Strategic Recommendations for Cloud Computing

Executive Summary

More than ever, higher education institutions including Virginia Tech are charged with providing improved or new services to students, instructional and research faculty members, and administrators, together with a fixed, or possibly reduced, set of resources. Within this context, cloud computing offers significant advantages by allowing us to focus our resources on value-adding solutions and innovation, and frees us from the need to purchase, manage, and refresh infrastructures and platforms now generally available as commodities.

Our objective in recommending a cloud strategy is to provide a guiding framework for the division as we work to deliver services and solutions, making effective and intentional use of cloud-based technologies in support of the IT Strategic Plan.

Key Recommendations

1. Adopt an **opportunistic approach** in the use of cloud computing to meet both new and existing needs.
2. Establish **standards and best practices** applicable to cloud computing.
3. Deliver a **common platform** environment.
4. Act as a **partner and broker** in obtaining access to cloud resources for the university community.
5. Provide **resources to help support faculty** who choose cloud-based solutions for their work in research, instruction, and/or outreach.
6. Provide **resources and support for experiential learning** opportunities in cloud-based technologies for students.
7. Ensure that university IT professionals have the **skills and training** needed to promote effective and responsible use of cloud-based technologies.
8. Establish a **reasonable basis for comparing the cost** of delivering an application via cloud-based computing to the cost of delivering an application on local infrastructure.
9. Create **business procedures and internal controls** that promote sound financial stewardship of application delivery, whether cloud-based or utilizing local infrastructure.
10. Approach the question of **funding sources** on an application-by-application basis, consistent with the recommended opportunistic approach to cloud computing.

Preface

In the fall of 2019, Vice President for Information Technology and Chief Information Officer Scott Midkiff directed the formation of a working group to:

1. assess the use of cloud computing at Virginia Tech; and
2. make strategic recommendations to address the division's cloud computing approach to meet enterprise needs and support the use of cloud computing by faculty and students in direct pursuit of the university's mission in research, instruction, and outreach.

I was asked to serve as chair for this working group and to assemble a team of thought leaders and technical experts from the various units of the division to undertake this important work.

There is a tendency to think of cloud computing as just "someone else's computer;" i.e. to think of it as merely a means to define and utilize virtual infrastructure (compute servers, data storage, and networking) as an alternative to buying hardware for an onsite data center. While every cloud provider offers these most basic services, a cloud provider's technology platform provides many additional services at higher levels of abstraction -- capabilities that are readily available and easily adopted. When we think of cloud computing only in the same familiar terms we use to describe our local infrastructure, we miss the most important advantages of cloud computing.

Cloud computing provides a platform with component services that can be used to create applications in whole or in part without the need to consider the underlying infrastructure required to deliver those services. Using platform services to store and manipulate data frees us from myriad considerations around availability, reliability, durability, scalability, and many other dimensions of infrastructure architecture. All of these important characteristics are addressed by the provider, allowing us to focus our energies on directly applying and combining capabilities to create the solutions needed by our business stakeholders. Much of the innovation in the space of software-as-a-service is rooted in those advantages of cloud computing that both reduce development effort and expense, and dramatically reduce time to market for new solutions.

We in the Division of IT must approach cloud computing by thinking about how we can create solutions using all that the cloud platform provides, and how best to apply "cloud" to the problems we wish to solve.

It is with these thoughts in mind that we present these Strategic Recommendations for Cloud Computing on behalf of the Division of Information Technology.

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Cloud Strategy Working Group Chair
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Introduction

In several important ways, the university has already adopted cloud computing.

Many of the university's needs are met today using software-as-a-service. *Office365, Google G-Suite, Canvas, Zoom,* and *Kaltura* are prominent examples. University business processes are now supported by cloud-based applications such as *PageUp, Jaggaer (HokieMart)*, *Slate, Visual Compliance*, and many others. In response to phishing scams and related vulnerabilities, the division adopted *Duo,* which provides middleware-as-a-service in the form of two-factor authentication. As of 2020, the division is responsible for at least twenty different software-as-a-service enterprise integrations and has approved more than 500 use agreements for software-as-a-service applications in university departments. It is reasonable to expect additional growth in university demand as the market for applications in this space continues to expand into new business domains.

In 2016, the Summit research administration application was the first enterprise-class application developed by Virginia Tech to be deployed using a combination of platform-as-a-service and infrastructure-as-a-service in the public cloud. Since that time, applications developed and operated by units across the division are designed for cloud-based deployment using the services of public cloud providers such as Amazon Web Services and Microsoft Azure.

Cloud computing offers many advantages and benefits. Using the cloud, we can readily adapt to new or changing needs without the need for new infrastructure investments. We can create new applications by thoughtfully combining platform services, reducing development costs and dramatically reducing time to delivery. We can store vast amounts of data bounded only by the cost per unit of storage, without having to also solve complex problems in ensuring the availability and durability of our data. We can bring to bear almost limitless compute capacity, scaling up and down as needed to optimize costs.

With these benefits come new challenges and new risks. Software-as-a-service deployments have strained existing approaches to enterprise integration for requirements such as security, privacy, and data access. The use of platform-as-a-service and infrastructure-as-a-service on the public cloud has created unique challenges in managing costs and mitigating the associated financial risks, while also creating a demand for professional development to ensure that our people have the right knowledge, skills, and abilities to get the most out of cloud computing for the university.

The working group began by engaging with the community to hear first-hand accounts of experiences in cloud computing at Virginia Tech, and to develop an understanding of the opportunity for the division to play an important role in helping the university better use the public cloud for competitive advantage. We formed a subgroup that engaged directly with faculty to assess how cloud computing is used in the direct pursuit of the university's core mission. Additionally, we formed a subgroup to interview IT professionals in the division and in the departmental IT community who are charged with operating or supporting the technologies that support business processes integral to the success of our mission.

While Virginia Tech's adoption of cloud computing is already well underway, our findings suggest a number of opportunities for strategic approaches that build on our early successes to allow the university's use of cloud computing to flourish to its best advantage.

In assessing the current uses of cloud computing we find that

1. The question of how the university will pay for cloud computing remains front and center. We will need to work collectively with university finance experts and our peers in the Commonwealth to overcome the constraints of the traditional investment-based approach to providing information technology resources in a future dominated by cloud computing's utility model.
2. Business processes and internal controls are needed to effectively and responsibly operate in a utility computing environment; optimizing expenditures, mitigating risks, and promoting sound stewardship of university resources while not undermining the *Essential Characteristics* that make cloud computing advantageous.
3. More guidance is needed in choosing between the various *Service Models* offered by cloud computing. When we choose a *Service Model*, we should do so fully understanding the tradeoffs of our selected approach and its alternatives.
4. Faculty need better support and resources that will allow them to use cloud computing in ways that enhance the university's effectiveness in research, instruction, and outreach.
5. IT professionals need additional opportunities to gain knowledge and skills in cloud computing technologies, and better guidance in the form of standards and practices governing the use of cloud computing in the university enterprise context.

In the sections that follow, we will first lay some of the groundwork for our recommendations by providing a baseline definition of cloud computing, further describing some of the benefits of a strategic approach (including tie-ins to existing strategic plans), financial considerations, and our community assessment and findings. With those supporting materials as context, we will then present specific strategic recommendations.

Cloud Computing Baseline

Cloud computing is the storage, processing, and access of information via the internet from a third party who provides the necessary infrastructure, platform, and/or applications. Cloud computing, or simply *the cloud*, allows organizations and individuals to accomplish computing tasks without the need to build or manage the necessary infrastructure. The cloud provides virtualized computing and storage resources, as well as services built on these resources, in a pay-as-you-go utility business model.

The landscape of cloud computing includes many providers that attract customers using a combination of competitive pricing for essentially equivalent capabilities along with the provision of some differentiating technologies that exhibit advantages for certain kinds of computing activities. The most prominent cloud providers today include Amazon, Google, and Microsoft, as well as more specialized providers such as Oracle and IBM.

The U.S. National Institute of Standards and Technology (NIST) provides (in Special Publication 800-145) a useful definition of cloud computing in terms of the following characteristics and models.

- ***Essential Characteristics***: On Demand Self-Service, Broad Network Access, Resource Pooling, Rapid Elasticity, Measured Service
- ***Service Models***: Software as a service (SaaS), Platform as a service (PaaS) Infrastructure as a service (IaaS)
- ***Deployment Models***: Private, Community, Public, and Hybrid

In this document, we utilize the NIST definitions of these terms and concepts. When referring to one of these terms, we style it with emphasis and capitalization (e.g. *Service Models)* as needed to unambiguously refer to these definitions.

Benefits of a Cloud Strategy

The business and technical benefits of adopting a cloud computing strategy include, but are not limited to:

- Faster time-to-delivery of solutions and services, resulting in
    - increased business performance; and
    - for IT providers, streamlined processes, simplified IT maintenance, cost savings, enhanced agility, and increased delivery capacity
- Higher availability of services
- Service scalability
- Greater business flexibility and access to a variety of inexpensive applications
- Savings on equipment (CapEx) expenditures, but with new operating costs
- Clear accounting for costs associated with a service
- Innovation enablement

Cloud Services and the Strategic and Operational Plans

Cloud services provide a key foundational component supporting all five focus areas (pillars) and all six process improvement transformational imperatives identified in the IT Strategic Plan.

The IT Operational Plan 2019 - 2021 identifies the initiatives undertaken during this period in support of the strategic plan. One or several projects may comprise an initiative.

The Strategic Goal to Project Map identifies the initiatives and projects in the operational plan and their alignment to the goals in the strategic plan. Many of the projects in the IT Operational Plan have cloud services activities and deliverables.

Financial Considerations

Traditionally, the division has pursued a strategy that makes technology investments to build out data center infrastructure and then exploits that infrastructure over a wide range of different business domains for the full lifetime of those investments. Cloud computing offers a radically different approach, in which we create virtual instances of the resources required to support a particular business need and pay for the resources used on a subscription basis, similar to other utility services such as electricity. This consumption-based utility model provides superior flexibility for meeting

needs, but comes with new challenges in identifying appropriate sources of funds, and a need for new procedures and controls to ensure that we remain good stewards of university resources.

Traditional Funding of IT Infrastructure

A significant funding source for technology investments made by the division is the Higher Education Equipment Trust Fund (HEETF). Established in 1986 by the General Assembly, HEETF was designed to provide supplemental funding to upgrade equipment needed for instruction and research. While the original focus was on upgrading existing general equipment, today the HEETF is a major source of funds for information technology purchases by Virginia higher education institutions. HEETF monies are backed by revenue bonds, whose terms are matched to the useful life of the equipment purchased, maximizing the leveraging effect of debt financing. Bonds for information technology purchases use either a three- or seven-year maturity period, after which an asset purchased with such funds may be dispatched as surplus property.

Changing the Traditional Model

The use of debt financing effectively implies that HEETF monies must be used only to fund the purchase of tangible assets; subscription services such as cloud computing are not eligible for HEETF funds. Therefore, a significant challenge for higher education institutions in Virginia who wish to exploit the benefits of cloud computing is identifying appropriate sources of funding to augment HEETF. Solutions to this challenge at Virginia Tech will require a cooperative approach between division and university finance experts. Creative solutions for the Commonwealth might be developed using a collaborative approach with our peer institutions, but this process will take significant time and effort. Our approach to cloud computing must strike a balance between making the right technology choices to meet each business need while making the best use of available funding sources as we work towards a finance solution better suited to a future that is dominated by cloud computing.

Adopting a Utility Model

Cloud computing provides unparalleled flexibility and the opportunity for an organization to be very nimble in meeting new or changing requirements. The utility model provides the ability to immediately take advantage of a vast array of different technologies by simply selecting the desired capabilities from a menu without the need to create or manage all of the necessary infrastructure required to reliably deliver those capabilities at scale. Because cloud computing requires little to no upfront investment, we can easily adapt as needs change with no significant penalties for failing to anticipate how needs might change in the future.

Each capability used has an applicable set of billable charges, and generally the only limits we encounter are those related to our willingness and ability to pay the associated bill. With this power and flexibility comes an obligation for us to be diligent in ensuring that we are deriving the expected value from what we spend. Billable expenses accrue without regard for whether the provider's resources are being used effectively in delivering the outcomes expected by our business stakeholders. The menu provides a vast array of choices and there are many different combinations that can satisfy almost any desired outcome. The onus is on us to determine which of many technology alternatives will most cost-effectively deliver the result we require given the constraints of our processes and our people.

Comparing Costs

Often when we consider a cloud-based solution to a given business need, we wish to compare it to the alternative of a solution based on local infrastructure. The actual costs payable to the cloud provider for any proposed solution are readily quantifiable. Reasonable budgetary estimates can be produced using either the provider's own tools for this purpose or any of several available from third-party vendors.

Unfortunately, we do not have an existing basis for comparing the projected costs for a cloud-based solution to an alternative solution delivered on our own infrastructure. It is relatively easy to quantify the total costs of creating a system of infrastructure to meet an assortment of needs, but we must go further in order to have a basis for understanding the marginal cost of delivering a given application on that infrastructure.

The problem of apportioning costs for shared infrastructure is complex, but not intractable. Cost allocation for technology infrastructure is a common element of models such as Total Cost of Ownership (TCO) and Total Cost of Consumption (TCC). As such, there are generally accepted practices that can be employed for the necessary calculations. Indeed, these practices go to the very core of a cloud provider's business model.

Too often, in pursuing the creation of such a model, we have distracted ourselves by focusing not on providing a useful partial model that solves a small set of cost comparison problems, but by attempting to create a "total" solution that would allow us to understand the cost of any service we might deliver using our technology, people, and processes. As we undertake to exploit the benefits of cloud computing, we must seek to create and refine a model that we can agree is accurate enough for the purpose of relative cost comparison. Our objective should be to create a model that can deliver value in the form of useful results despite its imperfections. With the benefit of experience, and by exploiting the data produced by the use of our model over time, we can iteratively refine and improve it.

Business Processes and Controls

When we deliver an application using any cloud computing *Service Model*, we periodically receive a bill for services rendered from the provider. Especially in the case of platform-as-a-service and infrastructure-as-a-service models, the payable charges vary according to the combination of services utilized and the quantity of service units consumed. We are generally liable for the billable charges incurred as a result of our use of the provider's services regardless of whether we derive any business benefit from the services consumed.

The flexibility to make use of any of the provider's offered services whenever we choose to do so implies that there are unique financial risks associated with cloud computing. Historically, our technical managers would consider cost only at those points in time when new infrastructure investments were needed, either in the form of upgrades or new technologies. The period between new investments would typically be several years. In the utility model, small changes in the technical implementation can have significant impact (either positive or negative) on expenditures and are immediately realized. This can be seen as a benefit -- technical managers are now positioned to play a significant role in cost optimization -- but it also creates new risks.

Mitigating these new risks will require effective business processes and internal controls. Controls should establish budgetary expectations for expenditures for each application and track actual expenditures against those expectations. Technical managers must continuously monitor the relationship between the configuration of an application and resulting cost. Oversight and approval processes are essential for configuration changes that significantly impact expenditures.

Reporting that supports such controls will not only serve to help mitigate financial risks -- it will also provide useful data for a variety of analytic purposes that seek to improve our effectiveness in using cloud computing. Using such reporting we can look across the units of the division, relating actual expenses to architectures and approaches with the goal of optimizing the way we approach the delivery of different classes of applications and arriving at a common understanding of best practices. We can also use such reporting to improve our ability to estimate the anticipated costs associated with cloud computing for both existing and future needs.

Community Assessment and Findings

In developing these recommendations we first engaged in an informal assessment process by interviewing faculty using the cloud for academic pursuits, as well as IT professionals supporting the delivery of enterprise applications and services at the university.

Our objective was to

- ensure alignment and relevance of our recommendations to the current set of experiences in cloud computing at Virginia Tech,
- develop a general typology of applications and user personas, and
- use the feedback gained from this process as an input in identifying opportunities for improvements bringing competitive advantage to the university.

In this context we use the term *academic* to mean activities that are in direct pursuit of the university's core mission in research, instruction, and outreach. We use the term *enterprise* to distinguish those activities that support the core mission by underpinning business processes necessary to the administration of the university, whether performed centrally by the division or by IT departments within the university.

Academic Cloud Computing

Our assessment team selected faculty members who made requests for cloud computing services or consultation through the IT service catalog. We set up informal interviews with those faculty members to ask about their experiences with cloud computing in the context of the university's research, teaching and learning, and outreach missions. Those we interviewed often identified other faculty members who also had cloud computing interests. We contacted those faculty and requested the opportunity to discuss their experiences as well. The assessment team analyzed the statements and opinions of those interviewed and developed this synopsis of findings.

- **Broad adoption of university-brokered software-as-a-service solutions**, addressing needs in instruction, research, outreach, and administration. Commonly cited examples included G Suite for Education, Microsoft Office365, Canvas, and Zoom.

- **A desire to provide students experiential learning opportunities enabled by cloud computing** such as machine learning, artificial intelligence, and big data analytics.
- **A need for ready-to-use cloud computing resources at the institutional level** so faculty can spend less time finding, setting up, and learning to use appropriate cloud services.
- **A need for cost-effective data management solutions** for short- and long-term storage of research data, addressing data storage, access, backup, and archiving, and enabling simplified collaboration with external partners.
- **A call for more resources to help faculty effectively use cloud computing**:
    - Professional development opportunities in cloud computing technologies
    - Consultation services in cloud-based data management and security
    - Quality documentation and tutorials to facilitate their learning of cloud tools
    - A cloud user community for sharing and exchange of ideas and information
- **Frustration with procurement and approval processes for cloud computing** resulting in a strong desire for streamlined processes allowing faculty to realize the *Essential Characteristics* of cloud computing and to accelerate the pace of innovation.
- **A need to raise awareness of the potential of cloud computing as a key resource** in achieving the university's mission, by:
    - articulating the benefits and challenges in terms that resonate with faculty
    - identifying available resources of support and services

The full details of the process and approach used by our team that assessed academic use of cloud computing is available in the supplemental *Academic Cloud Strategy Discovery Process* document.

Enterprise Cloud Computing

Our assessment team interviewed technical managers in the division and in the broader campus IT community to ask about their experiences with cloud computing in the context of enterprise applications and services. From our analysis of the statements and opinions of those interviewed, we identified these challenges to cloud adoption.

- **Inconsistencies between *Service Model* selection and application deliverables**, leading to inefficiencies and resource gaps in managing applications deployed on the cloud.
- **A diverse range of application architectures, languages, packaging, and resource dependencies**, resulting from a lack of division-wide standards and practices. Among other detriments, this leads to widely different incurred costs among applications that are otherwise similar in scale, complexity, and expected outcomes.
- **Processes for procuring cloud services and gaining access to already-procured public cloud resources create impediments and delays**, diminishing the advantages of *Essential Characteristics* such as *On-Demand Self-Service* and *Rapid Elasticity*.
- **Lack of a sustainable financial model** to support an increasing demand for cloud expenditures and a decreased dependence on local infrastructure investments.
- **Absence of centrally managed controls and oversight** for university information assets in the cloud.
- **Inability to determine the true cost associated with local-infrastructure-based computing solutions** at the level of detail necessary to allow objective comparison to cloud-based alternatives.

A recurring theme articulated by many of those interviewed were calls for clear guidance in cloud-specific knowledge areas.

- Selecting *Service Models* and *Deployment Models* for a given computing need
- Creating architectures appropriate to make efficient use of cloud resources
- Estimating and budgeting for cloud expenditures

Additionally, many identified the need for university standards and practices regarding security, auditing, cost accounting, monitoring, and ongoing development and operations, irrespective of whether the computing infrastructure is local or cloud-based.

Specific Recommendations

Informed by the findings of our assessment and analysis, we make the following strategic recommendations.

1. **Adopt an opportunistic approach in the use of cloud computing to meet both new and existing needs.**
   - **1.1.** Choose software-as-a-service when it can meet business stakeholder needs without sacrificing enterprise integration concerns.
   - **1.2.** Use cloud-based approaches for new applications with an emphasis on the use of platform-as-a-service to make the most cost-effective use of a provider's capabilities.
   - **1.3.** Choose software platforms in which license agreements support cloud deployments to afford future flexibility even when the immediate decision is to run on local infrastructure.
   - **1.4.** Take advantage of application software and/or hardware upgrade cycles to assess whether a given need could now be met more cost-effectively in the cloud.
   - **1.5.** Continue to provide support for on-premises computing serving specialized needs unique to our circumstances and context as a major research university.
   - **1.6.** Eschew the "lift and shift" anti-pattern, in which existing technology solutions are moved from local infrastructure to cloud-based infrastructure with little or no consideration of how to best meet the business needs using cloud computing technology.

2. **Establish standards and best practices applicable to cloud computing**
   - **2.1.** Addressing enterprise technology solutions in the context of cloud computing, with the aim of ensuring that our enterprise technology choices make appropriate, intentional, and effective use of cloud resources
   - **2.2.** Addressing the selection and procurement of software-as-a-service solutions with the aim of ensuring that requirements for enterprise integration, security, compliance, privacy, and other aspects of risk management are met by these solutions.

3. **Deliver a common platform environment** on a public cloud
   - **3.1.** That includes a standard configuration of controls and integration necessary to meet enterprise needs for security, privacy, operational support
   - **3.2.** With the ability to distinguish and apportion costs for each application

3.3. With an appropriate level of isolation and independence between applications managed by different teams

3.4. Suitable for supporting centrally managed applications as well addressing similar computing and storage needs in university departments

4. **Act as a partner and broker for obtaining access to cloud resources for the university community**, helping to resolve impediments and provide access in a timely manner.

5. **Provide resources to help support faculty who choose cloud-based solutions for their work in research, instruction, and/or outreach.**
   - **5.1.** Offer broad choices for cloud technology providers and technologies, limiting only where necessary to conform with applicable university policy, and/or state or federal regulations.
   - **5.2.** Ensure prioritization of administrative and technical support services for centrally provided resources identified as having the highest usage and/or highest need for additional support, in a manner consistent with faculty choices expressed through surveys, focus groups, and other assessment methodologies.
   - **5.3.** Provide cloud access accounts with major cloud providers for use by faculty that provide basic security protections consistent with university policy, standards, and best practices.
   - **5.4.** Construct cloud-based environments configured (to the extent possible) to comply with the specific requirements of a sponsoring authority, as appropriate.
   - **5.5.** Create professional development opportunities and additional resources such as onboarding support, tutorials, and documentation that faculty may use to gain skills and expertise in cloud-based technologies for specific research domains.
   - **5.6.** Establish processes and supporting services for timely access to public cloud resources for faculty and those who support them.
   - **5.7.** Provide mechanisms to help faculty and departmental administrative support personnel manage costs and cash flows associated with use of the cloud.
     - Provide and/or support tools to help faculty predict anticipated costs of a cloud-based solution.
     - Deliver reports of actual costs.
     - Issue alerts when costs reach certain predefined thresholds.
   - **5.8.** Provide some basic level of cloud computing and storage resources to any faculty member upon request.

6. **Provide resources and support for experiential learning opportunities in cloud-based technologies for students**, both for both coursework and self-exploration, helping to prepare students for life after graduation**.**
   - **6.1.** Explore mechanisms to pursue/manage/promote provider-offered credits for student use of cloud resources.
   - **6.2.** Establish a pool of funds and other resources to be used for constructing learning environments for student coursework
   - **6.3.** Create opportunities for graduate and undergraduate internship in cloud computing roles within the division

7. **Ensure that university IT professionals have the skills and training needed to promote effective and responsible use of cloud-based technologies.**
   - **7.1.** Identify the knowledge, skills, and experience in cloud technologies that candidates for employment in the division should possess and include these criteria in position descriptions and preferred qualifications for the appropriate positions.
   - **7.2.** Identify the organizational structure that supports a growing dependence on cloud-based technologies and a diminishing emphasis on local infrastructure, realigning positions and units as necessary to reflect these shifts in the technology landscape.
     - Create transition plans for employees that move from legacy technology support roles into roles that support cloud computing, with an emphasis on making the best use of existing skill sets to minimize the amount of "re-skilling" required for employee success.
     - Identify gaps and propose realignments or reallocations of existing (vacant) positions to add staff where needed skills are not available in existing resources.
   - **7.3.** Prepare professional development and performance plans within the division so that each employee having a technical role in deploying or maintaining cloud-based technologies will develop and possess the required skills and knowledge.
   - **7.4.** Extend professional development opportunities in cloud-based technology use and support to the broader departmental IT community.

8. **Establish a reasonable basis for comparing the cost of delivering an application via cloud-based computing to the cost of delivering an application on local infrastructure.**
   - **8.1.** Develop and execute a plan to apply generally accepted cost-accounting practices in the apportionment of fixed and variable overhead expenses to applications delivered via data center infrastructure.
   - **8.2.** Develop a cost model for shared computing and storage infrastructure, based on standard IT industry practices.

9. **Create business procedures and internal controls that promote sound financial stewardship of application delivery, whether cloud-based or utilizing local infrastructure.**
   - **9.1.** Establish standard operating procedures that specify budgeting requirements for applications to be delivered by units of the division.
     - A standardized budget should be prepared for any new application, as well as for upgrades or improvements to existing applications requiring additional funds in excess of projected maintenance costs.
     - Budgets should be required for both cloud-based approaches (delivered via any *Service Model*) and delivery via local infrastructure (if appropriate).
     - Budgets for cloud-based applications should make use of vendor-provided tools to estimate charges for any provider services utilized by the application.
     - Budgets for applications using local infrastructure should include standard apportionment of data center overhead, estimated compute and storage costs (based on the model developed for this purpose), as well as any applicable network costs (payable to the telecommunications auxiliary).
   - **9.2.** Establish appropriate internal controls to periodically monitor the spend for each cloud-based application, with the goal of ensuring that assessed charges are appropriate and

within the bounds of the associated budget, and to trigger management review in the case of unexpected charges or significant variance from budget. Reporting used to support these controls could also provide data to improve our cost estimation capabilities.

10. Approach the question of funding sources on an application-by-application basis, consistent with the recommended opportunistic approach to cloud computing.

10.1. In choosing between a cloud-based technology solution and a solution based on local infrastructure, the decision should be based primarily on what will best meet all requirements of our business stakeholders and the division. The source of funds needed must be considered, but should neither dominate the analysis nor dictate the decision.

10.2. Collaborate with university finance experts and business stakeholders to communicate our overall strategy and approach to cloud-based computing, and to secure funding sources to support each application, whether delivered in the cloud or using local infrastructure.

10.3. Collaborate with our Virginia-based peer institutions to develop shared strategies that address funding requirements for cloud-based computing as an alternative to technology infrastructure investments funded via HEETF.