An Exploratory Survey on User Perceptions and Adoption of NEES.org

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Introduction

Scientific communities have developed new technologies that allow them to collaborate and at the same time share resources such as data and tools. Technologies that can support these processes are internet-based science gateways defined as "technological innovations whose aim is to bring about a radical transformation in research" [1]. Such science gateways are also called cyberinfrastructure or e-science [1]. Cyberinfrastructure is considered to be the basis for dynamic clusters of individuals, organizations, and resources such as computational tools and services, which enable flexibility, security and collaboration among their users [2,3]. The George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) operates a cyberinfrastructure (centered on the *NEEShub* accessible at nees.org) for research and education aimed at reducing losses from earthquakes NEEScomm, the headquarters for NEES located at Purdue University, operates a network of 14 earthquake engineering laboratory sites located at universities across the United States, which can be used for testing in-place or through the Internet. NEES provides specialized equipment to the civil engineering community such as shake tables, geotechnical centrifuges, a tsunami wave basin, unique large-scale testing laboratories, and mobile and permanently installed field equipment [4].

The goal of the study described in this paper is to determine users' practices and perceptions of the attributes of the NEEShub based on their current experience. The guiding research question for this study is: How do earthquake engineering researchers and professors perceive and experience the NEEShub?

Background

The NEESHub is a shared resource of cyberinfrastructure for research and education to reduce losses from earthquakes. As described in the NEES cooperative agreement [5]:

> The George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) is an NSF-supported shared resource of experimental facilities and cyberinfrastructure for research and education to advance knowledge discovery and innovation to reduce losses from earthquakes and tsunamis. The NEES experimental infrastructure comprises a network of 14 earthquake engineering and tsunami research facility sites, located at universities across the United States. This network is available for testing on-site, in the field, or through telepresence. The NEES facilities include shake table, geotechnical centrifuges, a tsunami wave basin, and unique large scale testing laboratories, and mobile and permanently installed field equipment.

The goal of this study is to determine users' perception of the attributes of NEES hub based on their current experience. To this end, we designed and administered a survey instrument based on Rogers' Diffusion of Innovation stages [6] to collect users' perceptions as a result of their engagement with the NEESHub cyber-infrastructure. Specific research questions were:

- How can nees.org users be characterized based on their intentions of use of NEES.org cyberinfrastructure?
- How do earthquake engineering researchers and professors perceive NEES.org in terms of its attributes?
- What are users' different levels of interaction and frequency of use?
- What is the relationship between nees.org users' perceived attributes and frequency of use?

Theoretical Framework

Diffusion of Innovation [6] refers to a behavioral model used to describe social practice of adaptation of individuals towards an innovation of new technology. The main purpose of the model is to help guide understanding of (i) how potential adaptors embrace change (e.g., innovation or new technology) and (ii) how long it takes for participates to adapt change (e.g., accept, modify or reject). The diffusion process according to Rogers is a for stage process that includes five stages:

1. Knowledge stage: Users learn of the cyber-infrastructure and its basic functions.
2. Persuasion stage: Users repetitively return to the Hub looking to gain deeper knowledge about the capabilities of the cyber-infrastructure.
3. Decision stage: Users engage more deeply with the cyber-infrastructure through a series of trails that lead to a decision to accept or reject.
4. Implementation stage: Registered user have integrated the NEEShub into their work and research
5. Confirmation Stage: Users make a long-term commitment to the cyber-infrastructure and make it an integral part of their research.

This model also allows describing how users perceived innovations in terms of their characteristics or attributes. The diffusion of new technologies and the rate of their adoption can be characterized by attributes as individuals interact with innovations [7].

Design and Methods

NEESHub users were contacted by email and were invited to fill out an online and anonymous survey to describe their perceptions of the cyberinfrastructure and their frequency of use. The subjects of the study were students, professors, and researchers from all around the world who have used the nees.org for research, education and collaboration purposes. Participants who responded the survey included 27 users with a common interest to facilitate research towards mitigating earthquake damage and loss of life via the use of improved designs, materials, construction techniques, and monitoring methods.

The survey consisted of twenty-nine multiple choice questions. Each question used a five point Likert-Scale and each question had its own weight, which allowed us to calculate a quantitative measure. Questions from the survey measuring users perceptions of nees.org attributes were adapted from Hsu, Lu and Hsu [8]. Other questions associated with frequency of use were adapted from Hacker and Magana [9]. Each of the perception questions was scored on a scale from 1 (strongly disagree) to 5 (strongly agree) and descriptive statistics were computed for each question. Our interpretations for the responses were as follows. Scores from 1 to 2.4 were

interpreted as students having negative perceptions on a specific nees.org attribute. Scores from 3.5 to 5 were interpreted as users having positive perceptions on a specific nees.org attribute. Scores from 2.5 to 3.4 were considered inconclusive. Five open-ended questions were added at the end. These questions were analyzed qualitatively to identify patterns in participants' responses.

Validity and Reliability

The survey instrument was pilot tested with a population of seventeen professors from the same institution, prior to being sent to all participants affiliated with the NEESHub. Based on the pilot survey, all questions were validated in terms of wording and clarity. Also, some questions that were deemed too repetitive were eliminated. Similarly Cronbach's alpha [10] was used to identify the strength of the relationship between the question items within the same category. For the categories of perceived ease of use (α=0.68), relative advantage (α=0.77), perceived compatibility (α=0.71), and perceived demonstrability (α=0.73), the internal consistency between questions was considered to be acceptable. However, for the category of perceived observability (α=0.41) the internal consistency was determined to be poor.

Results and Discussion

This section presents the analysis and results describing users perceptions of the NEEShub at (nees.org) together with the way they experienced it in terms of frequency of use. Based on participants' responses we also characterize NEEShub users based on Rogers' Diffusion of Innovation model. For some of the survey questions, where appropriate, we coupled them with data from the open-ended responses to provide more insights into users perceptions and practices associated with nees.org.

In performing our analysis for the results and discussion we implemented descriptive statistics to help us describe the perceptions and experiences of the survey participants of this study. The research questions (RQ) allow us to profile the users based on their own self-identified level of adaptability to new technology (RQ1), the perceptions of different attributes (RQ2) and their frequency of use of nees.org (RQ3). In addition we used the last question to determine the relationship between user perceptions of nees.org and their frequency of use.

How can nees.org users be characterized based on their intentions of use of NEES.org cyberinfrastructure?

As shown in Figure 1, the majority of users decided to use the NEEShub on the basis of intuition, and they believe the platform will be useful. A minority of users agreed that NEEShub will become popular and plan to adapt the tool as part of their practice should the Hub fully matures to include standardized functionality and training.

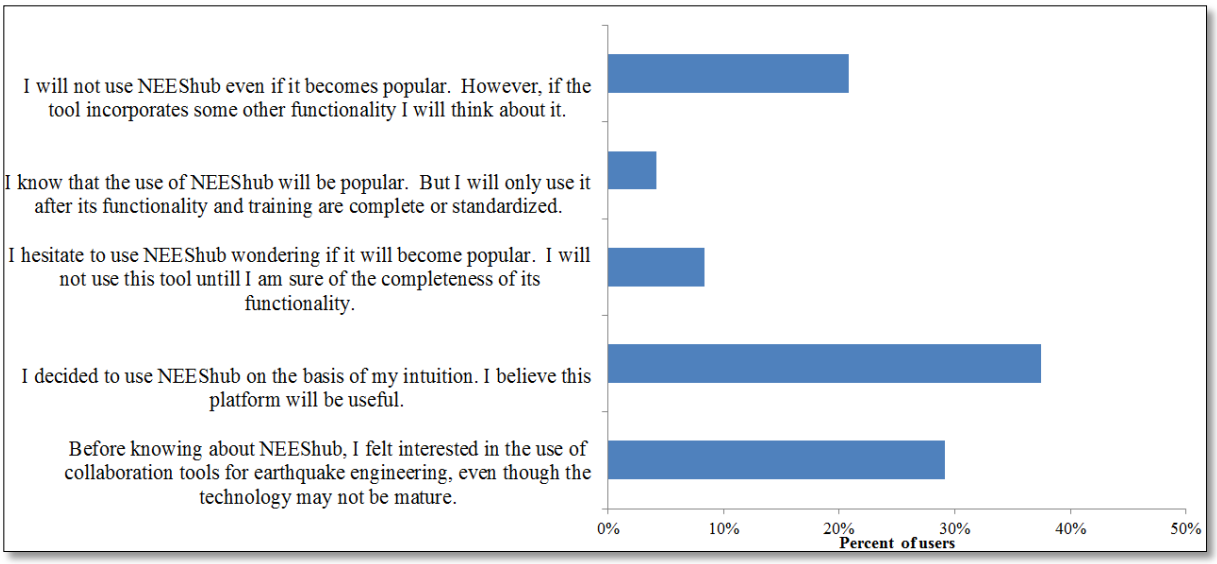

Figure 1. Characterization of nees.org users based on their level of adoption of nees.org

In addition these survey responses identify that the majority of users in the sampled population may fit the profile of early adaptors/early majority, as 66% of the all the participants decided to use the tool based on their belief that the tool would be useful. These estimates are not in alignment with Rogers's estimates. More of the participants in this study were more open to adopting the NEESHub as a tool for their research practices.

What are users' different levels of interaction and frequency of use?

There were a total of 27 responses per each of the questions as related to the frequency of use. As shown in Table 1, users' self-perceptions of their frequency of use indicated that the majority of users occasionally or rarely used NEEShub.

Table 1. Contingency table associating different uses of nees.org and their frequency of use

Frequency Questions	Frequently (more than once a week or twice)	Every once in a while (once or twice every other week)	Occasionally (once or twice per month)	Rarely (once or twice in six months)	Never
On average, how often do you use NEEShub in general?	5	5	4	**11**	2
How often have you used or downloaded NEEShub resources (e.g., software tool, document, database, video, or publication)?	1	3	8	**13**	2

Have you incorporated some of the resources (software tool, document, database, video, or publication) available at NEEShub into your work in earthquake engineering?	3	2	2	**11**	9
Have you made any kind of contributions to NEEShub of data, documents, tools, learning modules, or publications that resulted from your work in earthquake engineering?	3	5	3	7	**9**

The users' forms of interactions with nees.org and their frequency of use are profiled in this data. The data suggests that most of the participants rarely used the tool within a period of six months. Of the users that engaged more frequently with the tool, which we determined to be more than once every two weeks, were able to incorporate the resources available through the NEESHub into their own practice and some were even able to make contributions. However a large part of the population did not actively engaged in utilizing NEESHub resources nor provided contributions to the research community within the Hub space. We did not ask if they were able to participate through more traditional routes in academia such as journal publication so we can rule out that the community engaged in collaborations outside of the Hub space. The evidence for the survey suggests that the Hub space did not serve as viable platform for collaborations among participants.

In an open-ended question, we asked participants to describe how they primarily used NEEShub as a resource for earthquake engineering research and collaboration. From the 27 participants, 14 of them responded this question. Users' descriptions can be categorized into three major patterns of use: (a) to upload files of unprocessed data after experiments or to download data for model validation (8 responses): "I have used NEEShub to download experimental data required for model validation"; (b) to use it for collaboration and documentation purposes (3 responses): "I use it for the group space to share ideas and files with colleagues at other institutions. I use it to completely document my experiments so that they are available to others and to me in the years to come;" (c) to find disciplinary content (2 responses): "We look up references, videos, earthquake info, etc.;" (d) to perform simulations (1 response).

In the second open-ended question, we asked participants to report whether or not they were considering keeping using NEEShub in the future. From the 27 respondents 11 of them responded to this question. Three respondents mentioned that they would not use it in the future. The other eight reported they were planning to use it in the future: "Yes, it is getting better and/or I'm getting to understand it more. The concept of the hub is beneficial." More specific responses were related primarily to future uses as data repository: "I will use it to acquire experimental data, technology tools are ok, but they are available elsewhere. The data is the key." Fewer responses described future uses for computational purposes "Yes. Availability to computational resources and a platform for data preservation are two reasons I would continue using the NEEShub."

How do earthquake engineering researchers and professors perceive NEES.org in terms of its attributes?

Nees.org users' beliefs are described in terms of positive, negative or inconclusive perception of a given attribute. Each attribute is described and scored independently in tables 2 to 8.

Ease of Use. Refers to the perceived difficulty to comprehend or use the technology [6]. Table 2 summarizes NEEShub users' perceived ease of use with the technology. For NEEShub users, they were undecided on their perceptions of their level of ease of use in learning how to use the technology. They were also undecided in the level of mental effort they were required to put on while working with the technology. Finally, they were also undecided in the level of frustration they might have experienced while working with the technology.

Table 2. NEEShub users' perceived ease of use

Statement	Mean	Std. Dev.	N	Lower 95% CL	Upper 95% CL
Learning to use NEEShub is easy for me	3.04	1.16	27	2.58	3.50
Using NEEShub requires a lot of mental effort for me	2.96	0.96	26	2.57	3.35
Using NEEShub is often frustrating	2.89	1.40	27	2.34	3.44

Relative Advantage. Refers to the degree in which the innovation is observed as better than its predecessor [6]. Table 3 summarizes NEEShub users' perceived relative advantage of using nees.org. Overall, users reported very positive perceptions on their level of knowledge of the purpose and the resources and services nees.org provides to its users. However, these users were undecided on their experienced level of productivity of their research by using these services. They were also undecided in reporting as positive or negative the way their uses of nees.org fits well with the way they work.

Table 3. NEEShub users' perceived relative advantage

Statement	Mean	Std. Dev.	N	Lower 95% CL	Upper 95% CL
I am knowledgeable of the purpose and resources that NEEShub offers to its users	**3.85**	1.03	27	3.45	4.26
Using NEEShub increases my productivity in earthquake engineering research	3.00	1.21	27	2.52	3.48
The use of NEEShub fits well with the way I work	2.96	1.30	26	2.43	3.49

Compatibility. Refers to the degree of consistency with the adopters' needs based on values or previous experiences [6]. Table 4 summarizes NEEShub users' perceived compatibility of their uses of nees.org and their needs. Overall, the surveyed users reported a positive opinion about

their uses of this technology. And they were somewhat undecided about whether or not to recommend nees.org to their colleagues.

Table 4. NEEShub users' perceived compatibility

Statement	Mean	Std. Dev.	N	Lower 95% CL	Upper 95% CL
I can form a favorable opinion about the use of this technology	**3.54**	1.03	26	3.12	3.95
I would recommend the use of NEEShub to other colleagues	3.41	1.37	27	2.87	3.95

Demonstrability. Refers to the perceived ability to show to others the uses and benefits of the technology [8]. Table 5 summarizes NEEShub users' perceived demonstrability of nees.org uses and benefits to others. NEEShub users reported positive perceptions in their ability to communicate to others what are the advantages, scopes and constraints of using nees.org. However, they were uncertain of their ability of identifying the results of their uses of the technology.

Table 5. NEEShub users' perceived demonstrability

Statement	Mean	Std. Dev.	N	Lower 95% CL	Upper 95% CL
I believe I could communicate to others the consequences (advantages, scope and constraints) of using NEEShub	**3.48**	1.19	27	3.01	3.95
The results of using NEEShub are apparent (clear) to me	3.30	1.30	27	2.78	3.81

Observability. Refers to the perceived visibility to other members inside the social system [6]. Table 6 summarizes NEEShub users' perceived visibility of their uses of nees.org with colleagues in the community. NEEShub users were uncertain about the level of which other colleagues use nees.org and the ways in which nees.org could improve their level of visibility within their community.

Table 6. NEEShub users' perceived observability

Statement	Mean	Std. Dev.	N	Lower 95% CL	Upper 95% CL
Using NEEShub improves my visibility within my research community or organization	3.00	1.39	27	2.45	3.55
I have seen other colleagues using NEEShub	3.22	1.28	27	2.72	3.73

Trialability. Refers to the degree in which the innovation can be experimented on a limited environment before its complete use [6]. Table 7 summarizes NEEShub users' perceived

trialability of the uses of nees.org. Overall the users were somewhat uncertain about the level in which they could experiment with the various uses of nees.org.

Table 7. NEEShub users' perceived trialability

Statement	Mean	Std. Dev.	N	Lower 95% CL	Upper 95% CL
I know where I can go to satisfactorily try out various uses of NEEShub	3.07	1.17	27	2.61	3.54

Voluntariness. Refers to the degree in which a user chooses to use an innovation based on his or her free will [8]. Table 8 summarizes NEEShub users' level of voluntariness with which they use nees.org. NEEShub users were undecided about the level in which their supervisors were expecting them to use nees.org. This variability could be that many of the nees.org users might be students whose advisors require for them to use nees.org.

Table 8. NEEShub users' perceived voluntariness

Statement	Mean	Std. Dev.	N	Lower 95% CL	Upper 95% CL
My superiors expect me to use NEEShub	2.78	1.63	27	2.13	3.42

In the third open ended question we asked participants to describe if they think the implementation of NEEShub in their organization or personal work has been a success or not. We also prompted users to describe the reasons why they believed so. From the 27 participants, 15 users responded this question. Their explanations ranged from positive to negative experiences. For instance, two users reported not having a positive experience with nees.org. However the other 13 respondents, reported different advantages of the technology such as (a) capabilities for uploading, organizing, sharing and downloading large amount of data for experiments (7 responses):"As a researcher, the NEEShub is very valuable for organizing the data from our experiments. It is very helpful even before we share the data for general use by making it public;" (b) as a source of information of earthquake engineering content (2 responses): "It has useful information that we use;" (c) as a way to collaborate with other researchers in the field (2 responses):"it helps improve research collaboration. I am able to do include new and efficient features in collaboration that was not possible before;" and (d) as a resource that allows it users to perform simulations (1 response): "The NEEShub is allowing my students to perform simulations that otherwise would be difficult to implement with the current resources at my institution."

In contrast, we also asked users to describe how or in which ways they believed that the integration of NEEShub was challenging for them or for their organization. From the 27 participants, 13 users responded this question. Three major categories emerged from the responses including: (a) usability and user experience with nees.org (6 responses): "At times, find it confusing to navigate when looking for resources" or "The amount of time required to satisfying the data archival requirements was very frustrating and distracted from more productive work;" (b) users' required effort during learning curve in order to be able to start

benefitting from nees.org tools and services (3 responses): "It did require some learning time, but I think we are fairly comfortable in finding things now. It can be frustrating at times, but no more so than other sites. By and large it is a useful tool;" and (c) users' not knowing what services or resources nees.org provides (4 responses): "Some students and colleagues were hesitant to use NEEShub. In my opinion this is because of misconception of what can be done at the NEEShub."

Finally, we prompted respondents to share any suggestions of changes they could propose to be done to nees.org in order to be more effective or helpful to them or their organization. The majority of the responses, 6 out of 15, were related to improving processes for data curation, uploading and sharing: "Please focus on data repository and spend most of your resources on the data sharing. You cannot change people's preferred programs, but you can make this mandatory data uploading/sharing joyful. You can also make this data sharing an industry standard." Other user commented:

> "I believe NEEShub tries to do too much with all the different tools and resources. This result in support staff stretched thin, which in turn distracts from improving the quality of the most important feature - the archival of experimental data. If NEEShub focused on this more, the process would likely be easier and less frustrating, thus encouraging more researchers to archive and re-use data."

The other 10 responses were more generic suggesting improving the overall usability of the website; as user summarized it: "Streamline. Simplify. Make it work."

What is the relationship between nees.org users' perceived attributes and their frequency of use?

To examine the association between overall users' perception and their frequency of use, Pearson correlation test was performed. For each individual user we first computed an average score for their perceptions of nees.org attributes and then an overall average score for their frequency of use. These individual scores are plotted in Figure 2. This analysis suggests that there is a strong positive correlation (r=0.83) between users' perceptions of nees.org attributes and their frequency of use.

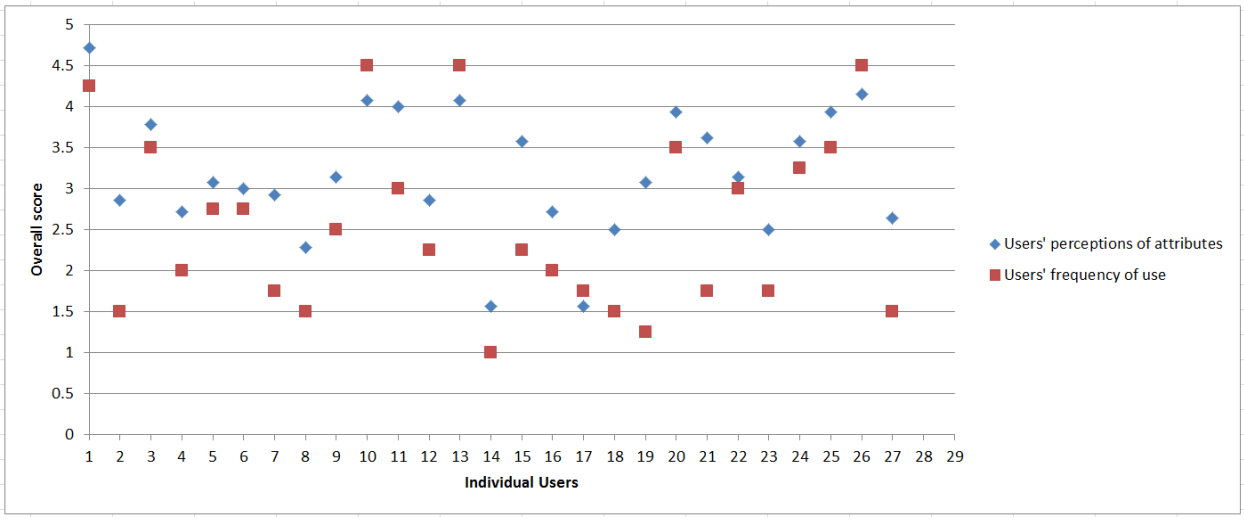

Figure 2. Individuals' average scores of their overall perceptions of nees.org attributes and their frequency of use.

Conclusion and Future Work

In a preliminary report conducted by Hacker and Magana [9], authors concluded that further research on users' perceived attributes of nees.org could provide ways in which they can provide users with content, services and other capabilities that could help users move from Knowledge Stage to the Confirmation Stage. Through this analysis we have identified that overall, the users who responded this survey demonstrated uncertainty in identifying the usefulness of attributes of nees.org in terms of ease of use, relative advantage, compatibility, demonstrability, trialability, and voluntariness. This suggests that users are still trying to decide if NEES cyberinfrastructure can help them effectively accomplish their goals more efficiently than other available technologies.

What it seems these users value the most are nees.org capabilities for uploading, storing, sharing and downloading experimental data. These users also appreciate the collaborative and planning capabilities. NEES requires from this users to provide specific metadata such as descriptors of what kind of sensor produced the time series data. However, this process appears to be difficult and confusing at times. These additional steps also seem to represent additional work for researchers who may not increase their individual research productivity. Thus, nees.org interface and usability can be improved in order to provide simple and transparent access to data and software tools within a framework that seems more natural and intuitive to earthquake engineers. Regardless of these limitations, overall users plan to continue to use nees.org. These users are researchers who are usually comfortable working with new technologies, as evidenced by the identified profile of the majority of them as early adaptors.

From the frequency data we can identify that nees.org users do not use it that often; and that fewer users contribute to it by uploading or sharing specific resources. It was also interesting to observe that there was a strong positive correlation between the frequency of use of the cyberinfrastructure and positive attitudes towards nees.org attributes. From this relationship we can hypothesize two ideas. One assumption could be that the more the users use the technology the more they learn how to operate it and therefore more comfortable become in continue to use it. Another assumption could be that since users do not use nees.org that often, they may not fully know their capabilities and resources and therefore may not see the value in continue to use it. However, these hypotheses need to be further investigated by perhaps interviewing experienced and inexperienced groups of researchers who have interacted with NEES cyberinfrastructure at different points in time.

One limitation of this study is the number of responses we obtained from the entire population of nees.org users. Regardless our limited sample size, we were able to gain deep insights into the profile of the population of users who participated in this survey. Although this does not allow for generalizations to the entire population, it does provide useful information into how uses may engage with the tools and resources available through nees.org. Thus, this exploratory study provides an initial analysis of how a subset of nees.org users perceives its attributes, the way they interacted with it, how often they used it, and what they value about it. Further user analytics are required to identify patterns of behavior in order to be able to determine how users progress

through different stages of the innovation process and at what point in time they decide to accept or reject the cyberinfrastructure.

Our future work will concentrate on identifying behavioral patterns of use of the technology and conduct ethnographic studies of research groups and see how they collaborate and share resources through this technology. Findings like this could allow us to identify what are the characteristics of the cyberinfrastructure that can be improved so it can provide better services to its users.

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