SANDBOX INFRASTRUCTURE

By Matthew Wisnioski and Kari Zacharias

Field notes from the arts research boom.

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The Moss Arts Center. Courtesy of Virginia Tech.

ANTICIPATION
Field Notes: Studio Heads Meeting. Wisnioski and Zacharias, October 7, 2013.[1]

In 1966, the nuclear physicist turned magazine editor Daniel Cooper defined research for a ballroom of journalists as a kind of intellectual nausea. Paraphrasing his interview subject, the famed science administrator Robert R. Wilson, he argued that the process was "a special state of grace," an "awful queasiness, this rumbling around inside, this subconscious knowledge that something is going to happen."[2]

We keep this fifty-year-old adage in mind during the first Studio Heads meeting of the Institute for Creativity, Arts, and Technology (ICAT) inside its $90 million building, designed by Snøhetta. We earned our seats at the table of Virginia Tech's new organization "at the nexus of the arts, design, engineering, and science" by convincing its director, Benjamin Knapp, that humanists also can be applied researchers.[3] *Kari, the project's ethnographer, distributes IRB forms that some sign with a passing glance and others parse skeptically. She has just arrived in rural Virginia from Vienna, Austria, where*

she worked as an aerospace engineer. Matt, a historian and ICAT-funded fellow, has been lurking at maker camps and grant proposal sessions throughout the summer in the institute's temporary home in Collegiate Square, a local shopping plaza.

Queasiness permeates the conference room. Two overlapping events are swiftly approaching. First, the grand opening of the Moss Arts Center[4] (MAC), in which ICAT will have second billing to the building's larger resident, the Center for the Arts (CfA). The celebratory week will feature an open house, a performance of Philip Glass's Powaqqatsi, *and a ribbon cutting. The second event, Tech or Treat, is a Halloween showcase of ICAT's fusion of playful collaboration with its land-grant mission. While we struggle to keep up with rapid-fire references to people and projects, the small group of digital artists, computer musicians, educational researchers, dance professors, electrical engineers, and managers debate seemingly endless challenges. From contractor blunders to equipment that has yet to arrive, little is going according to plan.*

Much of the conversation focuses on using a project called Mirror Worlds as a signature demonstration of ICAT. Mirror Worlds seeks to install sensing arrays in the MAC lobbies, galleries, concert hall, and research studios. Optical and infrared cameras will collect, process, and represent data in "bidirectional conduits between the real and virtual worlds."[5] Ideally, everyone will be able to access these "living labs" and in turn will be analyzed for the advancement of knowledge. The question in the meeting, however, is whether Mirror Worlds might provide momentary entertainment for gray-haired donors and costumed children. More accurately, the question is whether it will work at all.

Interactive map of a2ru partners. Courtesy of the Alliance for the Arts in Research Universities.

RESEARCH BUILDING

This article is our first dispatch from a set of studies of the network of people, institutions, and ideas that ICAT is helping to create. Over the past fifteen years, an international movement of university research centers, federal agencies, design firms, charitable foundations, museums, and nonprofits has arisen in pursuit of "transdisciplinary" incubators that merge art with technology to extend the boundaries of research and its beneficiaries. Among them, the adjectives *collaborative, creative, empowering, fun, innovative, integrative, living, open, organic*, and *unique* merge in differing combinations with *challenging, competitive, converging, emerging, evolving, inevitable, radical,* and *ubiquitous.* The composite message is of progressive necessity, a historical turn in which the arts have ascended to newfound importance as a research-based competency in an innovation economy.

Here we focus on one major thread—the interaction between ideals and practices of arts research and the efforts to establish infrastructure to support it.[6] Our larger inquiry spans design pedagogy, the rise of "STEAM" education, the lived experience of interdisciplinarity, the cultural meanings of innovation, and the politics of technoscientific institution-building.

In the United States alone, there are more than a hundred programs invested in the

construction, funding, and practitioner development of transdisciplinary, arts-based research.[7] From Rensselaer Polytechnic Institute's EMPAC to the Stanford Arts Institute, it is the rare Research 1 (R1) university that has not built an institution with a family resemblance to ICAT. One now can get an undergraduate degree in "disruption" (arts, technology and the business of innovation), an MFA in creative technologies, and a PhD in media arts or game design. Beyond academe, there are scores of artist-in-residence programs, cultural centers, and conferences similarly dedicated to supporting and expanding arts research, from New York's Art Science Research Laboratory, established by paleontologist Stephen Jay Gould, to David Edwards's ArtScience Lab.[8]

We point to this institution building in part because it is easier to describe arts research infrastructure than it is to capture the myriad perspectives of what constitutes "research" in these environments. Infrastructural studies, moreover, demonstrate the power of systems to reshape material and cognitive interactions.[9] Thousands of professional and apprentice artists, designers, engineers, and scientists are being drawn into transdisciplinary collaborations with substantial opportunities and risks that challenge institutional norms, practitioner identities, and research practices.

Our analysis looks beneath the rhetoric of a natural symbiosis to focus on everyday experience. To link local subjectivity with global patterns, we combine in situ descriptions of ICAT and its projects with historical and contemporary surveys of arts research institution building. Doing so focuses attention on the evolving meanings and practices of transdisciplinary arts research and on how researchers (ourselves included) continue to volunteer for these experiments.

The "Sandbox" after move-in day. Photo courtesy of Kari Zacharias.

MOVING IN
Field Notes: Community Playdate. Zacharias & Wisnioski, November 1, 2013.

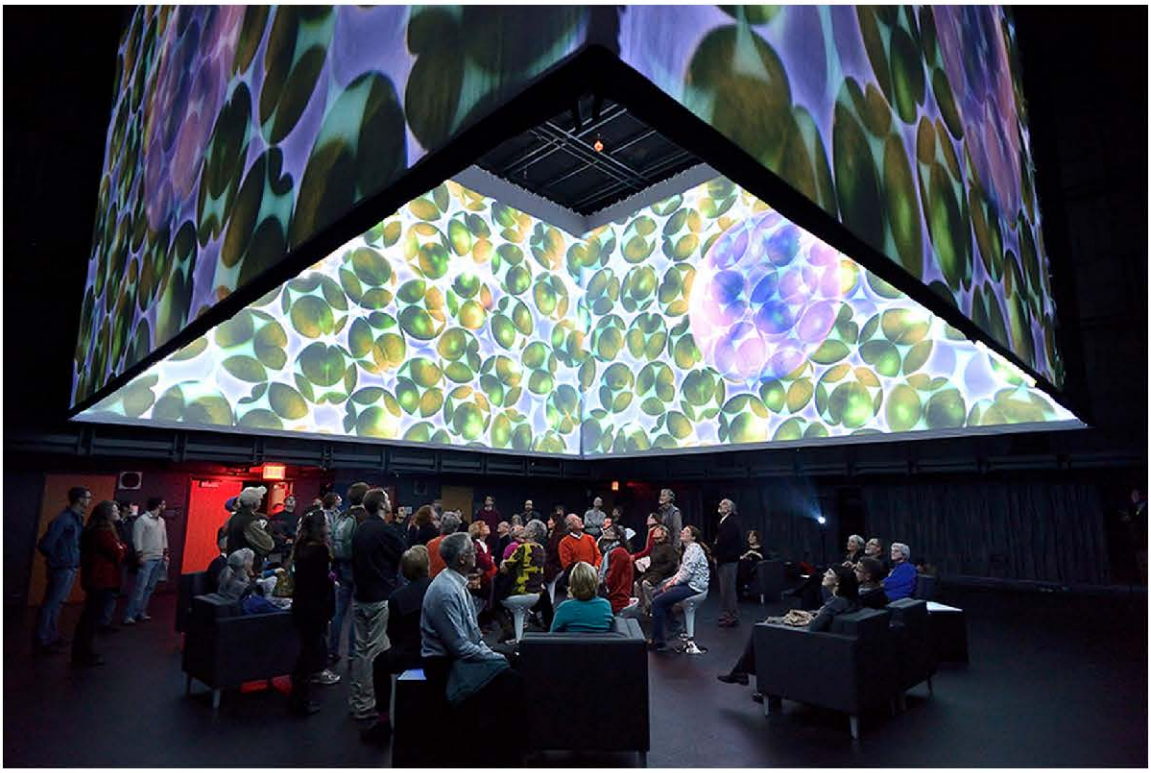
Instead of the usual relaxed chatter over muffins and coffee, a tour begins. We're standing in the MAC lobby with thirty colleagues and strangers for a "community playdate," one in a weekly series of public meetings at which ICAT faculty, graduate students, and grant recipients discuss their work.

We enter the "Sandbox," which Knapp introduces as a configurable environment "just

room provides workspace for graduate students and flexible options for project meetings, presentations, and installations. We will soon set up our own cluster, claiming a pair of tables and the room's only bookshelf.

"Welcome to the white innovation pit of despair," scribbled on a whiteboard, announces the room's contrast with the mix of electronic parts, conversations, discount sofas, and general disorder that the graduate students loved about the "real ICAT" at Collegiate Square. The new space is lit with overhead fluorescents and a giant window from the second-floor hallway, through which passersby can peer down on research in action.

As we proceed through the ground-floor studios, it's clear the building is still under construction. In the Create Studio, a prototyping lab, a MakerBot 3-D printer sits on a table, and a workbench covered with soldering kits and multimeters runs along the wall. Otherwise, it's just boxes and half-installed machines. Tom Martin, the engineering professor in charge of the studio, apologetically tells us that a bigger 3-D printer, a laser cutter, and electronic prototyping equipment are on their way. The Perform Studio, a space for motion capture has twelve infrared cameras and twelve wall-mounted speakers installed, with twelve more on order. No one can get the sophisticated light switch to turn on. Down the hall, we are barred from most of the Experience Studio because the occupancy certificate currently covers only half the room.



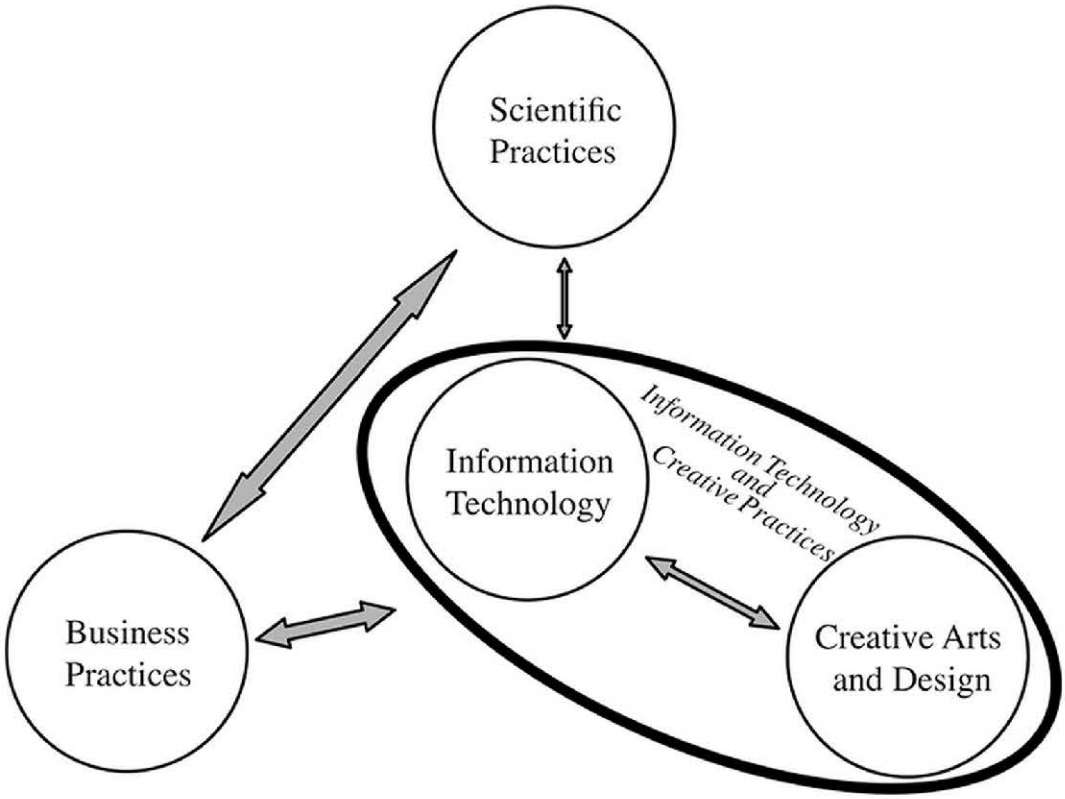
The "Cube." Photo courtesy of Virginia Tech.

Our next stop is the "Cube," the MAC's showpiece performance space and interactive acoustic laboratory. Inside the dark walls a group of artists and technicians are busily setting up an audio–video installation in time for morning visitors. Eventually, more than one hundred speakers will be mounted in different parts of the room. Seen through a head-mounted display, Knapp explains, the immersive sensory environment will create a complete virtual world.

We continue through the CfA's Performance Hall, where preparations are under way for Philip Glass, and into the Learning Studio, the new home of ICAT's K–12 education research and outreach work. Soon the Learning Studio will host maker camps, extracurricular design club meetings, elementary school field trips, and university classes for undergraduates and graduates. The space also can be used for observation: two cameras already are installed, and, the refrain goes, more are on the way.

As we move back to the gleaming lobby, a maroon and orange ribbon is stretched across the entrance to the Performance Hall. Hundreds of white chairs fill the lobby, where

donors, students, and town residents will hear dignitaries note the "breathtaking" architecture, declare it a "testament to how important the arts are," and assert that the investment will help Virginia keep pace with "the rise of STEM jobs."



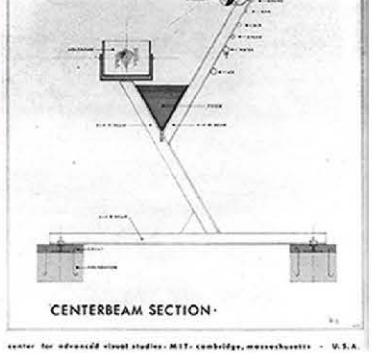
Information Technology and Creative Practices. Reproduced with permission from Beyond Productivity: Information Technology, Innovation, and Creativity, 2003 by William J. Mitchell, Alan S. Inouye, and Marjory S. Blumenthal. Courtesy of National Academies Press, Washington, D.C.

FOUNDATIONS

ICAT sits atop a half-century of arts research institution building across the nation that has occurred in roughly three stages. The first was the product of military-industrial-academic entanglements in the 1960s and 1970s.[10] It included now canonized organizations such as Experiments in Art and Technology, MIT's Center for Advanced Visual Studies (CAVS), Stanford's Center for Computer Research in Music and Acoustics (CCRMA), research at Ohio State and Bell Laboratories in computer graphics, and the arts research journal *Leonardo*.

These organizations drew their energy and form from two integrative impulses, one largely ideological, the other practical. We have previously described the former as a kind of "aesthetic virtue" that linked an extraordinary range of stakeholders together around the postwar quest for "creativity," manifest in the personae of Artist and Scientist.[11] The latter was the "multivocal" character of computing advances that similarly connected musicians, engineers, and research administrators on instrumental grounds.[12]

CAVS was the original test subject for institutionalizing arts research. György Kepes famously created an image of crosscultural unity and permanence. Behind the scenes, however, he was an adept manager who spent his days arguing for studio space, fund-raising (with little success), and setting up a fellows program. To do so, he capitalized on the desires of administrators to humanize MIT, their wives' campus beautification programs, the School of Architecture's research aspirations, scientists' creative impulses, and artists' ambitions for respect and financial support.[13]

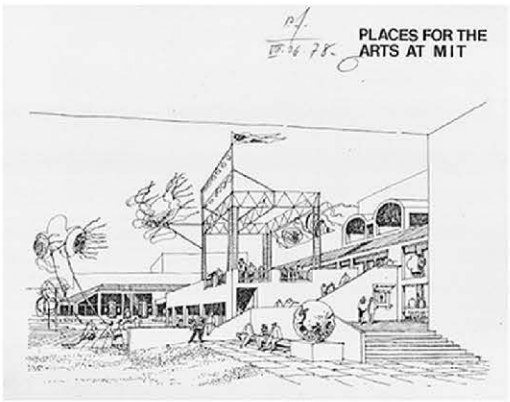


Left, CAVS, Centerbeam, National Mall, Washington, D.C. 1978. Photo: Dietmar Lörhl. Courtesy Of Center For Advanced Visual Studies Special Collection, MIT. Copyright Massachusetts Institute Of Technology. Right, CAVS, Centerbeam Section, 1977. Courtesy of Center for Advanced Visual Studies Special Collection, MIT. Copyright Massachusetts Institute of Technology.

When, in the early 1970s, the first building stage of arts research abruptly contracted, CAVS became the target of all manner of critique: that its "research" was metaphorical, that fellows did not collaborate, that artists were unappreciated or were defense-industry sellouts.[14] Nonetheless, the center successfully sanctioned the creation of a new kind of researcher. This credentialing, combined with CAVS's relative stability as it weathered the recession, shaped a generation of technological artists. Under Otto Piene's subsequent leadership, moreover, CAVS became a degree-granting unit in partnership with Nicholas Negroponte's Architecture Machine Group and others through the SMVisS program. When, in 1978, CAVS mobilized these resources in its first truly collaborative large-scale project, *Centerbeam*, the result was an artwork that represented two hundred years of infrastructure as performative experience.[15]

The second stage of institution building emerged in the 1980s. While this stage did not displace the earlier mode, it generated starkly different visions of arts research and the infrastructure for cultivating it. The MIT Media Lab was its defining institution, but it also included Xerox PARC's PAIR artists-in-residence program, the Interval Research Corporation, and Arizona State's Institute for Studies in the Arts.[16] In these institutions, aesthetic practices were aligned with architectural research, design engineering, human computer interaction, corporate investment, and the promise of consumer products. Their dynamism came from a problem-solving approach that merged creative "messing around" with the culture of entrepreneurship. The title "artist" generally was secondary to images of transdisciplinary "creators" or "innovators." At the same time, traditional government and foundation funding for the arts in the United States declined significantly.[17]

At MIT, the differences between this mode and the one it grew out of came to a head in an architectural dispute. While CAVS was touring with *Centerbeam*, Negroponte convinced MIT president Jerome Wiesner to invest in his institute. This happened at a rare moment of alignment between senior administrators, the traditional arts community, and donors to build a new center for the arts that was to include a museum gallery. CAVS argued for an outward-looking communal arts environment, which it likened to a "dirty" barn. The final I. M. Pei building instead hewed to Negroponte's vision of "the cockpit of an F-14," with distinct spaces for the Media Lab and the new List Visual Arts Center but no room for CAVS.[18]



Two visions for the future of transdisciplinary arts research at MIT. Left, Lyndon Associates, Places for the Arts at MIT, 1978. Copyright Massachusetts Institute of Technology. Right, The Wiesner Building. Courtesy of Madcoverboy at en.wikipedia.

The current infrastructural boom began in the late 1990s. Not simply a hybridized version of its predecessors, this third stage is notable for its scale and diversity. Much discussion of the technological arts has explained the remarkable expansion as a natural convergence of technological and cultural forces.[19] However, coordination is one of its most important characteristics.

Two major advocacy reports provide a glimpse into the movement's motivating forces and spotlight its persistent tensions. Both released in 2003 after years of data collection, the reports emphasize the political dynamics between artists and technologists in visions about how arts research ought to be constituted.

The first, "Truth, Beauty, Freedom, and Money," was a brisk art-world manifesto. Written for *Leonardo* by media artist Michael Naimark, it evoked the utopian realism of Kepes in a call for a new kind of "Arts Lab," a not-for-profit "hybrid art center and research lab" supported through grants, donations, and corporate consulting.[20] The Arts Lab would draw on technological research practices via three mechanisms: an Artist Patent Agency, an Artists Editions Agency, and an Artist PR Agency.

The second, *Beyond Productivity*, was a three-hundred-page committee report from the National Research Council that provided a roadmap for academic administrators, government agencies, foundations, and industry partners to invest in "information technology and creative practices (ITCP)."[21] It identified creativity as the central feature of cultural and economic growth, and arts- and design-based skills as crucial for American IT professionals to remain at the forefront of global change.

Though the place of the artist versus the technologist and the ends of the interaction differed widely in these studies, both were supported by the same patron, the Rockefeller Foundation. Both looked longingly to state-funded models in Europe and Asia, and both emphasized research as the convergence point between artists and technologists.

Programs with the profiles imagined in these reports now exist, and have begun to collaborate. In 2012, administrators and faculty from nearly thirty American universities created the Alliance for the Arts in Research Universities (a2ru).[22] With the aid of a $500,000 Mellon Foundation research grant, the a2ru aims to establish a national advocacy network for arts funding and for fostering cross-disciplinary research. To develop a rigorous set of institutional best practices, the a2ru is conducting site visits, practitioner interviews, and surveys of members. Its interim reports conclude that arts research has become highly valued in and across institutions but that administrators remain uncertain about how to overcome established cultural norms and reward structures.[23]

"Emerging Creatives." Photo: Yuto Watanabe. Courtesy of the Alliance for the Arts in Research Universities.

EMERGING CREATIVES
Field Notes: a2ru student conference. Stanford University. Zacharias, January 31, 2014

The nametag they gave me says "Wayfinder," but the first thing I do is get lost. Citrus trees and flowering bushes remind me that I'm a long way from the Blacksburg winter. Thanks to last-minute program changes and misplaced signs, I arrive a few minutes late. I skirt around an outdoor sculpture garden and hurry in.

It's the first day of the inaugural a2ru student conference, and my fellow wayfinders are arranged in a circle. Through the introductions, I discover that we range from college freshmen to PhD students and span disciplines from engineering to psychology and dance. We've been matched because we chose "general problem solving" from a list of reasons for collaborative work over entrepreneurship, social justice, "arts and hacks," or personal and professional growth.

Over the next two days, we will divide into smaller working teams to identify issues and develop project proposals related to our theme. At the conclusion of the conference, one working team from each session will present their idea to the plenary.

At first, we're confused and dismayed by the lack of specific instructions. Several people float vague project ideas to vague response. Eventually, someone points us to the expanse of whiteboard covering an entire wall. Markers are procured. Brainstorming begins. After a few minutes the wall fills up with project ideas. We divide again, this time into three groups. The largest group offers the "Idea Train," an expandable mobile workspace that travels between communities and universities to provide infrastructure for collaborative design projects. Another team suggests an art installation that uses human-powered vehicles to light an LED display in a public park. Inspired by the experiences of an Egyptian team member, my group sets out to design a Web interface that facilitates crosscultural communication and helps travelers avoid making faux pas.

During the rest of the conference, we have very little time to work on the projects. There are speeches from architects and executive directors, panel discussions among faculty mentors, and a design-thinking "bootcamp" at the nearby d.school. Between these activities and during meals, we are scheduled to "network." Although few business cards are exchanged, conversations erupt and continue by the hotel pool well into the night.

On the final day, project groups choose their representatives to share their work with the full conference. We frantically finish our written proposals and create prototypes. We discuss. Vote. Discuss. Vote. Vote again. Among the wayfinders, the Idea Train wins.

My team members are disappointed, but I secretly am relieved that we won't present our slapdash PowerPoint-based prototype in front of so many discerning "creatives." All week, I've battled the impression that I'm not creative enough to have earned my spot. We've heard a lot about music and theater, design and media arts. Writing seems too old-fashioned to matter.

The student presentations are uniformly impressive. The arts and hacks team entertains us with a mobile app that predicts how much closer your daily activities have brought you to death. The would-be entrepreneurs use showers of confetti to supplement their proposal for a luxury airline that facilitates collaborative work. The social justice group creates a moving performance piece about federal funding for the arts.

Leila Kinney, executive director for arts initiatives at MIT, gives the closing address alongside a group of MIT students. Together, they offer an overview of the arts at MIT. The projects they speak about are fascinating, but the contrasts between the Stanford sculpture gardens, the d.school's "design thinking," and MIT's conception of the "useful

arts" are striking.

In the days and weeks following the conference, we receive emails from the organizers with links to a2ru social media groups and requests for our reactions to the event. These responses, blog posts, and student newspaper articles are collected and enthusiastically displayed as part of the "Knowledge Base" on the a2ru website, along with descriptions of the student projects.[24] .

Back in Blacksburg, the three other Virginia Tech attendees and I give a playdate talk about our experiences. I'm not sure what to say. I try to focus on the varied kinds of arts research I encountered over the weekend. Inevitably, the first question from the audience is where ICAT fits within this national scene. That, I think to myself, is what I've been trying to figure out this whole time.

ICAT's mission. Courtesy of ICAT.

ESTABLISHING ICAT

A critical mass of networked peers is a defining strength of today's arts research boom and a central challenge to individual institutions. Collective demonstrations are important for advocacy efforts, but it is vital for organizations to stand out. Doing so requires constructing narratives that satisfy multiple stakeholders and reflect local history and culture, national policy initiatives, global patterns, and the combined experiences of ever-changing participants.

At Virginia Tech, ICAT was founded in 2011 as the research partner to its cultural counterpart, the CfA. The result of a decadelong commitment by senior administrators to enhance the university's reputation as a "comprehensive" global institution by expanding the arts, it was built on an earlier cluster hire for the Collaborative for Creative Technologies in the Arts and Design and smaller precursor organizations such as the Integrated Design + Education + Arts (IDEA) Studio.

ICAT reflects Virginia Tech's status as a land grant organization enmeshed in a global innovation economy. Befitting its heritage, ICAT's return on investment is measured in the domains of education, research, and engagement. ICAT highlights its educational research as a national strength. But it also devotes resources to community involvement and is partnering with organizations such as the National Science Foundation's Innovation Corps to foster a regional innovation network that includes NuSpark, a free, collaborative workplace for entrepreneurs that opened in ICAT's prior shopping plaza location.

The ideal ICAT project blends the institute's tripartite mission seamlessly. For example, the recent OPERAcraft saw local high school students write an operatic libretto, build virtual characters and sets in Minecraft, and perform their piece alongside student singers from Virginia Tech's department of music. Lantern Field, an interactive architectural installation at the Smithsonian's Freer and Sackler Galleries, combined paper lanterns folded by museum visitors with a responsive lighting and sound system configured by ICAT students and faculty.

Where peer institutions lean toward one side or the other of the arts/technology spectrum, or focus on a set of specialized research thrusts, ICAT thus far has pursued a catholic vision of transdisciplinary arts research. Its principal criteria for funding projects are the involvement of researchers, concepts, practices, and outcomes from at least two of its quadrants of art, science, engineering, and design.

This broad policy is in part an artifact of ICAT's position as one of seven research

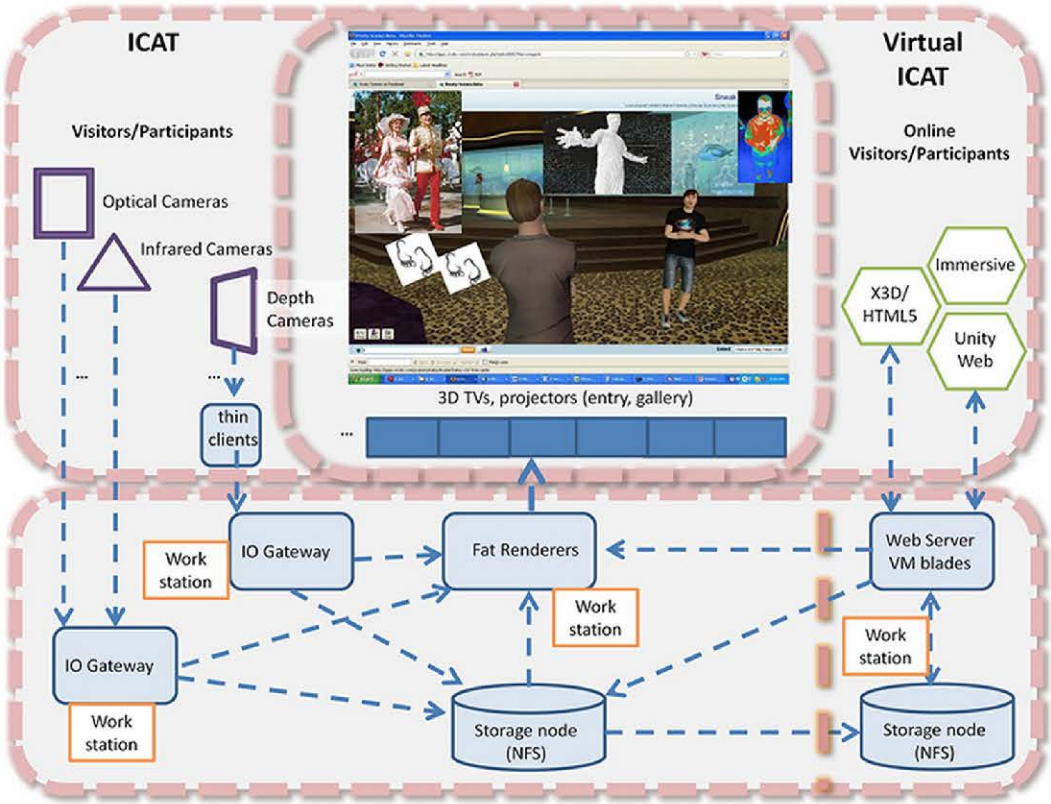
institutes that reside outside the university's system of colleges. As such, it is neither beholden nor immune to any faction of architects, artists, designers, engineers, musicians, scientists, center directors, or deans. ICAT's director reports to the provost and a cross-college advisory board.

ICAT's comprehensive approach is also the result of the eclectic career path of its director. Knapp was trained as an electrical engineer at North Carolina State University before earning his PhD at Stanford. In the early 1990s, while an assistant professor at San Jose State and visiting scholar at the CCRMA, he cofounded BioControl Systems, a bionic interface company that later produced the BioMuse musical trio as a side project.[25] During his subsequent work in industry and academia, Knapp has demonstrated an eagerness to study the links between technology, physiology, and emotion through collaborative projects as diverse as lie detection and the interaction between musician and audience during concert performances.[26]

Finally, this open-ended vision stems from building a human infrastructure around existing faculty, a necessity of the institute's surprisingly small budget. Knapp and a staff of three manage the business and daily operations of ICAT and coordinate its vision with a core group of studio heads, while students and other associated faculty receive project-based funding and volunteer their time at institute events. Much of ICAT's first two years was spent identifying who on campus might be interested, who might "gel" in the environment, and what projects they might pursue, as well as smoothing over relationships with individuals and departments to make it happen.

Not surprisingly, these diverse aims and stakeholders generate frequent tensions and conflicts. Participants come with various pictures of what ICAT is and what it should be doing. "Hybrid" researchers whose work spans multiple disciplines struggle to define the value of ICAT projects to their academic peers and tenure committees. Researchers are thrust into the open-concept, collaborative Sandbox. Artists fight to be considered equal partners in technological research. ICAT and the CfA face high demand for a shared set of physical resources and differing levels of financial support and community recognition.

Negotiating among these various resources, desires, and expectations runs throughout ICAT research projects.



Mirror Worlds Technological Infrastructure Map. Reproduced with permission from NSF Grant Proposal 1305231, "Living Lab for Asynchronous and Synchronous Investigation of Virtual and Real Environments" by Benjamin Knapp, Ivica Bukvic,

Yong Cao, James D. Ivory, and Nicholas F. Polys. Courtesy of ICAT.

MIRROR WORLDS
Field Notes, Multiple ICAT Sites. Zacharias & Wisnioski, October 30, 2013–April 4, 2014.

Soon we will invite the public inside. The Cube has been transformed into an interactive labyrinth of smart fabric "trees," 3-D-projected monster heads, skeleton-themed Kinect games, and flying robots. In the lobby, cameras will track visitors and display their likenesses on the wall as shimmering blue "ghosts." Dane Webster, ICAT studio head and the artist responsible for the projection, paces nervously. His own ghost flickers and glows.

Tonight's "Tech or Treat" is more than a haunted house. It is the first public demonstration of Mirror Worlds, an ambitious project to turn the entirety of the MAC into a research instrument.[27] Over the next two years, with funding from an NSF Computing Research Infrastructure grant, a team of faculty and students plans to install cameras and sensors in every part of the building, to construct a live, online, and interactive virtual MAC, data from which can be applied to a range of anticipated research questions, from crowd simulation to affect change in concertgoers.[28]

The Mirror Worlds demo dominates the lobby. Kari spends several minutes experimenting with it. She finds the edges of the camera's field. Speeds up and slows down—her avatar keeps pace. Stands still and waves her arms—this time, no reaction. The virtual form is only partially holiday-themed. What were originally humanoid projections have been changed to "wonderfully nebulous" shapes to ease concerns that people will feel "like they're being watched." The idea is to take this lesson into the future development of the project. Unfortunately, due to an extraordinary number of visitors, the collective image is a mass of specters waiting in line.

A week after the MAC's opening, an exhausted Knapp described the outcome as "perfect." The prototype entertained the overflow of nearly eight hundred children and parents and later caught the attention of symphony goers. It is now six months on, and though he promised the studio heads that the pace of demonstrations, development tours, and planning retreats would taper, such events continue to dominate ICAT's daily activity.

Both excitement and doubts exist about the future of Mirror Worlds. The team is still in the first semester of its two-year grant. Undergraduate students employed as project managers and technical specialists plan to scale up the infrastructure one room and hallway at a time. They work enthusiastically in the Sandbox, which now boasts carpeting, table lamps, and a lived-in atmosphere. Graduate students have claimed their own workspaces and filled them with computers, books, coffee machines, and virtual-reality headsets. They still grumble about the lack of natural light, but no one talks about Collegiate Square.

For his part, Webster is concerned about the planned scale of the project. A "build it and they will come" attitude persists at ICAT, but Webster and others are wary of building infrastructure before conceptualizing its use more completely. Other stakeholders praise this aspect of the project, citing the open-endedness of Mirror Worlds as the "exciting" part.

Related tensions exist between the infrastructure's perceived artistic and scientific values. An artist ruefully recalls a conversation from an early phase of the project, when a computer programmer was dismayed to discover that the visual representations "have to look good." The Mirror Worlds grant proposal suggests several technical and research outcomes but makes no mention of art. In conversations with project team members, suggestions of artistic outcomes range from informing "public engagement of space" to offering new interpretations of the MAC's architecture, but everyone acknowledges that these goals are nebulous. For Knapp, the aesthetics of the project are in the interaction itself. Exploring new representations of communication across the physical/virtual divide will help create a "nurturing" environment inside the modern, white-walled MAC.

Mirror Worlds: From Solid Bodies to Ethereal Ghosts. Left, Early Mirror Worlds rendering. Courtesy of Dane Webster. Right, Mirror Worlds at Tech or Treat. Courtesy of ICAT.

A SPECIAL STATE OF GRACE

Fifty years into the construction of a natural symbiosis, where do we stand?

From our vantage point, simultaneously trained in critical studies and acting as participant builders, transdisciplinary arts research often appears caught in a loop. As the definition of "research" and the practices of "art," "science," and "engineering" change, perennial roadblocks endure. Buzzwords pepper expressions of belief about the latest tool or creative approach and its promise to save nothing short of the world. "Collaboration" and "creativity" habitually function as ends within themselves rather than means to specific ends. Artists voice frustration and anxiety about their roles, and technologists claim they are misunderstood. Those on the outside bemoan both the combination of resources and attention these institutes garner. Occasionally, we want to throw up our hands, as Piene did at CAVS, and yell, "Jesus, another 'creative.'"[29]

Juxtaposing infrastructural growth at time scales of a half-century and half a year, however, shows that something new is happening. As ICAT grows, so too do other institutes across the country and around the world that are process—rather than goal—based. Future architectural historians likely will write volumes about the qualities of "statement" facilities for fostering or hindering innovation. Universities are becoming crucial sites for training hybrid researchers who in earlier generations created their own paths or traveled through a tiny group of elite institutions. Researchers in these environments also are being transformed by their participation, and not without risks. For our own part, as we share these reflections, we wonder how our home department will interpret our potentially "compromised" criticality and how our participation in ICAT will be altered as we draw on our colleagues as research subjects.

Despite the protestations of many of its builders, the construction of research infrastructure is in and of itself a kind of applied research. As in any research project, there are false starts, dead ends, delusions of grandeur, competitors, and anxiety about whether the result and its architects are good enough. Infrastructure building cannot be cleaved from the research it affords, and vice versa. In our interview with Knapp about Mirror Worlds, he explained the incremental pace as a consequence of coordinating action around a shimmery image. "Until we build it," he laments, "it's quite hard to describe."

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1. We thank Monique Dufour, Bernhard Böhm, and Molly Loberg for their sharp reading and suggestions. We also acknowledge the CAVS Archives, the Massachusetts Institute of Technology, Virginia Tech, the Alliance for the Arts in Research Universities, the National Academies Press, and Dane Webster for allowing our use of their photographs and figures. Most of all we thank our colleagues at ICAT for inspiring and tolerating our ongoing work. ^

2. Daniel I. Cooper, "Pop Science," *American Documentation* 17, no. 2 (1966), 53–54. Wilson was also a sculptor who applied his aesthetic vision to the construction of Fermi Lab. Joanna Ploeger, "The Art of Science at Fermi National Accelerator Laboratory: The Rhetoric of Aesthetics and Humanism in the National Laboratory System in the Late 1960s," *History and Technology* 18, no. 1 (2002). ^

3. "Institute for Creativity, Arts, and Technology (ICAT) Charter," (Charter document, Virginia Polytechnic Institute and State University, 2011), 1. ^

4. Named after the popular artist P. Buckley Moss, who donated $10 million to Virginia Tech. ^

5. Benjamin Knapp, Ivica Bukvic, Yong Cao, James D. Ivory, and Nicholas S. Polys, "Living Lab for Asynchronous and Synchronous Investigation of Virtual and Real Environments," NSF Computing Research Infrastructure, 1305231, October 23, 2012. ^

6. We use *arts research* broadly to encompass a range of existing categories such as ArtScience, Media Arts, and Information Technology and Creative Practices, in part to avoid getting caught in programmatic comparisons and in part to indicate that a key feature of arts research infrastructure is that artists are only one set of its stakeholders. For surveys of the state of the art, see e.g., Stephen Wilson, *Art + Science Now* (London: Thames & Hudson, 2010); Michael Biggs & Henrik Karlsson, eds., *The Routledge Companion to Research in the Arts* (New York: Routledge, 2010). We find that, while conversations about the relationship between art and technology take place daily at ICAT; few, if any, participants engage in this kind of theoretical boundary defining. We note additionally the term *arts research* first gained traction in the 1980s when arts educators renamed one of their lead journals *Visual Arts Research*. This and other art world interpretations persist (see e.g., the National Center for Arts Research at Southern Methodist University and the Berkeley Arts Research Center), but they are not our primary target. ^

7. We primarily limit our focus to the United States, for the sake of brevity and to uncover the specific national forces behind ICAT. A large number of relevant European institutions in particular are not discussed here. See e.g., Edward A. Shanken, "Artists in Industry and the Academy: Collaborative Research, Interdisciplinary Scholarship, and the Creation and Interpretation of Hybrid Forms," *Leonardo* 38, no. 5 (2005) for a more complete review. ^

8. Online hubs identify common causes among them and direct curious artists and researchers. See e.g., Kevin Kelly's website. ^

9. See e.g. Susan Leigh Starr, "The Ethnography of Infrastructure," *American Behavioral Scientist* 43, no. 3 (1999). ^

10. Arindam Dutta, ed., *A Second Modernism: MIT, Architecture, and the 'Techno-Social' Moment* (Cambridge, Mass.: MIT Press, 2013); Reinhold Martin, *The Organizational Complex: Architecture, Media, and Corporate Space* (Cambridge, Mass.: MIT Press, 2003); Douglas Davis, *Art and the Future: A History–Prophecy of the Collaboration Between Science, Technology, and Art* (London: Thames & Hudson, 1973). ^

11. Matthew Wisnioski, "Why MIT Institutionalized the Avant-Garde: Negotiating Aesthetic Virtue in the Postwar Defense Institute," *Configurations* 21, no. 1 (Winter 2013). ^

12. Cyrus C. M. Mody and Andrew J. Nelson, '"A Towering Virtue of Necessity': Interdisciplinarity and the Rise of Computer Music at Vietnam-Era Stanford," *Osiris* 28, no. 1, Music, Sound, and the Laboratory from 1750–1980 (2013). ^

13. Wisnioski, "Why MIT Institutionalized the Avant-Garde"; Anna Vallye, "The Middle Man: Kepes' Instruments," in *A Second Modernism: MIT, Architecture, and the 'Techno-Social' Moment*, Arindam Dutta, ed. (Cambridge, Mass.: MIT Press, 2013). ^

14. See .e.g., Jack Burnham, "Art and Technology: The Panacea That Failed," in *Video Culture: A Critical Investigation*, ed. John G. Hanhardt (Rochester, N.Y.: Gibbs M. Smith. 1986). pp. 232–248. ^

15. Matthew Wisnioski, "Centerbeam: Art of the Environment," in *A Second Modernism: MIT, Architecture, and the 'Techno-Social" Moment*, Arindam Dutta, ed. (Cambridge, Mass.: MIT Press, 2013). ^

16. Stewart Brand, *The Media Lab: Inventing the Future at MIT* (New York: Penguin Books, 1988); Harris, Craig, ed. *Art and Innovation: The Xerox PARC Artist-in-Residence Program.* (MIT Press: Cambridge, Mass. 1999). ^

17. Naimark, Michael, "Truth, Beauty, Freedom, and Money: Technology-Based Art and the Dynamics of Sustainability," *A Report for* Leonardo Journal *Supported by the Rockefeller Foundation* (2003), 5. ^

18. Wisnioski, "Centerbeam: Art of the Environment," 217–222; Meg Rotzel, "MIT's Wiesner Building, 'The Media Lab that Wasn't,'" 2009, unpublished manuscript. ^

19. In popular media and on the Web, this formulation has become a truism. For early nuanced looks, see Roy Ascott, *Telematic Embrace: Visionary Theories of Art, Technology, and Consciousness*, edited and with an essay by Edward A. Shanken (Berkeley: University of California Press, 2003); Stephen Wilson, *Information Arts: Intersections of Art, Science, and Technology* (Cambridge, Mass.: MIT Press, 2002). ^

20. Naimark, "Truth, Beauty, Freedom, and Money." Naimark is one of the few people to have played a foundational role in all three stages of arts research growth. ^

21. William J. Mitchell, Alan S. Inouye, and Marjory S. Blumenthal, eds. *Beyond Productivity: Information Technology, Innovation, and Creativity* (Washington, D.C.: National Academies Press, 2003). The three-year process included extensive input from computer scientists, engineers, politicians, new media artists, and STS scholars, and itself acted as an infrastructural development program. ^

22. These efforts developed out of a 2011 meeting hosted by the University of Michigan's ArtsEngine that was attended by 150 administrators and faculty from forty-one Tier One American research universities. "The Role of Art-Making and Arts in the Research University" (working group topics, draft vision, and background statements, University of Michigan, 2011). ^

23. Anthony J. Kolenic and Bruce M. Mackh, "Curricular Integration" (Arts Engine Mellon Research Project: Round One Interim Report, University of Michigan, 2013); Bruce M. Mackh and Anthony J. Kolenic, "Collaborative Research" (Arts Engine Mellon Research Project: Round One Interim Report, University of Michigan, 2013). ^

24. link, and link ^

25. Eric D. Lyon, "The Biomuse Trio" (paper presented at the annual meeting on Computer-Human Interaction (CHI), Atlanta, Ga., April 10–15, 2010). ^

26. Layeghi, S., M. Dastmalchi, E. Jacobs, and R. B. Knapp, "Pattern Recognition of the Polygraph Using Fuzzy Classification," In *Fuzzy Systems*, 1994. *IEEE World Congress on Computational Intelligence, Proceedings of the Third IEEE Conference*, pp. 1,825–1,829. IEEE, 1994.; R. Benjamin Knapp and Eric Lyon, "The Measurement of Performer and Audience Emotional State as a New Means of Computer Music Interaction: A Performance Case Study," *Proceedings of the International Computer Music Conference*, Huddersfield, England. July, 2011. ^

27. The term "mirror worlds" originates with David Gelertner's 1991 book of the same name: David Gelernter, *Mirror Worlds, or the Day Software Puts the Universe in a Shoebox...How It Will Happen and What It Will Mean* (New York: Oxford University Press, 1991). None of our interview subjects had heard of it. ^

28. Knapp, et al. "Living Lab for Asynchronous and Synchronous Investigation of Virtual and Real Environments." ^

29. Otto Piene, *More Sky* (Cambridge, Mass.: MIT Press, 1973), 53. ^

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