The Future of Markets is the Cloud

CS349F: Technology for Financial Systems
October 12, 2020

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TECHNOLOGY TRENDS SHAPING FINANCIAL SERVICES
Innovations Advancing The Landscape

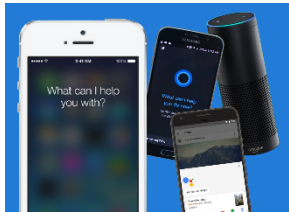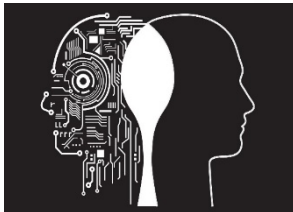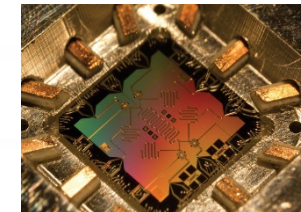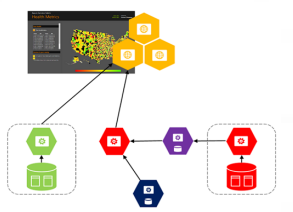|			
CLOUD SERVICES	**STREAMING / DATA LAKES**	**BLOCKCHAIN**	**INTERNET OF THINGS**
INTELLIGENT / PERSONAL VIRTUAL ASSISTANT	**AI / MACHINE LEARNING**	**CRYPTOGRAPHY**	**QUANTUM COMPUTING**
EDGE / FOG COMPUTING	**APIs / MICROSERVICES**	**AUGMENTED REALITY / VIRTUAL REALITY**	**DIGITAL MONEY**

Agenda

- Born of Innovation
- Nasdaq's Cloud Vision
- Why Cloud
- COVID-19 has accelerated trends
- The challenges & opportunities
- The road ahead

A Brief History of Nasdaq

1971

1980   1985   1986   2000   2001   2004   2008   2012

We transformed the financial markets with the introduction of the world's first electronic stock market. Today, there are 4,000+ company listings on our exchange.

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Nasdaq's Cloud Vision

Multi-Cloud architecture and deployment. All new initiatives and major reinvestments will leverage a multi cloud approach, built natively for cloud, utilizing the Nasdaq Financial Framework.

Every exchange system, for the most part, is on-premise, sits in a data center, and becomes a very bespoke offering by each exchange. And then you have an ecosystem that sits within the data center as well. If you lift that into the cloud, then you have an opportunity to look at it on a more broad basis in terms of it being a platform for transactions that occur across the world.
*- Adena Friedman – President and CEO, Nasdaq*

"The time has come to concentrate on building the critical market infrastructure in the cloud." -- Brad Peterson and Lars Ottersgård,Nasdaq

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Key Benefits

Convert CapEx to OpEx	Scalability and Elasticity	Increase Speed and Agility	Customer Focus	Innovation Acceleration
• No more guessing • Pay only when you consume • No planning for "peak" system loads	• Capacity can be scaled up or down based on need • Global Footprint	• Compute resources can be provisioned much faster • Faster release cycle & reduced time to market • Our SaaS solution will enable faster delivery to external customers	• Stay ahead of client buying preferences • Focus on work that differentiate business functions, not the infrastructure. • Expansion into non-financial Markets	• Take advantage of new innovations in the cloud (AI, ML, security, resiliency etc.) • Facilitates faster innovation loops and progress • Our customers expect our leadership in the technology adoption.

Moving Financial Trading to the Cloud: Opportunities

Legend:
- Business Capabilities
- On-Prem Services
- Cloud Services
- Data Lake
- AI / ML
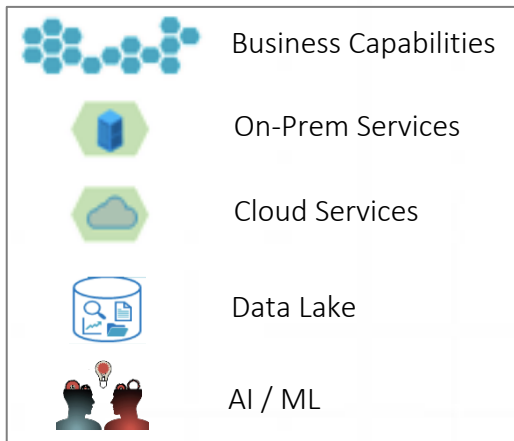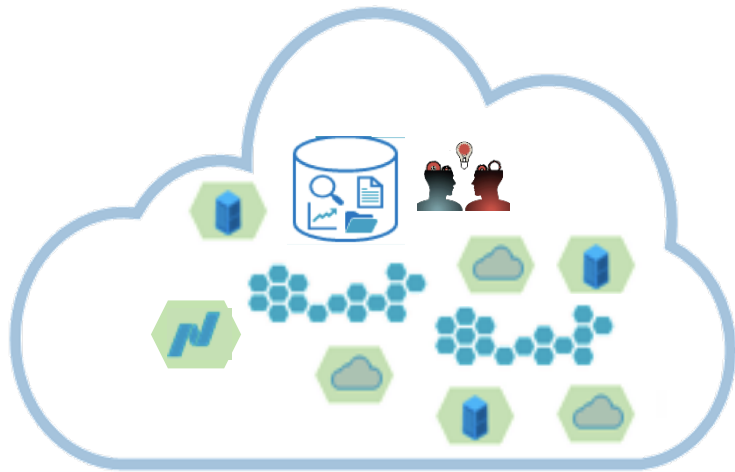
Transform the way in which products and services are developed and delivered

Derive insights using advanced analytics and AI/ML

Unlock the ability to leverage Nasdaq technology outside of the traditional customer base

Transform the way participants interact with data using modern APIs

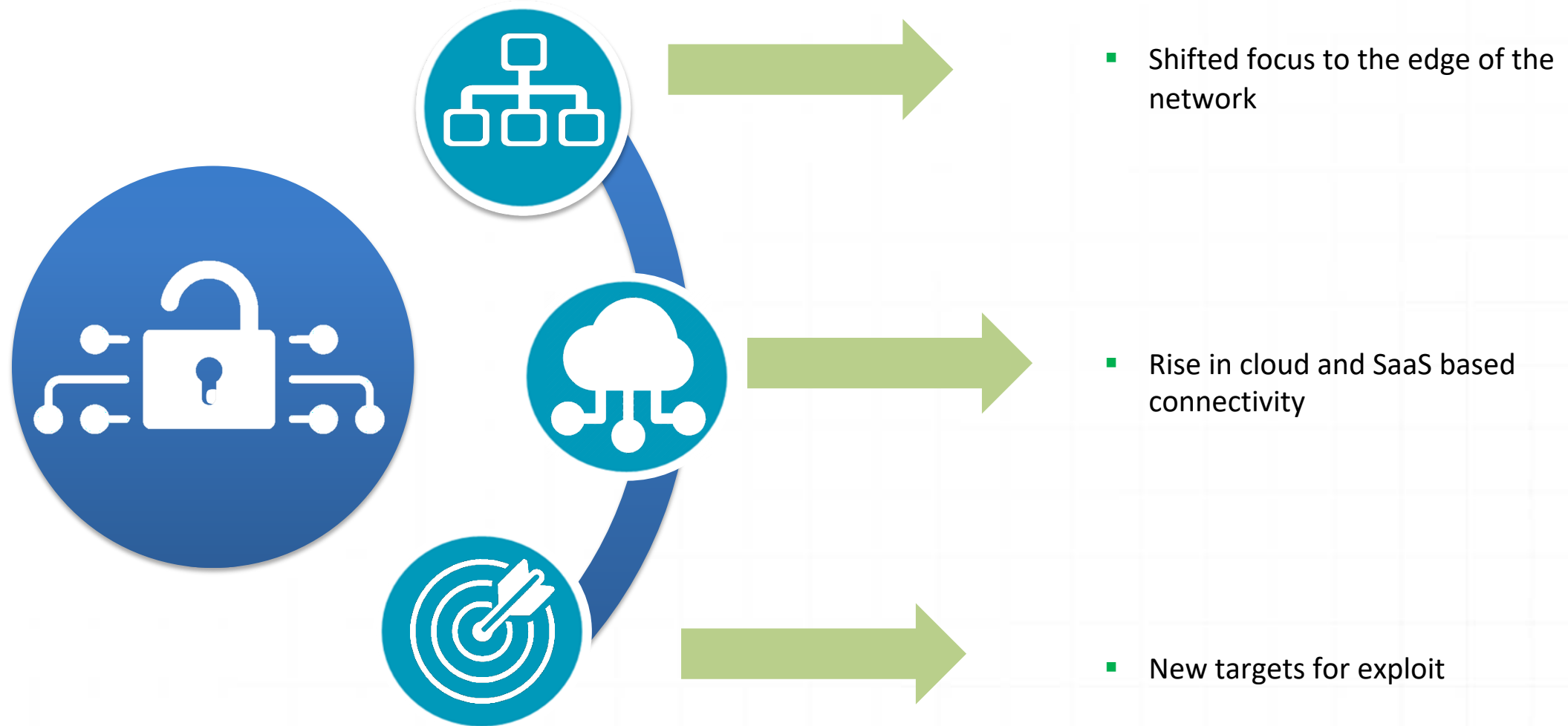Unfettered access to markets and data with PaaS and SaaS offerings at scale

Greater flexibility via on-demand infrastructure and decreased time to market

Provide a rich portfolio of mission critical business applications

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Accelerating Distributed Networks

- Shifted focus to the edge of the network

- Rise in cloud and SaaS based connectivity

- New targets for exploit

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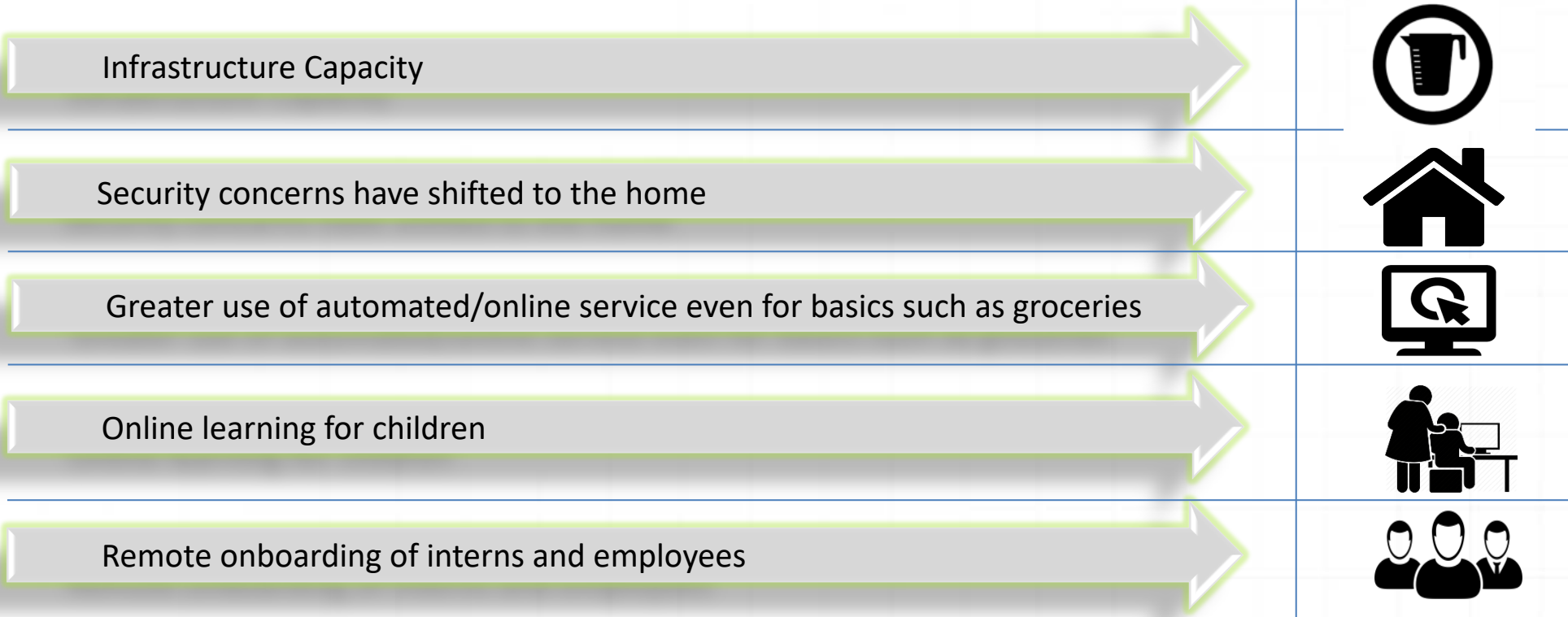
The Shift to Working From Home

The shift to WFH required a change in strategy of investments that were planned for major business campuses to residential/suburban regions:

Infrastructure Capacity

Security concerns have shifted to the home

Greater use of automated/online service even for basics such as groceries

Online learning for children

Remote onboarding of interns and employees

COVID, Cloud and Financial Services

Market volatility is something we plan in our daily cadence. We are continually testing our systems for resiliency and performance almost every weekend to ensure everything is ready as market opens on Monday. It's a process that we've memorialized into everything we do.

Our contribution comes from ensuring that our market participants can have the confidence that regardless of the external factors, we've put in place very strong practices and policies to ensure that our technology will work as it's supposed to.

Our environment has a mix of environment, on premise, private cloud, public cloud. The benefit we've seen just as many others in the industry is the ability to have public and private cloud flexibility without having staff go into the datacenters to install hardware.

Collaboration across geographies and with our customers has been aided by the use of various technologies such as Team and Zoom. It highlights the importance of these services also having the capacity to scale as more than 80% of the workforce globally moved to WFH and still stay connected.

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Shared Resources

01 Determinism

02 Latency

03 Throughput

04 Fairness

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All About Time…

Using Time to Address challenges

High Resolution Time

- ❑ Distributed Clocks providing ability to synchronize nodes in cloud based deployment
- ❑ Inter and Intra Datacenter support
- ❑ Synchronization within single digit nanoseconds

Use Time to ascertain fair access

- ❑ In public cloud, use Time as a means to guarantee fairness, transparency and compliance
- ❑ Access to Order Ports and/or Matching Engine and Market Data

Minimize Jitter in the system

- ❑ Guarantee ordered processing of transactions based on entry time
- ❑ Deliver a platform which provides deterministic behavior

Addressing Technical Challenges: Performance and Determinism
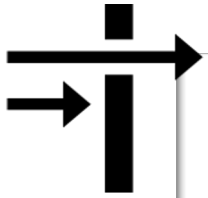
Kernel By-pass Solutions

- ❑ Access to low-level controls on Network Cards
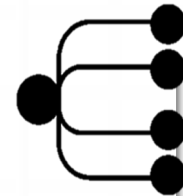- ❑ Accelerated Path to Applications

Performance Optimized Node

- ❑ Interrupt Steering
- ❑ Workload Isolation
- ❑ Bare-metal Instances
- ❑ Processor Selection

Workload Placement

- ❑ Isolate nodes when latency sensitive workloads are running
- ❑ Co-locate customer workloads in proximity
- ❑ Methods to minimize workload sprawl

Multicast Support in Public Cloud

- ❑ Support scale-out deployments
- ❑ Latency sensitive

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Moving Financial Trading to the Cloud: Non-Technical Challenges

❑ **Governance/Compliance**
- Increased effort for IT to provide governance, risks and data quality management requires.
- Compliance with industry standards. (regSCI, auditability).

❑ **Security**
- Confidentiality of user data can still be at stake due to the various types of attacks (man-in-the-middle, shoulder surfing, phishing, and insider attacks).

❑ **Cost management and Containment**
- Possibility of drawing unexpected cloud costs as a result of spinning up multiple cloud environments.
- Difficult to define and forecast quantities and costs.

❑ **Education**
- As cloud computing remains a fairly new concept, it's often difficult for stakeholders to understand the benefits, challenges or functionality of cloud computing.
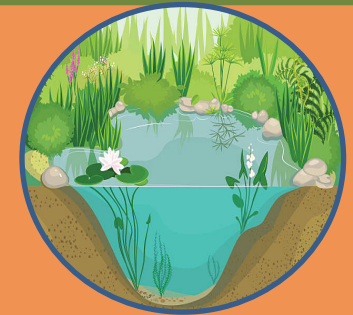
❑ **Ecosystem**
- Changes to co-location business/ revenue model as a result of migrating our markets to cloud.

Addressing Non-Technical Challenges

❑ **Governance/Compliance**

- Build a well-understood compliance framework.

❑ **Security**

- Have a comprehensive security posture incorporating the shared responsibility model with continuous governance and compliance checks.

❑ **Cost management and Containment**

- Predictive analysis of projected costs. Holistic view of resource demands and granular financial reporting.

❑ **Education**

- Comprehensive stakeholder engagement and education program such as CCOE.
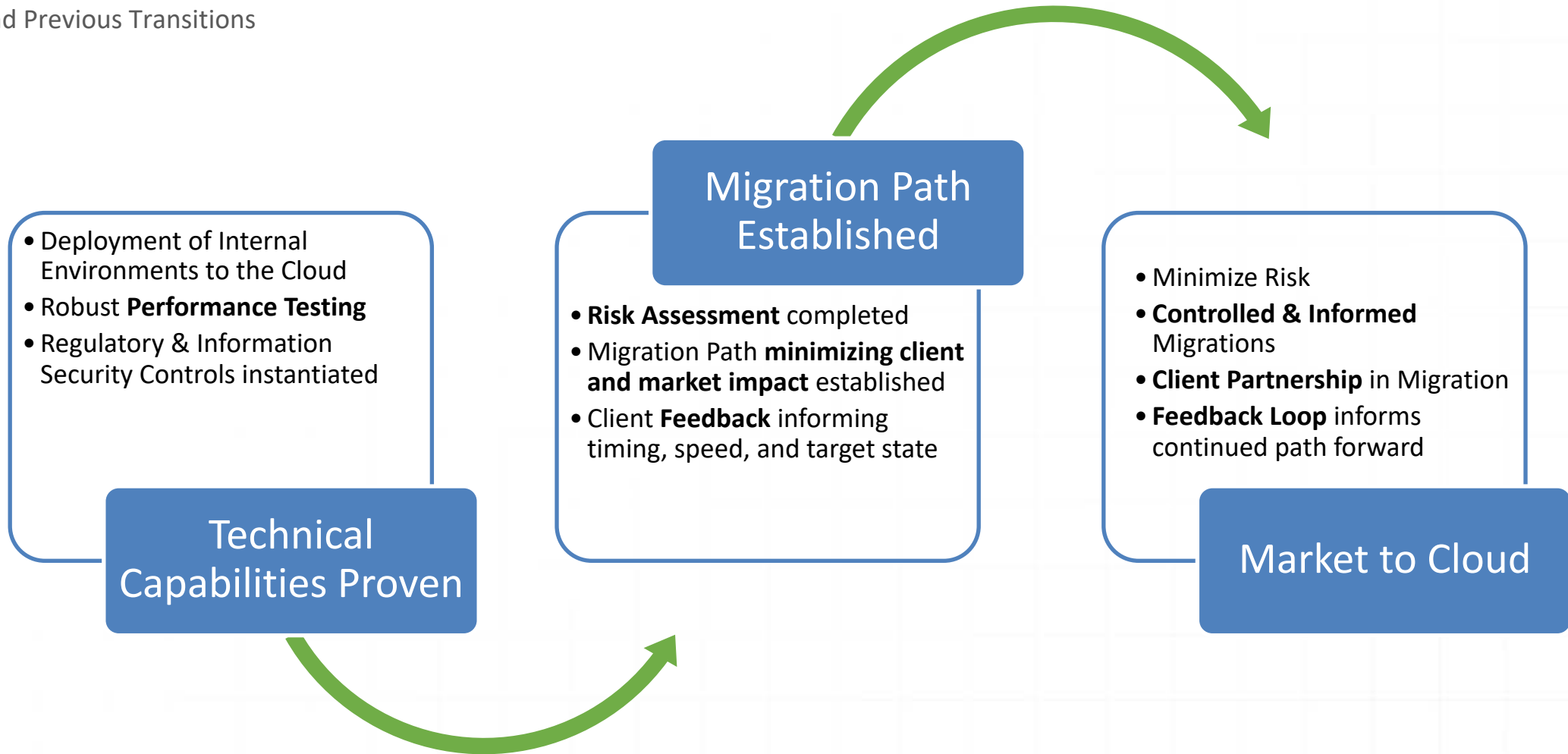
❑ **Ecosystem**

- Well-understood migration plan with continuous customer engagement.

Transitioning to the Cloud

Establishing a Migration Plan to Mitigate Risk and Client Impact

Timelines and Progression are informed by Clients, Cloud Capabilities, and Previous Transitions

- Deployment of Internal Environments to the Cloud
- Robust **Performance Testing**
- Regulatory & Information Security Controls instantiated

Technical Capabilities Proven

Migration Path Established

- **Risk Assessment** completed
- Migration Path **minimizing client and market impact** established
- Client **Feedback** informing timing, speed, and target state

- Minimize Risk
- **Controlled & Informed** Migrations
- **Client Partnership** in Migration
- **Feedback Loop** informs continued path forward

Market to Cloud

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Thank You

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