Thoughts on research for space networking

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Panel Discussion: Research

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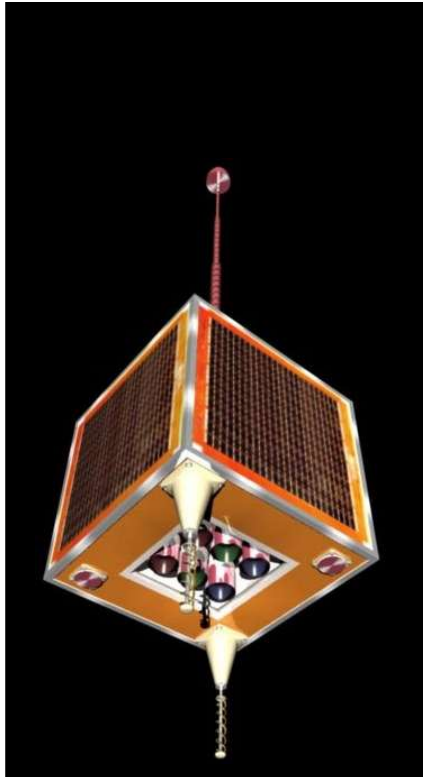
Introduction – *bona fides*

- We tested the *CLEO* Cisco mobile router in orbit, 2004.
  - onboard an Internet-enabled LEO imaging satellite.
  - UK-DMC, from Surrey Satellite Technology.
  - Conducted first tests from space of Bundle Protocol, 2008.
- Led to the follow-on *IRIS* space router, 2009.
  - onboard a GEO communications satellite.
  - Intelsat-14.
  - Later tested use of Bundle Protocol with *IRIS*, 2011.
- Delay-Tolerant Networking (DTN)
  - The Bundle Protocol was tested using both satellites…
  - …by running over the Internet Protocol (IP).
  - Internet infrastructure was *already in place* to be used.



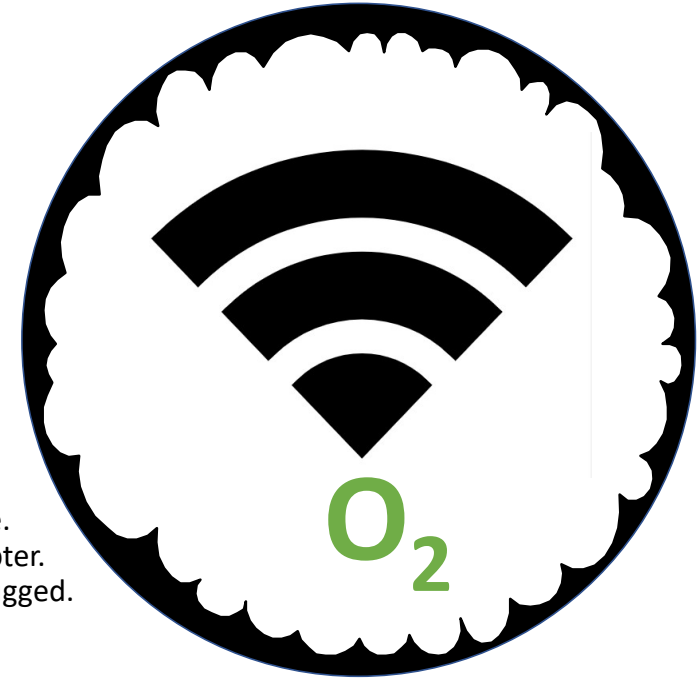
UK-DMC satellite

Achievements in space networking research

- The biggest win: *putting the Internet in space*

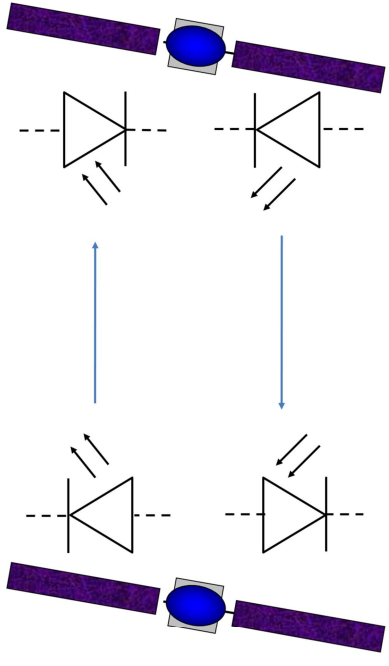
- Wherever you have people, you'll have:
  - Oxygen
  - Food
  - Internet communications
- And even where you don't have humans
  - Internet communications
  - …and, perhaps even later, you can add DTN?

- Commercial Off The Shelf (COTS) or custom?
  The line is blurring…
  The same software can drive both – increased reuse of code.
  Linux is *already* on Mars – NASA Perseverance rover, helicopter.
  TCP or UDP/IP networking and drivers are understood, debugged.
  People work with the software they're familiar with.



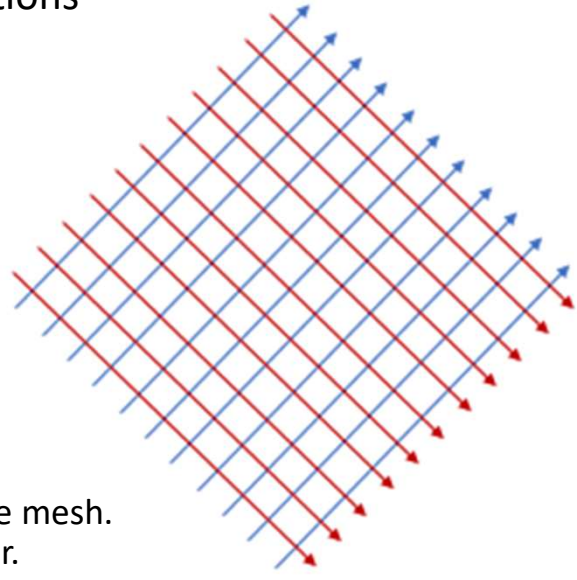
Challenges in future research? #1: LED ISLs

- Need more dedicated space-to-space links.
- Experience with intersatellite links (ISLs) helps.
- Radio or lasers? There's also a third way.
- Looking at light-emitting diodes (LEDs)
  - Slower than laser terminals. But *much* cheaper.
  - Robust, lightweight, easily embeddable.
  - And unregulated. Useful for Cubesats.
- University research, papers, testbeds underway.
  - North Carolina A&T: *systems engineering* perspective.
    - three PhDs awarded for work in this area so far.
  - Strathclyde: *photonics* perspective.
    - 20Mbps LED link demonstrated across Glasgow, December 2019.
- ISLs can be expected to carry Internet traffic!



Challenges in future research? #2 ISL meshes

- Intersatellite links as tests of in-space communications
  - Satellite constellations can use meshes of these links…
  - …to carry Internet traffic.

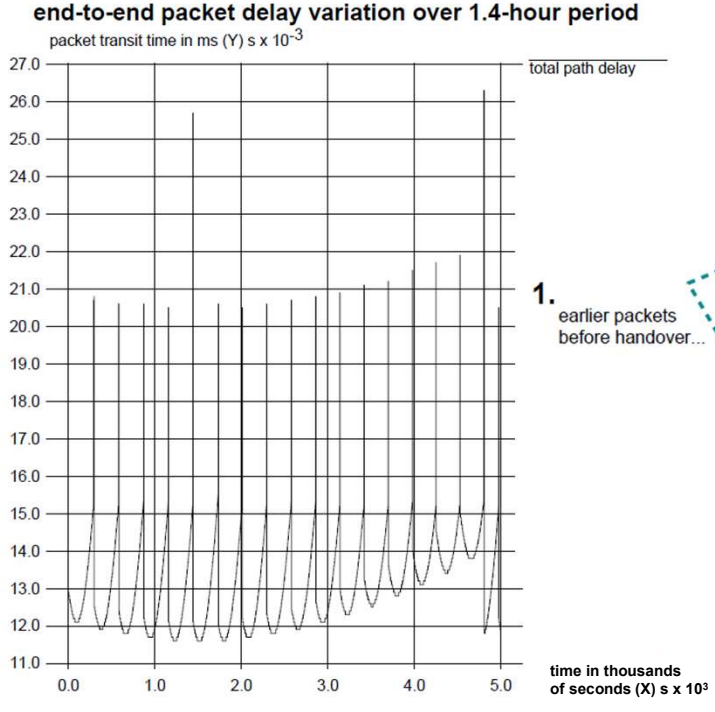


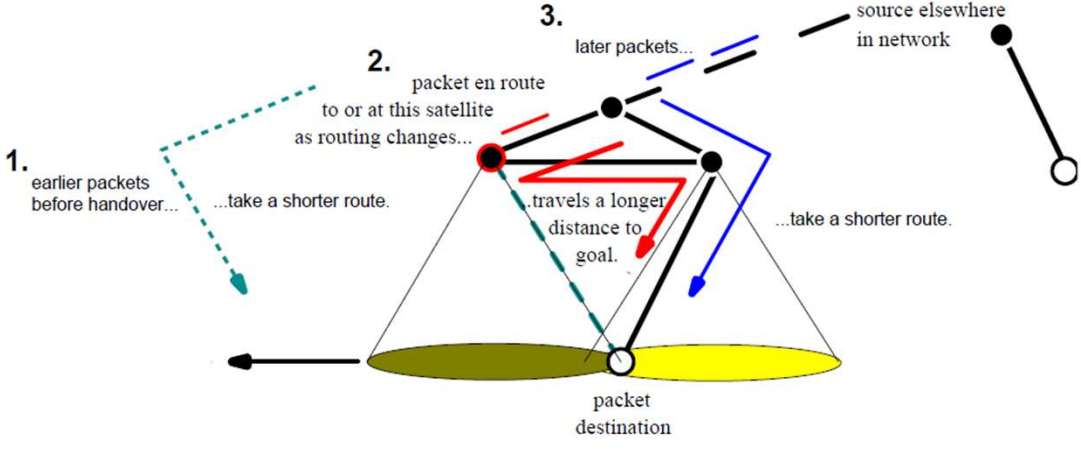
- Not yet a sure thing!
  - Iridium constellation does have intersatellite links
    - Radio for low-rate data, messaging, voice.
  - Starlink and other constellations may do too…
    - currently testing laser assemblies.

- Handovers *vs* guaranteeing low latencies
  - It's far more difficult than it may seem.
  - Don't want to hand over to satellites distant in a rosette mesh.
  - Must deal with possible delay spikes from any handover.

- Complexity of LEO mesh works against low-delay expectations.

ISL mesh handovers: delay spikes, reordering





Route changes due to satellite coverage change.
High-rate traffic flows will experience this most.

In twenty years...

The **Interplanetary Internet** *will be* **the Internet**.

Thankyou.