Caring for the "next billion" mobile handsets: opening proprietary closures through the work of repair

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ABSTRACT
ICTD is profoundly interested in the "next billion" users, and how to leverage technology to improve their everyday lives. In this paper we ask how the concept of care might be generatively extended to the 'lives' of the "next billion" mobile handsets. Drawing on a growing literature on repair in ICTD and HCI, and theories of care from the social sciences, this paper makes two central contributions. First, our ethnographic study of mobile phone repair in downtown Kampala, Uganda provides new insights into how technologies are sustained in developing contexts, with a special focus on how independent technicians in informal repair shops circumvent the proprietary closures that limit their work. Second, we show how attending to *care* in ICTD contexts can help us locate immediate forms of technical work (here, repair) within wider moral and political orderings. Thinking about repair and care together opens up new possibilities for ICTD to engage with the materiality of technologies over longer temporal horizons, beyond privileged moments of design and adoption.

Categories and Subject Descriptors
H.1.2 [**Human computer interaction**]: Human-centered computing – Empirical studies in HCI; Human-centered computing – Computer supported cooperative work

Keywords
Mobile telephony; repair; care; proprietary technology; ICT4D; ethnography; Uganda

1. INTRODUCTION
The "next billion" is a common phrase within ICTD, often used to call out the startling growth rates of mobile telephony in developing contexts, particularly within the euphemistically-named "bottom of the pyramid" of the world's poorest consumers. We repurpose this phrase to talk about the next billion mobile handsets that will feed this emerging market. Phones are globally circulating commodities that are being produced in astonishing numbers: over 1.8 billion phones were sold in 2014 alone [6] with over half the world's population maintaining a mobile subscription [8]. Nevertheless, the material lives of these handsets tend to be backgrounded in ICTD literature, as accounts of mobile adoption come to the fore. What might we learn by studying the precarious lives of mobile devices? We approach this question through the framework of repair, which we regard as fundamental to the shaping and sustainability of our social and technical worlds. Central to these practices are relations of *care*. We ask what it would mean to extend this relation of care to material objects in ICTD, to the billions of mobile handsets that are out there, playing a role in this mobile revolution?

This paper builds on a growing body of work in ICTD and HCI that has called attention to practices of repair in Southern (and indeed other) contexts [1,7,13,14,15]. Repair studies have called out the creative, resourceful and improvisational work of getting technological systems and artifacts going and keeping them working long beyond moments of adoption. They have also shown how repair workers contribute to the building of appropriate and resilient infrastructures, which may be particularly important in resource-constrained contexts. More broadly, repair studies have surfaced wider questions around how we live with socio-technical systems, drawing attention to larger processes of valuation, breakdown, and wasting. Through these processes, the materiality of technologies becomes visible in new ways. Plastics, glass, metals and minerals (sometimes extracted under unethical circumstances) are broken down, repurposed and discarded prompting a wide range of social and environmental justice concerns. ICTD researchers investigating the problem of e-waste remind us that handsets can burn or decay into collections of toxic materials with the potential for negative impacts on the environment and human health (though this is not the only e-waste story) [18, 23].

A parallel body of work in the field of Science and Technology Studies (STS) has addressed problems of *care*

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in and through our material environments [2,4,19,20,21]. Care as applied to the world of things foregrounds the fragility of material objects and the wider social and technical worlds in which they circulate. It plays an active part in the maintenance of objects and systems over their lifetimes, and establishes meaningful, practical and affective relations between human action and the built environment, some of which go beyond the purely functional or instrumental relations we tend to recognize in this space. Care is central to the ethos and practical orientation of repair work, and the work of repair technicians is shot through with precisely such extra-functional concerns as they go about restoring and remaking phones: from the pleasure generated in cracking a difficult case, to a professional pride of mastery that goes beyond any immediate economic calculation. At other times however, care is a burden: for example, as technicians negotiate the continual frustrations entailed in dealing with the indeterminate nature and endless frustrations of breakdown and failure. Caring for fragile technologies may also be precarious work, as technicians piece together small payments for successful repairs into livelihoods subject to the pressures of competition, ambivalent social standing, and an influx of cheap handsets which may favor discard-and-replace over repair strategies for dealing with broken or damaged objects.

This paper makes two central contributions to the ICTD and wider HCI literatures. The first concerns the role of repair in supporting and extending the lifetimes of the material things – mobile phones – that are increasingly at the center of ICTD research, practice, and aspiration. We show how repair builds new forms of durability and innovation that extend and maintain the core virtues of access, use, and participation that have long been central to ICTD work. By calling attention to repair work (and repair workers) we seek at the same time to bring new visibility to forms of technological practice too often obscured under predominant orientations towards technology in its moments of design and early adoption.

At the same time, repair faces strict limits, two of which we illustrate through examples drawn from our fieldwork with mobile phone repair technicians in downtown Kampala, Uganda. The first concerns mechanisms of material closure imposed by the organization of the global technology industry, from SIM locks to software updates. The second concerns access to the wider infrastructural factors that support repair – such as the availability of information about mobile handset design, knowledge about breakdowns, the availability of spare parts, access to tools to open and intervene in mobile hardware and software systems and digital artifacts such as firmware files.

Our second contribution concerns a theoretical synthesis between repair and care. Attending to care enables us to surface wider moral and political orderings that are enacted in and through this everyday socio-technical work. We show how different forms of access result in different distributions of care across these sites.

Our work demonstrates how care as an analytic lens opens up ways of reimagining ICTD thinking and practice. We explore how the proliferation of repair enterprises in developing contexts constitutes an important – albeit partial – response to problems of social and environmental justice arising from the mobile manufacturing industry in its global dimension. Thinking alongside technicians in Kampala, we ask: what moral and material responsibility do ICTD researchers bear towards the "next billion" mobile handsets and the human worlds they will touch?

The notion of "care" thus calls attention to two things at once: the forms of care practiced empirically (and with great skill) by the repairers in our study; and the forms of attachment and responsibility that we ourselves bring to our fields and sites of work. What forms of care do mobile devices demand from these different (and differently culpable) positions? Asking "who cares?" and "who receives care?" provides a telling window on the complicated sociotechnical orders that we engage (in Kampala as elsewhere). It is also a useful way into the ever-fraught politics of ICTD research itself.

The following paper begins by reviewing and bridging existing literatures around repair and care. We then turn to two empirical cases centering on the challenges that mobile phone repair technicians in downtown Kampala face in carrying out their work. The first compares practices of software repair in "authorized" and "independent" repair sectors, and shows the stark differences in access to tools, knowledges and materials that mark and separate these two "versions" of repair in Kampala. The second discusses the dynamics through which proprietary SIM locks are hacked and made open to third party tool developers and technicians. In our discussion we ask how actors in the ICTD space might be persuaded to care differently about repair and problems of proprietary closure, and argue for an activist agenda that establishes repair as a central matter of concern in ICTD research, practice, and policy.

2. BRIDGING REPAIR AND CARE

Current studies of repair owe much to ethnomethodological traditions within HCI and the anthropology of work. Suchman's seminal *Plans and Situated Actions* [27] has called attention to how photocopier users "repair" expert systems organized around planning models of human action by drawing on resources within the situation. Building on this work, Julian Orr's [22] wide-ranging ethnographic study of photocopier repair at Xerox focuses on the stories told in repair, in creating situated diagnoses at the machine interface and in sharing knowledge within the technician community - ultimately disrupting the corporate impetus to rationalize and codify repair. This work orients us towards repair as situated action, and highlights the political dimensions of repair within large organizations.

Writing more widely, Graham and Thrift [7] suggest that processes of repair represent essential but invisible ways in which social and material order is sustained within our environment, emphasizing how maintenance and repair are moments of learning and of politics, as values and orders are being negotiated and re-made in and through restoration and reproduction. Henke [10] makes similar observations in his study of maintenance workers, noting that as they repair the fabric of buildings they also restore workplace order. Jackson [13] has argued for attention to repair and maintenance as an important corrective to the "productivist" bias that tends to characterize research on human technology interactions, both within HCI and across the social sciences. Sites of repair may open up different moments and possibilities in the work of HCI, revealing practices and actors frequently obscured under the field's preoccupation with moments of design.

Such programmatic and theoretical interests in repair have recently been joined by a growing program of empirical work centered on the practice and challenges of repair in Southern contexts. Jackson et al.'s [15] study of ICT repair in Namibia uses "repair worlds" as a theoretical framing to account for the complex organization of repair practices across actors, sites and organizational forms, generating insights for development and policy. Work by Ahmed and colleagues [1,14] has explored the forms of collaboration, learning and apprenticeship central to the (re)production, circulation and innovation of repair knowledges. Other work has sought practical and imaginative links between Southern repair practices and moments of technological design: for example, Rosner and Ames' [25] study of "infrastructures and materialities of breakdown" in the One Laptop Per Child project and the activities of volunteer fixer collectives; or Wyche et. al.'s [30] study of mobile phone repair workers in Kenya and their imaginative efforts to speak back to sites of design. Still other work has explored the problem of "values in repair," calling to light the range of normative and affective values that may be enacted through repair activities in both Southern and Northern contexts [11].

Many of these themes around action and ordering are echoed in a recent body of social science around problems of material care. Theorists of "care in practice" [21] argue that it is not solely a human relation, but that technologies also participate in providing care and in turn, depend on care work [19]. STS researchers have described relations of care in settings ranging from nursing homes to farms [20] to transport systems [4]. Feminist readings of the labor of caring (both emotional and physical) have been particularly central to redefining conceptions of care. The gendered relations of caring also shift in this move from looking after people to nurturing animals and material objects. In bringing together literatures on care and repair it is worth noting that in Kampala, caring for technological things in repair is still largely a male occupation (as it is in much of the repair literature), while caring for people inside and outside the domestic sphere remains predominantly women's work.

Denis and Pontille [4] draw on these studies of care in practice to describe the maintenance of the Paris metro signage system. As material objects, the signboards are inherently fragile and vulnerable, open to wear and decay. Maintenance teams share the responsibility for monitoring them for deterioration, and then repairing and replacing those that have been damaged or decayed. Maintenance and repair work not only tends to the materiality of the signs themselves, but also contributes to the production of a unified and stable wayfinding system for the subway riders. Here, care is a matter of concern, *and* an active practice of monitoring and intervening in a system, in order to sustain the system itself and its wider relations over time. The decay of materials also becomes a troubling process in the work of Callén [2]. She notes that European electronic waste is often illegally exported to developing or emerging contexts, yet the problem is partially returned through the contamination of imported rice with high levels lead from the leaching of wasted technologies. Callén argues that the vulnerabilities surfaced in breakdown and repair prompt calls for a new ethics of care across increasingly globalized systems of production and consumption.

The idea that caring is both a practical matter and an ethical relation, is richly articulated by Annemarie Mol in her study of diabetes management in a Netherlands hospital, and in further theoretical work with colleagues Ingunn Moser and Jeanette Pols. Together they explore care as "a mode, a style, a way of working" [21 p7]. This "logic of care" [19,21] refers to the rationale that illuminates care practices: "what it is appropriate or logical to do in some site or some situation, and what is not" [21 p9-10]. For Mol et al. care is a practical and collective accomplishment, framed through material interactions in the world (and with people). As an ethical proposition, care is also resolutely local in nature, eschewing universalist and rule-giving pretensions in favor of more modest and collaboratively framed ambitions. Care, like repair, is what we do together to make the world a more livable place: a "persistent tinkering in a world full of complex ambivalence and shifting tensions" [21 p13].

3. METHODS AND FIELDSITES

The sections that follow report on a total of six months' ethnographic fieldwork in downtown Kampala, undertaken iteratively across three years, from October 2010 to September 2012. This included participant observation with a core set of twenty-one repair-related enterprises within the downtown area, including fourteen repair workshops, three mobile phone dealerships, one on-street broker, one repair school, and one spare parts shop. The work of participant observation involved shadowing repair workers in their daily routines, as they travelled around downtown on foot, visiting other technicians and spare parts shops. These meetings, talks, and observations provided access to a much

wider section of the repair ecosystem in downtown Kampala. The outputs from fieldwork included field notes from observation and hands-on participation in repair, interview transcripts and photographs of repairs in progress. These were coded for themes after each fieldwork segment, allowing for the development and refinement of research questions as the work progressed. All repair workers and businesses have been given pseudonyms.

To undertake this research, the first author travelled from her home in London, UK to Kampala, Uganda. This journey traced historical circuits of colonial power. Legacies of language meant that she could speak English with participants, but in translation a layer of participation and meaning was inevitably lost. Taking up residence in repair workshops meant learning to inhabit the identity of "mzungu" assigned by participants. Meaning "foreigner" in Kiswahili, this term was often used to describe white visitors, and was deeply tied to wealth. Relationships with participants were refracted through these differences in race, gender, and nationality, which often gave rise to convivial stories about how rites of passage for young people took place "here" and "there". But at times, telling stories about difference also surfaced tense and uncomfortable mismatches of life chances, opportunities and mobilities. Being "mzungu" meant accounting for the destructive effects of colonialism, and the current global inequalities between states, in repair workshops on the fly. Paraphrasing Helen Verran, (and like other sites of ICTD work), this involved a process of grappling with colonial histories in the making of a new, post-colonial present [28].

During fieldwork, initial access to workshops was facilitated through the personal connections of Makerere University staff, and expanded through referral sampling. Although the rollout of the mobile infrastructure has largely been funded by multinational corporate investment, repair workshops in downtown Kampala operate overwhelmingly as independent, informal and technician-owned micro-enterprises. As a counterpoint the first author looked for workshops that were differently organized and found a total of four businesses in the downtown area that were different in size, ownership and affiliation. All four of these workshops participated in field research, and we describe these relationships of authorization in the next section.

4. EMPIRICAL CASES

4.1 Case 1: Software repair in authorized and independent settings

Authorization is a term used by repair businesses themselves to describe endorsements from other companies, namely mobile manufacturers or network providers. Within the four workshops we located in downtown Kampala, authorization described very different relationships. We take time here to provide complex renderings of the linkages between these workshops and their authorizing partners, because they impact on the different modes of repair that businesses provide.

Relationships of authorization were often developed in order to fulfill warranties: the guarantees given by manufacturers and retailers to consumers that any faults with mobile handsets will be repaired, or the device replaced within the first year of use. Following Mol and colleagues [19,21] we argue that they constitute a particular "style" of caring. Warranties regularly form part of the marketing of devices, speaking directly to consumer concerns about material fragility. They aim to catch manufacturing faults and provide a minimum usage period for the device and as such, are a highly visible relation of care between manufacturers or retailers and consumers and their devices.

As part of the fulfillment of warranties, companies must put in place infrastructures of repair. To perform repair successfully, technicians require information about phones, knowledge of their patterns of breakdown and the embodied experience of a range of repair techniques, such as cleaning, parts replacement and soldering. Effective fixing relies on having access to spares: not only material parts, but also digital artifacts such as firmware files. Technicians also require tools: most obviously the hand tools used in hardware repair, such as the soldering iron or the toothbrush, but also software repair tools that gain access to the embedded systems on board devices. In this sense repair relies on information and artifacts generated during moments of design and production, yet also necessarily exceeds them, as phones go out into the world and fail in multiple and idiosyncratic ways.

Two of the four authorized workshops in downtown Kampala maintained relationships with mobile manufacturers. Servicemob was the service center of a fast-growing East Asian multinational company, which was one of over seventy others dotted across the African continent. Here, repair knowledges circulated from centers of design and manufacturing via migration, as two technicians had travelled in person from the mobile phone factory in China to develop the repair facility based in Kampala. This marks an intimate relation between sites of manufacturing and repair. Technicians within this workshop drew on a rich ecology of repair knowledge, including tacit and embodied aspects of repair demonstrated by the founders in addition to schematics, tools and firmware files which were updated via email and Internet file transfers.

Riftphone sold and repaired the phones belonging to two multinational manufacturers: one European and one East Asian. This was part of a larger mobile phone sales business that had outlets across East Africa. Both of the authorizing manufacturers provided technicians with access to online knowledge portals, where they could view information about handsets and repair tools. These also provided mechanisms for repair training, such as online courses (which technicians were required to take) and a

question and answer facility for troublesome repairs. However, within this workshop technicians also repaired phones made by other manufacturers, leading to an interesting juxtaposition of authorized and unauthorized practices. Both Servicemob and Riftphone have privileged access to information, knowledges, parts and tools.

The third workshop Cityphone, and the fourth, Repairtech, were authorized by network providers rather than manufacturers. Cityphone was a micro-enterprise of two staff owned by a Kampalan businessman who had a small contract to repair warranty phones. Technicians were provided with software tools and spare phones to cannibalize for parts, but no ongoing support. Repairtech was technician-owned and had scaled up from a micro-enterprise to encompass multiple concessions within the retail shops belonging to a network provider. In an inversion of the other sites, this workshop had to pay for their staff to undergo manufacturer-sanctioned training in order to become authorized. Here we see a slightly different picture: Cityphone has privileged access to tools and parts, but Repairtech has to forge their own relations with a mobile manufacturer to receive validated status from the network provider.

Outside of these relationships of authorization, mobile manufacturers restrict information about the design of mobile devices, knowledges about repair and tools and artifacts used in repair such as firmware files. The majority of technicians in downtown Kampala, who worked independently and informally, did not have access to information from sites of design. In our first case, we draw out the differences between performing software repair in authorized and independent sites.

The practice of software repair aims to fix any malfunctions, corruptions or errors relating to the software systems onboard mobile devices. It usually involves a process called "flashing," where technicians use software programs, cables and hardware interfaces in order to gain access to the embedded systems of the phone, and erase the content of the flash memory. After this is done, technicians re-write a new and trusted copy of the firmware files that correspond to this particular device, hopefully removing any corruption in the process. The term firmware refers to permanent software programmed into a read-only memory; it is crucial to the operation of electronic devices, from guiding the basic startup of the device and booting into the operating system. The vignette below describes the process of flashing at Riftphone, (the workshop authorized by both a European and East Asian multinational brand):

A phone came in for flashing, so Peter took me over to the computer to show me the system that they used. He connected the phone to the computer via USB. Then he opened the [authorized] software program, and typed in the model number from the back of the phone into a search box in the software window. Many different releases of firmware for that particular model were listed on-screen. The software also displayed the serial number of the phone, and Peter highlighted the first few digits. He explained that they were to do with the territory of the software release. Firmware was tweaked for different regions, and the newest releases weren't always available in all territories… He selected the correct firmware file and then checked a box on-screen that indicated the phone was completely dead. He told me it was better to re-write the firmware than to restore it, as this action entailed a proper erase and re-write and not just an update or overwrite. Then he clicked the 'refurbish' button and followed instructions given by the software to turn the phone on by holding the power button. The flashing began, and information about the process began to read out on the software log window. Field notes 31 August 2012

Authorized software tools are produced by device manufacturers for intervening into their phones. When Peter wants to undertake a repair, locating the firmware file (and its correct version) is straightforward. He simply types the model number of the phone into the software search function. If a copy is not already stored locally, it can be immediately downloaded using a wired connection to the Internet.

Figure 1. An "independent" software repair tool assemblage, Jason's workshop, 19 May 2011.

In contrast, independent technicians take advantage of a small but highly competitive global market for third party repair tools that enable access to similar functions. The photograph above shows a technician called Jason and a range of third party tools assembled in the process of gaining access to the embedded systems of a phone. The phone is in his left hand, connected to two power cables which allow it to boot without a battery. The third cable carries data, linking the phone to the tape-covered hardware device in the center of the photograph. This peripheral is known to technicians as a "flasher box" or simply a "flasher". The flasher contains a programmed circuit, which establishes a connection between the phone and the computer, acting as a hardware interface. On the computer screen, a window is visible. A software program operates with the flasher and across the assemblage to enable a range of interventions into the mobile phone.

Although technicians can use third party repair tools to access self-test procedures, reset factory settings, re-build serial numbers, and remove SIM locks (amongst other functions), they must find stable and working copies of the firmware files to be written back onto the phone in order to complete the repair. Independent technicians do not have ties back to sites of design and manufacturing, and therefore easy access to firmware files. Instead they look to two networks of repair knowledge: firstly their peers located within walking distance in the downtown area, and secondly trans-local sites of repair knowledge online, as this brief snapshot of repair action from the first author's field notes illustrates:

Jason's close friend Ibra came into the workshop with a Nokia 6500 phone. He wanted to flash the phone, but explained that he didn't have the firmware files. He demonstrated the phone's problem: on startup it just showed the Nokia logo, and then went black. Jason connected the phone by USB to the Turbo Flasher box, and using options on the software window, he tried to flash the phone using the firmware files that he had to hand on his computer. The rolling software log on-screen notified Jason that this process had failed. He connected the phone to the hardware box using a different connector - FBUS - and tried again, but that also failed. Then, Jason used Windows to search his own computer for matching files, using the internal model number of the phone "rm-240". He was not satisfied with the search results, and so he went online to the Shrak Mobile firmware file store, and browsed through the sections seeking the latest uploads for the rm-240 phone. Next, he searched on Google for "rm-240 latest flash file" and afterwards "rm-240 v10.60" and then "rm-240 v12.35"... Field notes, September 7, 2012

Independent technicians are excluded from trans-local flows of repair knowledges and tools that travel from sites of manufacture to downtown Kampala. The struggle to locate and download firmware files (particularly in the context of unreliable networked infrastructures) becomes a part of repair work for independent technicians Jason and Ibra. In contrast to the instant access to manufacturer resources available at Riftphone, independent technicians search longer and harder for the same resources. Exclusion drives technicians' participation in collaborative networks (though authorized workshops also participate in these networks in limited and often clandestine ways). For independent technicians peer support becomes a significant part of their infrastructures of repair, as they cultivate a network of peers in the downtown area that can assist with difficult repairs or bridge gaps in their knowledge or practice. Sometimes peer support was given freely between close friends, such as Jason and Ibra, but often technicians "sub-contract" work to others for a small fee, (mirroring findings in Bangladesh [1]).

Independent technicians also take advantage of the circulating copies of firmware files hosted online, which are available through Google, but also hosted on specific repositories such as Shrak file store that are created by technicians, for technicians. This example surfaces deeply networked knowledge practices, where infrastructures of repair are widely geographically distributed and crowd sourced, providing at least partial access to proprietary firmware. Here, infrastructures of repair are not given, but are actively pieced together by technicians in the work of searching, connecting and collaborating, leading to a very different "style" of care in independent workshops. These two vignettes foreground some of the most significant relations within the mobile ecology in downtown Kampala, that will be revisited in our later discussion on care.

4.2 Case 2: SIM Unlocking and "The Game"

Our second case concerns the third party software repair tools used by independent technicians, many of which also perform SIM unlocking as part of their function. SIM locks are operational restrictions encoded into mobile phone firmware by mobile manufacturers on behalf of telecommunications companies, which limit the operation of a device to certain networks, network providers or geographic areas. These are a prominent example of proprietary closures, given that the GSM standard otherwise enables the interoperability of devices and networks. SIM locking works against repair in downtown Kampala in two ways. Firstly, the aftermarket for used mobile handsets is particularly significant in developing regions. Mobile handsets travel to Uganda from other places with their SIM locks intact, for example through the reselling of used mobiles by "recycling" companies in the global North. SIM locking renders these devices useless in Kampala as they have travelled outside of a particular circumscribed geography, or they remain tethered to a network provider that is not present in the Ugandan market. If these phones are not unlocked then their useful lives will be over, and they will become waste, or be sold to technicians for repurposing as collections of spare parts.

Secondly, we observed an increasing trend for low cost handsets to be SIM locked by multinationals operating in East African markets. SIM locks inhibit the strategy of managing multiple phone numbers (and their corresponding SIM cards) used by Kampalan customers to reduce the overall costs of telephony, which is widely recognized in the literature on mobile use in developing contexts [16,26]. Customers call friends and relatives using the same network provider to reduce the call costs, and call at particular times to take advantage of incentives offered by telecoms carriers. These fractional savings made can help to reduce the amount of disposable income spent on telephony.

Our case tells the story of one particular flasher box and its accompanying software program, called "Just Another Flasher," or J.A.F. This flashing system unlocks Nokia models from the early 2000s with DCT4 architecture. Flasher boxes such as J.A.F. and their accompanying software play a vital part in repair work in downtown

Kampala. Technicians draw on computers, flasher boxes, software and cables in order to remove the SIM locks present on devices, and to get them working on Kampalan mobile networks, facilitating different modes of access and preventing the wasting of devices - forms of care to devices that extend their material lives.

Figure 2. Two dead J.A.F. boxes in Gilson's workshop, 13 November 2010.

Independent technicians described how they relied on the "geeks and hackers" who made flasher boxes and their accompanying software in order to be able to perform software repair. They met these tool developers on online repair sites such as the virtual message board known as GSM Forum, which was frequented by all of the technicians within our study who had access to the Internet (11 workshops). In order to produce unlocking tools, third party developers must reverse engineer the cryptographic algorithms that protect the SIM locks, and embed these into flashing software and flasher boxes. These tools together read information held locally on each particular handset, and calculate unlocking codes that are then written back onto the phone.

According to threads on GSM Forum, the DCT4 unlocking algorithm was extracted from a Nokia "authorized" repair tool, and then built into a whole generation of flasher boxes. Tool developers hack mobile manufacturers' products and systems in order to produce ways to remove the proprietary closures of SIM locking. However, this was not the only form of hacking that we saw within this ecosystem. During the first round of fieldwork the first author heard technicians complaining about how their J.A.F. boxes had died. A technician called David explained:

"I thought it had gone just because of electricity problem, just like any other gadget - a shock... when I saw it wasn't responding I had to consult others who get this problem. When I logged in [to GSM Forum] so many people were complaining so I realized it was this MXKey." Interview excerpt, 20 September 2012

A piece of malware that "killed" the J.A.F. box was written into the update of a rival tool called MXKey, by the MXKey developers. Technicians who owned both devices unwittingly downloaded and installed an update that went on to "kill" J.A.F., an entirely separate tool. The GSM Forum online community of repair technicians was a prominent location where this malicious update link was distributed to technicians. The "death" of the J.A.F. system, raises wider questions about the moral and practical dynamics of opening proprietary closures, within this highly competitive market of third party repair tool developers. It also highlights the instability of repair tools, and the continual change and reworking inherent in practices of repair, in finding and combining new tools to bring about access. These tools were difficult to care for, as systems that were fragile and vulnerable to attack. Caring necessitated vigilance on the part of technicians for emerging conflicts within the developer interactions on GSM Forum and other online sites.

As part of wider and ongoing discussions about the development of SIM locking and unlocking technologies, technicians highlighted how SIM lock cryptography was becoming more and more complex in newer, "smarter" devices. The SL3 security systems used in Nokia handsets presented a particular challenge. A technician called Stephen explained that flasher boxes and software:

"...will read what we call the LBF file, that file it consists of the security info, which you have to decrypt to get the unlock code so, that's what we do. That's the procedure. We read the file, try to decrypt via using a method like brute forcing. Brute forcing, it will require a more powerful computer with higher processing features and everything… we don't have those super computers so we send that file to servers, to people who have so much high speed computers, they process it quickly and easily and in return you have to pay." Interview excerpt 21 September 2012

This form of cryptography cannot be circumvented locally, but must be subjected to brute force attacks which require server power that technicians simply do not have access to. Technicians can read the LBF file locally, and submit it to an unlocking service via the Internet, which requires buying expensive credits. This raises multiple challenges for technicians, and the wider repair market in downtown Kampala, as David (a part-time Masters student of Economics) explains:

"SL3 has been the most challenging phones we've had, since I joined repair. Because, they require codes from the manufacturers or other contractors. So these people require visa card and all other online money transfer, so that they can get the money first and then they send you the codes, okay. It requires that strong trust in those agents and these are, these are people that are outside Africa. They are not in our neighbourhood that in time, if they mess up with one thing, I can run there and say "what have you done, you didn't send, I sent you this money you know", it involves a

lot of procedure. So that's it, I can't do SL3 unlocking, basically for fear of the risks. I don't know the right people to deal with online... There are those people that are timid, they are risk averse, like I'm an economist and I'm risk averse, no?" Interview excerpt, 20 September 2012

In this case SIM unlocking has to be performed by actors far outside the Kampalan local market. Technicians like David are excluded from these advanced forms of unlocking, because of their inability to confidently access and pay for online repair services, which represents a real limit to practice. If breaking increased security requires a mass of computing power, technicians will continue to be beholden to expensive online services. This may prevent a new generation of used smartphones from being adopted on Ugandan networks, or being used flexibly across a range of mobile network providers. In this sense, SIM locking may inhibit the potential for an increased range and uptake of mobile applications that is often highlighted in the ICTD literature.

However, technicians were confident that a local service for SL3 SIM unlocking would eventually be produced by the "geeks and hackers" within the developer community. Their narratives reveal interesting expectations about the breaking of security systems: Stephen explained:

"In the future I think it [an SL3 solution] will be, because we had SL1, SL2... from SL1 things were not easy, the Nokia programmers, they did so much in that area… we were using test points, it was hard, then they developed a software which can read and write back. So we are expecting the same thing to happen to SL3 anytime. Just because these people are still making money from the market then they will produce a simpler method. That is the game behind." Interview excerpt 21 September 2012

Stephen frames the breaking of SL3 as an inevitability. Systems get broken down over time, as part of larger trajectories of technological development, such as the movements from SL1, to SL2 and now SL3. However, the technical breakthroughs made by developers will not necessarily correspond with the moments that technicians get hold of new SIM unlock solutions. Developers have purchased the server equipment that runs brute force unlocking systems. Only when profits have been recouped and the market slows due to increased competition, will there be a greater impetus towards finding a more accessible solution for SL3. He comments:

"It's a game because, a group of people are making money. For sure people are investing and if someone invests they expect to get something. If you think you have got enough profit then he has to release a cheaper one so everyone can use it. So it's a game, and I enjoy that game." Interview excerpt 21 September 2012

Within this situation, independent technicians occupy a difficult position. On the one hand they are marginalised from authorized tools and knowledges by mobile phone manufacturers. Yet the tools that they rely on made by third party developers offer only partial solutions. This case also shows us that it is becoming more difficult for technicians to unlock newer devices, as manufacturers increase the sophistication of mobile cryptography. Unlocking requires advanced tools that are inaccessible to technicians in downtown Kampala (and perhaps in many other independent repair sites across the global South). This means that they risk being excluded from caring for newer devices entirely – or at least until time passes and "the game" evolves.

5. DISCUSSION

The empirical cases above make visible both the centrality and complexity of repair work within the wider infrastructures that support and sustain the much-celebrated 'explosion' of mobile telephony in Uganda and other African countries. Like other findings in the HCI and ICTD repair literatures, the empirical vignettes above speak to the distinct forms of skill and innovation to be found in the repair workshops of downtown Kampala – sites commonly obscured within design or adoption-centered accounts of technology in global development settings. The cases also speak to the complex global and local flows that sustain repair work, ranging from forms of local collaboration (though also competition) that connect technicians like David and Jason to the wider distributions of knowledge, expertise and material resources to be found in the tools and online resources that local repair workers regularly draw on in tackling the breakdowns they confront. Such findings confirm and extend a growing body of ICTD work affirming both the value and complexity of repair work within the wider sociotechnical infrastructures in developing contexts [1,14,15].

Our findings also speak however to the distinct role that proprietary closures play in challenging and limiting local repair work - the first contribution of this paper. Case 1 has drawn a distinction between authorized and independent forms of repair, surfacing problematic dependencies between sites of design and sites of repair. Authorized relationships forge connections between moments of production and repair, facilitating the travel of technicians from manufacturing to repair sites, the movement of repair knowledges through corporate channels, and connections via the Internet to repositories of firmware files. Authorization itself is a claim to value that both relies on and asserts this privileged status. Mobile manufacturers and network providers authorize local sites of socio-technical practice in order to offer their customers care that has been validated or endorsed by the company. Local practices of getting phones working are set into wider regimes that incorporate the resources – but also the policies and standards – of multinational companies. Relationships of authorization are often tied to particular "logics" or "styles" of care for devices [19,21], such as warranties, where manufacturers or network providers undertake to repair or

replace a faulty handset free of charge within the first year of use. This is a common relation of care for devices within the global market of mobile telephony, but it is oriented towards a very limited post-manufacturing horizon.

By contrast, stories of software repair in independent workshops surface a very different set of sites and actors. Third party flashing tools purchased by technicians provide access to embedded systems that would otherwise remain closed. Local peer networks in downtown Kampala and trans-local hosting sites offer the means to get hold of firmware files. We can see that resources generated in and through collaborative production and peer organization are extremely important for independent technicians, as relations of care involved finding and assembling sets of resources that enable repair. In comparing the two organizational contexts and sets of practices, our empirical vignettes raise critical questions about the distributions of care and possibility across sites of repair in downtown Kampala. Although relationships of authorization evince a form of care (for some), they are also deeply exclusionary, giving rise to deeply asymmetric knowledge flows that contour and frequently frustrate more widely accessible forms of repair. They also protect the power and prestige of (distant) global manufacturers over the interests of (local) users, extending proprietary privilege and control well beyond the point of sale.

Case 2 centers on the proprietary control of mobile handsets introduced through SIM locking. Here, our ethnographic work reveals complex patterns of access and foreclosure. Where used devices have travelled to Kampala from elsewhere, SIM locks are artifacts of previous "lives," which must be removed to get phones working on Ugandan networks. Caring here means repurposing phones that would otherwise be wasted, and giving them a second life in the hands of a Ugandan customer. SIM locks are also encountered by customers buying new phones, where caring is about enabling more flexible usage of the device.

The story of the J.A.F. flasher system and its demise shows how tool developers work hard to circumvent the security systems encoded by manufacturers, and to provide technicians ways of removing SIM locks. But this is not a story about heroic hackers who go up against powerful corporations in pursuit of openness and for the good of the community. Instead it is a portrait of an ecology of tool developers, who sometimes hack each other's devices in the pursuit of unlocking algorithms. The repair tools that they create are protected by security systems themselves, as they seek to make the most of their position in the market.

Technicians used the evocative metaphor of "the game" to lay out the different positions played by actors in this space: manufacturers designing more sophisticated cryptography, tool developers working hard to crack it, and technicians as "end users" trying to navigate unstable tools and a continually changing market. While technicians understood the breaking of security systems as inevitable in the fullness of time, they also struggled in the short term with the proprietary locks and barriers that limited and sidelined their skills. They are increasingly priced out of unlocking newer smartphones with more advanced security systems, which necessitate an excess of computing power and reliable electrical infrastructures. Heroic hacker (or fixer) stories aside, manufacturers remain all too often one step ahead.

Beyond these immediately practical questions, putting repair and care into dialogue powerfully surfaces the moral and political orderings of ICT infrastructure - the second contribution of this paper. Care shows us how the consumption of technologies is, (following Latour [17]) both a matter of fact - of practical acting in the world - and a matter of concern. Closures in wider infrastructures determine how and when care is withdrawn and devices die, with affective and practical impacts on customers, whose communication practices are disrupted, and on technicians whose work and livelihoods are challenged. Care also recognizes the wider interdependencies between humans and technologies in a shared environment over the lifetimes of people and devices. Handsets that falter or die may emerge as a site of material concern. While (ideally) repurposed or recycled, they may also get stripped, and burned or buried, with deep and negative consequences for the health of people and local environments. As Callén reminds us these consequences can become globalized, for example through the contamination of food production [2].

Furthermore, the empirical accounts of repair analyzed here raise wider questions of proprietary closure that structure and subtend the mobile ecosystem within which ICTD operates. Voices within the field have argued that ICTD has failed to engage with the political economy of mobile telephony, promoting it uncritically as the predominant infrastructure for development. As Anita Gurumurthy asserts, "in its atheoreticism, the discourse studiously avoids any examination of the incumbent mobile telephony architecture—the fact that the mobile phone model is a proprietary network with most applications and services locked in with the network provider" [9 p60]. Similar questions and concerns motivate an emerging strand of work on "open development", which weighs the complex tradeoffs between proprietary investments and the benefits of a more open model [5]. Under such circumstances, attending to the logics and limits of care offers ICTD researchers a way to attend to infrastructures as a site of critical work. In particular, a focus on care uncovers the affective and material consequences of infrastructural politics that may be obscured in more abstract discussions of infrastructural standards and architectures.

Care as an analytic lens also poses questions to ICTD scholars around the kinds of moral and material responsibilities that we as researchers and practitioners bear towards the "next billion" handsets (and the lives they touch). We return to the ethics of care in practice for

resources to think through these issues. An ethics of care for materials is about recognizing human and material vulnerability, finding ways to sustain and remake the ties that matter to us, and finding local and 'good enough' resolutions through processes of patient enquiry and experimentation. Mol advocates good care as "tinkering in practice" [21 p13]. Tinkering in turn, we propose several implications that might follow if relations of care were moved to the center of ICTD practice and concern.

At a first and most immediate level, this study adds to calls for repair to be taken into consideration during processes of design and manufacturing. This necessitates designing devices in ways that anticipate the actions required to repair common malfunctions: screwing instead of gluing cases, using standard rather than proprietary fittings, making spare parts widely available (and across an extended period of time). Repair relies on embodied skills that range in difficulty, such as screwing, levering, heating, bending and soldering. Designers might treat the inner workings of devices as truly user-accessible areas, and mark out more and less attainable tasks based on the complexity of these techniques.

Yet as Rosner and Ames point out, [25] breakdown also exceeds factors that can be anticipated at the point of design, suggesting that mobile manufacturers must also work downstream from moments of production to support wider infrastructures of repair. Manufacturers could contribute to this project by selling their proprietary software repair tools on the open market and providing access to firmware files (if necessary using licenses to allow for purposes of repair). This would lessen the marginalization of informal, independent technicians, enabling them to avoid some of the circumvention work that currently lengthens and frustrates mobile repair in these contexts. It would also diminish asymmetries between authorized and independent repair settings. Such a move would parallel commitments recently undertaken by automobile manufacturers in the U.S.A. – inspired in part by Right to Repair legislation in Massachusetts, subsequent Memoranda of Understanding reached with aftermarket groups, and the looming threat of antitrust action against what have been decried as the "repair monopolies" of the U.S. auto industry [29]. Under this arrangement, proprietary repair tools and manuals are being made available to customers and independent repair shops, in the first of a staged series of reforms that will enable access to the internal systems of vehicles from model year 2018.

As an alternative to this open model, we suggest that barriers to "authorization" could be lowered to allow access to independent technicians meeting appropriate thresholds of skill and experience. Manufacturers could help to regularize and elevate the standing of informal and independent micro-enterprises by recognizing them as sites of repair. Where the informal nature of repair operations limits and challenges such partnerships, efforts to support and institutionalize repair micro-enterprises (for example, through access to bank accounts and payment cards) may further enhance connections between local repair operations and global technology firms – and represent a real and tangible instance of capacity building commitment.

Finally, mobile manufacturers and network providers could radically rethink the use of artificial limits on technologies such as SIM locking. SIM locks are significant in a model of consumption where the up-front costs of handsets are subsidized. These sales practices are most obviously associated with mature markets (where SIM locks are linked to contracts of 12, 18 or 24 months). Under such conditions, manufacturers have strong economic logics for SIM locking – but not all markets operate in this way, and SIM locking may be notably ill-fitted to a world in which handsets circulate more globally and over longer stretches of time, including as they move into the global mobile aftermarket. These questions around the "lives" of devices are particularly interesting in light of consumption trends in mature markets of the global North, where smartphones are increasingly similar in terms of baseline functionality, and discussions of "good enough" computing [3] point towards new modes of consumption organized less around an upgrade culture and more around longer relationships with material devices.

Such insights remain partial and exploratory—an example of the kinds of tinkering with care that we believe that can open up new avenues and challenges for ICTD research and practice. In this paper, putting care center stage has moved us from empirical insights towards new possible roles of advocacy and activism. Thinking from repair, and with care, enables us to more deeply engage the rich interconnections between social and material lives as they are sustained across time.

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7. REFERENCES

1. Ahmed, Syed Ishtiaque, Steven J. Jackson, Md. Rashidujjaman Rifat. "Learning to Fix: Knowledge, Collaboration and Mobile Phone Repair in Dhaka, Bangladesh" *Proc. ICTD'15* ACM (2015) 4:1–4:10.
2. Callén, Blanca. "Repairing (electronic) vulnerabilities: towards an Ethics of e-waste". In: Mark Rainey and Theo Reeves-Evison (eds.) *Cultures of Repair*. London: Pavement Books (In press).
3. Crichton, Danny. "The Era of Good Enough Smartphones" *TechCrunch* (2014) Retrieved from: http://techcrunch.com/2014/05/22/the-era-of-good-enough-smartphones/

4. Denis, Jérôme and David Pontille. “Material Ordering and the Care of Things”, *Science, Technology & Human Values*, (2015) 40(3), 338-67.
5. Galperin, Hernan. “Goodbye digital divide, Hello digital confusion? A critical embrace of the emerging ICT4D consensus” *Information Technologies and International Development*, (2010) 6 (SE) 53-5.
6. Gartner. “Gartner says smartphone sales surpassed one billion units in 2014.” (2015) Retrieved from: http://www.gartner.com/newsroom/id/2996817
7. Graham, Stephen and Nigel Thrift. “Out of Order: Understanding Repair and Maintenance”. *Theory, Culture, Society* (2007) 24, 3, 1-25
8. GSM Association. *The Mobile Economy Report 2015*. Retrieved from: http://www.gsmamobileeconomy.com/GSMA_Global_Mobile_Economy_Report_2015.pdf
9. Gurumurthy, Anita. “From Social Enterprises to Mobiles-Seeking a Peg to Hang a Premeditated ICTD Theory”, *Information Technologies & International Development*, (2010) 6(SE) 57-63
10. Henke, Christopher R. “The mechanics of workplace order: toward a sociology of repair”. *Berkeley Journal of Sociology*. (1999) 44 55-81.
11. Houston, Lara, Steven J. Jackson, Daniela Rosner, Syed Ishtiaque Ahmed, Meg Young, Laewoo Kang. “Values in Repair” *Proc. CHI’16* ACM (2016).
12. Ilahiane, Hsain and John Sherry “Joutia: street vendor entrepreneurship and the informal economy of information and communication technologies in Morocco”, *The Journal of North African Studies*. (2008) 13(2), 243-55.
13. Jackson, Steven J. “Rethinking Repair”. In *Media Technologies: Essays on Communication, Materiality, and Society.* Tarleton Gillespie, Pablo J. Boczkowski, Kirsten A. Foot (eds.) MIT Press, Cambridge, USA. (2014) 221-240.
14. Jackson, Steven J., Syed Ishtiaque Ahmed, and Md Rashidujjaman Rifat. “Learning, innovation, and sustainability among mobile phone repairers in Dhaka, Bangladesh”. *Proc*. *DIS’14*, ACM. (2014) 905–914.
15. Jackson, Steven J., Alex Pompe, and Gabriel Krieshok. “Repair worlds: maintenance, repair, and ICT for development in rural Namibia” *Proc*. *CSCW’12*, ACM. (2012) 107–116.
16. James, Jeffrey, and Mila Versteeg. “Mobile phones in Africa: how much do we really know?” Social indicators research (2007) 84(1) 117-126.
17. Latour, Bruno “Why Has Critique Run out of Steam? From Matters of Fact to Matters of Concern” *Critical Inquiry* (2004) 30(2) 25-248
18. Lundgren. Karin. *The global impact of e-waste: addressing the challenge*. International Labour Office. (2012).
19. Mol, Annemarie *The Logic of Care: Health and the Problem of Patient Choice.* New York: Routledge (2008)
20. Mol, Annemarie, Ingunn Moser, and Jeanette Pols, eds. *Care in Practice. On Tinkering in Clinics, Homes and Farms.* London, UK: Transcript (2010)
21. Mol, Annemarie, Ingunn Moser, and Jeanette Pols, “Care: Putting practice into theory” Mol, Annemarie, Ingunn Moser, and Jeanette Pols (eds). *Care in Practice. On Tinkering in Clinics, Homes and Farms.* London, UK: Transcript (2010) 7-25
22. Orr, Julian E. *Talking about machines: An ethnography of a modern job*, Ithaca, USA: Cornell University Press. (1996)
23. Puckett, Jim “High-tech's dirty little secret: the economics and ethics of the electronic waste trade” Smith, T., Sonnenfeld, D. A., & Pellow, D. N. (Eds.). *Challenging the chip: Labor rights and environmental justice in the global electronics industry*. Temple University Press, (2006) 225-233
24. Rangaswamy, Nimmi and Sumitra Nair. “The Mobile Phone Store Ecology in a Mumbai Slum Community: Hybrid Networks for Enterprise”, *Information Technologies & International Development*, (2010) 6(3), 51-65.
25. Rosner, Daniela K. and Morgan Ames. “Designing for repair?: infrastructures and materialities of breakdown.” *Proc*. *CSCW’14*, ACM. (2014) 319–331.
26. Sey, Araba. “Managing the cost of mobile communications in Ghana.” *Communication Technologies in Latin America and Africa* (2010) 143-166.
27. Suchman, Lucy A. 1987. Plans and situated actions: the problem of human-machine communication. Cambridge University Press.
28. Verran, Helen *Science and an African Logic*. University of Chicago Press. (2001).
29. Wiens, Kyle “You gotta fight for the right to repair your car” *The Atlantic* (2014) Retrieved from: http://www.theatlantic.com/technology/archive/2014/02/you-gotta-fight-for-your-right-to-repair-your-car/283791/
30. Wyche, Susan, Tawanna R. Dillahunt, Nightingale Simiyu, and Sharon Alaka. “If God Gives Me the Chance I will Design My Own Phone: Exploring Mobile Phone Repair and Postcolonial Approaches to Design in Rural Kenya”. *UbiComp’15*, Osaka, Japan, (2015). 463-473.