Heads in the Clouds: Measuring the Implications of Universities Migrating to Public Clouds

Tobias Fiebig*, Seda Gürses*, Carlos H. Gañán*, Erna Kotkamp*, Fernando Kuipers*,
Martina Lindorfer¶, Menghua Prisse*, Taritha Sari*
*TU Delft, Netherlands
{T.Fiebig,F.S.Gurses,C.HernandezGanan,E.Kotkamp,F.A.Kuipers,P.T.Sari}@tudelft.nl, M.M.G.C.Prisse@student.tudelft.nl
¶TU Wien, Austria
martina.lindorfer@tuwien.ac.at

***Abstract*—With the emergence of mandatory remote education and work in universities due to COVID-19, the 'zoomification' of higher education, i.e., the migration of universities to the clouds, reached the public discourse. Ongoing discussions reason about how this shift *will* take control over students' data *away* from universities, and may ultimately prevent privacy from being an attainable goal for researchers and students alike. However, there has been no comprehensive measurement of universities' use of public clouds and reliance on Software-as-a-Service offerings to assess how far this migration has already progressed.**

In this paper, we perform a longitudinal study of the migration to public clouds among universities in the U.S. and Europe, as well as institutions listed in the Times Higher Education (THE) Top100 between January 2015 and December 2020. We find that cloud-adoption differs between countries, with one cluster (Germany, France, Austria, Switzerland) showing a limited move to clouds, while the other cluster (U.S., U.K., the Netherlands, THE Top100) frequently migrates universities' core functions and services to public clouds—starting long before the COVID-19 pandemic. We attribute this clustering to several socio-economic factors in the respective countries, including the general culture of higher education and the administrative paradigm taken towards running universities.

We then analyze and interpret our results, finding that the implications reach beyond individuals' privacy towards questions of academic independence and integrity.

I. Introduction

Over the past decade, we have seen a shift in IT operations towards the use of cloud infrastructures [58, 83]. Instead of running IT services with on-site teams and on infrastructure owned by organizations, services are now often deployed on public cloud infrastructure. Especially for web services, the model of using Software-as-a-Service (SaaS) has become prominent. However, this operational paradigm shift also leads to a change in control. While, before, user data would remain on infrastructure controlled by an organization, this data is now stored and processed by an external operator.

For universities using cloud infrastructures, this leads to hard challenges. These stretch from limiting universities' ability to audit or implement privacy by design, e.g., privacy guarantees ensured through technical means, or ensure privacy-as-compliance, e.g., in terms of following privacy regulations [25, 94], to impacting a universities' ability to obtain meaningful informed consent when they employ cloud operators. During the past year, for example, much debacle surrounded the use of Zoom as the now de facto standard for remote lectures and events. Zoom only started to systematically attend to privacy and security concerns raised by educational institutions when pressure was handed down to the company from investors [57]. At the same time, universities that adopted Zoom for their remote lectures practically reduced students' consent choices to either using Zoom, and having their personal data processed by Zoom, or not participating in lectures.

The infrastructural and data control acquired by companies like Zoom have a knock on effect on academic freedom. In 2020, Zoom ultimately prevented faculty and students at New York University from conducting a guest lecture—incidentally on censorship by Zoom and other tech companies—using their Zoom license [67]. The question hence expands beyond *'what private data do universities share with cloud platforms,'* to include *'in what way can these cloud platforms use their infrastructural position and data practices to influence academic processes in universities.'*

The adoption of educational technology ('*EdTech*'), i.e., the use of "market-facing digital technologies in education" [62], has already prompted critical studies from the social sciences, warning about blurring lines between public educational institutions and private corporations as a threat to academic self-governance [48, 62, 79, 87]. Despite these concerns for privacy and academic freedom, there are no comprehensive measurements of *how* reliant universities are on public cloud infrastructures. Hence, in this paper, we address this gap by measuring cloud adoption in universities over the past six years in seven countries (the U.S., the U.K., Germany, Switzerland, Austria, the Netherlands, and France) and in the Times Higher Education (THE) Top100. We do this by measuring universities' hosting on cloud platforms as well as their use of cloud-based email providers; cloud-based learning management systems (LMS); and, cloud-based video and lecturing tools.

We find that universities in the Netherlands, the U.K., the U.S. and those in the THE Top100 are significantly more prone to depend on cloud infrastructures, while especially those in France and Germany rely far more on in-house services. We attribute these differences to a diverse set of socio-economic factors, including a historically different understanding of *what* higher

education means, the university functions (research, education, administration) the IT infrastructure is commonly aligned with, and the value placed on academic independence in these countries. Furthermore, we observe that universities' migration to centralized cloud infrastructures (Google/Amazon/Microsoft) does not show a clear pandemic effect as observed for the Internet as a whole [33]. The notable exception here are video conferencing tools (apart from Skype-for-Business), where we see a clear uptick of adoption across the board, *except* for the U.S., where especially Zoom adoption was on the rise years before the pandemic.

In summary, we make the following contributions:

- We are the first to map out the cloud dependence of universities in Europe, the U.S., and the THE Top100, and find that this is an ongoing process that predates the COVID-19 pandemic.
- We document severe *differences* in cloud adoption between countries and trace this back to fundamental differences in how these countries approach university IT and higher education.
- We demonstrate how an increasing reliance on cloud infrastructure may ultimately prevent privacy from being an attainable goal in universities.
- We find that questions of data and infrastructure control have implications beyond privacy, including threatening academic freedom as a core value of universities.

Structure: In Section II, we provide an overview of university IT. We introduce our general methodology in Section III, and present an overview of cloud use in Section IV. Next, we zoom into universities' use of cloud-based email solutions (Section V), cloud-based learning management systems (Section VI), and their use of cloud-based video communication and lecturing tools (Section VII). Finally, we contextualize our findings and provide recommendations for researchers and universities in Section VIII, and conclude in Section XI.

II. University IT

Generally speaking, universities are *organizations* with a *purpose* or *function*, which can be supported by IT pillars [93]. Commonly, these major functions are: (1) *Education*, (2) *Research*, and to enable these two, (3) *Administration* [84]. Note that while these functions may seem intuitively discrete, they partially overlap, also in the tools and applications used to address the needs associated with each function.

In terms of cloud adoption, universities look towards cloud infrastructure as a way to reduce their own IT investments, and potentially even a chance to free up and monetize assets bound there, e.g., IPv4 addresses [3, 69]. While the use of specific tools may lead the university to enter into agreements with a multitude of companies, many of these tools themselves are hosted on one of the three largest cloud platforms: The offerings of Google, Amazon EC2, and Microsoft Azure.

A. Education

IT infrastructure for education includes all tools that enable students to learn. Traditionally, this means all systems used for assessment and learning management systems (LMS), as for example Moodle [14]. While educational software for remote teaching already received attention before the COVID-19 pandemic in the context of blended learning and MOOCs (Massive Open Online Courses), COVID-19 increased the importance of learning infrastructure like video chat tools and streaming solutions, as well as examination and proctoring software. In most universities, these tools are offered institution-wide as centralized services, usually with the support of a central IT department. In addition, specific programs might need additional infrastructure, e.g., a program on system and network engineering may also need dedicated server rooms and networking labs [15], often offered in a decentralized manner.

Several vendors offer cloud-based LMS (see Section VI), which allow universities to outsource one of their largest (in terms of users) systems to an SaaS provider. Even though tools for self-hosted remote lectures exist, the common perception, especially since COVID-19, associates remote lecturing mainly with Zoom, and—to a lesser extent—other cloud-based platforms like Microsoft Teams and WebEx. Similarly, proctoring solutions—already a concept of questionable ethics [23]—that became prominent during the COVID-19 pandemic are almost exclusively provided as cloud-hosted services.

B. Research

In contrast to educational tooling, research IT infrastructure is often more dependent on the individual needs of researchers, and therefore tends to be decentralized. Applications here range from the—in our field—common experimental systems (IoT test labs, network measurement infrastructure, and machines vulnerable to certain exploits) to IT systems used to control a diverse set of research instruments, such as electron microscopes or chemical processing lines. In addition, super computing capabilities [37], data storage/open data platforms [106], and research software that support quantitative and qualitative methods, e.g., survey and statistical analysis tools [70] are often centrally provided.

Cloud services can replace both types of research infrastructure. Researchers may use Platform-as-a-Service infrastructure for running measurement and experimental systems, and especially GPU supported compute is often outsourced to cloud platforms. Furthermore, universities may opt to use outsourced and cloud-hosted instances of survey and interview platforms to provide this service to their researchers. Especially Amazon's Mechanical Turk has become a common tool in human factors and human subject related work, ranging from the social sciences to usable security and privacy [71].

C. Administration

The administrative function of a university entails all services and operations needed by a university to *support* (not execute) its primary functions for education and research. This means budgeting and accounting tools, HR systems including

personnel management databases and applicant management systems, and—arguably—also student application management. Furthermore, this entails foundational services like email, and the operation of a universities' network. Similarly, telephony and business communication tools—before the pandemic tools like Skype-for-Business (SfB), Microsoft Sharepoint, as well as Microsoft Teams and other video chat solutions that now overlap with educational tooling—*traditionally* fall into this category.

Applications for specific use cases (hiring, student admission, finance and accounting) are inherently complex and highly business critical. Hence, outsourcing allows universities to not only reduce the needed local expertise to run these tools, but also allows the outsourcing of responsibility in case these tools become inoperable. Especially for highly business critical applications, as for example email (see Section V) or security management, cloud setups promise higher reliability.

III. Methodology Overview

In this section, we describe our general methodology in terms of the dataset we use and which institutions we selected. We describe the more specific aspects of our methodology for the individual services in the corresponding sections.

A. Selection of Institutions

To investigate cloud usage in higher education institutes, we focus on universities (PhD awarding institutions) in the global north, specifically the U.S., Germany, Switzerland, Austria, the U.K., the Netherlands and France. In addition, we also include the institutions listed in the Times Higher Education Top100 for 2020 [88]. Please see Appendix A-H for the full list of institutions and corresponding domains for each category.

For the U.S., we selected all R1 [19] and R2 [20] universities based on the Carnegie Classification of Institutions of Higher Education, as also referenced in the corresponding Wikipedia article [98]. For the remaining countries, i.e., for Germany [100], the U.K. [103], Switzerland [101], Austria [99], France [97], and the Netherlands [102], we utilized the corresponding Wikipedia pages listing universities. We argue that Wikipedia is a sufficiently reliable source for this information, given the general nature of this information, and that we manually investigated each listed university to identify their associated domain name(s). Furthermore, we do not claim completeness, but instead try to estimate a lower bound with our measurements, see Section IX. If a university uses multiple domains, or used a different domain in the past—especially common in France due to a history of reorganization of the university system—we check all domains and aggregate the results under the name of the institution.

Thereafter we filtered out all institutions for which we did not see at least ten distinct names in at least one month within our six year dataset. We do this to ensure that our data is not influenced by institutions into which we only have limited visibility. In total, this lead to the following exclusions: *(i)* In the Netherlands the Theological University Apeldoorn, a small topic-specific university with no considerable IT infrastructure, *(ii)* For France, 16 domains, all of which belong to other listed institutions and are remnants from before the merging processes of French universities in the late 1990s and early 2000s, *(iii)* In the U.K., 28 domains, 27 of which belong to universities that are included in the dataset with other domains they predominantly use, e.g., `ox.ac.uk.` being used instead of `oxford.ac.uk.` and the remaining one being the Courtauld Institute of Art, and *(iv)* For Austria four domains, one of which is a secondary domain for the University of Salzburg, which is included via its mainly used domain `uni-salzburg.at`, and three small private Universities in Vienna.

Table I: List of data fields in the Farsight SIE dataset.

Field Name	Description	Example
count	Number of times the unique tuple of rrname/rrtype/bailiwick/rdata has been seen.	`12`
time_first	Unix timestamp of the first occurrence of the unique tuple during the data slice.	`1422251650`
time_last	Unix timestamp of the last occurrence of the unique tuple during the data slice.	`1422251650`
rrname	Requested name in the DNS.	`www.example.com`
rrtype	Requested RRtype of the query.	`A`
bailiwick	Zone authoritative for the DNS reply.	`example.com`
rdata	List of all responses received in a single query.	`["93.184.216.34"]`

B. Dataset

We use the Farsight Security Information Exchange (SIE) dataset [32] to measure (1) to what extent universities depend on cloud infrastructure, and, (2) how this dependency developed over time.

The Farsight SIE dataset is collected via recursive resolvers of ISPs. Collaborating ISPs can install a sensor, which sends all DNS cache misses [51, 63] of their clients to Farsight. Farsight explicitly chose to only collect cache misses and filters additional data that might reveal the identity of individual clients, thereby limiting the chance of accidentally collecting personally identifiable information (PII) [32]. Nevertheless, we handled the data following established best practices [4].

In our study, we use a historic dataset spanning from January 1, 2015 to December 18, 2020 in per-month slices. The dataset contains all cache misses observed by participating DNS resolvers during this timeframe, where a unique cache miss is defined by the tuple of `<rrname, rrtype, bailiwick, rdata>` (see Table I). As we only receive cache misses, we cannot make statements about the *popularity* of names seen in the Farsight SIE dataset. Therefore, we focus our analysis on establishing a lower bound on the use of cloud resources, or, to put it into more practical terms, we determine *if* an organization utilizes specific cloud resources, but not *how much* they utilize it.

In comparison to actively collected large-scale DNS datasets, for example, OpenINTEL [40, 73], the Farsight dataset enables us to look *deeper* into the DNS tree of individual organizations. As we see all names that were requested by clients behind DNS recursors participating as sensors, we can see application-specific names (e.g., `application.example.com.`) that are not part of the set of names gathered by active measurement platforms (as prior knowledge on these names is necessary).

At the same time, this also means that we might miss specific names or institutions, as the corresponding DNS resources have not been requested by a client behind a sensor contributing to the Farsight SIE dataset. However, this does not pose a problem in the context of our objective to identify a *lower bound* of cloud usage in universities, as those records we *do* observe are certainly there.

For a complete discussion of the limitations in our dataset, how we address them, and what impact they have on how our results should be interpreted, please see Section IX.

IV. Universities and Public Clouds

In this section, we provide a first overview of universities' reliance on cloud infrastructure of the 'Big Three' (Amazon, Google, and Microsoft). We want to understand to which extent names under universities' domains point toward these infrastructures, regardless of their popularity. This way, we do not only capture the most frequented names—for example the main website, or resources commonly used by students—but also capture, e.g., HR and administration tools, along with systems used for research. Hence, in this section, we look at whether universities have *at least one* name under one of their domains that points to each of the three providers above.

A. Methodology

To identify universities' hosting in cloud infrastructure, we first collect all `A`, `AAAA`, and `CNAME` resource records (RRs) for each university domain from the dataset. We then try to resolve all `CNAME` RRs from the dataset of the corresponding month in which they were observed. If we are unable to resolve a `CNAME` to an IPv4 or IPv6 address, we match RRs for products regularly hosted in certain infrastructure to IP addresses of the corresponding hoster. For example, we will consider `CNAME`s like `www.example.com. IN A ec2-203-0-113-25.compute-1.amazonaws.com.` as a resource hosted by Amazon.

Subsequently, we use the Team Cymru bulk DNS service to associate the identified IP addresses' announcing Autonomous System (AS). Note that we performed this resolution on January 19, 2021 and Team Cymru does not offer a historic WHOIS service. Hence, our data may over-report *historic* cloud usage, with numbers becoming more reliable the closer we get to the current date. Nevertheless, the error we may incur with this is an *over-reporting* error, i.e., historic numbers may seem higher than they are, while an *increase* over time is unlikely to be caused by this, as cloud providers accumulate addresses and do not trade them away, given the increasing IPv4 address exhaustion [69].

B. Results

We present an overview of our findings in Figure 1. On a macroscopic level, we already see major differences between institutions from different countries. Having at least one system located at a major cloud provider is common for the U.S., the U.K., and the Netherlands. The THE Top100 also show a pattern similar to that of the U.S.. Cloud usage in these three countries and the THE Top100 shows a high share of using services hosted at Amazon. For the other two major cloud operators (Google, Microsoft), we find that the U.S. developed towards a situation where all of the three major operators are used at universities at the same time, rising from 79 institutions (30.38%) in January 2015 to 213 (81.92%) in December 2020. For the Netherlands and U.K., we see a lower share of Google over time, starting at 30 (26.09%) of all institutions for the U.K. and 4 (21.05%) for the Netherlands in January 2015, reaching 59 (51.30%) for the U.K. and 7 (36.84%) for the Netherlands in 2020, almost exclusively in a setting where all three major providers are used. Instead, a combination of Amazon and Microsoft based hosting is more common than in the U.S..

France, Germany and Austria form a clear contrast to this picture. All three of these countries have a lower cloud usage, with less than 50% of universities relying on cloud providers for any services (2 (2.47%) to 37 (45.68%) for Germany, 10 (13.51%) to 23 (31.08%) for France, and 0 to 11 (32.35%) for Austria from January 2015 to December 2020). Note that the uptick of Microsoft-related cloud infrastructure use for German universities in December 2020 relates to the sudden introduction of names like `(lync)autodiscover.example.com` pointing to Microsoft Azure addresses. Without this increase, Germany was at 24 (29.63%) of institutions using public cloud infrastructure in November 2020. Switzerland, starting at 5 (35.71%) in January 2015 and 8 (57.14%) in December 2020 forms a middle ground between these two clusters. We conjecture, also see Section VII, that this connects to the wider introduction of Microsoft Teams (the specific name is a necessary condition for using Skype-for-Business use, but *may* also occur for an Office365 or Microsoft Teams deployment).

In general, we find that cloud infrastructure dependence across all sampled countries is on the rise. However, in the Netherlands, the U.S., the THE Top100, and the U.K., we find that this increase occurs on a high level, i.e., especially U.S., U.K., Dutch, and THE Top100 universities already frequently used cloud infrastructure before the start of our measurement period on January 2015. Nevertheless, we do find an increase in the number of cloud providers used for these countries.

We note that we *do not* find a 'pandemic effect' [33] in the use of cloud infrastructure across institutions. Instead, the migration of higher education seems to be an ongoing process that started more than five years ago. Furthermore, we find that the use of cloud resources fundamentally differs between countries. We revisit this pattern in our discussion in Section VIII, as we can observe similar effects for other facets of cloud infrastructure as well.

V. Cloud-Based Email Infrastructure

In this section, we investigate universities' use of cloud-based email infrastructure. Email is arguably one of *the* most essential services on the Internet for professional communication. It regularly carries significant PII, when students have questions on courses, or seek advice in professional and personal matters. It serves as the transport for grades and course assignments, but also job applications, research data, academic discourse, and ideas.

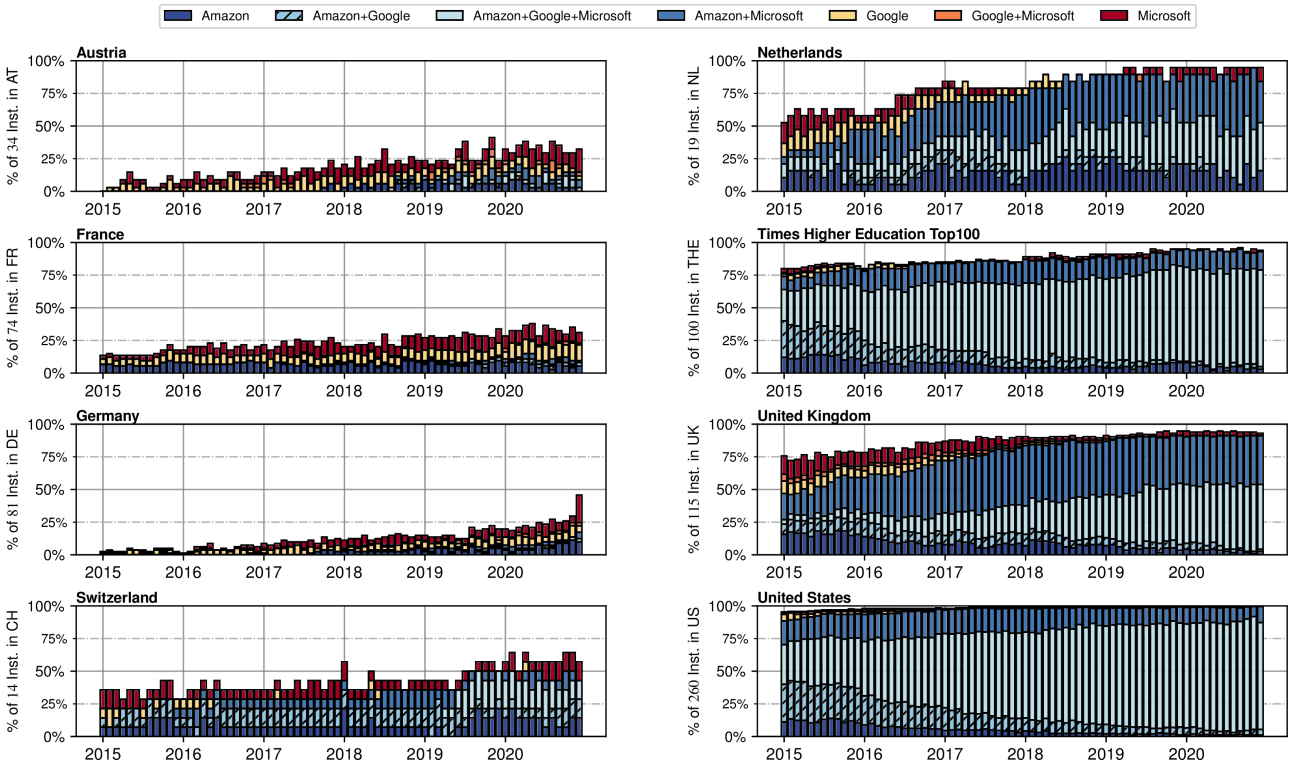

Figure 1: Overview of universities' use of 'the Big Three' cloud providers (Amazon, Google, Microsoft) from January 2015 to December 2020.

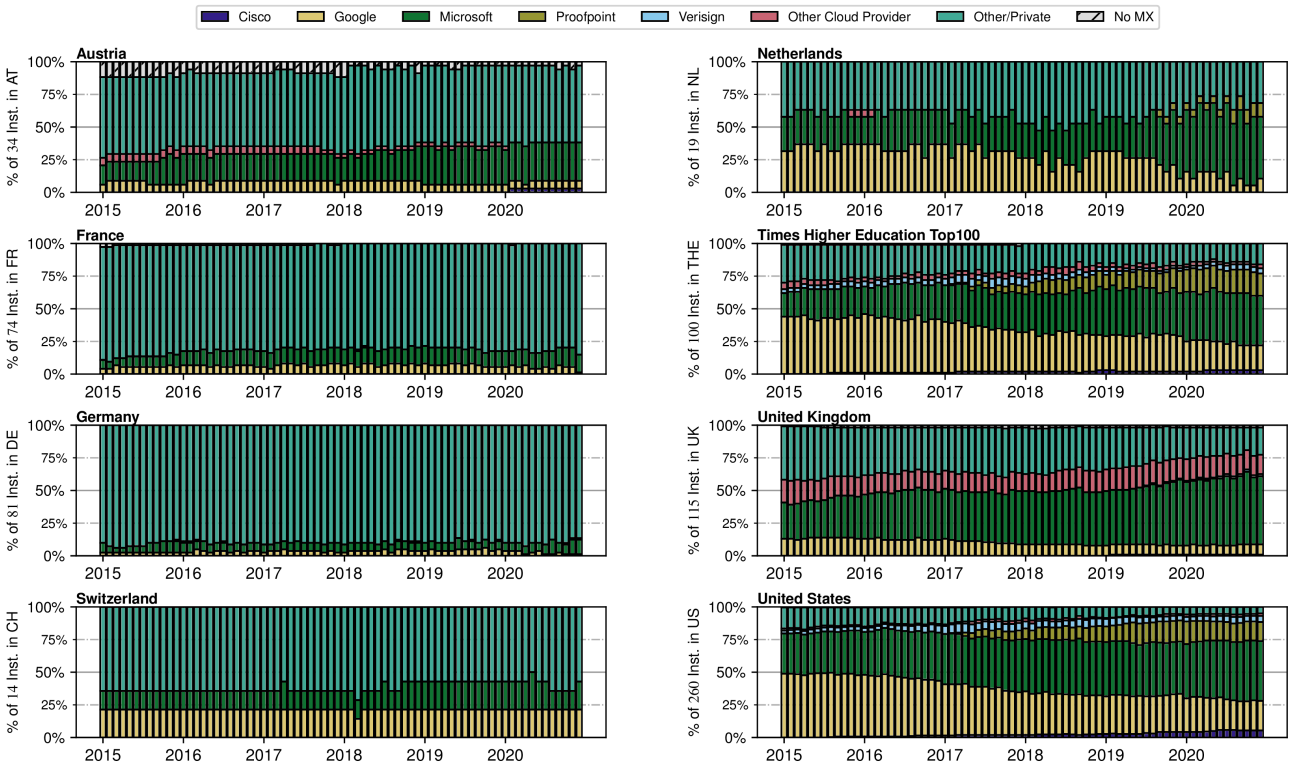

Figure 2: Overview of email providers used by universities between January 2015 and December 2020.

Table II: Overview of selected MX domains.

Operator	MX Domains
Microsoft	outlook.com, hotmail.com
Google	google.com, googlemail.com, smtp.goog
Verisign	pphosted.com
Cisco	iphmx.com
Other	trendmicro.eu, messagelabs.com, schlund.de, spamfighters.net, mailcontrol.com, spamhero.com, emailsrvr.com, mailspamprotection.com, fireeyecloud.com, mailanyone.net, secureserver.net, mailgun.org, icritical.com, barracudanetworks.com

While there are—commonly unused (or unusable) [80]—methods to encrypt emails to ensure contents remain confidential, security, reliability, and control are also significant dimensions of using email in this context. Email is a common gateway for attackers to convince users to install malware [95] and extract credentials [28]. Hence, spam and malware filtering are common services offered by outsourced email platforms, and usually a significant selling point in moving to cloud-based email providers [26]. However, as Patrick Breyer, a member of the European Parliament, recently noted this also means that the operator gets in control of which emails are and which are not delivered to users.[1] Given the strict inbound rules of major providers, which can lead to false positives [35, 61], this means that universities relying on these services may not only outsource their email service, but also the decision about which emails reach their faculty and students.

A. Methodology

To identify whether universities use a cloud-based mail service, we investigate their MX records. Note, that we only measure who handles *inbound* email for a university. Their user mail access and mail storage may be handled on-site or via another cloud-based solution. Still, this means that all mail to this institution flows via the identified service operator.

To identify the used operators, we first check if, for any of the second-level domains (SLDs) of a university (see Appendix A-H) any of the MXrecords points to a domain associated with a cloud-based email provider (see Table II). If we do not find an MX record for any of the SLDs, we decent further down the DNS tree. This happens, for example, if an institution has dedicated sub-domains for email, similar to using staff.example.com. and students.example.com. Only if the SLD does not have an MX record, we consider the university as using a cloud provider if at least one of their third-level domains' MX records matches a known cloud provider.

In addition, we also check whether a university uses Proofpoint's email security solution. Contrary to the cloud products, e.g., from Cisco, Proofpoint uses a dual approach, where they place an appliance on-site, which pre-inspects emails. Attachments and links included in emails are then analyzed in Proofpoint's cloud infrastructure. We indirectly measure this by evaluating universities' DMARC [50] records. If the rua or ruf of a university points to an email address under emaildefense.proofpoint.com., we assume that this university uses Proofpoint's services.

If we do not find an MX record that points to hosts under a cloud providers' domain, or a DMARC record indicating the use of Proofpoint, we count the institution as 'Other/Private'. We acknowledge, that this approach may under-match the number of cloud providers we find. Furthermore, if we are unable to observe an MX record for an institution included in our dataset for a given month, we mark this as 'No MX.'

B. Results

When looking at the results of our measurements, we find that they align with our observations from Section IV. The U.S., the U.K., the Netherlands, and the THE Top100 are again the countries with the most frequent use of cloud-based email providers, reaching 96 (83.48%) for the U.K., 81 (81.00%) for the THE Top100, and 13 (68.42%) for the Netherlands in December 2020. In the U.S., a total of *five* companies control email services for 242 (93.07%) of all R1 and R2 universities in 2020. Again, Germany and France have a lower use of cloud resources, with neither of those countries exceeding 25% in December 2020 (11 (13.58%) for Germany and 11 (14.86%) for France). Both Austria and Switzerland see a higher adoption of cloud-based email services than Germany and France among universities, with 6 (42.86%) for Switzerland, and 13 (38.24%) for Austria in December 2020, with both of them staying well below 50% adoption. We see a slight upward trend in cloud email service adoption in the U.S. and the THE Top100, and a notable increase in the U.K. (from 67 (58.26%) in January 2015 to 89 (77.39%) in December 2020). For the remaining countries, adoption of cloud email services seems to stagnate over the measurement period.

The two most prominent operators are Google, most likely with their classroom product—a work-suite containing email, document handling and integration with Chrome Books—as well as Microsoft with their cloud-hosted Exchange/Office365/Teams product. Other cloud providers only play a notable role in the U.K., where they occupy around 17.39% of the market in December 2020. The most prominent smaller cloud providers here are FireEye and Trend Micro. Furthermore, we find that Proofpoint as a product is most prominent in the U.S. and major institutions in the THE Top100, where we see the service being used by 38 (14.61%) and 17 (17.00%) institutions in December 2020 respectively. We also see a slow move into the Dutch market by this company, where between September 2019 and December 2020 the first two organizations deployed the product.

VI. Cloud-Based Learning Management Systems

In this section, we take a look at universities' use of cloud-based Learning Management Systems (LMS). Learning management systems are—as most academics should be familiar with—online tools that allow lecturers to manage and automate courses, reaching from course registration, via providing course contents, to assessment and examination of enrolled students.

[1] *"Incredible: Microsoft decides which e-mail Members of the European Parliament get to read in their inbox. It's called Outlook spam filter and cannot be disabled."*, Patrick Breyer, MEP, https://twitter.com/echo_pbreyer/status/1363854606132858882 (February, 22, 2021)

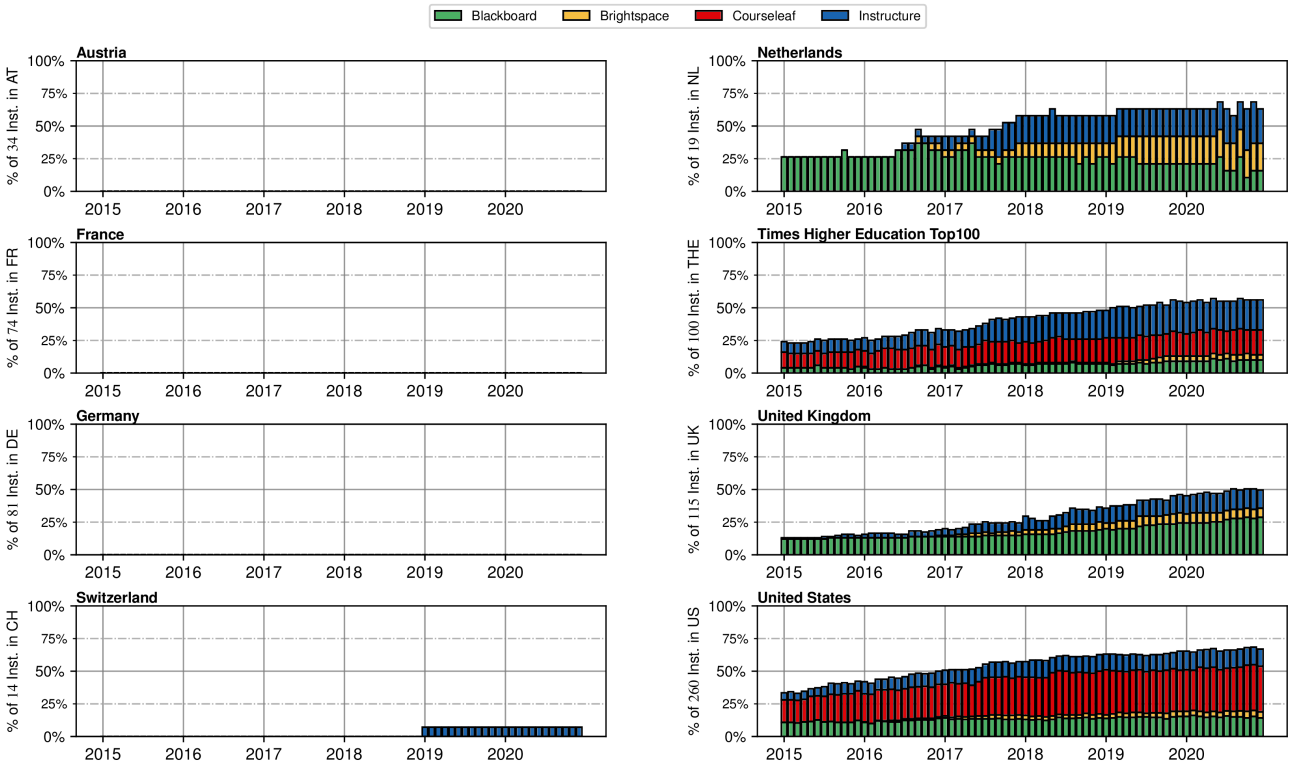

Figure 3: Overview of cloud-hosted Learning Management Systems used by universities from January 2015 to December 2020.

As such, these systems provide some of the core functionality of what a university *does*. It also means that these systems hold some of the most sensitive data a university stores on their students: Grades, course deliverables, and overall study performance.

Putting these systems into cloud infrastructure potentially provides access to this confidential data to unauthorized entities, e.g., via the cloud act [76]. At the same time, it also prevents students from effectively consenting to their data being processed by cloud companies, as an opt-out is only possible by *not* studying at a university using one of these products. Furthermore, these systems are also especially susceptible if a cloud provider decides to enforce their own policies and principles. If, for example, a U.S.-based LMS provider decides to enforce U.S. sanctions against citizens of specific countries for an LMS, including customers outside the U.S., it can effectively dictate which students a university enrolls by controlling the 'means of study.' Given the precedent of GitHub [1] restricting accounts for developers located in Crimea, Cuba, Iran, North Korea, and Syria to comply with U.S. trade sanctions this is by far no hypothetical scenario.

A. Methodology

In our measurements we focus on the four largest providers of cloud-based LMS: Brightspace (Desire2Learn, `brightspace.com`), Courseleaf (`courseleaf.com`), Blackboard (`blackboard.com`), and, Canvas (Instructure, `instructure.com`). What these tools have in common is that they provision their services by having a name in a university's zone pointing a `CNAME` to their own infrastructure. For example: `canvas.example.com. IN CNAME example-com.instructure.com.` Hence, to measure whether a university uses one of these LMS, we have to check whether we find a `CNAME` with a target that is below one of the domains used by the above cloud LMS. Naturally, we do not see whether and which on-site LMS, like Moodle, a university uses, or if it uses—for example—a locally hosted version of Blackboard.

B. Results

We find that cloud-hosted LMS are mostly relevant in the U.S., the U.K., and the Netherlands. We find no instances of cloud-hosted LMS in Germany, France, and Austria. In Switzerland, we only find a single Canvas instance at the University of St. Gallen, which has been in operation since January 2019. We revisit the question what universities in these countries are then using *instead* in Section VIII. For the THE Top100, we find that the use of cloud-hosted LMS is mostly related to U.S. universities. In fact, 35 of the 56 universities in the THE Top100 that use a cloud-based LMS in December 2020 are U.S. universities, while U.S. universities only make up 40 universities in the THE Top100. The remaining 22 institutions using cloud-based LMS in the THE Top100 are from the Netherlands (6), the U.K. (5), Canada and Australia (3 each), Hong Kong (2), Singapore, and Sweden (1 each). Courseleaf seems to be exclusively catering to the U.S. market, as we find no instances outside of the U.S..

For all four groups which we find to be using cloud-based LMS, we find a steady growth over time between January 2015 to December 2020: in the U.S. from 87 (33.46%) to 174 (66.92%), in the U.K. from 15 (13.04%) to 57 (49.57%), in the Netherlands from 5 (26.32%) to 12 (63.16%), and in the THE Top100 from 24 (24.00%) to 56 (56.00%).

Note that the use of LMS ties in with our observations in Section IV. While the cloud instances of Blackboard are hosted on Microsoft Azure, those for Brightspace, Courseleaf, and Instructure are located in Amazon EC2.

VII. Zoom et al.

Tools for video chatting and VoIP solutions have already carried longstanding significance in professional communications, especially in the form of Skype-for-Business (SfB). However, with the emergence of COVID-19, these tools—especially Zoom—have gained significant public attention, with academic core activities—teaching, research meetings, and conferences—heavily relying on these tools. In fact, the discussion around the reliance of universities and education on commercial infrastructure often frames this as the 'zoomification' of education. Also, as mentioned in Section I, Zoom—as one of the more prominent video chat platforms—has been a source of incidents around the issue of academic freedom [67].

Hence, in this section, we review universities' reliance on centralized/cloud-hosted video chat solutions. Following our reflection on universities' IT setups in Section II, we look at traditionally more business-focused toolchains—Skype-for-Business, Cisco WebEx, and Adobe Connect—but also the (relative) newcomer Zoom. Finally, we also estimate the use of Microsoft Teams, however, due to the way it is implemented, we are limited to an upper-bound estimate in this case.

A. Methodology

To identify universities' use of centralized video chat solutions, we follow three different approaches, based on the platform we are looking at. For Zoom (`zoom.us`), Cisco WebEx (`webex.com`), and Adobe Connect (`adobeconnect.com`), we follow the naming scheme of these services for clients to match universities to names under these domains. Specifically, we check if we find a RR under these services' domains that starts with (1) the second-level domain of a university, (2) the full domain name of a university (second-level + top-level domain) with dots replaced by hyphens, or (3) the second-level domain of a university appended with `-live` (see Table III). If we find a corresponding name lookup in our dataset during a month, we consider a university as using this service during that month. In addition, we also consider a university as using Zoom if we observe a `TXT` record that starts with `ZOOM_verify`, i.e., a Zoom domain verification token. To get an indication of the reliability of this approach, we manually verified all Zoom links we encountered via the page branding and used Single-Sign-On (SSO) system. Among the 363 Zoom links we identified, 12 (3.31%) were incorrectly attributed to an organization or could not be verified through other channels, e.g., if a Zoom sub-domain does not use a university's SSO, but the university itself links to that Zoom domain in its documentation.

Table III: Overview of permutations on university domain names checked below `zoom.us`, `webex.com`, and `adobeconnect.com` for the example of Zoom.

Input	Permutation	Resulting Service Domain
`example.com`	Second Level	`example.zoom.us`
	Dot Replacement	`example-com.zoom.us`
	SLD + `-live`	`example-live.zoom.us`

To establish if a university uses SfB, we check for required DNS entries when operating SfB [60], specifically `lyncdiscover.example.com`, with `example.com` being replaced by a university's domain. Note that this overlaps with the prior product name of SfB, Microsoft Lync.

Finally, we check for universities which *may* be using Microsoft Teams. Unlike SfB, Microsoft Teams does not require special DNS entries that make its use uniquely identifiable [59], even though using the voice components of Teams is common, which requires the same DNS entries as SfB [60]. However, to be able to use Microsoft Teams, an operator still has to set a Microsoft cloud verification token of the form `MS=ms12345678`. Even though the presence of this record does not mean a site *does* use Microsoft Teams—it may be using a cloud-hosted Microsoft Exchange instance or Office365 as well—we also count the number of sites using this token and report the number of *additional* universities that may be *exclusively* using Microsoft Teams, i.e., that *do not* use any of the other tools (SfB, Zoom, WebEx, Adobe Connect).

B. Results

Taking a macroscopic look at our data, we again see a similar segmentation as with the previous cases of general cloud usage, email, and cloud-based LMS, see Figure 4. We see a heavy adoption of SfB (from 2015 to 2020) in the Netherlands (one with a large increase mid-2015 to 11 (57.89%)), the U.S. (110 (42.31%) to 176 (67.69%)), the U.K. (9 (7.83%) to 73 (64.48%)) and the THE Top100 (30 (30.00%) to 67 (67.00%)). At the same time we see close to no SfB instances in France, and limited adoption in the remaining countries with 5 (35.71%) in Switzerland, 11 (32.35%) in Austria, and 25 (30.86%) in Germany. Note that in Germany we observed an increase of 20 institutions using SfB between November and December 2020, most likely due to the introduction of Microsoft Teams, which partially uses DNS entries overlapping with those for SfB. We conjecture that this overall picture connects to different operational paradigms between universities in these two clusters, also in terms of administrative centralization (see Section II), and we revisit this point in our discussion in Section VIII.

When we look at the adoption of the other three video chat platforms, we find an interesting picture, also in relation to the COVID-19 pandemic. In the U.S., we find that the adoption of Zoom and—to a slightly lower extent—WebEx has been an ongoing process that already started back in 2016 leading to 205 (78.88%) U.S. universities using Zoom and 85 (32.68%) using WebEx in December 2020. However, in comparison to December 2019 these numbers only rose by 61 from 144

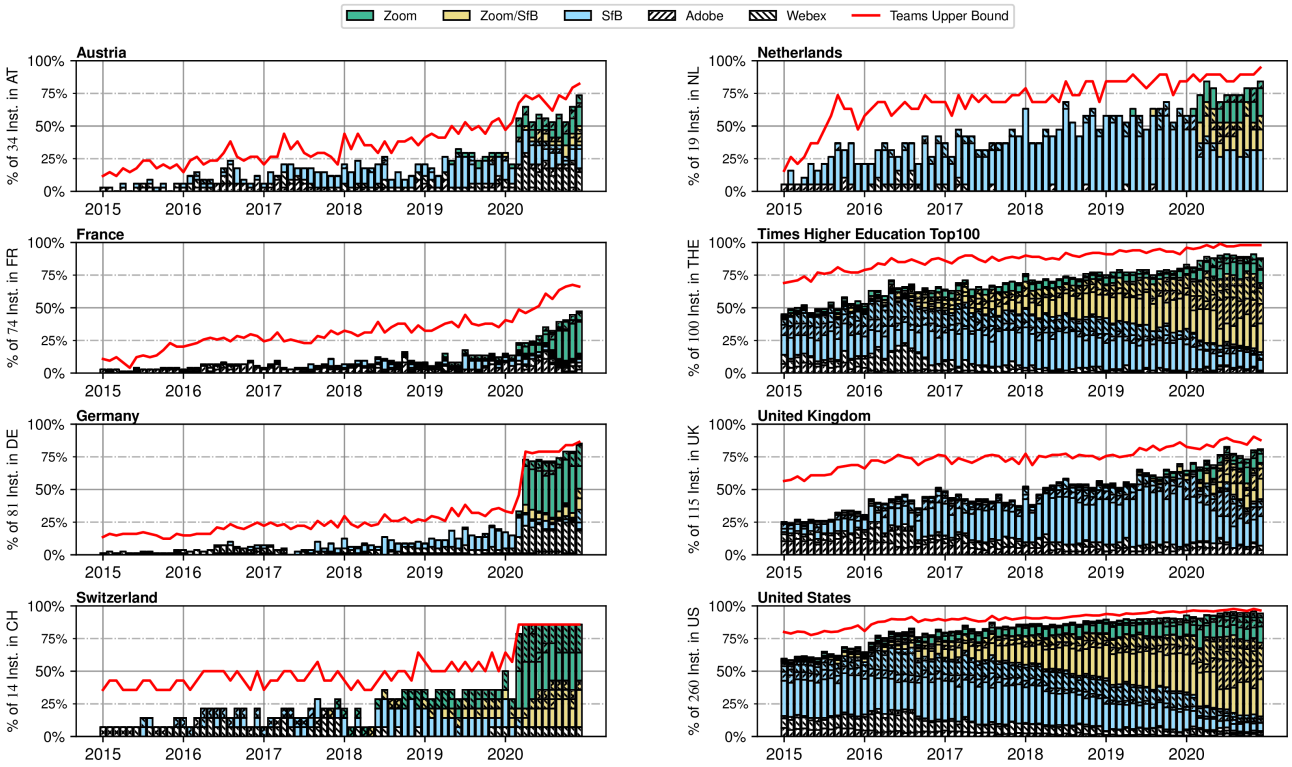

Figure 4: Overview of video chat solutions used by universities between January 2015 and December 2020.

for Zoom and by 17 from 68 for WebEx, meaning that the pandemic effect is not as large as in other countries, mostly due to the already high adoption of Zoom in the U.S.. Adobe Connect, in general, has a market share similar to WebEx, with 64 (25.00%) of U.S. universities using it in December 2020. We also note that U.S. universities seem to generally be using a multitude of video chat solutions, with 103 (39.62%) using two, 75 (28.85%) three, and 11 (4.23%) all four of the surveyed tools in December 2020.

This effect can be—again—found to a similar extent in the THE Top100. Please note that only 40 universities in the THE Top100 are U.S. universities. Here, we also see a continuous adoption of Zoom starting in 2016, leading up to 72 (72.00%) institutions using Zoom in December 2020. We also observe an apparent lack of a significant pandemic effect, and a large diversity of employed tools across universities, with 35 using two, 30 three, and 4 all of the surveyed video chat solutions.

With the remaining countries, we do see a pandemic effect, especially in terms of Zoom adoption. While Zoom played essentially no role in European universities before February 2020, its adoption quickly increased with the sudden onset of remote teaching. Interesting observations here are that most European universities are much more discrete in their choice of video teaching platform—either Zoom or WebEx, and that the onset of these tools was sudden, i.e., within a month in the beginning of 2020. The only remarkable outlier here is France, which shows a comparatively slow increase, which is also—contrary to other European countries where we also observe an increase in WebEx use—highly focused on Zoom. In the end, we find that in December 2020 Zoom/WebEx use in German universities is at 41 (50.61%)/44 (54.32%), in the U.K. 44 (38.26%)/20 (17.39%), in the Netherlands 10 (52.63%)/2 (10.52%), in Austria 13 (38.24%)/11 (32.35%), in Switzerland 11 (78.86%)/5 (35.71%), and in France 26 (35.14%)/10 (13.52%).

Looking at the possible upper bound for universities using Microsoft Teams *without* using the SfB/voice and video chat component, we find that this number is close to zero for the U.S. (5/1.92%), Germany (1/1.23%), and Switzerland (0) in December 2020. In the U.K. (7/6.09%), the THE Top100 (9/9.00%), Austria (3/8.82%), and the Netherlands (2/10.53%) we see a modest number of additional institutions that *might* be using Microsoft Teams. France is the only country where we find a comparatively large amount of potential Microsoft Teams users who do not use *any* of the other solutions of SfB, with 14 (18.91%) institutions in December 2020. However, this difference is relatively static over the past years, and likely not related to an increase in Microsoft Teams adoption by universities not *already* using Microsoft cloud services (or providing access to Microsoft software licenses to users from their domain) in the beginning of 2020.

VIII. Discussion

In this section, we discuss the implications of our findings and provide additional context and recommendations.

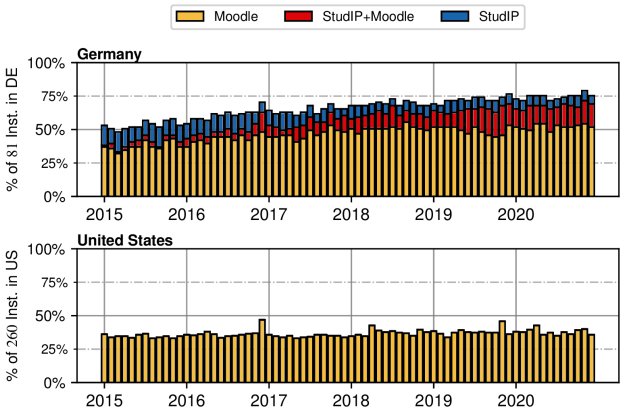

Figure 5: Share of universities with at least one name containing 'moodle' or 'studip' for Germany and the U.S. (January 2015 to December 2020).

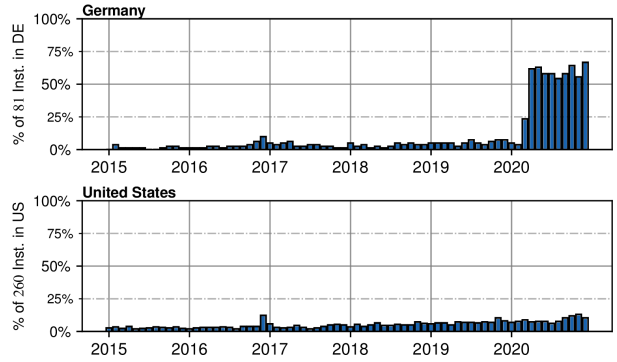

Figure 6: Share of universities with at least one BigBlueButton related DNS entry for Germany and the U.S. (January 2015 to December 2020).

A. Cloud Adoption in Europe: The German Case

The differences we observe in Section IV to Section VII beg the question what digital learning tools universities use instead of cloud products, e.g., in Germany. Hence, we look at the use of common self-hosted alternatives for LMS (Moodle [14] and Stud.IP [5, 38]) and video chats (BigBlueButton [9]) in Germany, which are reportedly deployed in 90% of higher education institutions [21]. Self-hosted tools may—by default—not be necessarily more privacy preserving than offerings of large cloud providers. However, *control* over data nevertheless remains with the university hosting them, and they are able to audit and—if necessary—reconfigure and patch these tools to conform to privacy regulations and requirements. This could, for example, be seen with BigBlueButton, where the user group around German universities made significant contributions towards the privacy preserving operation of BigBlueButton once privacy limitations in its design became apparent [8, 41].

To estimate self-hosted LMS and BigBlueButton use in Germany and the U.S., we count the number of universities that either have Moodle/Stud.IP or BigBlueButton related names under their domain. For Moodle and Stud.IP, these are names containing either `moodle` or `studip`. For BigBlueButton we check for `bbb`, `bigbluebutton`, `scalelite` (the load balancer component of BigBlueButton), and `greenlight` (a common BigBlueButton frontend).

We find that 75.31% (61) of universities in Germany have Moodle or Stud.IP related names vs. 35.77% (93) in the U.S. for Moodle alone, see Figure 5. Similarly, we find that 54 (66.67%) universities in Germany have BigBlueButton related names under their domain, while this is the case for less than 10% in the U.S., see Figure 6. We see a clear pandemic effect for the adoption of BigBlueButton in Germany, starting in February 2020.

Please note that our matching is fuzzy, as we might overmatch on hostnames that contain these product names without running the associated service, while we may also undermatch when universities host these tools under different names. For example, in Germany, we often found BigBlueButton systems being called `konferenz`, the German word for conference, explaining the difference between our measured 66.67% and the 90% reported in the media [21].

We tie the higher share of self-hosting in German universities to multiple factors:

- Strong commitment to academic freedom and self-governance [30, 75] rooted in the events of the '68 student revolution [46].
- Historic prevalence of university datacenters aligned with research and education [52, 85].
- Several institutions showing strong leadership in terms of self-sovereign learning environments, as for example the University of Osnabrück with the Center Virtuos [47], which has also significantly contributed to Stud.IP and—since the onset of the pandemic—BigBlueButton open-source development.
- A societal understanding of universities as *public* infrastructures [7].
- A collaborative and active operators community at German universities supported by the DFN (German Research Network), leading to a strong exchange about self-sovereign educational tooling [34].

These factors *may help* explain the significant difference between Germany and, other countries. However, we also find an uptick in cloud use in Germany in December 2020. This may indicate that, with the COVID-19, universities are starting to shift away from this paradigm (not just due to the sudden introduction of cloud-based remote teaching tools), similar to the slow introduction of Zoom in France (see Section VII), which—on a national level—also implemented a strict ope-source software favoring policy [2].

B. Cloud Infrastructures and Power

The last decade has seen big tech companies, and especially Amazon and Microsoft, honing in on cloud infrastructures as an alternative source of growth to the somewhat saturated ad-based business [31, 90]. Growth for these new markets relies on two effects: Realizing the value proposition of reducing costs

in terms of Capital Expenses (CapEx) and local Operational Expenses (OpEx) for lower OpEx paid in service charges to a cloud provider, and—for individual cloud providers—by attaining a market position that makes them 'the default' platform to be used [96].

The increasing dependency of big tech on cloud computing for their financial success means that the companies use political, economic and technical resources to ensure that the clouds are the 'default' infrastructure in as many domains as possible. Their political force is brought to bare using international initiatives, e.g., New Pedagogies for Deep Learning is a global partnership between the OECD, Gates Foundation, Pearson and Microsoft [104]; government partnerships, e.g., the U.K. government has incentivised schools to opt for platforms that are both free to use and bundled up with government-funded technical assistance [104]; and lobbying efforts [65]. Cloud providers use economic mechanisms for the move to the cloud by mounting the benefits of economies of scale, financing and physically migrating data to the cloud, and by providing free services that can also bypass regular procurement rules. Through their economic incentives, these companies can capture educational IT either by providing storage, compute, communication platforms, or by becoming the default infrastructure for smaller EdTech companies [45].

The trend of big tech monopolies shifting from *"being mere owners of information, ... to becoming owners of the infrastructures of society"* [81] has prompted an ongoing public discussion about the implications of this 'platform capitalism' on different aspects of society [13, 22, 81], yet without zooming in on its implications on higher education. At first sight, the political economic advantages put forth by cloud companies make good fellows with the economized management of universities. However, this also comes with power shifts. Mirrlees and Alvi [62] argue that universities focus on cutting costs, while allowing the big five (Apple, Alphabet/Google, Amazon, Microsoft, Facebook) and a growing ecosystem of start-ups, e.g., in the area of MOOCs, to compete with—and ultimately replace—public education. Most universities do not have the economic or political power to insert their own values and interests in such a market, unless they coordinate on these issues. The international initiatives these companies support make up informal policy networks that increasingly dominate educational policy [91]. Aside from potential impact on democratic societies and educational values, these networks are likely to promote certain forms of education, e.g., the individualised pursuit of mastery' enacted primarily through adaptive software, in favor of education that, for example, promotes interpersonal dialogue and relations with others [104]. In the bigger scheme of things, there are also concerns about 'platform imperialism:' US-based companies providing the global digital infrastructure could be used as a tool for 'soft power' and economic control that influences global norms and values of digital cultures [43], including control over curriculum and research activities.

C. Cloud Use vs. Academic Freedom

The increasing dependence of universities on cloud platforms for teaching, communication, and research that we observed has serious implications in terms of academic freedom. If education and research *depend* on an external cloud service, researchers may become bound to comply with requirements set by these organizations. We could recently observe Google's handling of Timnit Gebru's involvement in a paper not 'deemed worthy for publication' by the company [66], as well with other instances of Google telling its researchers to put a positive spin on 'sensitive topics,'[2] or remove references to Google products [27]. One might argue that this concerns *employees* of Google, but it also begs the question of whether cloud operators could leverage their power over universities to influence critical research in a similar way. In fact, Google has already been in the spotlight for sponsoring favorable research that is in line with its business and policy interests [64], both in the U.S. [17], and Europe [18].[3] In the field of educational technology research particularly, Mirrlees and Alvi [62] observed a lack of critical research, likely because of *"...little incentive to 'bite the hand that feeds"'* [78].

It may certainly be conceivable that a major cloud provider simply indicates that a continued business relation with a university may not be desirable in case the institution and its researchers continue to voice positions critical of that cloud provider. That institution would then face the dilemma of either 'aligning' their researchers, or—suddenly—having to migrate essential services like their LMS, email, or (currently essential) remote teaching setup away from its current provider. Such a migration could easily cost millions while severely interrupting research and teaching. And, hypotheticals aside, this did already occur twice with Zoom [67].

Similar cases can be made for cloud operators enforcing their business rules in terms of, e.g., global sanctions. A case similar to that of GitHub [1] may effectively put universities in a position where they either bar their Iranian (or any other potentially sanctioned country) students from attending the university, or at least from using their digital learning environment. Thereby, the centralization of power we currently observe may indeed inadvertently threaten core functions of universities.

The ultimate question we have to ask here as academics is not whether cloud operators *would* use these powers. Instead, we have to ask ourselves if we are willing to risk that they *could* do this.

D. Privacy and Academia

The move to the cloud raises a number of concerns with respect to the application of privacy by design or compliance. Past studies have shown that educational institutions do not

[2]Sensitive topics include the oil industry, China, Iran, Israel, COVID-19, home security, insurance, location data, religion, self-driving vehicles, telecoms and systems that recommend or personalize web content. [27]

[3]We note that the reports published as part of the *Google Transparency Project* [17, 18] by the Campaign for Accountability have also drawn criticism as they seem to be largely funded by Google's competitor Oracle [74].

fare well in making *transparent* the data collection and processing practices of cloud providers to their faculty, staff and students [44, 53, 56]. This can, for example, happen when a university implements a blanket privacy policy for all digital tooling, including all cloud services. Depending on the diversity of data collection and processing these services entail, privacy policies may become very generic, potentially falling short of legal transparency requirements [72]. It may also not be clear to the university what data is going to the cloud. Universities may evaluate and make data agreements with cloud providers, but ensuring these are effective can be a challenge. Aside from having vague privacy policies [49], cloud services come with the promise of being plug-and-play, and recursively, they leverage the benefit of service architectures, and often bundle dozens of third parties [36]. As a result, even cloud service providers may fail to make their data flows transparent. The promise of plug-and-play also means that university IT departments are often not given the time or the resources to evaluate these services. Even when they generate privacy evaluations, these happen against the backdrop of digital branding efforts of the university and the partnerships between public institutions and cloud providers [104], which may trump privacy concerns.

In addition, when students, faculty and administrators access these services, they are not asked for explicit consent. Universities can, for example in the case of GDPR [94], use *legitimate interest* or *performance of a contract* to justify all the data flows that come with cloud services. This means that students and faculty may not have a (meaningful) option to opt-out of these services. When there is an opt-out process, people may be incentivized not to use them, e.g., reserving them for "severe cases" and with time and capacity burdens for faculty and staff. When incentive structures are set up by-design and by-policy to push people onto cloud infrastructures, it is hard to speak of choice. Especially when their resources are limited, public education institutions end up leveraging their structures to on-board students, faculty, and staff as cloud service consumers [53].

If universities continue to outsource core functions to cloud platforms, students will no longer have *a choice* on whether they want to expose some of their most private information—their academic development during their most formative years—to these major cloud providers. Considering that these cloud services are economically under pressure to monetize either the data they collect (e.g., by creating a recruiting business [86]), or the infrastructural dependency they create, the practices that are being established here are concerning. Universities may have to consider whether it is ethical or legal to create an environment where informed consent to data collection is, essentially, no longer possible.

E. Universities as Enterprise Networks

In Section VII we observe a correlation between the early adoption of SfB and universities' general adoption of cloud platforms. Revisiting Section II, we noted that tools like SfB would be expected for *centralized* enterprise IT setups. Hence, we argue that SfB adoption can serve as a proxy to assess the general operational paradigm of a university, i.e., if it is run more like an *enterprise network* or a *university network*.

This mechanic of administrative alignment of IT infrastructures with administration leading to centralization and organizations *behaving* in a similar way is also a well documented effect in the field of Information Systems (IS). DiMaggio and Powell [29] discuss how bureaucratization—via coercive, memetic, and normative processes—leads to a structural alignment of organizations within a market, see also Scott for a more recent comprehensive reflection on these theories [77]. This institutional perspective was transferred to the introduction of IT systems and their connection to organizational change by Avgerou [6]. To synthesize, the findings from IS indicate an effect in organizations where administrative alignment leads to IT transformation as *a goal in in itself*, lacking *"adequate legitimacy" [6]*, without any *"contribution to the process of organizational change." [6]*

Following SfB as a proxy, we conjecture that we observe an increased adoption of cloud technology for countries in which the university system has seen a stronger commoditization—the U.S., the U.K., the Netherlands, and THE Top100—as also discussed by Bosetti and Walker [12]. In these countries, organizational alignment lead to a situation where academic leaders governing a body of scholars have been replaced by administrators and business managers who oversee university operations. These new managers have imported and integrated enterprise tools and culture into the heart of public education institutions, leading towards greater cloud adoption.

F. Recommendations for Decentralization

Following our discussion of the impact of cloud usage among universities and exploration of the Germany case study, we identified four recommendations for researchers and universities to counteract these developments and preserve academic freedom. Specifically, these are:

- **Invest Into Self-Hosted Open-Source Tools:** Tools to enable self-sovereign IT operations for universities exist. By favoring Open Source during procurement [21] and contributing to their development, universities can fill their role as public infrastructures.
- **Local Capacity Building:** Using self-hosted tools heavily relies on local capacity in terms of resources and skilled system operations departments within universities. Hence, universities should build and sustain their local IT departments.
- **Organize:** In the German case we saw the importance of collaboration (DFN) and universities investing into open-source tools to provide these to other universities with a smaller infrastructure focus (Virtuos). This way, universities can attain scale-effects they are hoping to leverage by migrating to public clouds.
- **Align IT Operations with Core Functions:** By aligning IT operations closer with their core functions, i.e., teaching

and research, universities can refocus their IT from a purely supportive function to an element in which they demonstrate leadership [47].

Especially the last point is crucial, as it begs the question what role universities want to play in the development of our digital society: Do they want to lead, or follow.

IX. Limitations

Here we list the limitations of our work. The Farsight SIE dataset may not contain all cloud related names, if these are not queried from a client behind a sensor. While those instances of cloud hosting we identify are certainly there, more universities may be using major cloud providers without it being recorded in the dataset. Similarly, Farsight SIE only collects DNS cache misses [32]. Hence, we cannot provide information on the popularity of the names we observe. Furthermore, the number of universities among the surveyed countries differs (14 in Switzerland, 260 in the U.S.). This may amplify the effect of individual institutions' choices in smaller countries. Our work relies, in several places, on heuristics, e.g., in the identification of Zoom/WebEx/Adobe Connect domains in Section VII, the use of Proofpoint's email security system, and the estimation of Moodle, Stud.IP, and BigBlueButton instances in Section VIII. To address this, we manually verified a set of our heuristics, e.g., for Zoom in Section VII finding no significant error, and outline the impact of these limitations in the corresponding sections.

Given the large effect sizes we observe, the general alignment of ratio changes between smaller and larger countries, our additional spot-checks, and our generally good coverage of domain names, we are confident that our results paint an accurate picture of universities' cloud use since January 2015.

X. Related Work

In this section, we discuss related work on measuring cloud infrastructures and usage, the impact of the COVID-19 pandemic on the Internet, and discusses the implications of public cloud infrastructure in the educational sector.

A. Cloud Infrastructure Measurements

Similar to us, Borgolte et al. [11] also use the Farsight SIE dataset to identify domains pointing at cloud infrastructure. Jacquemart et al. [42] performed their own active DNS measurements on the most popular domains according to Alexa to measure the adoption of cloud services from 2013–2018. Furthermore, Portier et al. [68] and van der Toorn et al. [89] identify cloud service usage via `TXT` records. Streibelt et al. [82] and Calder et al. [16] use the `EDNS0` extension to map cloud infrastructure. Henze et al. [39] focused on the adoption of cloud-based email services and identified them based on email headers on a dataset collected from mailing lists, spam traps, and volunteer users. As we essentially conduct a form of targeted asset discovery using a passive dataset, a comprehensive picture of recent related work can also be obtained from Vermeer et al.'s taxonomy of asset discovery techniques [92].

B. COVID-19 and the Internet

With the emergence of COVID-19, it became apparent that the continued lock-down situation would have an extended effect on the Internet. As such, several researchers studied this effect, including the increased utilization of cloud based services. Feldmann et al. [33] studied the impact of COVID-19 through the lens of a major Internet Exchange Point from a European perspective, while Liu et al. [54] performed a similar study on changes in network traffic patterns in the U.S.. Boettger et al. [10] provide a similar perspective from the vantage point of the Facebook social network. Along the same lines, Lutu et al. [55] investigate the impact of COVID-19 on mobile network traffic.

C. Educational Technology in the Cloud

Cohney et al. [24] perform a study into the privacy implications of virtual classroom technology. Contrary to us, they root their evaluation of technology use in a self-reported study among 49 educators in U.S. universities, obtaining results similar to our Internet measurement data. In addition, they also analyze privacy policies of common virtual classroom tools. Similar to us, Komljenovic [48] theoretically analyzes the implications of the progressing centralization and platformization of educational technology, particularly noting the de-institutionalization of public education accelerated by centralized platforms. Zeide and Nissenbaum [105] analyze—before the COVID-19 pandemic—learner privacy in MOOCs and virtual education, finding it to often violate established norms in terms of privacy and education, supporting our assessment that the 'zoomification' of education is a long-standing process predating the COVID-19 pandemic. Besides these major related publications, several small-scale evaluations often limited to specific tools (usually Zoom) were undertaken during the last year. For brevity, we refer to the summary of Cohney et al. [24].

XI. Conclusion

In this paper, we investigated the reliance of universities in seven countries and in institutions listed in the Times Higher Education Top100 on cloud infrastructure. We found that the continuous move to cloud infrastructures has been an ongoing process for the past several years, and—apart from video lecturing tools—not heavily influenced by the COVID-19 pandemic. Our results also highlight that university systems highly differ in their susceptibility to migrate to the cloud. We conjecture that this ties in with a multitude of factors, including the academic and administrative culture, and the history of university IT in the corresponding countries. Furthermore, we discuss the potential impact of this progressing development on the very essence of academic freedom.

In the end, as academics, we have to ask ourselves: Now that we know, do we want this? If we are content with this development, we also have to ask whether we can live with the broader implications we outline in Section VIII. If not, we have to find ways to counteract these developments, by building and funding decentralized capabilities for independent research and teaching infrastructure, learning from—certainly not perfect—cases like Germany.

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Appendix

A. Investigated Institutions in Austria

1) Akademie der Bildenden Künste Wien: `akbild.ac.at`
2) Anton Bruckner Privatuniversität: `bruckneruni.at`
3) Bertha von Suttner Privatuniversität: `suttneruni.at`
4) Central European University: `ceu.edu`
5) Danube Private University: `dp-uni.ac.at`
6) Graz University of Technology: `tugraz.at`
7) Jam Music Lab - Privatuniversität für Jazz und Popularmusik Wien: `jammusiclab.com`
8) Johannes Kepler Universität Linz: `jku.at`
9) Karl Landsteiner Privatuniversität für Gedundheitswissenschaften: `kl.ac.at`
10) Katholische Privatuniversität Linz: `ku-linz.at`
11) Kunst Uni Graz: `kug.ac.at`
12) Kunst Universität Linz: `ufg.ac.at`
13) Medizinische Universität Graz: `medunigraz.at`
14) Medizinische Universität Innsbruck: `i-med.ac.at`
15) Medizinische Universität Wien: `meduniwien.ac.at`
16) Modul University Vienna: `modul.ac.at`
17) Montanuniversität Leoben: `unileoben.ac.at`
18) Paracelsus Medizinische Privatuniversität: `pmu.ac.at`
19) Privatuniversität Schloss Seeburg: `uni-seeburg.at`
20) The Tyrolean Private University: `umit.at`
21) University of Graz: `uni-graz.at`
22) University of Innsbruck: `uibk.ac.at`
23) University of Klagenfurt: `uni-klu.ac.at`
24) University of Vienna: `univie.ac.at`
25) Universität Mozarteum Salzburg: `moz.ac.at`
26) Universität Salzburg: `uni-salzburg.at`
27) Universität für Bodenkultur Wien: `boku.ac.at`
28) Universität für Musik und Darstellende Kunst Wien: `mdw.ac.at`
29) Universität für Weiterbildung Krems: `donau-uni.ac.at`
30) Universität für angewandte Kunst Wien: `dieangewandte.at`
31) Veterinärmedizinische Universität Wien: `vetmeduni.ac.at`
32) Vienna University of Economics and Business: `wu.ac.at`
33) Vienna University of Technology: `tuwien.ac.at`
34) Webster Vienna Private University: `webster.ac.at`

B. Investigated Institutions in France

1) Institut Catholique de Lyon: `ucly.fr`, `univ-catholyon.fr`
2) Institut Catholique de Paris: `icp.fr`
3) Institut Catholique de Toulouse: `ict-toulouse.fr`
4) Institut National Universitaire Champollion: `univ-jfc.fr`

5) La Rochelle Université: univ-larochelle.fr
6) Sorbonne Université: paris-sorbonne.fr, sorbonne-universite.fr, univ-paris4.fr
7) Universität Paris 8 Vincennes-Saint-Denis: univ-paris8.fr
8) Universität Paris III Sorbonne Nouvelle: univ-paris3.fr
9) Universität des Oberelsass: uha.fr
10) Université Blaise Pascal Clermont-Ferrand II: univ-bpclermont.fr
11) Université Bordeaux Montaigne: u-bordeaux-montaigne.fr
12) Université Bretagne Sud: univ-ubs.fr
13) Université Catholique de Lille: univ-catholille.fr
14) Université Catholique de l'Ouest: uco.fr
15) Université Claude-Bernard-Lyon-I: univ-lyon1.fr
16) Université Francois Rabelais de Tours: univ-tours.fr
17) Université Grenoble Alpes: u-grenoble3.fr, ujf-grenoble.fr, univ-grenoble-alpes.fr, upmf-grenoble.fr
18) Université Jean-Monnet-Saint-Etienne: univ-st-etienne.fr
19) Université Jean-Moulin-Lyon-III: univ-lyon3.fr
20) Université Lille Nord de France: cue-lillenorddefrance.fr, univ-lille.fr, univ-lille1.fr, univ-lille2.fr, univ-lille3.fr, univ-littoral.fr
21) Université Lumière Lyon 2: univ-lyon2.fr
22) Université Paris 1 Panthéon-Sorbonne: pantheonsorbonne.fr, univ-paris1.fr
23) Université Paris 2 Panthéon-Assas: u-paris2.fr
24) Université Paris-Est Marne-la-Vallée: univ-mlv.fr
25) Université Paris-Nanterre: parisnanterre.fr, u-paris10.fr, univ-paris10.fr
26) Université Paris-Sud: u-psud.fr
27) Université Paul Cézanne Aix-Marseille III: univ-cezanne.fr
28) Université Paul Sabatier Toulouse III: univ-tlse3.fr, ups-tlse.fr
29) Université Savoie Mont Blanc: univ-savoie.fr
30) Université Savoie-Mont-Blanc: univ-smb.fr
31) Université Sorbonne Paris Nord: univ-paris12.fr, u-pec.fr
32) Université Toulouse 1 Sciences Sociales: univ-tlse1.fr, ut-capitole.fr
33) Université ToulouseJean Jaurès: univ-tlse2.fr
34) Université d'Angers: univ-angers.fr
35) Université d'Artois: univ-artois.fr
36) Université d'Avignon et des Pays de Vaucluse: univ-avignon.fr
37) Université d'Orléans: univ-orleans.fr
38) Université d'Evry: univ-evry.fr
39) Université de Bordeaux: u-bordeaux.fr, u-bordeaux1.fr, u-bordeaux4.fr
40) Université de Bourgogne: u-bourgogne.fr
41) Université de Caen Basse-Normandie: unicaen.fr
42) Université de Cergy-Pontoise: cyu.fr, u-cergy.fr
43) Université de Franche-Comté: univ-fcomte.fr
44) Université de Haute Bretagne Rennes 2: univ-rennes2.fr
45) Université de La Réunion: univ-reunion.fr
46) Université de Limoges: unilim.fr
47) Université de Lorraine: univ-lorraine.fr
48) Université de Lyon: universite-lyon.fr
49) Université de Montpellier: umontpellier.fr, univ-montp1.fr, univ-montp2.fr, univ-montp3.fr
50) Université de Nantes: univ-nantes.fr
51) Université de Nice Sophia-Antipolis: unice.fr
52) Université de Nmes: unimes.fr
53) Université de Paris: univ-paris5.fr, univ-paris7.fr, univ-paris-diderot.fr, u-paris.fr
54) Université de Pau et des Pays de l'Adour: univ-pau.fr
55) Université de Perpignan Via Domitia: univ-perp.fr
56) Université de Picardie Jules Verne: u-picardie.fr
57) Université de Poitiers: univ-poitiers.fr
58) Université de Provence Aix-Marseille I: univ-provence.fr
59) Université de Reims Champagne-Ardenne: univ-reims.fr
60) Université de Rennes 1: univ-rennes1.fr
61) Université de Rouen: univ-rouen.fr
62) Université de Strasbourg: u-strasbg.fr, unistra.fr
63) Université de Toulon: univ-tln.fr
64) Université de Valenciennes: univ-valenciennes.fr
65) Université de Versailles-Saint-Quentin-en-Yvelines: uvsq.fr
66) Université de la Mediterranée Aix-Marseille II: univmed.fr
67) Université de la Nouvelle-Calédonie: unc.nc
68) Université de la Polynésie francaise: upf.pf
69) Université de technologie de Compiègne: utc.fr
70) Université des Antilles et de la Guyane: univ-ag.fr
71) Université du Havre: univ-lehavre.fr
72) Université du Maine: univ-lemans.fr
73) Université d'Aix-Marseille: univ-amu.fr
74) Université d'Auvergne Clermont-Ferrand: uca.fr, u-clermont1.fr

C. Investigated Institutions in Germany

1) Brandenburgische Technische Universität: b-tu.de
2) Europa-Universität Viadrina Frankfurt (Oder): euv-ffo.de
3) FU Berlin: fu-berlin.de
4) FernUni Hagen: fernuni-hagen.de
5) Friederich-Alexander University Erlangen: fau.de
6) HU Berlin: hu-berlin.de
7) Heinrich-Heine-Universität Düsseldorf: hhu.de
8) Jacobs University Bremen: jacobs-university.de
9) Karlsruhe Institute of Technology: kit.edu
10) Katholische Universität Eichstätt-Ingolstadt: ku.de
11) RWTH Aachen: rwth-aachen.de
12) Ruhr Uni Bochum: ruhr-uni-bochum.de
13) TU Berlin: tu-berlin.de
14) TU Braunschweig: tu-braunschweig.de
15) TU Chemnitz: tu-chemnitz.de
16) TU Clausthal: tu-clausthal.de
17) TU Darmstadt: tu-darmstadt.de
18) TU Dortmund: tu-dortmund.de
19) TU Dresden: tu-dresden.de
20) TU Freiberg: tu-freiberg.de
21) TU Hamburg: tuhh.de
22) TU Ilmenau: tu-ilmenau.de
23) TU Munich: tum.de
24) Uni Augsburg: uni-augsburg.de
25) Uni Bamberg: uni-bamberg.de
26) Uni Bayreuth: uni-bayreuth.de
27) Uni Bielefeld: uni-bielefeld.de
28) Uni Bonn: uni-bonn.de
29) Uni Bremen: uni-bremen.de
30) Uni Duisburg/Essen: uni-due.de
31) Uni Erfurt: uni-erfurt.de
32) Uni Flensburg: uni-flensburg.de
33) Uni Frankfurt: uni-frankfurt.de
34) Uni Freiburg: uni-freiburg.de
35) Uni Giessen: uni-giessen.de
36) Uni Goettingen: uni-goettingen.de
37) Uni Greifswald: uni-greifswald.de
38) Uni Halle (Saale): uni-halle.de
39) Uni Hamburg: uni-hamburg.de
40) Uni Hannover: uni-hannover.de
41) Uni Heidelberg: uni-heidelberg.de
42) Uni Hohenheim: uni-hohenheim.de
43) Uni Jena: uni-jena.de
44) Uni Kaiserslautern: uni-kl.de
45) Uni Kassel: uni-kassel.de
46) Uni Kiel: uni-kiel.de
47) Uni Koblenz: uni-koblenz-landau.de
48) Uni Koeln: uni-koeln.de
49) Uni Konstanz: uni-konstanz.de
50) Uni Leipzig: uni-leipzig.de
51) Uni Luebeck: uni-luebeck.de
52) Uni Magdeburg: ovgu.de
53) Uni Mainz: uni-mainz.de
54) Uni Mannheim: uni-mannheim.de
55) Uni Marburg: uni-marburg.de
56) Uni Muenchen: uni-muenchen.de
57) Uni Münster: uni-muenster.de
58) Uni Oldenburg: uni-oldenburg.de, uol.de
59) Uni Osnabrueck: uni-osnabrueck.de, uos.de
60) Uni Paderborn: uni-paderborn.de
61) Uni Passau: uni-passau.de
62) Uni Regensburg: uni-regensburg.de
63) Uni Reutlingen: reutlingen-university.de
64) Uni Rostock: uni-rostock.de
65) Uni Saarbruecken: uni-saarland.de
66) Uni Siegen: uni-siegen.de
67) Uni Speyer: uni-speyer.de

68) Uni Stuttgart: uni-stuttgart.de
69) Uni Trier: uni-trier.de
70) Uni Tuebingen: uni-tuebingen.de
71) Uni Ulm: uni-ulm.de
72) Uni Vechta: uni-vechta.de
73) Uni Weimar: uni-weimar.de
74) Uni Witten/Herdecke: uni-wh.de
75) Uni Wuerzburg: uni-wuerzburg.de
76) Uni Wuppertal: uni-wuppertal.de
77) Univ. d. Bundeswehr Munich: unibw.de
78) Univ. d. Kuenste Berlin: udk-berlin.de
79) Universität Lüneburg: leuphana.de
80) Universität der Bundeswehr Hamburg: hsu-hh.de
81) Zeppelin University: zu.de

D. Investigated Institutions in Switzerland

1) EPFL: epfl.ch
2) ETH Zürich: ethz.ch
3) FernUni Schweiz: fernuni.ch
4) Graduate Institute Geneva: graduateinstitute.ch
5) Universita della Svizzera italiana: usi.ch, unisi.ch
6) University Basel: unibas.ch
7) University Bern: unibe.ch
8) University Fribourg: unifr.ch
9) University Geneva: unige.ch
10) University Lausanne: unil.ch, idheap.ch
11) University Luzern: unilu.ch
12) University Neuchatel: unine.ch
13) University St. Gallen: unisg.ch
14) University Zürich: uzh.ch

E. Investigated Institutions in the Netherlands

1) Erasmus Universiteit Rotterdam: eur.nl
2) Maastricht School of Management: msm.nl
3) Maastricht University: maastrichtuniversity.nl
4) Nyenrode Business Universiteit: nyenrode.nl
5) Open Universiteit: ou.nl
6) Protestantse Theologische Universiteit: pthu.nl
7) Radboud Universiteit: ru.nl
8) Rijksuniversiteit Groningen: rug.nl
9) TIAS School for Business and Society: tias.edu
10) Technische Universiteit Delft: tudelft.nl
11) Technische Universiteit Eindhoven: tue.nl
12) Tilburg University: uvt.nl
13) Universiteit Leiden: leidenuniv.nl, universiteitleiden.nl
14) Universiteit Twente: utwente.nl
15) Universiteit Utrecht: uu.nl
16) Universiteit van Amsterdam: uva.nl
17) Universiteit voor Humanistiek: uvh.nl
18) Vrije Universiteit Amsterdam: vu.nl
19) Wageningen Universiteit & Research: wur.nl

F. Investigated Institutions in the THE Top100 (Alphabetical)

1) Australian National University: anu.edu.au
2) Boston University: bu.edu
3) Brown University: brown.edu
4) California Institute of Technology: caltech.edu
5) Carnegie Mellon University: cmu.edu
6) Charité - Universitätsmedizin Berlin: charite.de
7) Chinese University of Hong Kong: cuhk.edu.hk
8) Columbia University: columbia.edu
9) Cornell University: cornell.edu
10) Dartmouth College: dartmouth.edu
11) Delft University of Technology: tudelft.nl
12) Duke University: duke.edu
13) ETH Zurich: ethz.ch
14) Emory University: emory.edu
15) Erasmus University Rotterdam: eur.nl
16) Georgia Institute of Technology: gatech.edu
17) Harvard University: harvard.edu
18) Heidelberg University: heidelberg.edu
19) Humboldt University of Berlin: hu-berlin.de
20) Imperial College London: imperial.ac.uk
21) Johns Hopkins University: jhu.edu
22) KU Leuven: kuleuven.be
23) Karolinska Institute: ki.se
24) King's College London: kcl.ac.uk
25) Kyoto University: kyoto-u.ac.jp
26) LMU Munich: uni-muenchen.de
27) Leiden University: universiteitleiden.nl, leidenuniv.nl
28) London School of Economics and Political Science: lse.ac.uk
29) Lund University: lu.se
30) Massachusetts Institute of Technology: mit.edu
31) McGill University: mcgill.ca
32) McMaster University: mcmaster.ca
33) Michigan State University: msu.edu
34) Monash University: monash.edu, monash.edu.au
35) Nanyang Technological University, Singapore: ntu.edu.sg
36) National University of Singapore: nus.edu.sg
37) New York University: nyu.edu
38) Northwestern University: northwestern.edu
39) Ohio State University (Main campus): osu.edu
40) Paris Sciences et Lettres PSL Research University Paris: psl.eu
41) Peking University: pku.edu.cn
42) Penn State (Main campus): psu.edu
43) Princeton University: princeton.edu
44) Purdue University West Lafayette: purdue.edu
45) RWTH Aachen University: rwth-aachen.de
46) Seoul National University: snu.ac.kr
47) Sorbonne Université: univ-paris4.fr, sorbonne-universite.fr
48) Stanford University: stanford.edu
49) Sungkyunkwan University (SKKU): skku.edu
50) Technical University of Munich: tum.de
51) The Hong Kong University of Science and Technology: ust.hk
52) The University of Chicago: uchicago.edu
53) The University of Queensland: uq.edu.au
54) The University of Tokyo: u-tokyo.ac.jp
55) Tsinghua University: tsinghua.edu.cn
56) UCL: ucl.ac.uk
57) UNSW Sydney: unsw.edu.au
58) University of Amsterdam: uva.nl
59) University of Basel: unibas.ch
60) University of Bristol: bris.ac.uk
61) University of British Columbia: ubc.ca
62) University of California, Berkeley: berkeley.edu
63) University of California, Davis: ucdavis.edu
64) University of California, Irvine: uci.edu
65) University of California, Los Angeles: ucla.edu
66) University of California, San Diego: ucsd.edu
67) University of California, Santa Barbara: ucsb.edu
68) University of Cambridge: cam.ac.uk
69) University of Edinburgh: ed.ac.uk
70) University of Freiburg: uni-freiburg.de
71) University of Glasgow: gla.ac.uk
72) University of Groningen: rug.nl
73) University of Helsinki: helsinki.fi
74) University of Hong Kong: hku.hk
75) University of Illinois at Urbana-Champaign: illinois.edu
76) University of Manchester: manchester.ac.uk
77) University of Maryland, College Park: umd.edu
78) University of Melbourne: unimelb.edu.au
79) University of Michigan-Ann Arbor: umich.edu
80) University of Minnesota: umn.edu
81) University of Montreal: umontreal.ca
82) University of North Carolina at Chapel Hill: unc.edu
83) University of Oxford: ox.ac.uk
84) University of Pennsylvania: upenn.edu
85) University of Science and Technology of China: ustc.edu.cn
86) University of Southern California: usc.edu
87) University of Sydney: sydney.edu.au
88) University of Texas at Austin: utexas.edu
89) University of Toronto: utoronto.ca
90) University of Tübingen: uni-tuebingen.de
91) University of Warwick: warwick.ac.uk
92) University of Washington: wustl.edu
93) University of Wisconsin-Madison: wisc.edu
94) University of Zurich: uzh.ch
95) Utrecht University: uu.nl

96) Wageningen University & Research: wur.nl
97) Washington University in St Louis: uw.edu
98) Yale University: yale.edu
99) Ecole Polytechnique: polytechnique.edu
100) Ecole Polytechnique Fédérale de Lausanne: epfl.ch

G. Investigated Institutions in the United Kingdom

1) Abertay University: abertay.ac.uk, tay.ac.uk
2) Aberystwyth University: aber.ac.uk
3) Anglia Ruskin University: anglia.ac.uk
4) Aston University: aston.ac.uk
5) Bangor University: bangor.ac.uk
6) Bath Spa University: bathspa.ac.uk
7) Birkbeck University of London: bbk.ac.uk, birkbeck.ac.uk
8) Birmingham City University: bcu.ac.uk, uce.ac.uk
9) Bournemouth University: bournemouth.ac.uk
10) Brunel University London: brunel.ac.uk
11) Canterbury Christ Church University: cant.ac.uk
12) Cardiff Metropolitan University: uwic.ac.uk, cardiffmet.ac.uk
13) Cardiff University: cardiff.ac.uk, cf.ac.uk
14) City University of London: city.ac.uk
15) Coventry University: coventry.ac.uk
16) Cranfield University: cranfield.ac.uk
17) De Montfort University: dmu.ac.uk
18) Durham University: dur.ac.uk, durham.ac.uk
19) Edinburgh Napier University: napier.ac.uk
20) Glasgow Caledonian University: gcal.ac.uk
21) Goldsmiths University of London: gold.ac.uk, goldsmiths.ac.uk
22) Harper Adams University: harper-adams.ac.uk
23) Heriot-Watt University: hw.ac.uk
24) Imperial College London: ic.ac.uk, imperial.ac.uk
25) Institute of Cancer Research: icr.ac.uk
26) Keele University: keele.ac.uk
27) King's College London: kcl.ac.uk
28) Kingston University: king.ac.uk, kingston.ac.uk
29) Lancester University: lancaster.ac.uk, lancs.ac.uk
30) Leeds Beckett University: lmu.ac.uk
31) Liverpool John Moores University: livjm.ac.uk
32) London Business School: london.edu
33) London Metropolitan University: londonmet.ac.uk
34) London School of Economics: lse.ac.uk
35) London School of Hygiene & Tropical Medicine: lshtm.ac.uk
36) London South Bank University: lsbu.ac.uk
37) Loughborough University: lboro.ac.uk, loughborough.ac.uk
38) Manchester Metropolitan University: mmu.ac.uk
39) Middlesex University: mdx.ac.uk
40) Newcastle University: ncl.ac.uk, newcastle.ac.uk
41) Northumbria University: northumbria.ac.uk, unn.ac.uk
42) Nottingham Trent University: ntu.ac.uk
43) Open University: open.ac.uk
44) Oxford Brookes University: brookes.ac.uk
45) Queen Margaret University: qmuc.ac.uk
46) Queen Mary University: qmw.ac.uk, qmul.ac.uk
47) Queen's University Belfast: qub.ac.uk
48) Robert Gordon University: rgu.ac.uk
49) Royal Academy of Music: ram.ac.uk
50) Royal Central School of Speech and Drama: cssd.ac.uk
51) Royal College of Art: rca.ac.uk
52) Royal Holloway: rhbnc.ac.uk, rhul.ac.uk, royalholloway.ac.uk
53) School of Oriental and African Studies: soas.ac.uk
54) Sheffield Hallam University: shu.ac.uk
55) Staffordshire University: staffs.ac.uk
56) Swansea Uniiversity: swan.ac.uk, swansea.ac.uk
57) Teesside University: tees.ac.uk
58) Ulster University: ulst.ac.uk, ulster.ac.uk
59) University College London: ioe.ac.uk, ucl.ac.uk, ulsop.ac.uk
60) University of Aberdeen: abdn.ac.uk
61) University of Bath: bath.ac.uk
62) University of Bedfordshire: beds.ac.uk
63) University of Birmingham: bham.ac.uk, birmingham.ac.uk
64) University of Bradford: brad.ac.uk, bradford.ac.uk
65) University of Brighton: brighton.ac.uk, bton.ac.uk
66) University of Bristol: bris.ac.uk, bristol.ac.uk
67) University of Buckingham: buckingham.ac.uk
68) University of Cambridge: cam.ac.uk
69) University of Central Lancashire: uclan.ac.uk
70) University of Derby: derby.ac.uk
71) University of Dundee: dundee.ac.uk
72) University of East Anglia: uea.ac.uk
73) University of East London: uel.ac.uk
74) University of Edinburgh: eca.ac.uk, ed.ac.uk, edinburgh.ac.uk
75) University of Essex: essex.ac.uk, sx.ac.uk
76) University of Exeter: ex.ac.uk, exeter.ac.uk
77) University of Glasgow: gla.ac.uk, glasgow.ac.uk
78) University of Gloucestershire: glos.ac.uk
79) University of Greenwich: gre.ac.uk, greenwich.ac.uk
80) University of Hertfordshire: herts.ac.uk
81) University of Huddersfield: hud.ac.uk
82) University of Hull: hull.ac.uk
83) University of Kent: kent.ac.uk, ukc.ac.uk
84) University of Leeds: leeds.ac.uk
85) University of Leicester: le.ac.uk, leicester.ac.uk
86) University of Lincoln: lincoln.ac.uk
87) University of Liverpool: liv.ac.uk, liverpool.ac.uk
88) University of Manchester: man.ac.uk, manchester.ac.uk, mcc.ac.uk, umist.ac.uk
89) University of Northampton: northampton.ac.uk
90) University of Nottingham: nott.ac.uk, nottingham.ac.uk
91) University of Oxford: ox.ac.uk
92) University of Plymouth: plym.ac.uk, plymouth.ac.uk
93) University of Portsmouth: port.ac.uk
94) University of Reading: rdg.ac.uk, reading.ac.uk
95) University of Roehampton: roehampton.ac.uk
96) University of Salford: salford.ac.uk
97) University of Sheffield: shef.ac.uk, sheffield.ac.uk
98) University of South Wales: newport.ac.uk
99) University of Southampton: soton.ac.uk, southampton.ac.uk
100) University of St Andrews: st-and.ac.uk, st-andrews.ac.uk
101) University of Stirling: stir.ac.uk
102) University of Strathclyde: strath.ac.uk
103) University of Sunderland: sund.ac.uk, sunderland.ac.uk
104) University of Surrey: surrey.ac.uk
105) University of Sussex: sussex.ac.uk, susx.ac.uk
106) University of Wales Trinity Saint David: lamp.ac.uk
107) University of Warwick: warwick.ac.uk
108) University of West London: tvu.ac.uk
109) University of Westminster: westminster.ac.uk, wmin.ac.uk
110) University of Wolverhampton: wlv.ac.uk
111) University of Worcester: worc.ac.uk
112) University of the Arts London: arts.ac.uk, linst.ac.uk
113) University of the West of England Bristol: uwe.ac.uk
114) University of the West of Scotland: paisley.ac.uk
115) Universiy of York: york.ac.uk

H. Investigated Institutions in the United States

1) Air Force Institute of Technology Graduate School of Engineering & Management: afit.edu
2) American University: american.edu
3) Arizona State University: asu.edu
4) Arkansas State University: astate.edu
5) Auburn University: auburn.edu
6) Azusa Pacific University: apu.edu
7) Ball State University: bsu.edu
8) Baylor University: baylor.edu
9) Binghamton University: binghamton.edu
10) Boise State University: boisestate.edu
11) Boston College: bc.edu
12) Boston University: bu.edu
13) Bowling Green State University: bgsu.edu
14) Brandeis University: brandeis.edu
15) Brigham Young University: byu.edu
16) Brown University: brown.edu
17) CUNY City College: cuny.edu
18) California Institute of Technology: caltech.edu
19) Carnegie Mellon University: cmu.edu
20) Case Western Reserve University: case.edu
21) Catholic University of America: catholic.edu
22) Central Michigan University: cmich.edu

23) Chapman University: chapman.edu
24) Claremont Graduate University: cgu.edu
25) Clark Atlanta University: cau.edu
26) Clark University: clarku.edu
27) Clarkson University: clarkson.edu
28) Clemson University: clemson.edu
29) Cleveland State University: csuohio.edu
30) College of William and Mary: wm.edu
31) Colorado School of Mines: mines.edu
32) Colorado State University: colostate.edu
33) Columbia University: columbia.edu
34) Cornell University: cornell.edu
35) Dartmouth College: dartmouth.edu
36) DePaul University: depaul.edu
37) Delaware State University: desu.edu
38) Drexel University: drexel.edu
39) Duke University: duke.edu
40) Duquesne University: duq.edu
41) East Carolina University: ecu.edu
42) East Tennessee State University: etsu.edu
43) Eastern Michigan University: emich.edu
44) Emory University: emory.edu
45) Florida Agricultural and Mechanical University: famu.edu
46) Florida Atlantic University: fau.edu
47) Florida Institute of Technology: fit.edu
48) Florida International University: fiu.edu
49) Florida State University: fsu.edu
50) Fordham University: fordham.edu
51) Gallaudet University: gallaudet.edu
52) George Mason University: gmu.edu
53) George Washington University: gwu.edu
54) Georgetown University: georgetown.edu
55) Georgia Institute of Technology: gatech.edu
56) Georgia Southern University: georgiasouthern.edu
57) Georgia State University: gsu.edu
58) Hampton University: hamptonu.edu
59) Harvard University: harvard.edu
60) Howard University: howard.edu
61) Idaho State University: isu.edu
62) Illinois Institute of Technology: iit.edu
63) Illinois State University: illinoisstate.edu
64) Indiana University Purdue University Indianapolis: iupui.edu
65) Indiana University Bloomington: indiana.edu
66) Iowa State University: iastate.edu
67) Jackson State University: jsums.edu
68) Johns Hopkins University: jhu.edu
69) Kansas State University: k-state.edu
70) Kennesaw State University: kennesaw.edu
71) Kent State University at Kent: kent.edu
72) Lehigh University: lehigh.edu
73) Louisiana State University and Agricultural & Mechanical College: lsu.edu
74) Louisiana Tech University: latech.edu
75) Loyola Marymount University: lmu.edu
76) Loyola University Chicago: luc.edu
77) Marquette University: marquette.edu
78) Marshall University: marshall.edu
79) Massachusetts Institute of Technology: mit.edu
80) Mercer University: mercer.edu
81) Miami University: miamioh.edu
82) Michigan State University: msu.edu
83) Michigan Technological University: mtu.edu
84) Mississippi State University: msstate.edu
85) Missouri University of Science and Technology: mst.edu
86) Montana State University: montana.edu
87) Montclair State University: montclair.edu
88) Morgan State University: morgan.edu
89) New Jersey Institute of Technology: njit.edu
90) New Mexico State University: nmsu.edu
91) New York University: nyu.edu
92) North Carolina A & T State University: ncat.edu
93) North Carolina State University: ncsu.edu
94) North Dakota State University: ndsu.edu
95) Northeastern University: northeastern.edu
96) Northern Arizona University: nau.edu
97) Northern Illinois University: niu.edu
98) Northwestern University: northwestern.edu
99) Nova Southeastern University: nova.edu
100) Oakland University: oakland.edu
101) Ohio State University[4]: osu.edu
102) Ohio University-Main Campus: ohio.edu
103) Oklahoma State University: okstate.edu
104) Old Dominion University: odu.edu
105) Oregon State University: oregonstate.edu
106) Pennsylvania State University: psu.edu
107) Ponce Health Sciences University: psm.edu
108) Portland State University: pdx.edu
109) Princeton University: princeton.edu
110) Purdue University: purdue.edu
111) Rensselaer Polytechnic Institute: rpi.edu
112) Rice University: rice.edu
113) Rochester Institute of Technology: rit.edu
114) Rockefeller University: rockefeller.edu
115) Rowan University: rowan.edu
116) Rutgers University: rutgers.edu
117) SUNY College of Environmental Science and Forestry: esf.edu
118) Saint Louis University: slu.edu
119) San Diego State University: sdsu.edu
120) Seton Hall University: shu.edu
121) South Dakota State University: sdstate.edu
122) Southern Illinois University: siue.edu, siu.edu, siumed.edu
123) Southern Methodist University: smu.edu
124) Stanford University: stanford.edu
125) Stevens Institute of Technology: stevens.edu
126) Stony Brook University: stonybrook.edu
127) Syracuse University: syracuse.edu
128) Temple University: temple.edu
129) Tennessee State University: tnstate.edu
130) Tennessee Technological University: tntech.edu
131) Texas A&M University: tamu.edu
132) Texas A&M UniversityCorpus Christi: tamucc.edu
133) Texas A&M UniversityKingsville: tamuk.edu
134) Texas Christian University: tcu.edu
135) Texas Southern University: tsu.edu
136) Texas State University: txstate.edu
137) Texas Tech University: ttu.edu
138) The New School: newschool.edu
139) Thomas Jefferson University: jefferson.edu
140) Tufts University: tufts.edu
141) Tulane University: tulane.edu
142) University at Albany: albany.edu
143) University at Buffalo: buffalo.edu
144) University of Akron Main Campus: uakron.edu
145) University of Alabama: ua.edu
146) University of Alabama at Birmingham: uab.edu
147) University of Alabama in Huntsville: uah.edu
148) University of Alaska Fairbanks: uaf.edu
149) University of Arizona: arizona.edu
150) University of Arkansas: uark.edu
151) University of Arkansas at Little Rock: ualr.edu
152) University of California, Berkeley: berkeley.edu
153) University of California, Davis: ucdavis.edu
154) University of California, Irvine: uci.edu
155) University of California, Los Angeles: ucla.edu
156) University of California, Merced: ucmerced.edu
157) University of California, Riverside: ucr.edu
158) University of California, San Diego: ucsd.edu
159) University of California, Santa Barbara: ucsb.edu
160) University of California, Santa Cruz: ucsc.edu
161) University of Central Florida: ucf.edu
162) University of Chicago: uchicago.edu
163) University of Cincinnati: uc.edu
164) University of Colorado Boulder: colorado.edu
165) University of Colorado Colorado Springs: uccs.edu
166) University of Colorado Denver: ucdenver.edu
167) University of Connecticut: uconn.edu
168) University of Dayton: udayton.edu
169) University of Delaware: udel.edu
170) University of Denver: du.edu

171) University of Florida: ufl.edu
172) University of Georgia: uga.edu
173) University of Hawaii: hawaii.edu
174) University of Houston: uh.edu
175) University of Idaho: uidaho.edu
176) University of Illinois at Chicago: uic.edu
177) University of Illinois at UrbanaChampaign: illinois.edu
178) University of Iowa: uiowa.edu
179) University of Kansas: ku.edu
180) University of Kentucky: uky.edu
181) University of Louisiana at Lafayette: louisiana.edu
182) University of Louisville: louisville.edu
183) University of Maine: umaine.edu
184) University of Maryland, Baltimore County: umbc.edu
185) University of Maryland, College Park: umd.edu
186) University of Maryland, Eastern Shore: umes.edu
187) University of Massachusetts Amherst: umass.edu
188) University of Massachusetts Boston: umb.edu
189) University of Massachusetts Dartmouth: umassd.edu
190) University of Massachusetts Lowell: uml.edu
191) University of Memphis: memphis.edu
192) University of Miami: miami.edu
193) University of Michigan: umich.edu
194) University of Minnesota: umn.edu
195) University of Mississippi: olemiss.edu
196) University of Missouri: missouri.edu
197) University of MissouriKansas City: umkc.edu
198) University of MissouriSt. Louis: umsl.edu
199) University of Montana: umt.edu
200) University of Nebraska at Omaha: unomaha.edu
201) University of NebraskaLincoln: unl.edu
202) University of Nevada, Las Vegas: unlv.edu
203) University of Nevada, Reno: unr.edu
204) University of New England: une.edu
205) University of New Hampshire: unh.edu
206) University of New Mexico: unm.edu
207) University of New Orleans: uno.edu
208) University of North Carolina Wilmington: uncw.edu
209) University of North Carolina at Chapel Hill: unc.edu
210) University of North Carolina at Charlotte: uncc.edu
211) University of North Carolina at Greensboro: uncg.edu
212) University of North Dakota: und.edu
213) University of North Texas: unt.edu
214) University of Notre Dame: nd.edu
215) University of Oklahoma: ou.edu
216) University of Oregon: uoregon.edu
217) University of Pennsylvania: upenn.edu
218) University of Pittsburgh: pitt.edu
219) University of Puerto Rico: upr.edu
220) University of Rhode Island: uri.edu
221) University of Rochester: rochester.edu
222) University of San Diego: sandiego.edu
223) University of South Alabama: southalabama.edu
224) University of South Carolina: sc.edu
225) University of South Dakota: usd.edu
226) University of South Florida: usf.edu
227) University of Southern California: usc.edu
228) University of Southern Mississippi: usm.edu
229) University of Tennessee: utk.edu
230) University of Texas Rio Grande Valley: utrgv.edu
231) University of Texas at Arlington: uta.edu
232) University of Texas at Austin: utexas.edu
233) University of Texas at Dallas: utdallas.edu
234) University of Texas at El Paso: utep.edu
235) University of Texas at San Antonio: utsa.edu
236) University of Toledo: utoledo.edu
237) University of Tulsa: utulsa.edu
238) University of Utah: utah.edu
239) University of Vermont: uvm.edu
240) University of Virginia: virginia.edu
241) University of Washington: washington.edu
242) University of WisconsinMadison: wisc.edu
243) University of WisconsinMilwaukee: uwm.edu
244) University of Wyoming: uwyo.edu
245) Utah State University: usu.edu
246) Vanderbilt University: vanderbilt.edu
247) Villanova University: villanova.edu
248) Virginia Commonwealth University: vcu.edu
249) Virginia Polytechnic Institute and State University: vt.edu
250) Wake Forest University: wfu.edu
251) Washington State University: wsu.edu
252) Washington University in St. Louis: wustl.edu
253) Wayne State University: wayne.edu
254) West Virginia University: wvu.edu
255) Western Michigan University: wmich.edu
256) Wichita State University: wichita.edu
257) Worcester Polytechnic Institute: wpi.edu
258) Wright State University: wright.edu
259) Yale University: yale.edu
260) Yeshiva University: yu.edu