

Singapore Government Cloud Journey and Experience

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GOVTECH
SINGAPORE



Purpose of Presentation



To share cloud migration journey and experience gained from large scale migration of Singapore government systems from on-premise to public cloud over the last 4 years



We Were In “Isolated Living” For Too Long – Moving to Modern Cloud World Was Scary At That Time...

Before 2019, Majority of the applications were running in government data centres with only websites running on the public cloud. Limited experience with cloud at that time.



Singapore Government Public Cloud Journey

Panel for public cloud service providers

2010 to Nov 2017

"Commercial Cloud First"
Policy for Restricted &
below systems

2018

Gcloud Systems
Migrated to Cloud

Dec 2019

Digital Government
Blueprint (DGB) Cloud
KPI - 70% Restricted &
Below Govt Systems in
Cloud by
Dec 2023

2016

Content Website Platform



2019

Launch of Government
on Commercial Cloud



2021

"Commercial Cloud
First" Policy for cloud
eligible confidential
systems

Overall Cloud Migration Approach

Cloud Strategy

- 1  "Commercial Cloud First" Policy
- 2  Right Classification of Systems
- 3  Multiple Cloud Service Providers
- 4  Established Cloud Security Policy













Government on Commercial Cloud (GCC) Platform

5

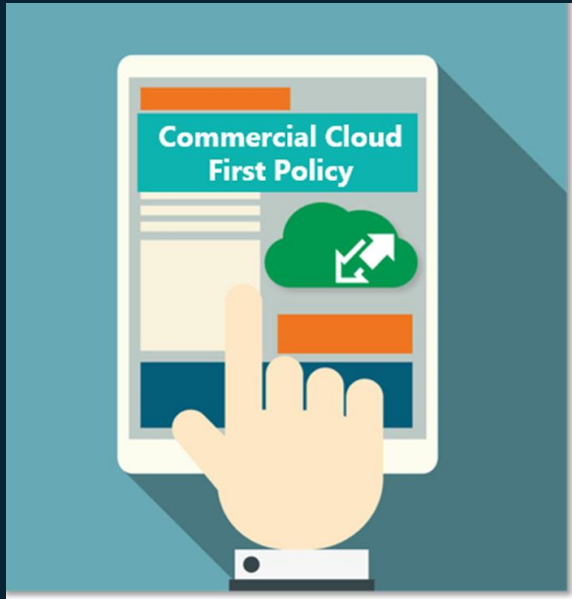
Build Cloud Expertise

- 6  Established Central Cloud Adoption Team
- 7  Established Close Collaboration with CSPs
- 8  Built Cloud Competency in "Bite Size"
- 9  Shared Knowledge through Cloud Playbook

Agency Workload Migration

 Cloud Adoption Planning	 Establish "Fly Way" for Migration	 Get Ready for Cloud Operations	 Continuous Optimization
 Cloud Adoption Planning Guidelines Published 10	 Engage Agencies to Guide Them Through Different Stages 13	 Plan Your Cloud Operating Model Early 16	 Develop Situational Awareness on Cloud Cost 19
 Maximise the Cloud Benefits 11	 Standardise Your Tech Stack & Cloud Practices 14	 Practise Day 2 Operations 17	 Establish A Proactive Culture Around Cloud Cost Optimization 20
 Chose Migration Options Based on Workload Analysis 12	 Automate to Migrate@Scale with Speed 15	 Develop Situational Awareness on Cloud Security 18	 Measure & Track Cloud Adoption Maturity 21

1 “Commercial Cloud First” Policy Effective from 2019



- Adopt a Cloud First Policy for all new ICT systems that are:
 - Classified Restricted (R), Official Closed (OC) and Official Open (OO)
 - Restricted data are to be geo-fenced to Singapore
 - Restricted systems to use in-country commercial cloud with access to white-listed overseas cloud services
- Agencies asked to plan for cloud migration of all existing eligible systems by 2023
- Central directives on Overall cloud adoption targets and schedule helped to drive adoption pace
- Expanded the policy to include cloud eligible confidential systems as we gained the experience in the cloud

2 Right Classification of Systems



- Agencies tend to over-classify their systems. Guidelines provided to agencies on how to right classify the systems
- Data protection/privacy of individuals and businesses addressed through adoption of commercial best practices
- Agencies reviewed and right-classified systems to enable commercial cloud adoption
- Separated data protection/privacy considerations from classification considerations
- Introduced information sensitivity markers to facilitate right-classification

3 Multiple Cloud Service Providers (CSP)

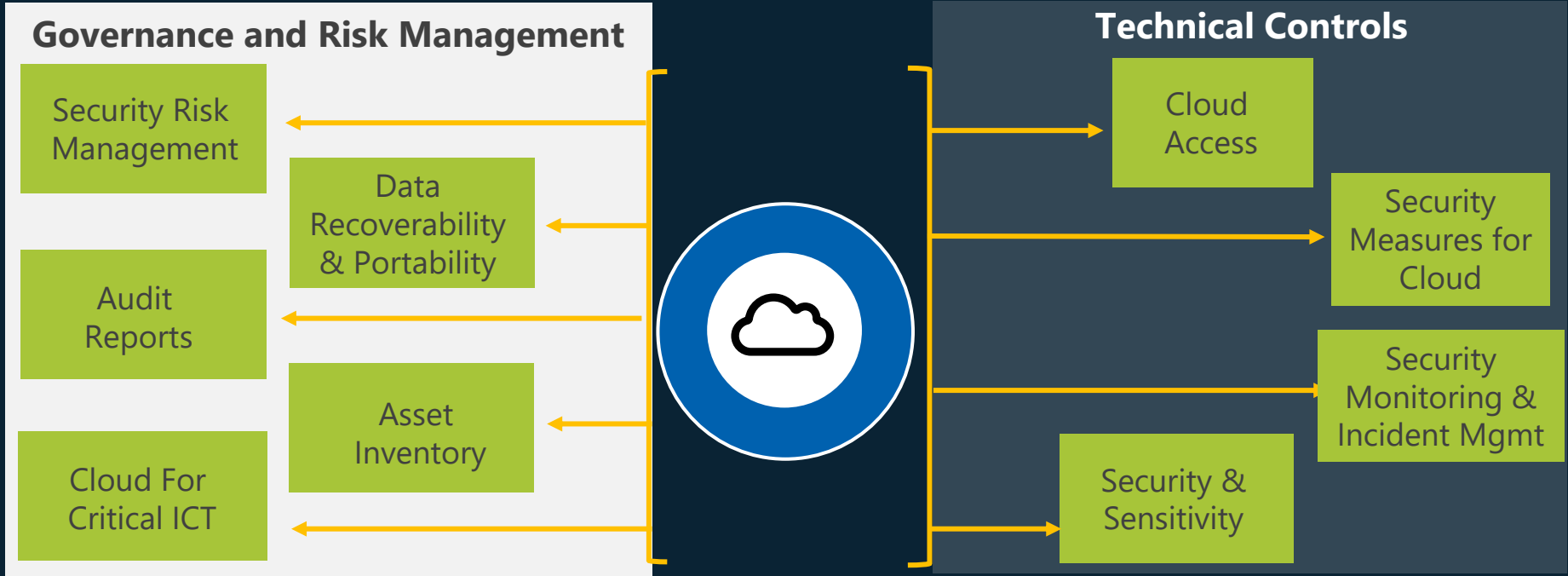


- A multi-cloud approach has been adopted as each CSP is different and has their own unique strengths which the Government can leverage
- Amazon Web Services (AWS), Microsoft Azure & Google Cloud Service Providers selected



- Established Enterprise Agreements with the Cloud Service Providers to simplify the procurement of cloud services by agencies and speed up cloud adoption

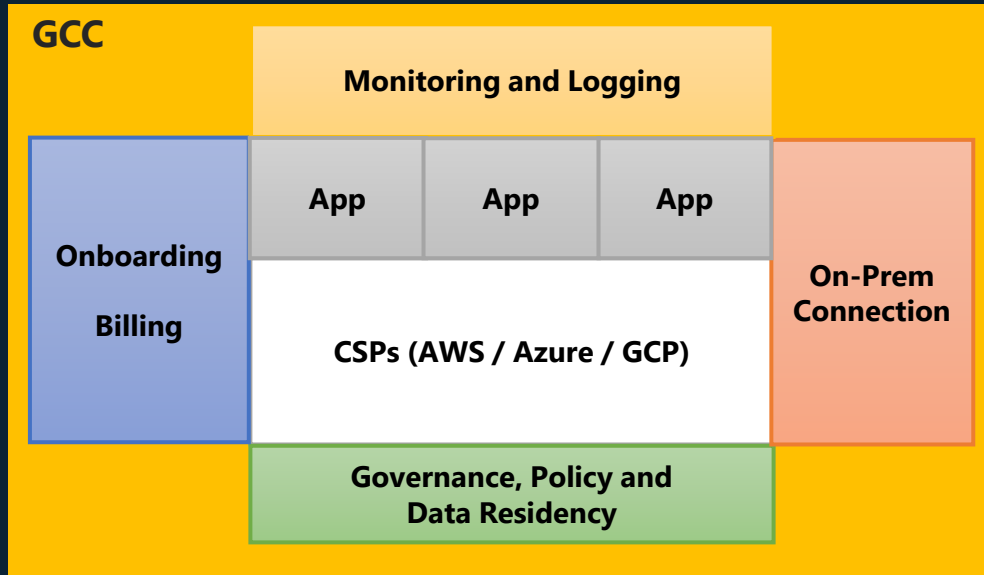
4 Establish Cloud Security Policy



For RESTRICTED In-Country Data Security Overseas Cloud SaaS

5

Government on Commercial Cloud (GCC) Platform



- Visibility of online Government assets & consumption patterns
- Centralised log repository & Oversight of Agencies' compliance to minimum security baselines: quick incident response
- Secure On-prem connectivity extending Government Intranet (SG-Net) to CSP Cloud
- Central cloud identity source for single-sign on
- Centralised billing

6 Establish Central Cloud Adoption Team (CAT) To Provide Cloud Expertise and Drive Migration

Agencies are new to cloud
– Need to uplift capabilities



Wide range of choices for multi-cloud services



Need for secure implementation of systems in cloud with validated architectures



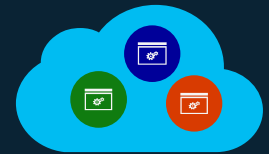
Contextualisation of CSP services to govt. and controls requirement



Agencies to adapt to operations and management of cloud applications



Need to keep pace with rapid advances in cloud technologies






Establish Close Collaboration with CSPs to Develop Cloud Competency

Define Cloud Competency Framework

Proficiency Level	Capability	Specialisations		
Level 3 – Advanced	Advanced Cloud Architectures, network and security	Advanced Architectures	Network	Security
Level 2 – Intermediate	Design and set up cloud infrastructure, applications. Run & operate systems	Cloud Architecture	Cloud App Development	DevOps & SysOps
Level 1 – Foundation	Foundation knowledge on commercial cloud services, capabilities, operations, basic security and services	Cloud Basics		

Partner with CSP to establish central training & certification programs to uplift Agency IT Teams Cloud Competency

Target Audience	Proficiency Level	CSP Courses Available	CSP Certifications Available
Agency IT Team	Level 1 – Foundation	Foundation knowledge on commercial cloud services and its capabilities AWS Cloud Practitioner or Azure Fundamentals	 <ul style="list-style-type: none"> - AWS Cloud Practitioner - Azure Fundamentals
Agency's Cloud Team	Level 2 – Intermediate	Design and set up cloud infrastructure & applications. Able to run & operate systems on cloud. Solutions Architect, Administrator, DevOps, Developer	 <ul style="list-style-type: none"> - AWS Solutions Architect Associate - AWS SysOps Administrator - Azure Administrator - Google Associate Cloud Engineer - AWS Developer - Azure Developer
	Level 3 – Advanced	Design and implement advanced Cloud architectures. Specialisation in cloud network and security Solutions Architect, Administrator, DevOps, Developer, Network & Security	 <ul style="list-style-type: none"> - AWS Solutions Architect Professional - Azure Solutions Architect Expert - Google Professional Cloud Architect - Google Professional Cloud Developer - AWS DevOps Engineer - Azure DevOps Engineer - AWS Security Engineer - Azure Security Engineer
			GCC Foundation*



Co-develop guidelines, runbooks and best practices for cloud adoption and migration with CSPs

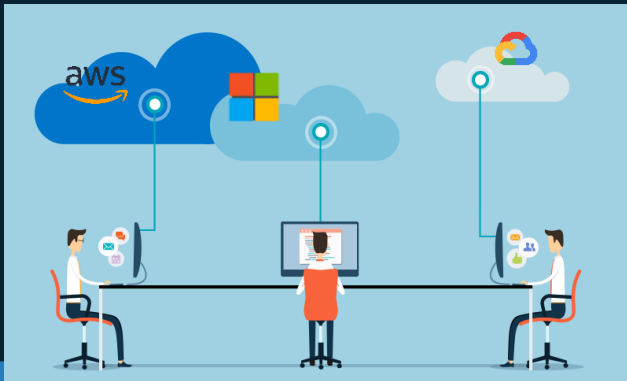


Work closely with Agency IT teams to build cloud competency in agencies through agencies' systems migration



Conduct Regular Deep Dive Sessions, Technology Update Sessions by CSPs

Build Cloud Competency in “Bite Size”



- ❖ Standard one-off trainings not very effective
- ❖ **“Bite-size”** weekly cloud sharing sessions on specific cloud topics over 4 months quite useful
- ❖ Going for **certification** in parallel resulted in greater success
- ❖ Move beyond certification with **actual practice**
- ❖ Conduct of **agency-specific clinics** enabled wider cloud competency building and project learnings
- ❖ **Keep up to date** – establishing **community practice group** to share cloud services updates / cloud project related discussions quite useful
- ❖ **Experimentation** is critical to success

9 Established Cloud Playbook Early For Effective Knowledge Dissemination to Align Cloud Practices

Provided a common body of knowledge and lessons learned to help agencies in their cloud adoption



01

Cloud Architecture & Security Guidelines

02

Reference Implementations / Best Practices Sharing

03

Incremental Knowledge Building by Distilling Experience through Project Execution

Serves as important reference for projects starting at different times, relieve central consultants bottleneck given limited resources.

Cloud Adoption Planning Guidelines Published to Facilitate Agencies in Cloud Adoption Planning



 **Agency Cloud Adoption Plan Template**

To capture Agencies' Cloud Adoption Plans

 **Application Portfolio Data Templates**

To capture information about Agencies' application portfolio.

 **Cloud Migration Decision Tool**

Tool to assist agencies in deciding the cloud migration approach for each application

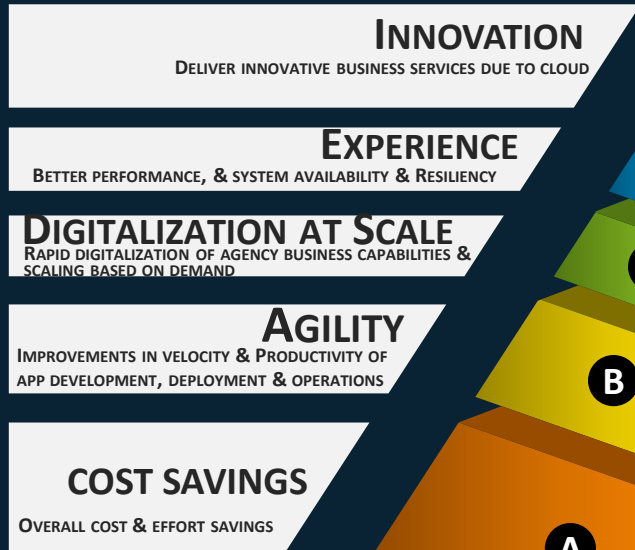
 **Cloud Resource Budget Planning Template**

Sample cloud resource budget planning template

11

Maximise the Cloud Benefits by Adopting Modern Cloud Delivery & Infrastructure Operations Practices

Cloud Benefits



How to Achieve ?

Adopt readily available cloud services such as NLP, Machine Learning to deliver innovative business services

Adopt cloud application design and operation management practices to deliver better performance and resiliency

Adopt modular application design practices to scale cloud resources consumption based on demand

Adopt DevOps, Infra-As-Code and Operations Automation Practices

Adopt continuous cost optimization by reviewing governance, architecture, operations, product management, and application development

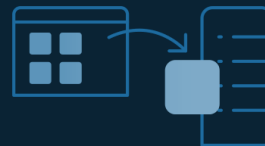
Chose Migration Options Based on Workload Analysis



Replace



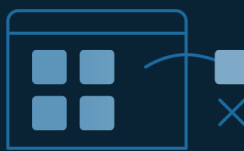
Re-Develop



Re-Platform



Re-Host



Retire



Retain

Although Re-Host / Re-Platform is faster, to get cloud benefits, workloads and processes must be re-architected using cloud native services

Establish “Fly Way” For Migration

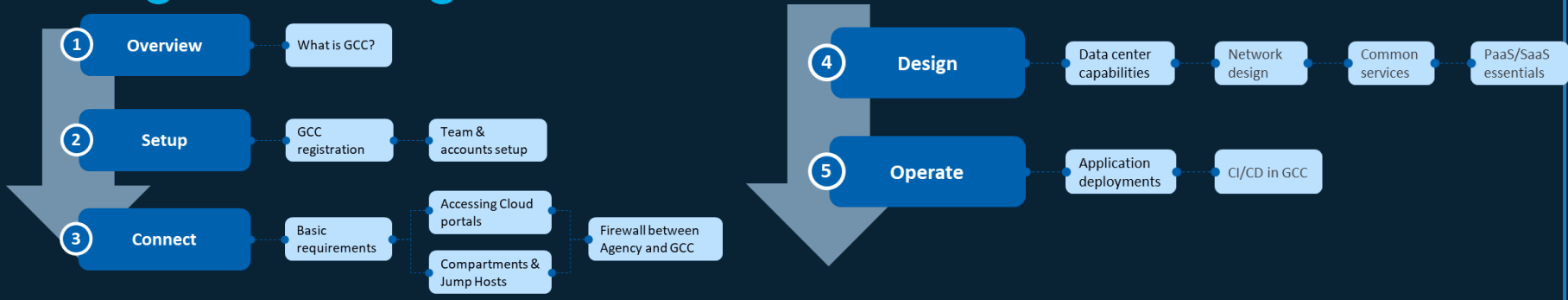
The background of the slide is a photograph of a sunset. The sky is a mix of blue, orange, and red, with wispy clouds. In the foreground, there are dark, silhouetted mountains. Several birds are shown in flight, their wings spread, scattered across the sky. The overall scene is peaceful and evokes a sense of natural migration.

Bird migration is a highly complex phenomenon – Fly Way denotes the migration paths adopted by the birds

Define the “fly way” to enable orderly, safe and efficient migration of large numbers of systems to Cloud

ESTABLISH "FLY WAY" FOR MIGRATION

13 Engage Agencies to Guide Them Through Different Migration Stages



Example : Working through initially with each application team including vendors on their solutioning to address foundation setup :

Agency Cloud Data Center – What foundational capabilities are needed?		
Internet Application		
Cloud Native <input type="checkbox"/> E-mail	Agency Existing/Reuse <input type="checkbox"/> WAF/DDoS <input type="checkbox"/> Defacement monitoring <input type="checkbox"/> Public DNS	Agency-Managed <input type="checkbox"/> IPS <input type="checkbox"/> Forward Proxy
Intranet Application		
Central Service <input type="checkbox"/> E-mail (SGMail-AMR)		Agency-Managed <input type="checkbox"/> Intranet user login
Management, Security and Deployment		
Cloud Native <input type="checkbox"/> Active Directory (AD) <input type="checkbox"/> Internal DNS <input type="checkbox"/> Backup, Restore, Archival <input type="checkbox"/> Key and certificate management <input type="checkbox"/> Firewall <input type="checkbox"/> Networking monitoring <input type="checkbox"/> Log monitoring	Central Service <input type="checkbox"/> Remote administration <input type="checkbox"/> Application & infra deployment ATFM/FM Managed <input type="checkbox"/> Patch mgmt. & repository <input type="checkbox"/> Service monitoring (app. and infra)	Agency-Managed <input type="checkbox"/> Vulnerability assessment <input type="checkbox"/> Anti-malware Agency-Managed (CI/SII/Sensitive High) <input type="checkbox"/> Privileged user activity monitoring <input type="checkbox"/> Database activity monitoring <input type="checkbox"/> Endpoint detection and response

Standardise Your Tech Stack & Cloud Practices

Standardise Tech Stack



- Lessons learnt in cloud services configurations (eg. ALB, RDS, etc..) were shared with other agencies to prevent same issues from recurring
- Reduce the proliferation of tools and reduce complexity and support effort required – embrace cloud native tools

Standardise Cloud Practices



- Standardise timeout values at different layers
- Watch out for cloud services timeout values
- Pipe application logs to CSP Log Monitoring
- ...



Adopt CSP Managed Service if Available & Suitable

1

Managed Service Preferred



Adopt Open Source

2

Avoid Lock-In and reap cost benefits, easier for scaling without license constraints



Adopt Subscription Licences In CSP Market Place

3

Adopt Auto-Scaling & Usage Based



Avoid Bring Your Own Licence BYOL

4

Avoid use of On-Prem Products in Cloud if Possible - it affects costs, scalability and agility

15 Automate to Migrate@Scale with Speed

Automation can bring agility, and also helps in FM paradigm shift. Instead of upfront process control which required service request, allow apps team to have more flexibility, but control through standardized scripts, IAC & PAC to check for drift and compliance.



Infra-As-Code (IAC) & Policy-As-Code (PAC)

- Use IAC to speed up deployments and achieve immutable infrastructure
- Use Automated 'Policy-As-Code' to Ensure Your Cloud Configurations are Hardened



CI / CD Practices

- Faster Time-to-Implementation and Lead Time to Change
- Improved Apps Security, Quality and Policy Compliance

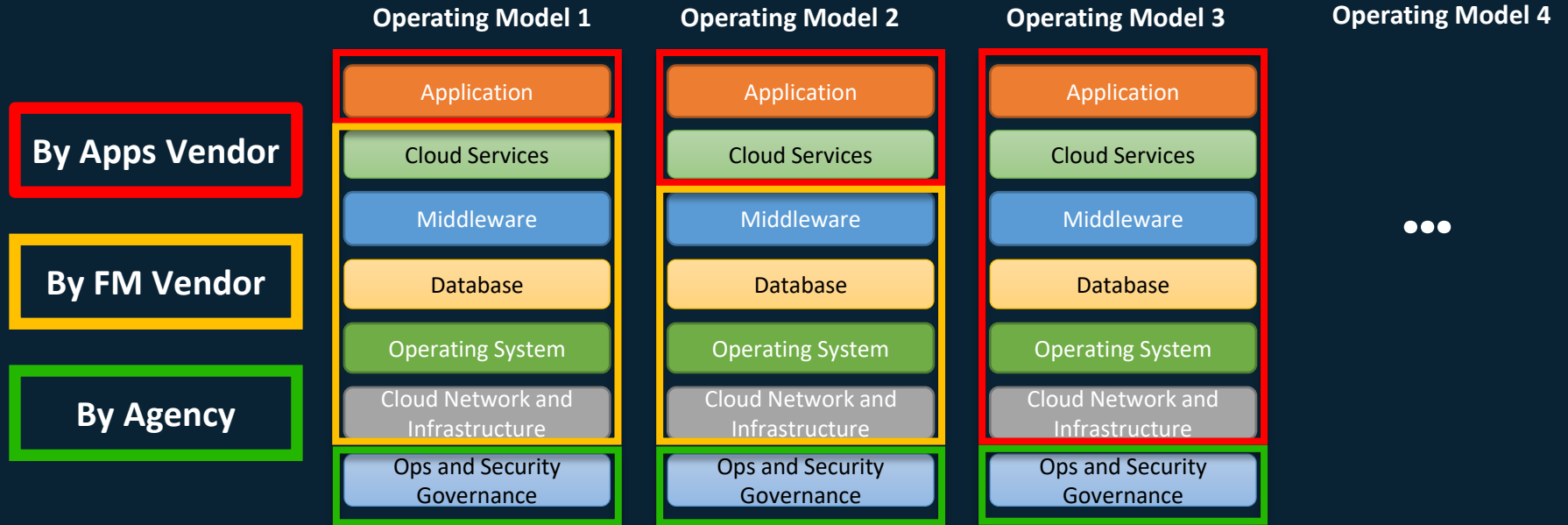


Assemble / Build Automated Tools to Facilitate Faster Migration

- Cloud Watchdog
- Cloud Architecture Visualisation
- Cloud Bills Visualisation
- RDS Optimizer
- Start / Stop Instances
- Enforce Resource Tagging
- Dashboard Scripts
- Configuration Enforcement Scripts
-

16 Plan Your Cloud Operating Model Early

Cloud enables different operating models with different levels of agility vs governance;
Plan early to design your Day 2 Operation Processes



FM management cost should be aligned to cloud resource management – as you gain more experience with cloud and optimise more, it reduces the number of cloud resources which FM needs to manage

17 Practise Day 2 Operations

Establish operation processes and practices early

Define all the Day 2 Operations Activities



- Roles assignment & IAM Appointment
- Applications Availability Monitoring
- Security Threat Monitoring
- Compliance Monitoring
- Operational Resiliency
 - Application & Infrastructure Monitoring
 - Cloud Resource Tagging
 - Log Management
 - Backup & Batch Job Management

Define Responsibilities & Practices Early



- People
- Specific tasks
- Frequency of the task
- Cloud Tools to use
- What to monitor
- ...

Develop Situational Awareness on Cloud Security

Policy-As-Code (PaC)

Provides security misconfiguration checks and auto remediation

- Automated scripts to **augment human/manual security misconfiguration checks and remediations.**
- customized rules mapped against selected policies and industry hardening best-practices.
- Non-compliances are measured in *per cloud-resource* metric.
- All rules/checks are reviewed periodically.

Real-time Operations Monitoring

Provides visualization of contextualised data

- Provides **consolidation of data-feed from PaC and other sources** to provide visualization for Agencies.
- Multi-tenanted in design, Agencies gain insights into their current state of security compliance.
- Provides a construct for self-service security remediation actionable by Agency IT team directly.

19 Develop Situational Awareness on Cloud Cost Spend Across Agencies and Accounts



Plenty of fine grained data available from cloud platform – need to make sense out of it to decide on most appropriate cloud cost optimization actions delivering maximum business value



Recommendations available from **multiple sources** – CloudWatch metrics, Cost Usage report, Compute Optimizer, Savings Plan, etc., Need to **contextualize the recommendations** to agency applications



Cost analysis required to caters to needs of **stakeholders at different levels** – CIOs, project managers, systems analysts and engineers

lineitem/Proc	lineitem/UsageType	lineitem/Operati	lineitem/Resourc	lineitem/l	lineite
Usage	AWSLambda APS1-Request	Invoke	arn:aws:lambda:a	5	USD
Usage	AWSLambda APS1-Lambda-GB-Second	Invoke	arn:aws:lambda:a	0.458875	USD
Usage	AWSLambda APS1-Lambda-GB-Second	Invoke	arn:aws:lambda:a	3.0405	USD
Usage	AWSQueueSe APS1-Requests-Tier1	Send	arn:aws:sqs:ap-sc	8	USD
Usage	AmazonS3 APS1-DataTransfer-Out-Bytes	ReadLocation	sst-s3-gvt-saocdb	6.48E-06	USD
Usage	AmazonS3 APS1-DataTransfer-Out-Bytes	ReadCostAllocati	lambda-sao-get-a	8.58E-07	USD
Usage	AmazonS3 APS1-DataTransfer-Out-Bytes	ReadLogProps	sst-s3-gvt-saocdb	2.15E-06	USD

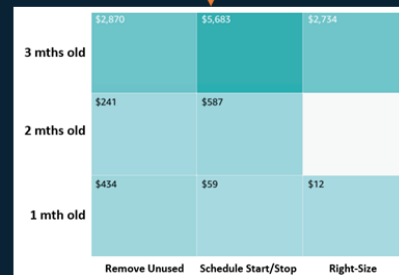
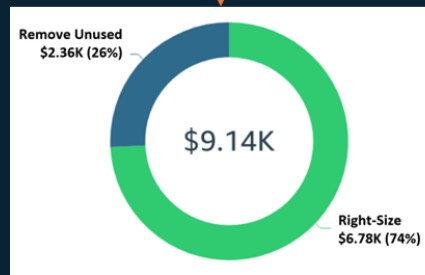
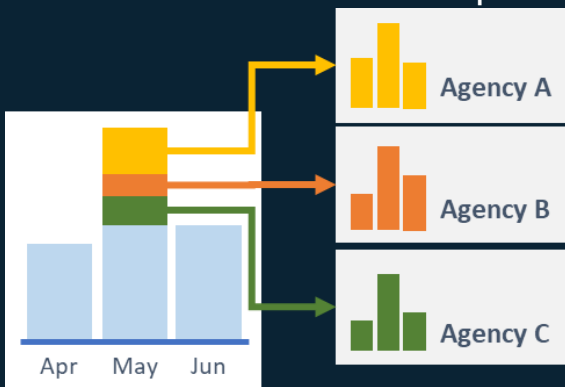


Establish A Proactive Culture Around Cloud Cost Monitoring, Management, And Optimization

- Auto-generated Monthly report on potential savings & Aging report to CIO
- Establish monthly cloud cost review forum
- Cloud solution architects to drive cost optimized cloud architecture – drive serverless solutions and truly scalable applications architecture
- Automated trend analysis & anomaly detection across all applications
- Mandatory to onboard the cloud cost optimization tool before going live

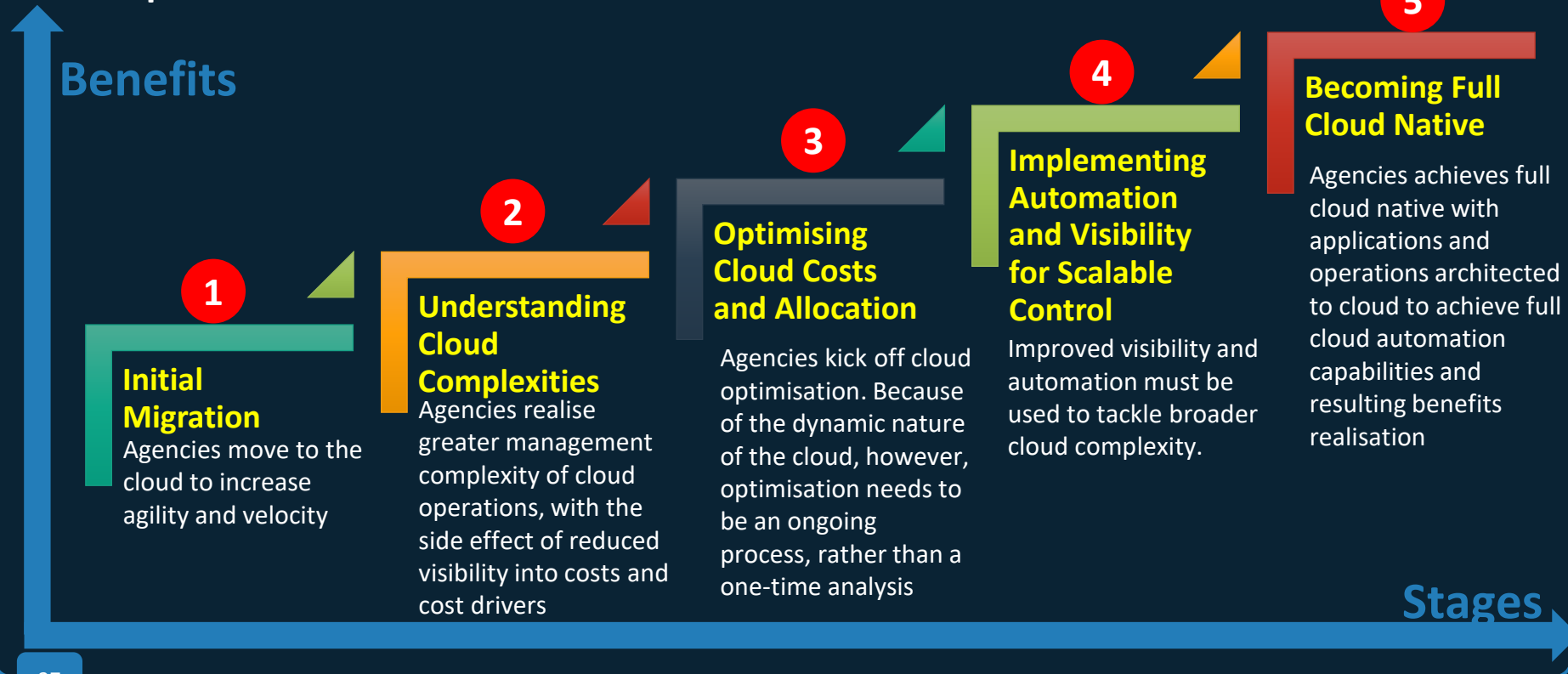
Application	Mar 2022	Apr 2022	May 2022
Application 1	▲ \$657	▼ \$329	▲ \$450
Application 2	▲ \$1,707	▼ \$1,258	▲ \$1,329
Application 3	▼ \$6,590	▼ \$3,433	▲ \$3,925

Trend Analysis & Anomaly Detection



21 Measure & Track Cloud Adoption Maturity

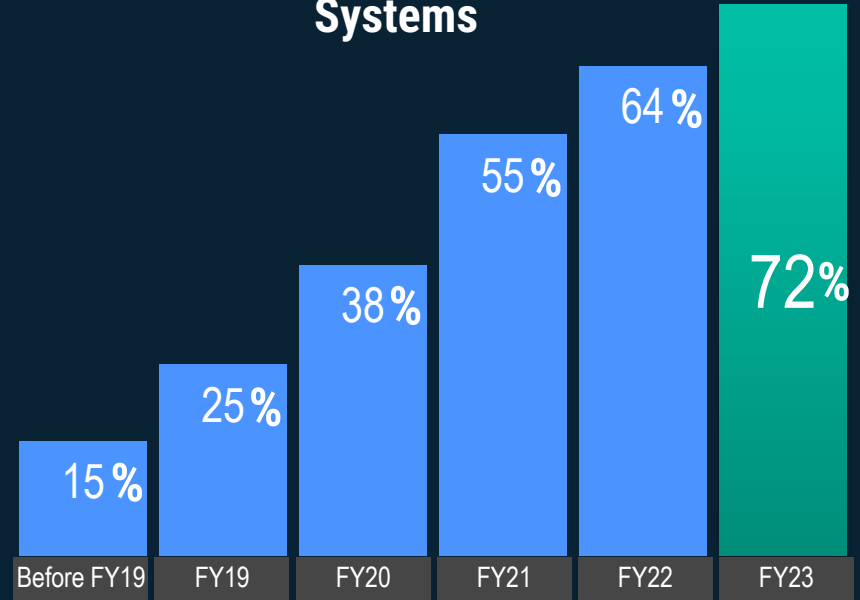
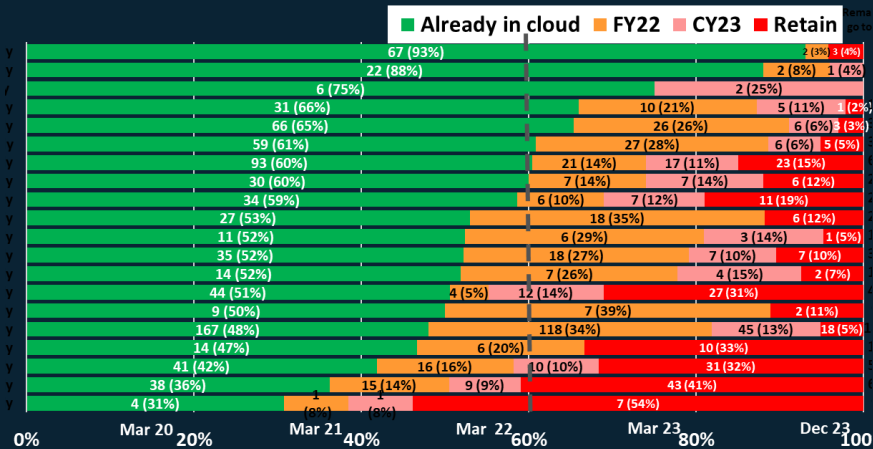
Faster cloud adoption can help cut costs and increase flexibility, but building out a mature cloud operations and full benefits realisation takes time



Agencies' Cloud Adoption Achieved Over The Last 4 Years

Agencies' Cloud Adoption is monitored and tracked closely over the last 4 years

Agencies' Cloud Adoption % Achieved Over the 4 years for Restricted & Below Systems



Cloud Adoption Helped Singapore Government Agencies to Achieve Significant Agility & Speed

COVID-19 Forced Us Into A Digital Revolution in Education with One Week Notice – We Could Respond Only Because MOE System Already Modernized in Cloud

Apr. 8th to May 4th 2020

About 96% of students took part in home-based learning

Some 3,300 primary, 700 secondary students returned to school daily for several reasons

Amelia Teng
Education Correspondent

About 96 per cent of all students took part in the month of full home-based learning, said Second Minister for Education Indraneel Rajah in Parliament yesterday.

"The few who did not participate were largely on medical leave, and those who did not participate persistently were encouraged to return to school," she said, in response to Ms Rahayu Mahzam (Jurong GRC), who asked how schools assessed whether students have the necessary support at home.

During this period of full home-based learning, about 3,300 primary school pupils and 700 secondary school students returned to school daily for several reasons, said Ms Indraneel.

Ms Rahayu had also asked if there

were requests from parents for students to attend school, which could not be acceded to.

Said Ms Indraneel: "Requests from parents for their children to return to school were met, as long as there were genuine needs.

"The challenge has in fact been the opposite, where schools invite the student to come back to school, but the parents were reluctant over various reasons. But schools will continue to try."

Full home-based learning, which started on April 8 and ended yesterday, was implemented in line with Singapore's circuit breaker measures aimed at curbing the spread of the coronavirus.

Ms Indraneel said schools had also identified a proportion of students who would benefit from returning to school during this period, based on their understanding of the student and his/her family circum-



Full home-based learning, which started on April 8 and ended yesterday, was implemented in line with Singapore's circuit breaker measures. ST PHOTO: GIN TAY

stances, parents' requests, and referrals from social workers.

These include students whose parents are in essential services and do not have alternative care-

arrangements. These students can also access limited services offered by school-based student care centres.

Schools also reached out to stu-

dents who face significant challenges learning at home, as well as those who require face-to-face support, said Ms Indraneel.

"Schools proactively identified these students and encouraged them to return to school, by providing a welcoming environment and additional small-group activities, such as non-contact sports and enrichment modules, while practising safe distancing," she added.

"This has helped them to stay connected and engaged, and maintain a school-going routine."

Another group of students who needed more support were those who lacked digital devices or Internet access at home for learning.

Ms Indraneel said that schools have loaned more than 20,000 computing devices and 1,600 Internet-enabling devices to date, with some corporate support.

"The numbers coming back to schools for this purpose have dropped significantly since, to a small group whose parents are not wise to (take up the) loan for personal reasons," she added.



The period of full home-based learning has been a learning process for families as well as schools, said Ms Indraneel in response to Ms Rahayu's question on the challenges that parents and teachers had faced.

"Certainly the first week, there was quite a lot of adjustment and learning that had to take place, but a couple weeks on... things have more or less stabilised," said Ms Indraneel. "It has gone on much better than we had hoped, but not without challenges."

These challenges include parents learning how to use software while handling their work from home, and supporting multiple children, some with special needs.

"No two children are exactly alike. Some have taken to home-based learning very well. Some others need more offline learning," she said, adding that teachers have tried to maintain contact with parents and find solutions together.

For students who need support beyond lessons, school counsellors and social welfare officers have also reached out to them, through phone or video calls, or e-mails, she said.

The Education Ministry is starting to look at the feedback it has received, she said.

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- MOE System scaled from **100,000** concurrent students to **300,000** concurrent students usage to meet the Home-Based Learning (HBL) demand
- System made use of many of the cloud services to deliver a smooth HBL experience for the students and teachers

Thank You