM's Engineering Institute. He and his team worked from the evidence they already had to develop a mode of distinguishing between the small, medium, and large quakes that the coast could produce (see figure 5.2).[33] They did not possess a great deal of data on which to draw, maybe as few as one hundred readings from the same place, many of which they had to discard. Ultimately, they did the job with just fourteen earthquake readings.

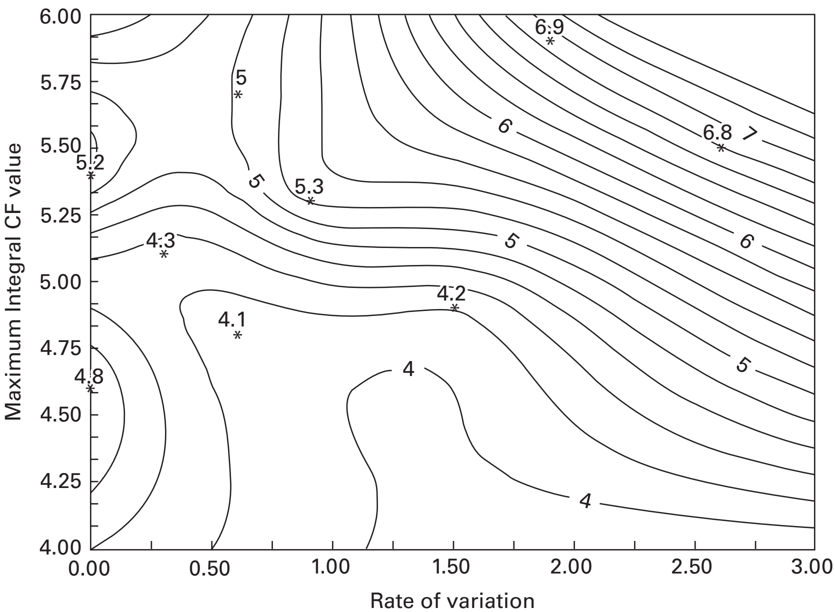

FIGURE 5.2
Magnitude calibration curves, in which magnitude is plotted against rate of variation and maximum integral characteristic function (CF). The lines designated 5 or larger are trigger criteria for SASMEX alerts. *Source*: Espinosa Aranda et al. (2000).[34]

Antonio Duran talked me through this process, explaining choices. This data set was much smaller than one that scientists might have used, but, as Duran explained, it is a very typical engineering strategy to make careful choices about data and sample some rather than analyzing it all. Using data from those fourteen quakes, engineers were able to find patterns and establish the kinds of relational rules that they could build into a circuit board: If the energy of the P wave and S wave relate as *so*, trigger an alert. If the energy of the P wave and S wave do *this* instead, do not.[35] The algorithm worked, though it took over ten seconds to produce a decision about what size the earthquake it was analyzing would probably be.[36]

As the people working at CIRES today explain, it was a sensible thing to build the system like engineers: to select sensors and develop algorithms around the needs of their project, not in light of broader knowledge. There are, however, other ways to approach earthquake early warning that respond to earthquakes not as phenomena to be better understood, but as conditions with which to scale their encounters and navigate carefully and pragmatically.[37] In other words, these engineers were orienting to earthquakes—and consequently the work of earthquake early warning—in entirely different ways than their scientific counterparts. The kinds of early warnings that engineers and scientists might produce were distinct, signaling divergent ways of engaging with threatening environments, data, technical tools, and design constraints and opportunities.

SCIENTIFIC KNOWLEDGE, ENGINEERING KNOWLEDGE

When López and his colleagues contrasted their work with "science," they were invoking an alternative vision of earthquake early warning. The CIRES team had ideas about what forms SASMEX could have taken. They could have chosen other accelerometers and arrayed them in alternate patterns across Mexico. They could have developed another kind of algorithmic analysis. This would have made, or would make, earthquakes understandable in other ways in light of differing social identities and commitments.

All the choices that CIRES engineers have made are up for debate, critique, and refinement. This is as true within the CIRES laboratories, as engineers investigate new strategies and tools that could be integrated into system components, as it is beyond CIRES's doors.[38] CIRES engineers, after all, were not the only people concerned with SASMEX and how it worked.

Emergency managers, policy makers, entrepreneurs, and scientists often had informed opinions about what might constitute an effective earthquake early warning system, though they were guided by their own disciplinary priorities. These stakeholders might articulate these interests in the context of policy spaces or in shared research communities.

We often understand engineers in relation to their ongoing, everyday practices with technologies. These practices are sometimes more or less emergent and improvisational, but they often have to do with design, use, or repair.[39] Engineering is thus often a matter of intimate encounters with technological objects. This is certainly evident in how people at CIRES explained their status as engineers. It is important to consider, however, how exactly, in López's words, "measuring like engineers" becomes a matter of knowing "if people should run," and that both technical problems at hand and the articulation of utility could be understood in alternate ways by people with disparate ideas about what knowledge is useful. Indeed, in their work on scientific identity in Mexico, Fortes and Lomnitz examine the role that ideologies about knowledge and its utility play for scientists in formation.[40] Indeed, in one controversy about how best to organize an earthquake early warning system, the kinds of knowledge a system produces and what information does for people at risk were crucial elements about which engineers and scientists disagreed.

While the debate I refer to manifested in many sites, one article provides an excellent overview. In 2007, five researchers published an article pointedly titled "The Seismic Alert System for Mexico City: An Evaluation of Its Performance and a Strategy for Its Improvement."[41] In it, they explored another way that SASMEX could work. With algorithms designed around alternate priorities and stations repositioned, their suggestions incorporated alternate principles than the engineers' designs. The article was published in the *Bulletin of the Seismological Society of America*, a well-respected English-language publication that circulates both scientists' and engineers' writing. The authors' analysis of the strengths and weaknesses of the current earthquake early warning system revealed scientific priorities, CIRES team members told me, despite the fact that several held PhDs in engineering and were employed at UNAM's prestigious Institute of Engineering.

The authors advanced two critiques of the earthquake early warning system as it stood: first, the system covered only part of the region where damaging earthquakes could originate; and second, the data analysis strategies did not produce strictly accurate results. They proposed more sensors—a suggestion that CIRES engineers could get behind—as well as a wholly distinct calculative strategy that they were more hesitant about. The strategy would produce more accurate assessments of earthquakes but would take longer to do so. It would leave a smaller window in which people could take action between a warning and an earthquake than the one CIRES engineers had built.[42] The argument in support of this latter suggestion reveals a great deal about measuring like an engineer and how scientists and other critics might perceive these efforts. In the paper, the authors compared records of SASMEX's alerts against magnitude assessments generated by geophysicists. The researchers used data related to the fifty-seven earthquakes for which the system had issued alerts over its thirteen years of operation. They found that forty-two of those quakes were not, in the end, measured at the magnitude that the algorithm had indicated. In fact, the researchers found that SASMEX's algorithm commonly issued alerts—or as they put it, "false alarms"—for earthquakes that fell beneath the rough cutoff that the engineers had designated for "moderate" quakes (greater than or equal to magnitude 5 and less than 6, and subject to a "restricted" warning dissemination in schools and emergency services agencies) and "large" quakes (greater than or equal to magnitude 6, and disseminated widely). It was, the scientists wrote, a matter of "poor performance."[43] The "failure and false alert rate is high."[44]

CIRES engineers, on the other hand, analyzed these data differently, reporting only one missed event and one false alert during the time under consideration.[45] From the engineers' perspective, the system had functioned largely as expected. Indeed, when I brought this paper up with López and others, this is what they told me. Despite some coauthors' positions in the prestigious Engineering Institute at the UNAM, the engineers at CIRES dismissed them as scientists, regardless of their disciplinary training. The system that the CIRES team had designed could operate quickly, producing information that might better be rendered as "likely to be something like a magnitude 5 earthquake" rather than "a magnitude 5 earthquake." People had time to run, and from the engineers' perspective, the precise magnitude of the earthquakes involved was beside the point. The scientists did not understand these priorities. López never said that they lacked common sense, but in his broad dismissal of the critique, it was heavily implied.

Table 5.1
The early warning system's accuracy between August 1991 and July 2004. True magnitude refers to Harvard CMT or report from Mexican Seismological Service.

Type of Alert Issued	Magnitude Estimated by the SAS that Formed the Basis of the Alert	No. of Alerts Issued	"True" Magnitude Distribution of the Events		
			$4 \leq M < 5$	$5 \leq M < 6$	$M \geq 6$
Restricted	$5 \leq M < 6$	46	27	12	7
Public	$M \geq 6$	11	4	4	3

Source: Iglesias et al. (2007).

Both explanations of the system's function are, in their own way, entirely correct; either model for system design might well work. Where the scientists and engineers diverge is in the level of accuracy that they think is appropriate for producing warnings and the size of the system that they consider necessary for the project of early warning. The CIRES team is not unhappy with their system. However, when the seismic motion for a particular event was eventually established as magnitude 4.8 and SASMEX issued an alert indicating that it was "likely to be something like a magnitude 5 earthquake," it opened space for debate about the system's efficacy.

It was not the only debate that CIRES engineers had with scientists. López and other engineers described presenting findings at geophysical conferences and having their work critiqued on grounds that they found inappropriate. The CIRES engineers were interlopers in scientific space, without theory, without accuracy. Their way of understanding earthquakes, while productive and true to their training and commitments, was simply not what the scientists they encountered seemed to require. CIRES engineers wanted to share their findings. They wanted to proceed in a way that was distinct from those that many members of the national and international community working on earthquake early warning favored. Doing so had consequences, though.

These debates over the right way to produce knowledge about earthquakes could have effects on their system's reputation. When scientists are addressing algorithmic functions and questions of alerting communication, they sometimes use value-laden terms like "failure" and "poor performance." In the institutionally precarious world of earthquake risk mitigation, some engineers voiced concerns that these efforts to assess and govern SASMEX could pose a serious threat to both CIRES's existence and that of public earthquake early warning in Mexico. In policy and scientific circles, reviews can impact the kinds of support that a technology receives. While critiques are always part of technological development, they are particularly fraught in these circumstances. CIRES engineers were concerned not only with pragmatic uses of seismic data but with pragmatic uses of critique—and they suspected their scientific counterparts had very different ideas about both.

When the article described previously was published, SASMEX was the only earthquake early warning system in Mexico, and it operated with tenuous public support. At the time, there were no backups if state sponsors decided to defund the system. Without the broad mandate for earthquake risk mitigation present in the late 1980s, building a new public system certainly was not an option. There was no easy way to supplant the leadership of an independent NGO like CIRES, and accumulated knowledge related to running such a system could not easily be passed along. More importantly, CIRES engineers were sure that they were right.

In the wake of this article and other critiques, CIRES recruited a scientific advisory board. This strategy allowed the organization to have open discussions about divergent ways that data could be handled and that the technology itself could be interpreted. This board even included some of the paper's authors. Meetings of the scientific board became friendly opportunities for scientists and engineers to share new techniques, discuss priorities, and manage how distinct ways of understanding earthquakes could relate to each other.

Engineers and scientists enacted their identities through their practices like measurement and argumentation and their orientations toward theory and practice. The disciplinary approaches were not wholly incommensurable. They did, however, emerge in the context of divergent work practices and goals, with their own ways of encountering and making sense of seismicity. Naming these orientations helped engineers at CIRES understand their system as it could have been as well as how they would prefer it not to be. It helped them consider their work and their priorities, not just as "common sense" but as a matter of particular ways of approaching earthquakes that were distinct from those that others might develop.

A WORKING ALERT

There are many possible ways to make sense of earthquakes. There are even many strategies for producing seconds of warning before an earthquake reaches a population at risk and many ways to make those seconds valuable. Invoking an opposition between “science” and “engineering” is one of the key ways that various experts in this Mexican technoscientific community parse and choose between multiple, sometimes mutually exclusive, approaches to earthquake early warning and, simultaneously, describe how they see technology and its relationship to environments in which it is embedded and communities it might serve. The stakes are high because early warnings are supposed to protect people. Debates around early warning strategy continue in many forms. They emerge in arguments about whether alerts like the ones I described in the first and second chapters actually “worked” and also in discussions of other early warning systems.[46] As the paper described earlier showcases, though, utility of one approach over another is not always easy to determine even as the distinctions between them are important to their advocates.

A conference held on the thirty-year anniversary of the 1985 earthquake in a new modern conference center on the south side of the UNAM campus was just one more place where people discussed and debated their approaches. The meeting was designed to bring engineers, policy makers, and geophysicists together. For an entire day of the two-day event, the CIRES team sat in a small room with alerting experts including a British entrepreneur, a Japanese engineer, the scientists developing a robust system for earthquake early warning in the United States, and me. Their presentations covered recent developments in their algorithms and data work and shifted between English and Spanish.

These talks were followed by questions about data derived from seismic sensors, strategies for analyzing it, and the applications of these processes, some quite direct but not unusually so for the genre. Had this kind of data been considered? Or another? Why was such a calculation necessary? In the day’s conversation, sensory data and its analysis were topics of presentations. There was no other place in the conference for discussion of the issues that concern me here: the bigger-picture goals of a such a system or its use. These were rolled up into the discussion time scheduled after presentations.

Discussions about data became, inexorably, frank discussions about priorities. Dr. López, as he was wont to do, was clear. He used English, so that the people in the room who did not speak Spanish would understand him as he explained that the Mexican system was unlike their similar, still-nascent system ShakeAlert, which had largely been developed at Berkeley and CalTech and was closely integrated into ongoing scientific research. SASMEX was a matter of engineering. He told the room in his usual booming voice: "It's not very accurate. We know. Everybody knows!"[47] If people were going to ask questions about the system and how it worked, they needed to start there and see its limitations as the product of certain priorities, politics, and capabilities of pursuing some opportunities and not others.

López's efforts to explain SASMEX highlighted contrasts between the extant system and visions of critics or projects that foreigners were in the process of developing—and the ways that engineering identities are mobilized in context. His explanation of the system and its goals offered excellent insight into how he and his colleagues consider their engineering identities while attempting to change how Mexicans live with earthquakes. As I discuss in the next chapter, though, CIRES technologies can frame transformative encounters with Mexican environments and society in other ways too.

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¡Alerta!
Engineering on Shaky Ground

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