



Cloud Adoption Survey in Major Facilities and Mid Scale Institutes



A survey of the community by NSF CI Compass Cloud Topical Working Group

Authors: Bruce Berriman¹, Bob Flynn², Rajiv Mayani³, Benedikt Reidel⁴, Mats Rynge³, Tyson Swetnam⁵, Amanda Tan², Karan Vahi³

¹NASA Exoplanet Science Institute - IPAC, California Institute of Technology; ²Internet2; ³University of Southern California Information Sciences; ⁴IceCube Neutrino Observatory, Wisconsin IceCube Particle Astrophysics Center, University of Wisconsin-Madison; ⁵CyVerse, University of Arizona

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About the NSF CI Compass Cloud Topical Working Group

The NSF CI Compass Cloud Topical Working Group (TWG) was formed in 2020, consisting of staff from various U.S. National Science Foundation (NSF) Major Facilities (MFs), cloud providers, and cloud practitioners. Over the past two years, this diverse group engaged in in-depth discussions about the various MF's cloud requirements, and how best to leverage the cloud and other national cyberinfrastructure (CI) supported by NSF, and in 2024 published a technical report *NSF Major Facilities Cloud Use Cases and Considerations* [1]. The goals of this TWG are to “enhance access to existing infrastructure, e.g., computing power; foster collaboration and team science; and promote standards and best practices in the community for synthesis research” as they relate to the vast cloud computing ecosystem.

Executive Summary

This survey targeted personnel from NSF-funded Major Facilities (MFs) and Mid-scale Research Infrastructure (MRIs) awardees to assess their current and future use of cloud services (commercial and academic) and identify barriers to adoption. These facilities handle vast amounts of data (i.e., Petabyte or PByte+ scale), requiring significant storage, processing, and serving resources.

The survey was sent to 288 personnel across 21 MFs and 10 MRIs, yielding responses from 13 facilities, 7 mid-scales and 2 NSF projects. Most respondents identified as technical leaders or managers, with the majority indicating some level of cloud adoption. Organizations reported using major commercial cloud providers (e.g., Amazon, Google, Microsoft), academic providers (e.g., Jetstream), and self-hosted solutions (e.g., OpenStack). Respondents generally recognized cloud benefits, including improved reliability, scalability, on-demand access, and better storage services.

*Despite acknowledging cloud benefits, respondents cited major barriers to adoption, including **lack of funding, complexity in re-architecting deployments, and workforce skill***

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gaps. *Cost concerns - particularly for storage, compute, and data egress - were the top challenge, often leading organizations to adopt hybrid (i.e., on-premise and cloud) strategies. Additionally, many on-prem data centers were found to undercharge for computing, often lacking proper cost models. These findings align with long-standing discussions within the CI Compass Cloud TWG.*

The survey was approved for human-subject research through the Indiana University Institutional Review Board, IRB #23534.

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Survey Data and Discussion

In this report, we share anonymized response data and some analysis of the questions posed by the NSF CI Compass Cloud TWG survey. Hyper-scale computing, or "cloud technology," is a toolset in modern IT infrastructure that offers near-limitless, scalable, disposable computing power and services on demand with ubiquitous access. Questions 1-3 related to the role of the respondents in the facility. Q3 also allowed survey respondents to self-identify themselves for future follow-ups from the Cloud TWG. Questions 4-6 related to perceived benefits of cloud adoption for their organization, state of adoption so far, and plans, if any, to integrate cloud in their operations.

Questions 7-10 dealt with challenges in cloud adoption, i.e. cost concerns and impact on using cloud for storage if commercial cloud providers were to drop data egress charges. Questions 11-12 dealt with what commercial and academic cloud providers the survey respondents have used. Questions 13-14 dealt with interest in joining the Cloud Working group and what they would like to gain from participation in the group. Question 15 allowed respondents to share their cloud experiences and Question 16 is about if they wanted to do a 30-45 minute session with the Cloud TWG about cloud adoption in their organization.

Q1 - What Facility are you associated with?

The survey was sent to 288 personnel from 21 MFs and 10 MSRIs. Of the 36 total responses, 23 listed their affiliations with an MF, 10 listed an MSRI, and two can be characterized as NSF-funded projects (Figure 1, Table 1). One respondent declined to identify their facility. Overall, Major Facilities generally speak with one voice. Hence, we can assume that the respondents are representative of the facility they identify themselves to.

Figure 1: Pie-chart representing the affiliations breakdown of the survey respondents.

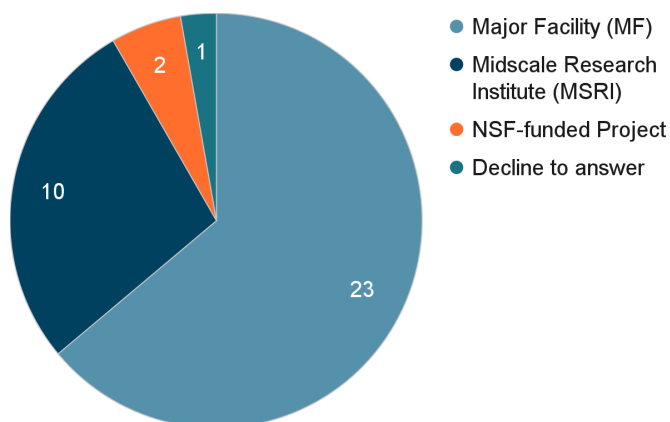


Table 1: Survey respondent facility affiliations

FACILITY NAME	Number of Respondents	Type
Earthscope (SAGE/GAGE)	4	MF
Vera C. Rubin Observatory	3	MF
IceCube Neutrino Observatory	2	MF
National Center for Atmospheric Research (NCAR)	2	MF
SafeInsights	2	MSRI
National Ecological Observatory Network (NEON)	2	MF
National Hazards Engineering Research Infrastructure (NHERI)/ NHERI University of Washington RAPID Facility	2	MSRI
Research Data Ecosystem at ICPSR	2	MSRI
Cornell High Energy Synchrotron Source (CHESS)	1	MSRI
CloudLab	1	NSF Project
Compact Muon Solenoid (CMS) at Large Hadron Collider (LHC)	2	MF
Compact X-ray Free-Electron Laser (CXFEL)	1	MSRI
Laser Interferometer Gravitational Wave Observatory (LIGO)	1	MF
National High Magnetic Field Lab (MagLab)	1	MF
National Radio Astronomy Observatory (NRAO)	1	MF
Ocean Observatories Initiative (OOI)	1	MF
Rolling Deck to Repository (R2R)	1	NSF Project
Academic Research Fleet (Regional Class Research Vessels (RCRV)/ R/V Sikuliaq / University-National Oceanographic Laboratory System (UNOLS))	2	MF
Texas Advanced Computing Center (TACC)	1	MF
International Ocean Discovery Program (IODP)	1	MF
Network for Advanced NMR (NAN), University of Connecticut Health Center	1	MSRI
Zettawatt-Equivalent Ultrashort Pulse laser System (ZEUS), University of Michigan	1	MSRI
blank	1	N

Q2 - What is your role at the facility?

We asked this question to better understand the perspectives of the respondents. Respondents were asked to choose from six predefined role types and a seventh option as Other with space to expand on their role. Table 2 lists the responses.

Table 2: Roles of survey respondents

Role	Count
Project Management	6
Data Manager	2
DevOps / IT	5
Data Scientist	5
Software Engineer	3
Domain Researcher	1
Other, please specify	14

Amongst the “Other” responses, we summarize them along the categories listed in Table 3.

Table 3: “Other” roles of survey respondents

Technical Director / Technical Leadership/ Product owner (architect, chief engineer, chief tech office, data services lead, software and computing coordinator, IT Director , leadership, Technical product owner)	7
Management (Director, Director of operations, Leadership, IT Director, PI)	6
Systems Engineer	1

Q3 - Would you like to identify yourself and also may we contact you in the future such as sharing the results of the survey; related follow-up cloud discussions and presentations by the community?

Of the 35 people who responded, a majority 29 (82%) of the respondents agreed to a future follow-up. This indicates a general larger interest in the community about cloud adoption and expressing a desire to be abreast of the developments in the community.

Q4 - What benefits do you think the cloud provides/could provide for your facility?

The respondents were asked to select the main benefits they perceived for their organization from cloud adoption. They were presented with a multiple-choice selection of the benefits listed in Table 4.

Table 4: Multiple choice options for the benefits of cloud adoption at the respondent's facility

Benefit	Choice Count
Increased reliability and availability	23
Better options for storage and archiving	23
On-demand use	23
Dynamic Scalability	21
Flexibility	20
Rapid innovation	15
Other, please specify	9

Most respondents (i.e., a choice count of 20 or higher) agree that cloud adoption provides tangible benefits in terms of increased reliability, better options for storage and archiving, on-demand use, dynamic scalability, and flexibility. A much lower proportion of respondents (43%) agreed that cloud adoption spurs rapid innovation.

Among the “Other” responses, three respondents also highlighted better physical and technical security. This, we hypothesize, stems from the ability to do fine-grained access control on users and permissions using native cloud services that most of the commercial cloud providers offer. Two of the respondents also emphasized the availability of Kubernetes and the ability to do Infrastructure as Code (IaC) deployments.

It is also worth noting that one of the respondents responded that they were unconvinced about whether there were any benefits.

Q5 - What is your current scope of cloud usage?

The intent with this question was to gauge the current state of cloud adoption within these organizations. The options ranged from none (i.e. no usage whatsoever) to Cloud First (i.e. all the operations are in the cloud). Table 5 shows the summary data of the responses.

Table 5: Summary of the respondent's current scope of cloud usage

Scope	Number
None	3
Not anymore (we have used it in the past, but currently not used)	3
Curious (don't use Cloud currently, but curious about possibilities)	0
Experimental (exploring, but nothing in production)	3
Emerging (small amount of cloud usage)	10
Hybrid	10
Cloud First	6
Total	35

The data indicates that 26 respondents (74%) indicate that their organizations have started using the Cloud for part or all of their operations. Of these, 46% (16 respondents) characterize their organizations using the Cloud in a meaningful way, either as hybrid or being Cloud First. It is worth noting that 6 respondents (17%) from 5 different organizations indicated their facilities are Cloud First. Equally, 6 respondents (17%) responded that their organizations did not use cloud, or have explored it in the past but are no longer using it. The survey did not ask respondents for reasons why they moved away from the cloud. It would have been worthwhile in order to understand that. The survey authors plan to follow up on this in the future.

Q6 - If you are not already a cloud user, do you plan to integrate cloud for your operations in the future?

This question attempted to gauge for users who don't identify their organizations as a cloud user, on their plans for cloud adoption.

Table 6: Future interest in cloud adoption for users whose facilities aren't already cloud users

Already in the process of doing it	10
In the current funding cycle	0
In the next funding cycle	0
Long Term	9
Not at all	4
Not applicable	12
Total	35

In Table 6, “Not applicable” indicates that the respondents’ facilities are already cloud users. Removing those leaves 23 responses. Of those, 10 (43%) respondents indicated that they are already in the process of adopting cloud, and nine (39%) have plans to do it in the long term. Four respondents (17%) indicated that they have no plans for cloud adoption.

Q7 - How challenging are the following in relation to using cloud resources?

This question ascertained the main challenges respondents felt concerning using cloud resources. The respondents were asked to rate the following concerns:

- Skepticism
- Security Concerns
- Lack of funding
- Lack of Technical Expertise
- Cost
- Complexity for rearchitecting for migration
- Workflow Skill gap
- Vendor Lock in concerns

Below are two figures illustrating the breakdown of the responses. Figure 2 highlights the data as a stacked bar chart.

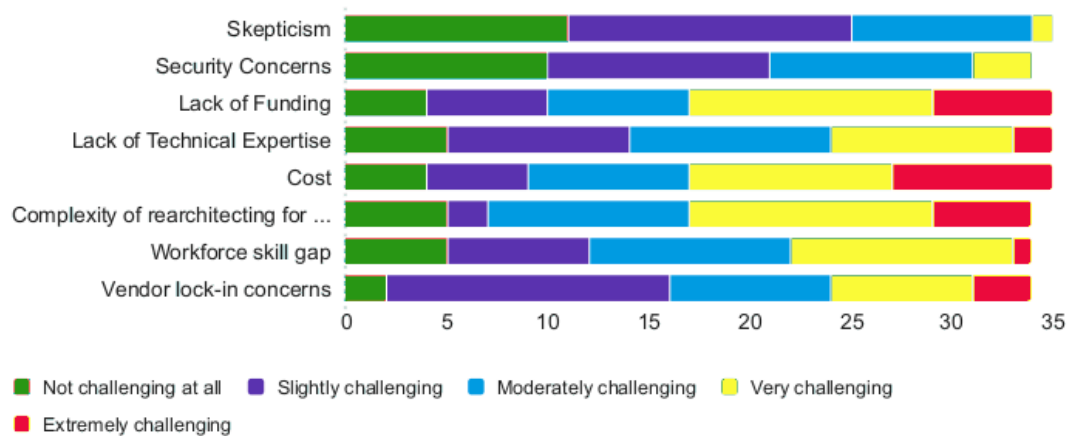


Figure 2: Severity of challenges with respect to cloud adoption

MFs and MSRIIs often have a fair amount of machinery built for their on-prem deployments. Most of these organizations are on 24/7, and hence, any move away from on-prem requires additional funding, re-architecting their current technical stack and retraining of existing employees, while at the same time maintaining on-prem operations. The findings indicate that the respondents see the value of cloud adoption, as indicated by the low level of cloud skepticism. The findings also suggest that respondents perceive “Lack of Funding”, “Complexity for rearchitecting their deployments,” and a “Workforce Skills Gap/ Lack of Technical Expertise” as significant barriers to Cloud adoption. They also rate the “Cost” of doing operations in the cloud as a significant challenge. Costs are also discussed in detail in the subsequent Q9, where respondents were asked to rank various Cost concerns.

Skepticism:

In this context, skepticism refers to the hesitation or resistance organizations and individuals exhibit toward adopting cloud computing. This skepticism often stems from concerns about the platform as a whole, as opposed to a single issue. These concerns may include security, reliability, cost, or other factors, which, when combined, lead to the organization or individual dismissing cloud computing as a viable solution. Occasionally, cloud enthusiasts may find themselves working for an organization skeptical of cloud computing. The survey results show that skepticism is the least challenging aspect, with only one respondent feeling it is very challenging and 10 moderately challenging.

Security Concerns:

Most of the respondents are not concerned about any security challenges concerning using cloud resources. Twenty-one of the 34 responses indicate that they have little or no concerns (i.e., “Not challenging at all” and “Slightly challenging”). Ten respondents felt that it was “Moderately challenging,” and only three respondents felt it was “Very challenging.” None of the respondents thought it was “Extremely challenging.”

Lack of Funding:

Cloud adoption requires significant upfront investment in terms of moving legacy applications to the cloud or rewriting them, which requires time from technical personnel. Eighteen (51%) of the 35 respondents indicated that lack of funding is a big concern for them (“Very challenging”/“Extremely challenging”). Seven respondents (20%) felt it was “Moderately challenging,” while only 10 respondents (28%) thought it was not a big concern (“Not challenging at all” or “Slightly challenging”). Overall, the data does indicate that lack of funding is a primary concern in cloud adoption.

Lack of Technical Expertise:

Cloud technologies are a fundamentally different paradigm in computing compared to on-prem deployments. Application developers are required to configure and set up their virtual machines for cloud deployments, configure networking and firewalls, tasks which normally would be done by a system administrator (sysadmin) on an on-prem deployment. It also necessitates the need for automating and codifying your infrastructure setup for easier spin up and deployment. Cloud adoption requires staff to have a different set of technical expertise than they may possess in their current roles. Fourteen of the 35 respondents indicated that it is not an issue (rated “Not challenging at all” or “Slightly challenging”). Ten of the respondents felt it was “Moderately challenging,” whereas 11 of the respondents felt it was a big concern (rated “Very” or “Extremely challenging”). Eight of the respondents thought it was “Moderately challenging.”

Cost:

Moving to the cloud brings with it many recurring operating expenses that may not be present when organizations are operating in their data centers. It is very hard for a project to have sufficient insight to accurately calculate operational costs (e.g., cost of data center, staff to keep it running, and energy costs). The most common cloud cost model is pay-as-you-go, where these costs are included in the price of the services. There are many

factors to consider, such as capital expenditure vs. monthly operational expenditure, discounts and overhead costs, and alignment with the project's funding, which makes comparisons difficult. The survey data indicates that a majority of respondents are concerned about costs, with 18 respondents (51%) indicating it to be "Very challenging" or "Extremely challenging." Eight (23%) indicated it was "Moderately challenging," while only 9 (25%) thought it was "Not challenging at all" or "Slightly challenging."

Complexity for rearchitecting for migration:

When moving current operations to the cloud, organizations often need to re-architect their software stack for better deployment and to make the best use of additional capabilities that the cloud offers. This re-architecting can be complex. Only 7 of the respondents (21%) indicated that it was "Not challenging" or "Slightly challenging," whereas 17 (50%) thought this as "Very challenging" and "Extremely challenging." Another 10 (29%) indicated it was "Moderately challenging."

Workflow skill gap:

Organizations also have to deal with a workflow skill gap, wherein the existing staff may not have relevant cloud experience and require additional training to migrate their operations to the cloud. The survey data indicates that 12 of the respondents (35%) thought it was "Extremely" or "Very challenging." Twelve other respondents (35%) thought it was "Not challenging at all," while the remaining 10 (30%) thought it was "Moderately challenging."

Vendor Lock-in concerns:

A significant challenge that organizations might encounter is "vendor lock-in." Transitioning between vendors can become costly, primarily because of differing APIs, tools, and services offered by various cloud providers. This question attempted to gauge how the respondents view this risk.

A large number of respondents (16, 47%) felt it is only "Slightly challenging" or "Not challenging," with 14 (41%) rating it as "Slightly challenging." On the other end, 10 respondents (29%) felt it was "Very" or "Extremely challenging."

Q8 - Please describe any other challenges related to using cloud resources not listed above.

Respondents to the survey also shared other concerns about using cloud resources, some of which overlap with the categories surveyed in the previous question. They do note that it is easier to share data via cloud platforms to other countries and remote geographical locations.

Concerns were noted about cloud vendors' cost structures for data archival and data egress. One of the respondents highlighted that the move to the cloud should replace the need for staff in on-prem IT operations; when that does not happen, overall costs do become prohibitive. Another indicated a vendor lock-in concern where they heavily utilize Cloud storage for all of their document needs but are concerned about contract renewal and that they might have to move to another provider.

A few people also highlighted internal politics in their organizations as well as the fact that on-prem data centers tend to undercharge for on-prem computing and often do not use proper cost models (e.g., labor/staff time spent maintaining these resources). Others also highlighted that in large awards, there are often a set of smaller awards to independent contractors or groups that are in pseudo-competition with each other, which prevents developing program-wide collaborative solutions.

While the cloud is suitable for operations and running services 24/7, few respondents noted that cloud providers do not provide good support for HPC capabilities and workloads. One of the respondents also stated that finding the right cloud option and deployment strategy requires a lot of work. Respondents also noted that the time to migrate to cloud native solutions and integration with existing infrastructure (hybrid deployments) can be significant.

One of the respondents highlighted:

“These questions are framed around our internal use of cloud resources; our biggest challenges are around adoption of cloud resources by their users.”

A respondent also highlighted the fact that collaboration over cloud adoption can be a challenge in a large multi-institutional project, where each of the sub-awards may be in *“pseudo-competition with each other”*. They also underlined the challenge of heavily using cloud storage provided by their parent institution but not having control over the cloud contract itself. They see this as a significant risk, as they could be forced to move to

another provider if the parent institution does not renew the contract with the cloud provider.

Q9 - Rank the following cost concerns

The following figure summarizes the responses.

Note One indicates the most concerning, and 6 the least concerning.

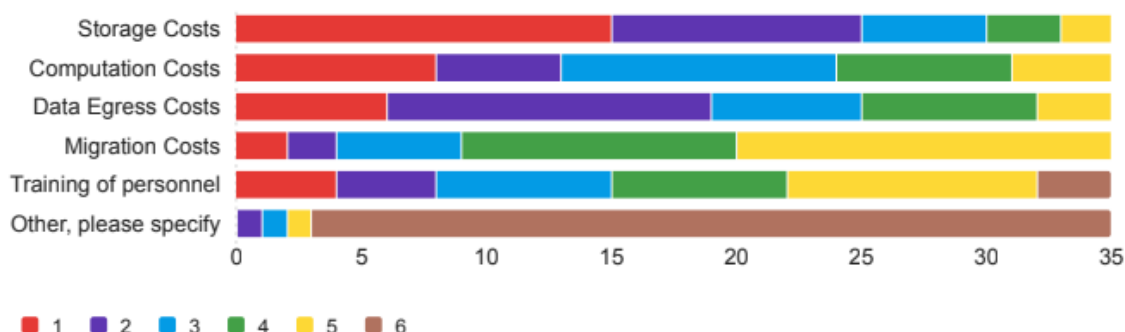


Figure 3: Summary of cost concerns

MFs and MSRIs handle vast amounts of data, reaching the PByte+ scale, requiring significant resources for data storage, processing, and serving. Consequently, the responses to this question highlighting cost concerns related to storage, compute, and data egress are quite understandable. These findings align closely with the long-standing discussions within the Cloud TWG [1]. Among these concerns, storage stands out, with nearly half of the respondents (43%) ranking it as their top concern.

While migration and training costs remain important to respondents, they are clearly secondary to the ongoing operational costs associated with storage, compute, and egress (Figure 3). A possible explanation for this prioritization is that migration and training are often viewed as one-time investments, whereas the other concerns represent recurring costs over the facility's lifecycle. Moreover, until projects are assured they can afford storage, compute, and egress, there is little incentive to support training and migration.

Q9 - Other, please specify

The three "Other" responses emphasized the importance of considering vendor lock-in and highlighted the significant difference between the cost models of commercial cloud services and those within academic organizations. One perspective on these contrasting

models is to question why a facility should consider using a commercial cloud when funding agencies and universities often provide computing and storage resources at no cost or heavily subsidized rates. Alternatively, this response could be interpreted as an acknowledgment that all the listed concerns are valid. Vendor lock-in has long been a concern of projects considering moving to the cloud.

An intriguing follow-up question for a future survey could involve a cost-benefit analysis—not merely focusing on the costs but also examining the additional services and capabilities that might justify the extra expense. For instance, do the benefits of using a cloud-hosted storage system or a higher-level managed service outweigh the additional costs, especially when compared to the resources required to configure and maintain an on-premises solution with in-house staff?

It is possible that substantial institutional overhead charges for the use of cloud services may influence decisions on whether to use the cloud.

Q10 - If commercial cloud providers were to make data egress free, would it increase your willingness to use commercial cloud for data storage?

Table 7: Responses for willingness to use commercial cloud for data storage if it were made free.

Definitely	11
Most probably	9
Maybe	11
Not at all	3

Table 7 shows the responses to Q10. With egress ranking high in the previous question regarding cost concerns, this is a very expected response distribution. It is worth noting that commercial cloud providers sometimes provide reduced egress costs, for example, based on spending a certain amount on storage and computing. However, these types of cost models are sometimes difficult to navigate and introduce uncertainty when facilities are trying to predict costs of longer time frames.

Q11 Which commercial cloud providers have you used?

Table 8: Commercial cloud providers used by the respondents

Amazon Web Services (AWS)	24
Google Cloud (GCP)	21
Microsoft Azure	11
Oracle	1
Others	4

The responses were as expected (Table 8). The top three cloud providers Amazon Web Services, Google Cloud Platform, and Microsoft Azure were the most used.

Q11 - Other, please specify

Two of the four "Other" responses used Google Drive, Box, Dropbox storage for collaboration. Other responses specified the use of Wasabi, Druva, and Digital Ocean. One respondent used the cloud only for prototypes and spin-off projects.

Q12 - Which academic providers have you used?

Table 9: Academic cloud providers used by the respondents

IU Jetstream2 (ACCESS)	10
Fabric	1
Chameleon	1
Self-hosted cloud (OpenStack for example)	7
OSG	4
Other ACCESS Resources	4
Other, please specify	11

The most used non-commercial cloud resources were IU Jetstream2, Self-hosted cloud, OSG, and Other ACCESS resources. Some users reported using Fabric and Chameleon, but there were too few responses for them to be statistically significant.

Q12 - Other, please specify - Text

“Other” responses specified a variety of resources: Open Storage Network, HPC Centers, Kubernetes, OSF.io, Globus, CyVerse, and TACC.

Q13 - Would you or somebody in your organization be interested in learning more about the Cloud Working Group?

The full question was: CI Compass has a Cloud Topical Working Group. This working group aims to understand the current practices for Cloud Infrastructure used by Major Facilities; research alternative solutions and keep up to date with emerging cloud technologies; and develop a general set of best practices that can inform the Major Facilities and how those can be adapted for specific facilities. Would you or somebody in your organization be interested in learning more about the Cloud Topical Working Group?

A majority (57%, 17/30) of the respondents indicated interest in participating in a potential group of cloud practitioners.

Q14 What would you like to gain from participation in the Cloud Working Group?

By participating in a cloud working group, respondents are looking to (ranked):

1. Share and learn from the community about their experiences with the cloud
2. Identify training needs
3. Work with Open Data
4. Shift towards a more “cloud-centric” approach

Q14 - Other, please specify - Text

In addition to the above options, people sought a way to bring down costs and build solutions for federally funded research and development centers. A separate response showed that there is some institutional pushback to a shift to the cloud.

Q15 - Please share any experiences related to the use of Clouds or on-premise infrastructure in your facility

The percentages and numbers presented in the analysis of this question were derived through a systematic analysis of the dataset. The survey included 20 valid responses (out of 36 total), which were analyzed to identify recurring themes related to experiences and

challenges in cloud adoption. Each response was categorized into one of four key challenge areas: ownership and long-term cost implications, financial barriers to full cloud adoption, long-term commitments and maintenance, and data locality and compliance issues. The analysis involved counting responses mentioning specific keywords and phrases associated with each theme and calculating percentages relative to the total valid responses. For instance, 10% of respondents highlighted ownership concerns, while 30% identified financial barriers as their primary challenge. These insights were further enriched with representative quotes from participants, offering qualitative context to the quantitative findings. This approach ensures that the data is both numerically precise and reflective of real-world experiences.

Ownership and Long-Term Cost Implications

Two respondents expressed concerns about losing ownership of infrastructure when transitioning to cloud services. They highlighted the financial impact of relying on operational budgets rather than capital expenditure for in-house infrastructure. One respondent shared:

“After construction funding runs out, we don’t own the infrastructure like we would for at least some physically purchased in-house infrastructure, therefore there are greater operational costs.”

Another emphasized the disparity in cost-effectiveness for specific use cases:

“It’s really not cost competitive with owned resources the way HEP uses them.”

These insights underscore the importance of evaluating the long-term financial trade-offs between cloud and on-premise solutions.

Financial Barriers to Full Cloud Adoption

Cost-related concerns emerged as the most significant challenge, with 30% of respondents identifying financial barriers as a primary hurdle. Organizations cited prohibitive costs for full cloud adoption and the difficulty in offsetting operational savings. Respondents noted:

“Cost is the only reason we are not fully in the cloud.”

“Costs are challenging. If you do not replace the need for people in IT Operations, thus lowering costs on the other side, cloud can be prohibitive.”

These quotes reflect the necessity of developing cost structures that align with an organization's financial capabilities and strategic goals.

Long-Term Commitments and Maintenance

Though only one respondent raised this issue, long-term contractual commitments and maintenance requirements were still a concern for some organizations. One participant explained:

"Concerns of long-term commitments and maintenance, and speed."

This feedback highlights the need for cloud providers to offer flexible contracts that adapt to the dynamic needs of their clients.

Data Locality and Compliance Issues

Data locality and compliance issues were identified by 10% of respondents as significant challenges. This includes the geographical location of data storage and its impact on compliance and performance. Respondents expressed concerns about governance and evolving vendor cost structures:

"Politics. On-premises NSF/DOE-funded data centers are fighting the cloud and undermining it by appearing to undercharge for on-prem computing."

"Vendors changing cost structure for data archival and data egress in the future. Ability to share data via cloud platform to other countries and remote geographical locations."

These observations highlight the growing importance of regulatory compliance and transparent cost structures in cloud adoption.

Q16 - Would you be willing to talk with us for a 30-45 minute interview regarding Cloud implementation at your institution?

Fifteen respondents agreed to be interviewed. The Cloud working group plans to set up the interviews in the coming months with these respondents.

References

- [1] G. B. Berriman *et al.*, “NSF Major Facilities Cloud Use Cases and Considerations.” Zenodo, Jan. 2024. doi: 10.5281/zenodo.10481410.