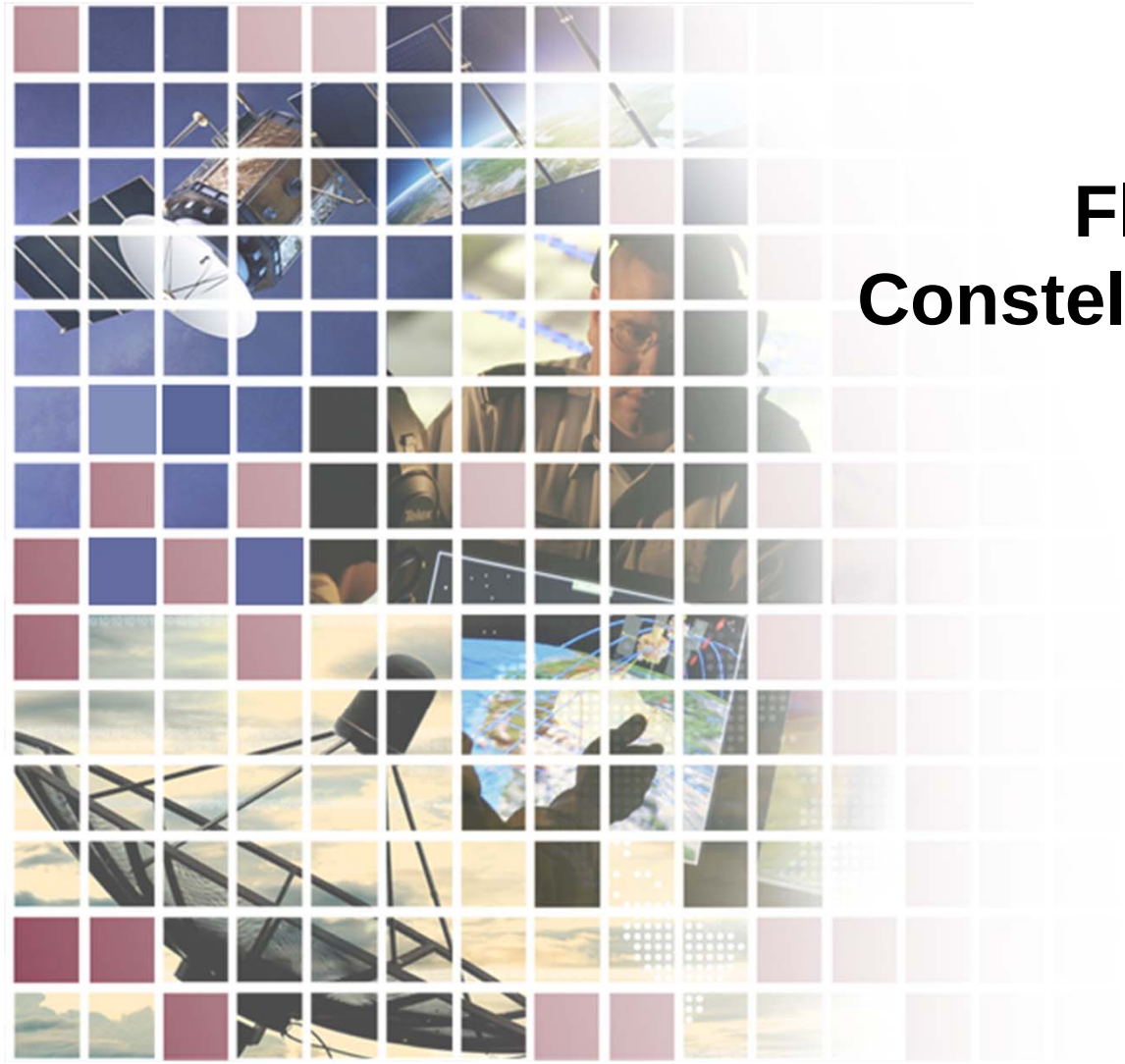

Flying Small Satellite Constellations in the Cloud

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KRATOS | RT LOGIC

Small Sat Ground Systems

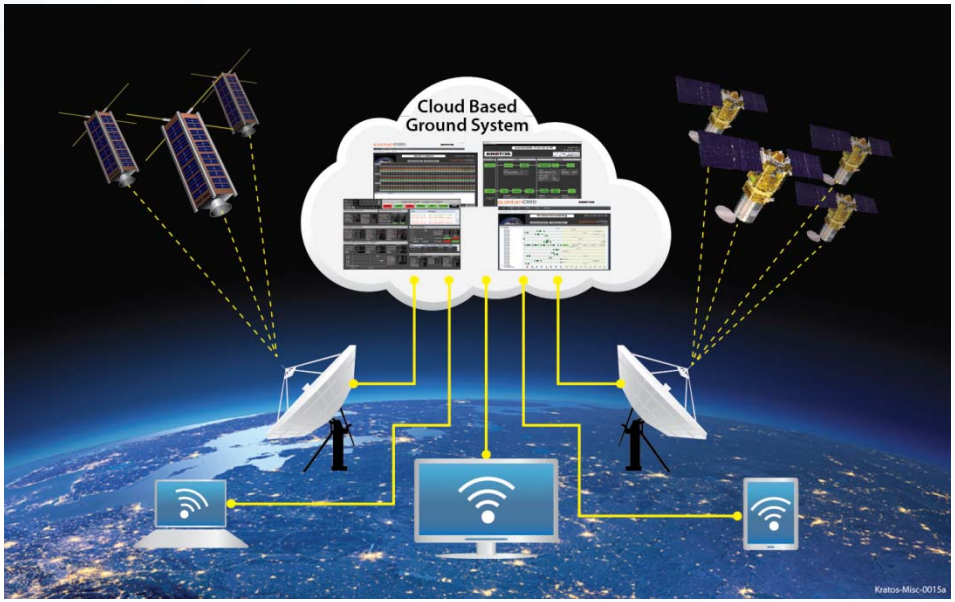
- Kratos has long tradition in building satellite ground systems
  - Created quantum product line for small satellites
    - Traditional functionality in software based solution
    - Flexible deployment
    - Reduced footprint
    - Scalable
  - Wanted to look at other options for small satellite ground architectures

Large Constellations

- Large constellations now feasible with small satellites
  - Cost to build, launch and operate traditional satellite negated concept of a large constellation
  - Small satellites now have companies looking at constellations in the thousands
- Traditional ground system architecture is not feasible
  - Stovepipe architectures and hardware reliance is too costly to operate constellations of hundreds much less thousands

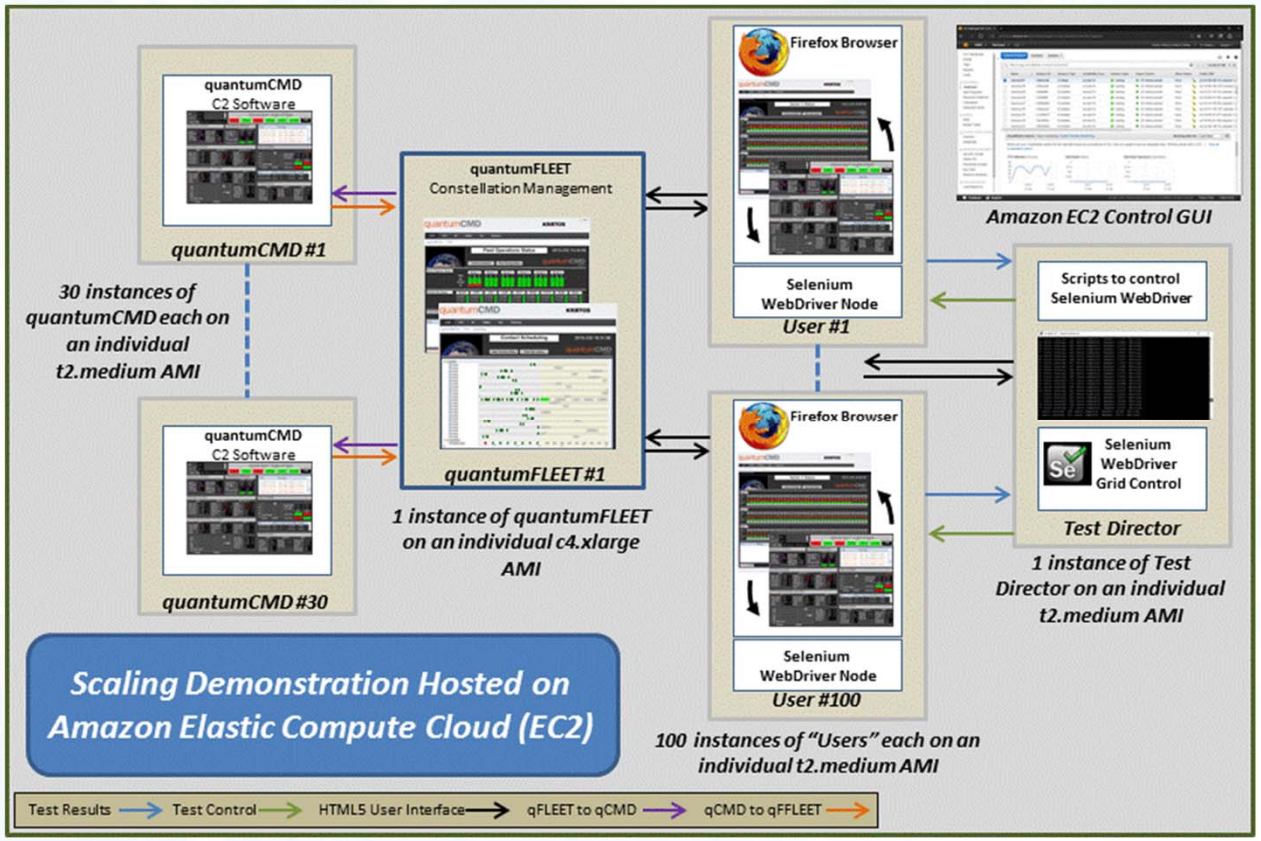
Cloud Computing Services

- Deploy a ground system in a cloud
  - Eliminate hardware costs
  - Eliminate maintenance costs
  - Reduce floor space
  - Scalability
  - Collaboration



Kratos Cloud Study

- Study Goals
  - Is building a satellite ground system in the cloud realistic?
  - Will a cloud based architecture work for 1,000 satellite?
  - Are Kratos products favorable to operate in a cloud?
- Parameters
  - 1,000 satellite constellation
  - 30 simultaneous satellite contacts
  - 100 simultaneous system “Users”



Parameters

- Command and Control only
- 30 quantumCMD apps
  - C2 and M&C
- Fleet management tool for contact schedule
- 100 simulated web browser "Users"
- A test director using scripts to simulate "User" activity

Process

- The scripts started each “User” individually, spacing them out randomly
  - Each “User” started at the Fleet management tool page for 10-14 seconds
    - Screen shot saved by Test Director for quality check to show page filled in correctly
  - “User” drilled down to assigned spacecraft page on quantumCMD for 8-10 seconds
    - Screen shot saved by Test Director for quality check to show page filled in correctly
  - The “User” increments s/c contact number by 1 and cycles through remaining 29 active contacts doing same process for each s/c
- Test Director script tracked all “Users”, logging times, events, and completions
- Image thumbnails were checked to ensure data filled in correctly for pages
  - Full size images were spot checked to ensure data was as expected

Lessons Learned

- VMs were easily imported to the cloud
  - This enabled us to import official quantumCMD virtual machines without having to recreate them
  - Updating instances running in the cloud is identical to traditional VM upgrades
- Largest performance concern was Fleet Management tool, maintains connectivity to 30 quantumCMD appliances, maintains a wide data set for all spacecraft, and receives frequent network traffic from “User” browsers
  - Running on a more powerful instance type helped address performance concerns
  - Tuning in a few software areas was also made to reduce latency and enable faster data access performance

What's Next

- Include FEP & Ground Modem
  - Cmd/Tlm processing
  - Signal modulation
  - Digital RF from Cloud to Ground Station
- Use cloud-based ground system for end-to-end ConOps
  - Bench/compatibility testing
  - Launch & On-Orbit Checkout
  - On-Orbit Operations

Summary

- Satellite operations via a cloud is feasible
  - Significant cost savings versus building/maintaining physical ground system
  - Easily manage new applications or performance upgrades
- Trade offs
  - Importance of data security
  - Maintaining control over infrastructure
  - Access assurance