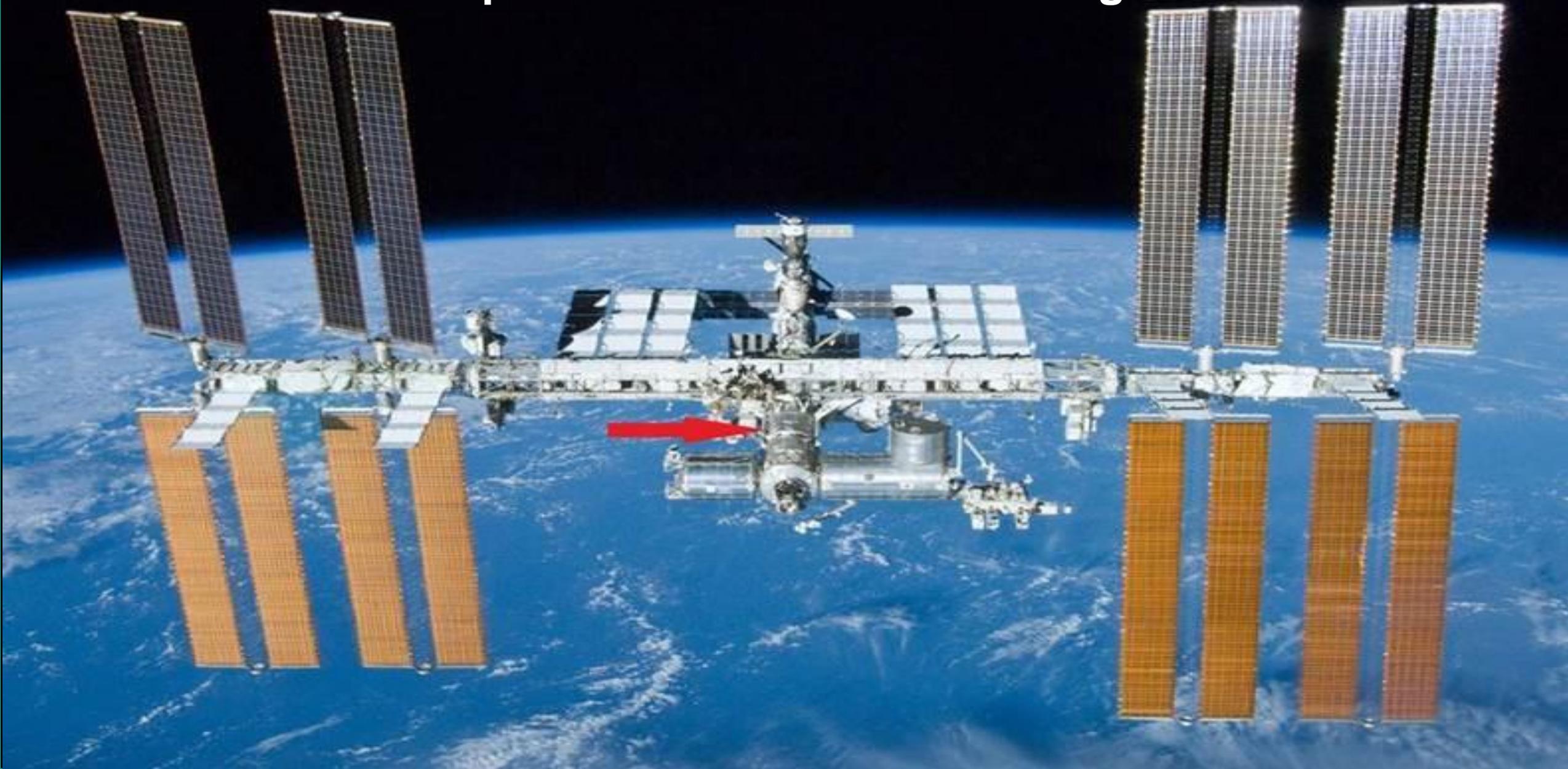


Storage in Space Enables and Accelerates Edge of the Edge Computing on the International Space Station (ISS)

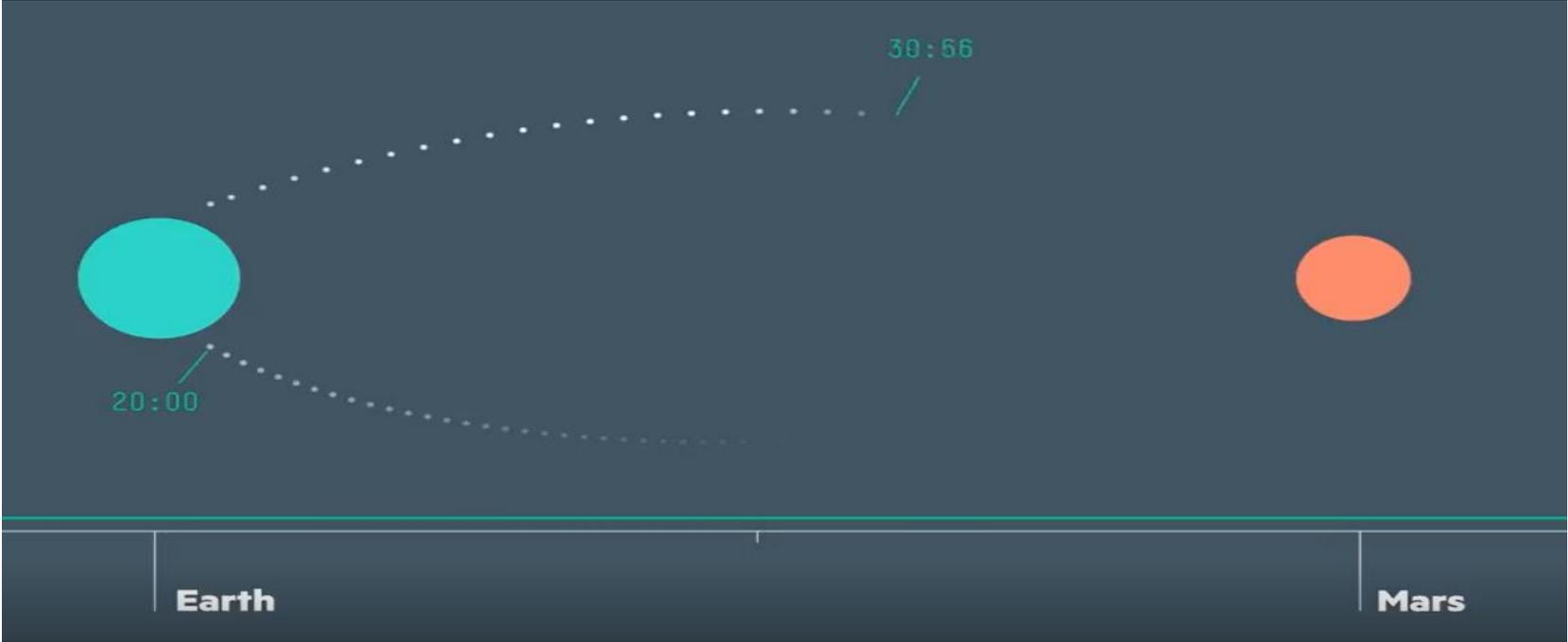
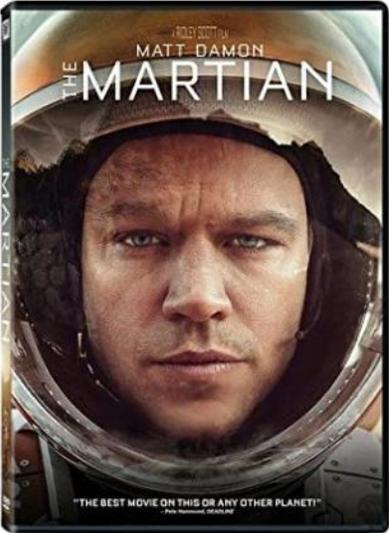
Mark R. Fernandez, Ph.D.

Principal Investigator, Spaceborne Computer-2
Chief Scientist, Space Technologies and Solutions
mark.r.fernandez@hpe.com

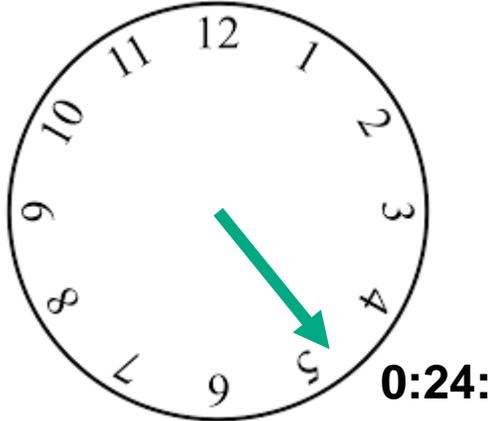
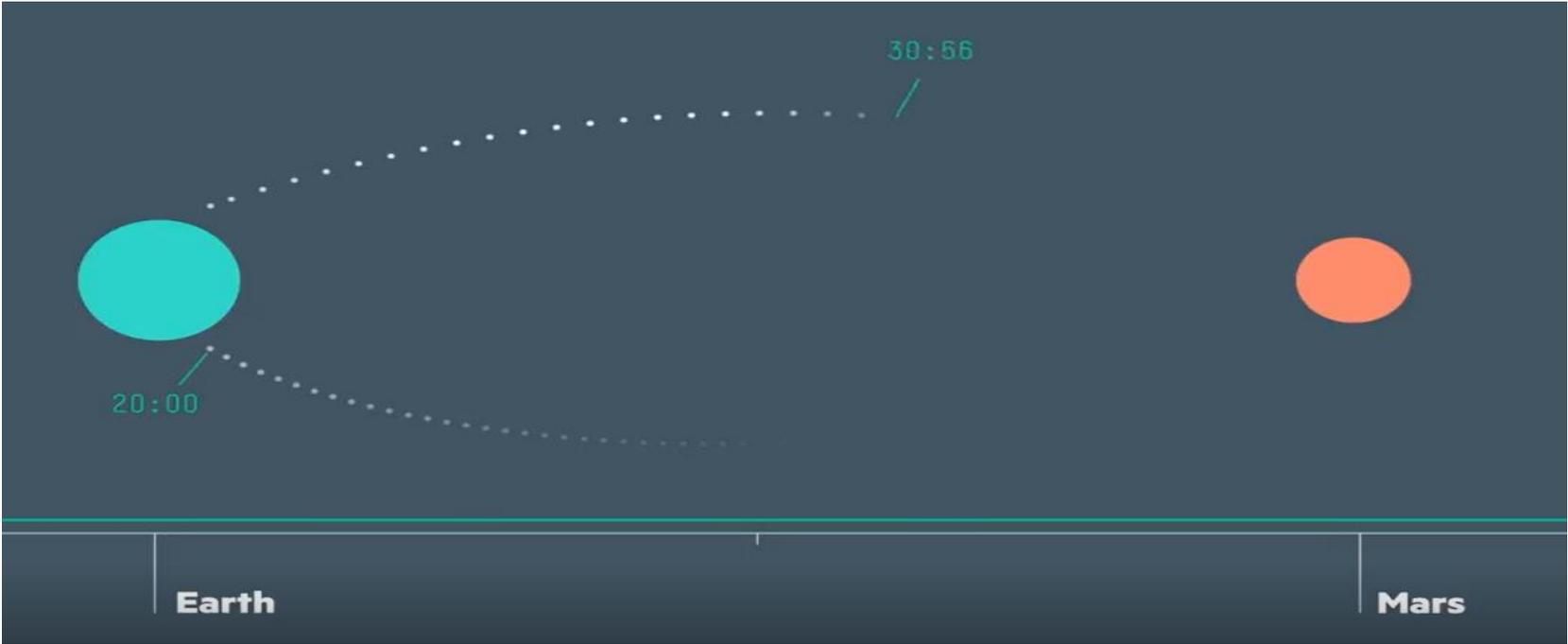
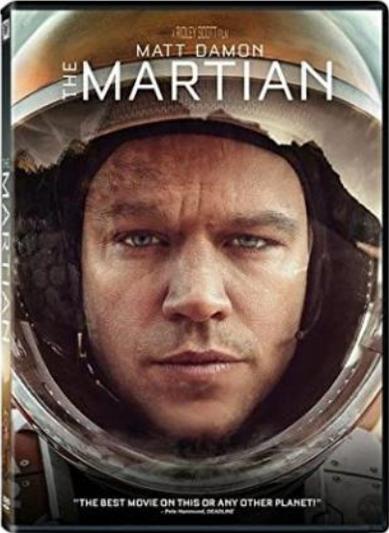
Spaceborne Computer: An “Out of this World” Data Center ... complete with KIOXIA SSD Storage



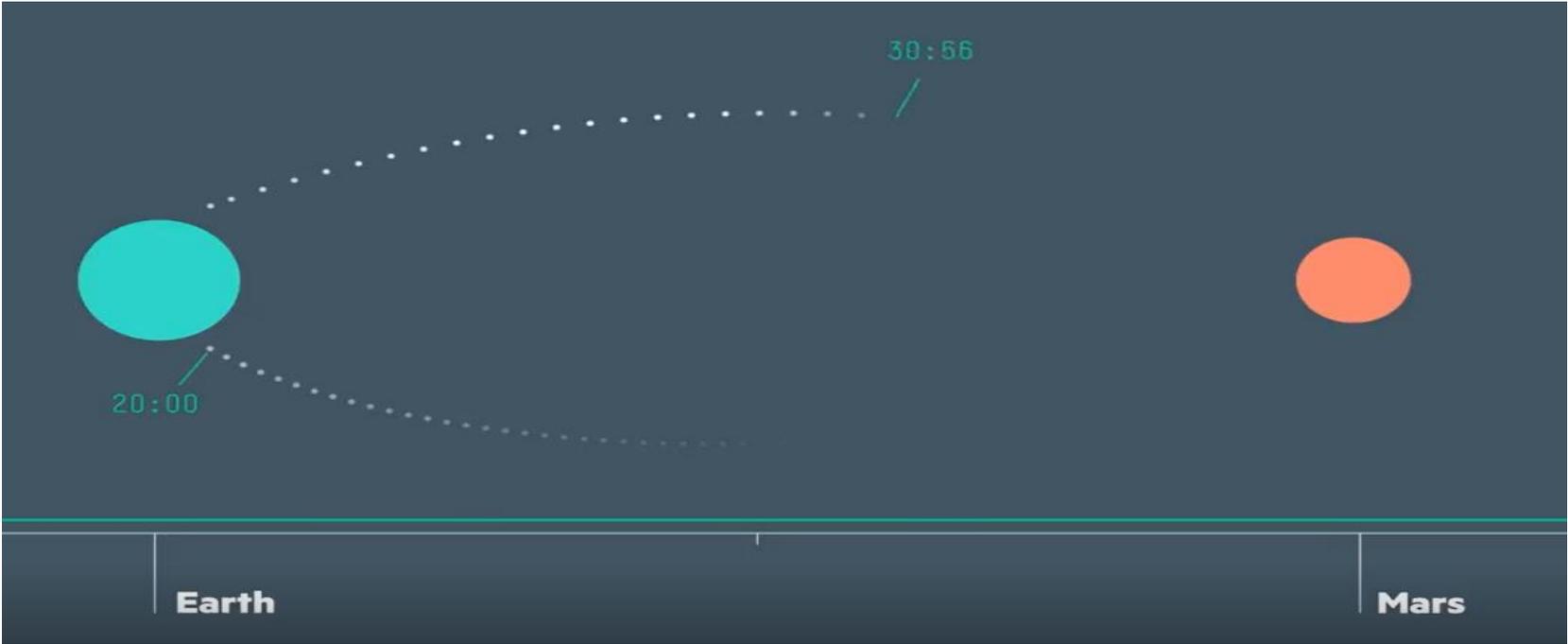
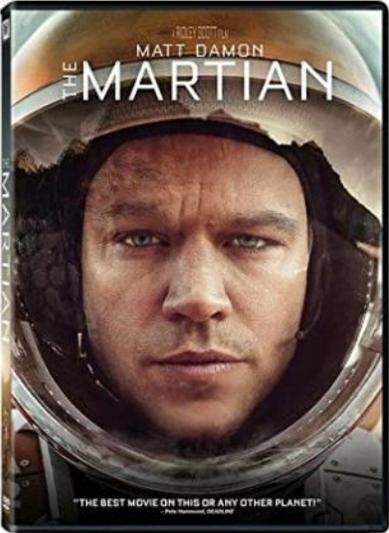
Spaceborne Computer: Objective / Mission: Why?



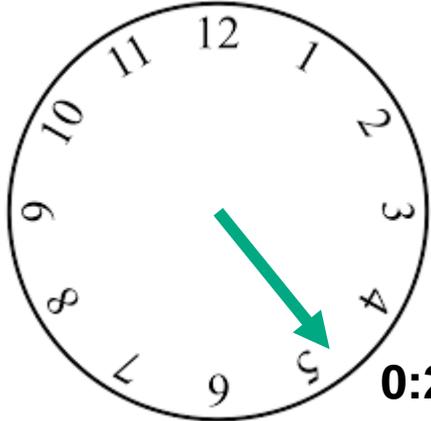
Spaceborne Computer: Objective / Mission: Why?



Spaceborne Computer: Objective / Mission: Why?

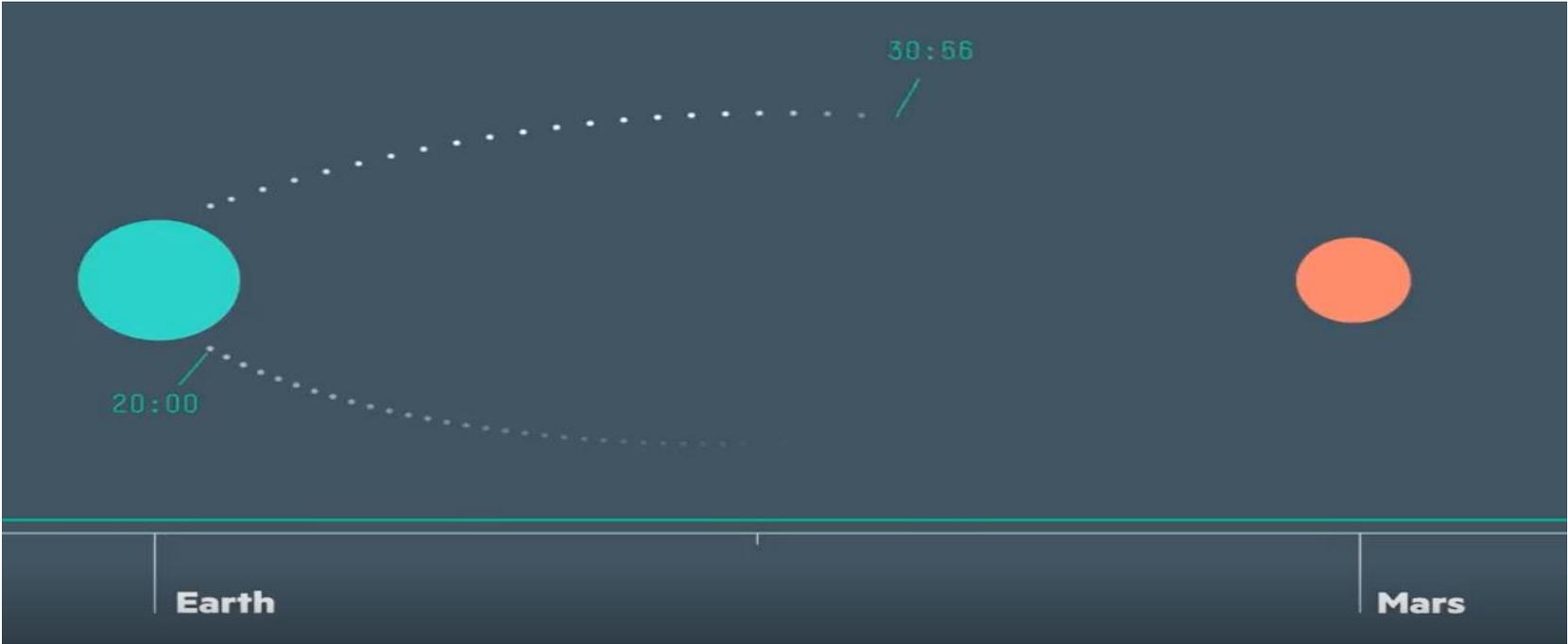
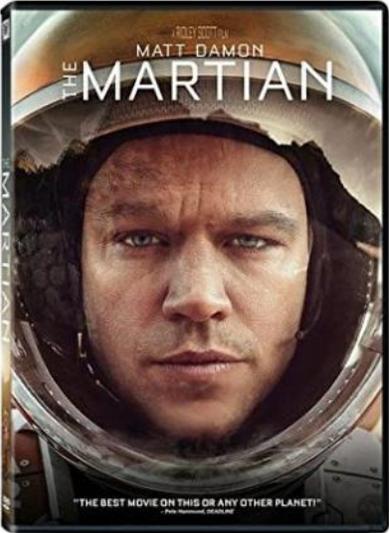


0:00:

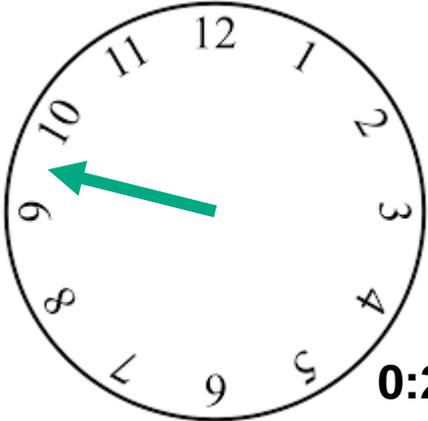


0:24: **“Okay, Houston, we’ve had a problem here.”**

Spaceborne Computer: Objective / Mission: Why?

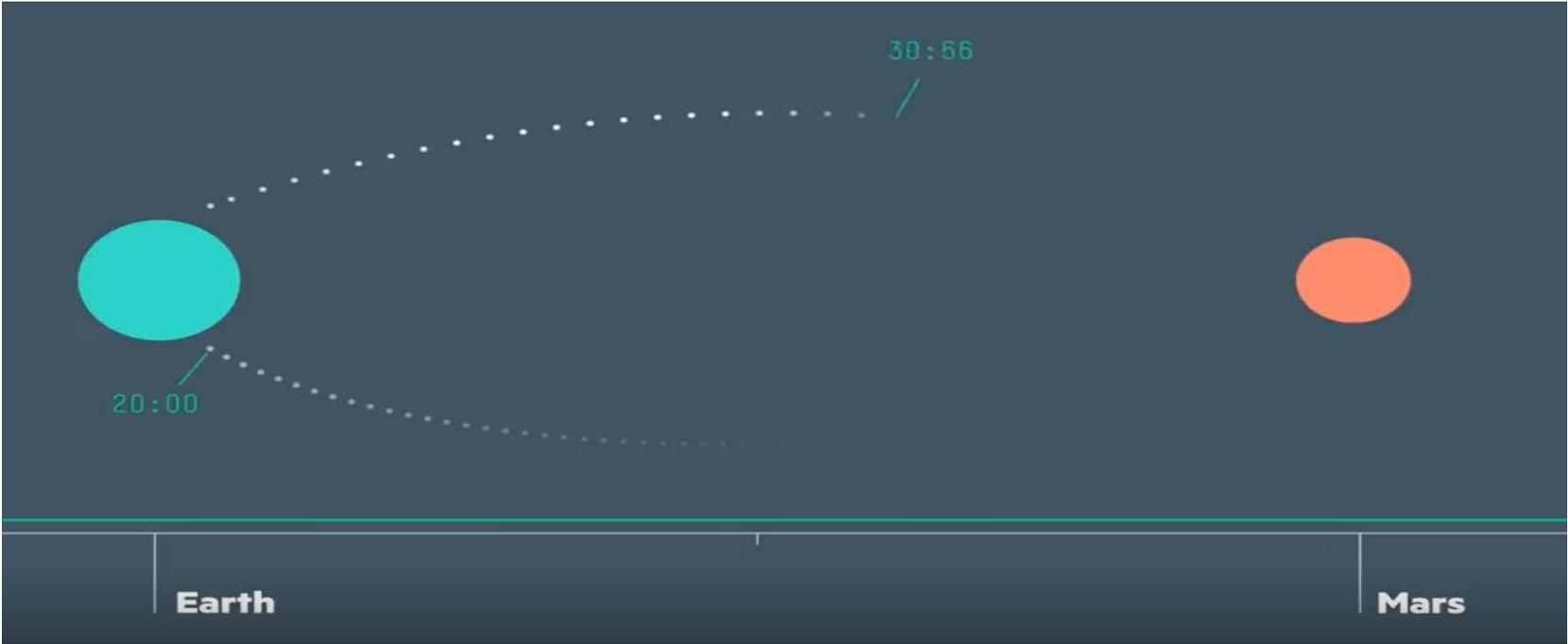
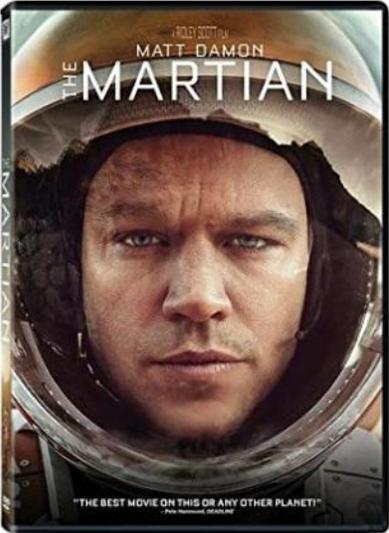


0:48:

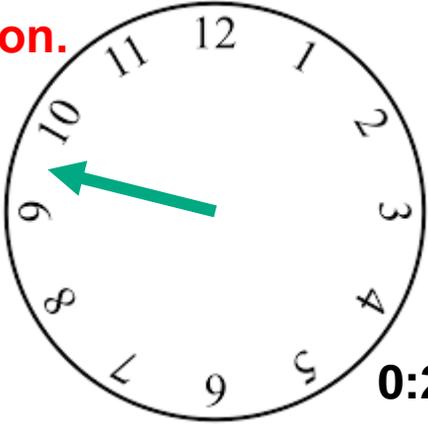


0:24: “Okay, Houston, we’ve had a problem here.”

Spaceborne Computer: Objective / Mission: Why?



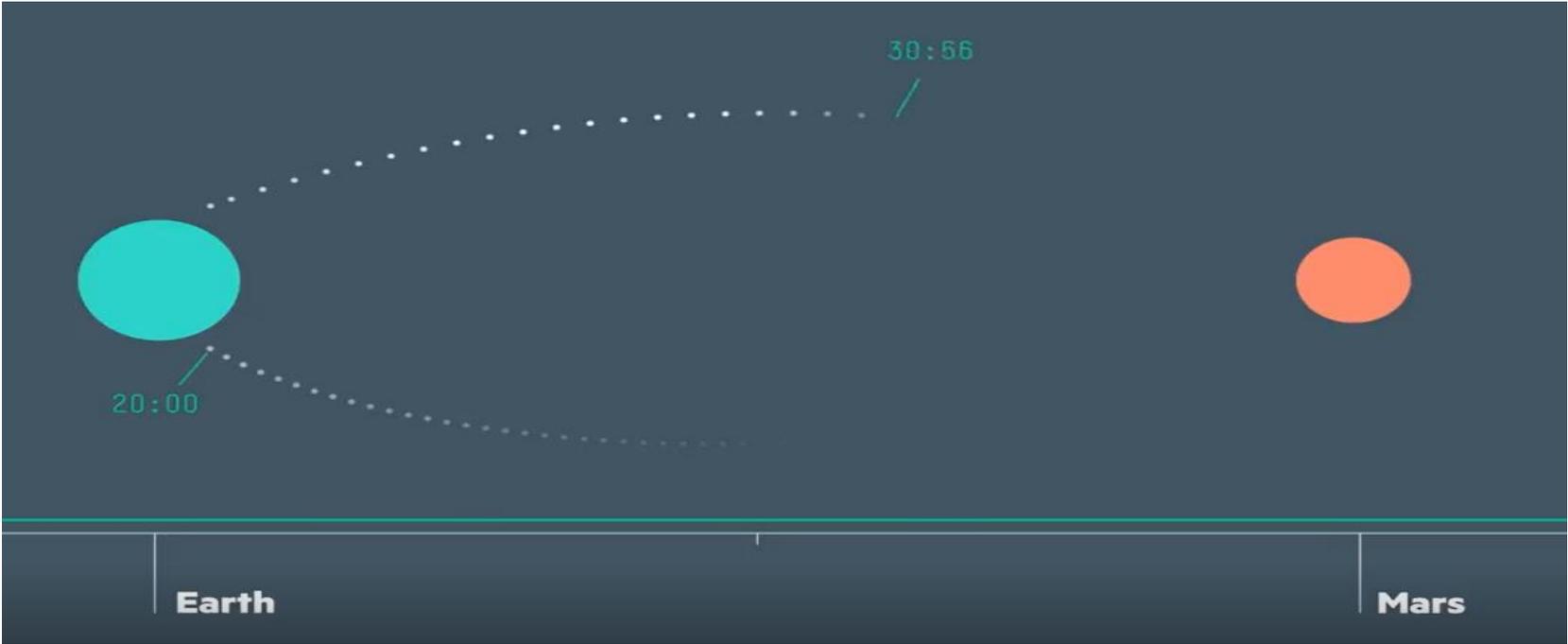
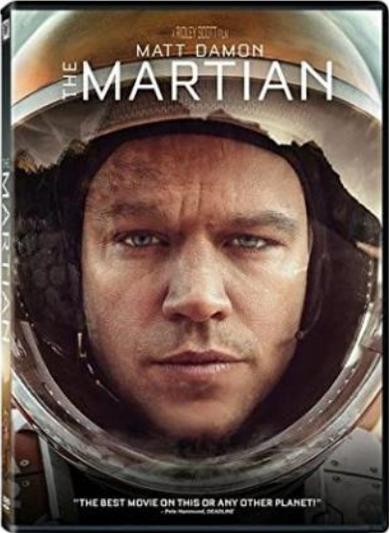
0:48: **“This is Houston. Say again, please.”**



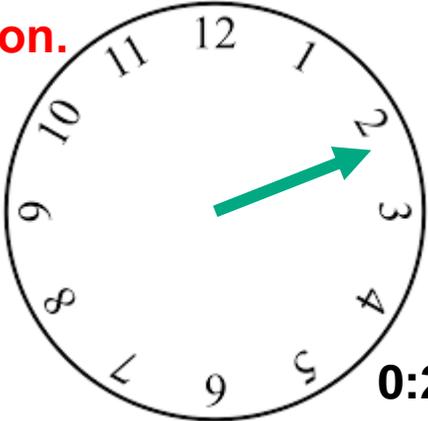
0:24: **“Okay, Houston, we’ve had a problem here.”**



Spaceborne Computer: Objective / Mission: Why?



0:48: **“This is Houston. Say again, please.”**



1:12: **“Houston, we’ve had a problem.”**

0:24: **“Okay, Houston, we’ve had a problem here.”**



Spaceborne Computer: Objective / Mission

Run **a year long experiment** on the ISS to verify
if a high performance commercial off-the-shelf computer system – **COTS HPC** –
can still **operate correctly**.

... and to capture the parameters under which this occurs.

ISS : “... investigate human exploration *beyond Low Earth Orbit (LEO).*”





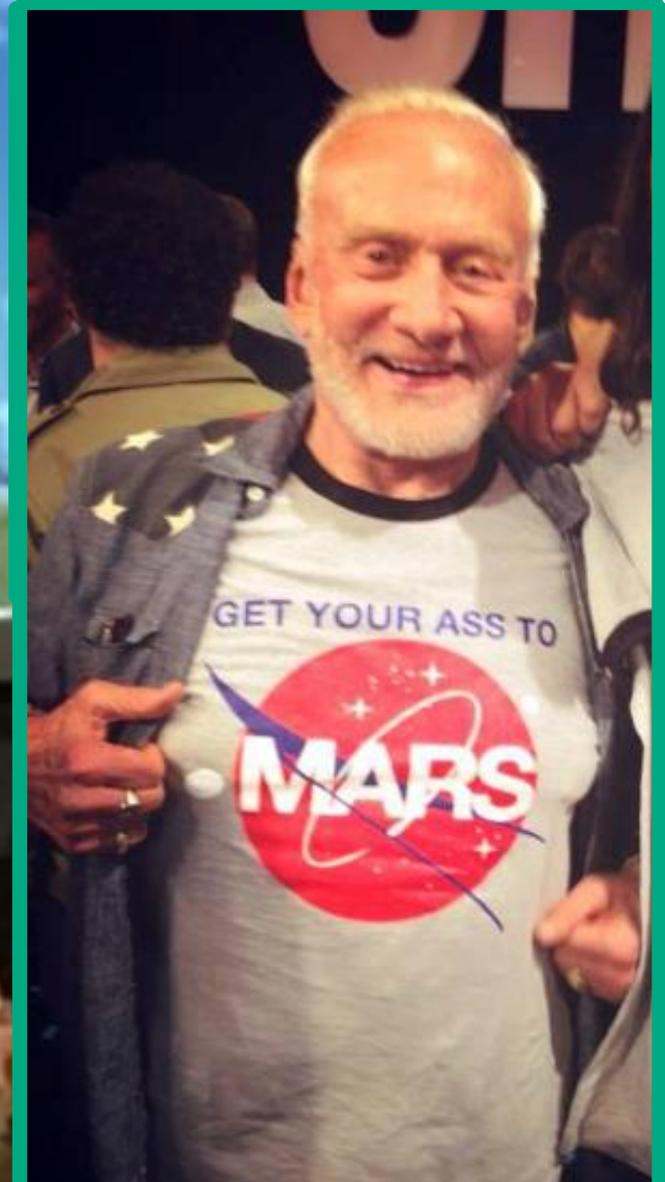
Spaceborne Computer (SBC): Buzz Aldrin Talk Before Launch



Spaceborne Computer (SBC): Buzz Aldrin Talk Before Launch



Spaceborne Computer (SBC): Buzz Aldrin Talk Before Launch



SBC: SpaceX-12 Launch!

Monday, 14-Aug-2017 @ 12:31 p.m. EDT



SBC: SpaceX-12 Launch!

Monday, 14-Aug-2017 @ 12:31 p.m. EDT

_____ And Landing!!!

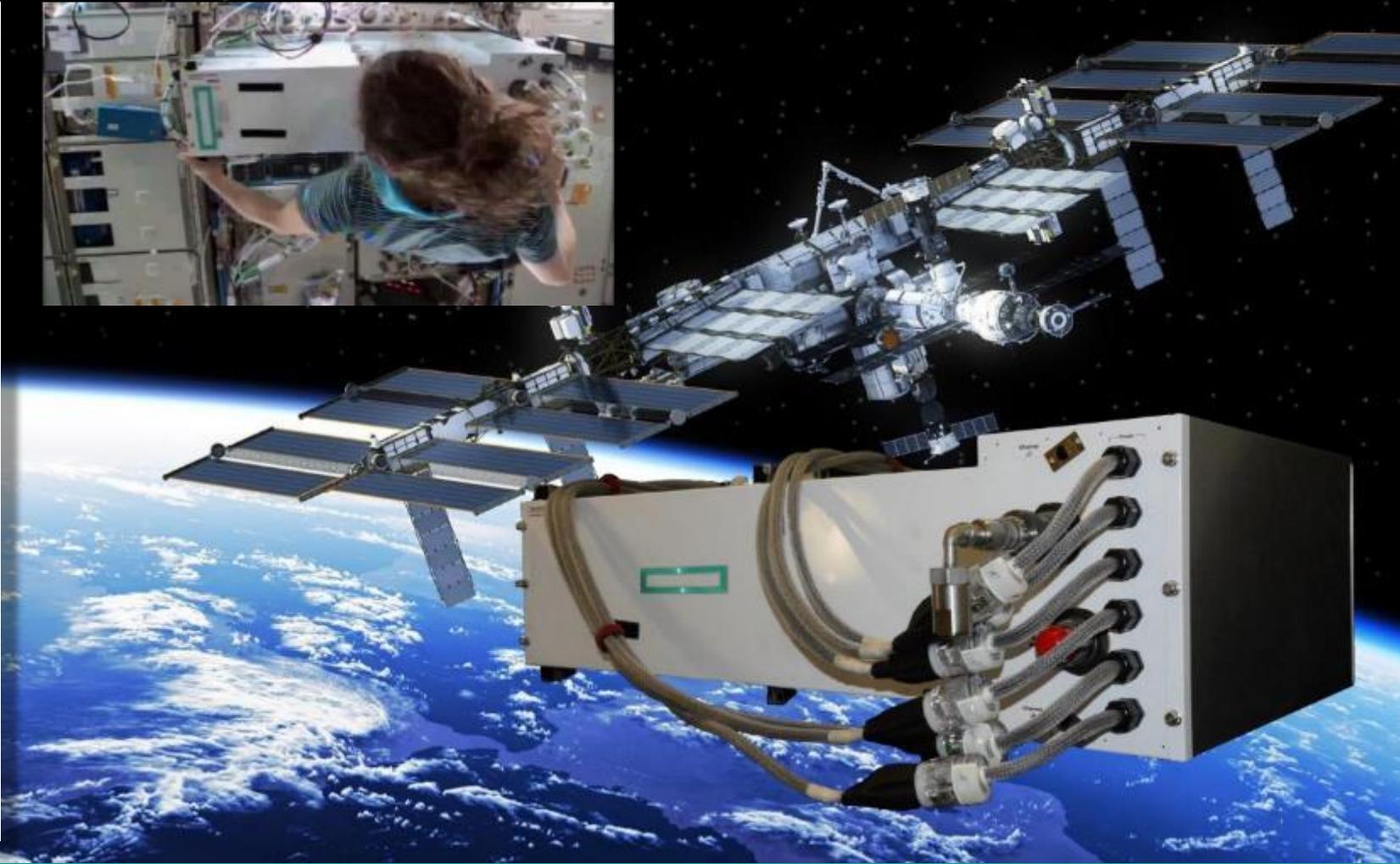
Monday, 14-Aug-2017 @ 12:39 p.m. EDT



Spaceborne Computer: The Dawn of HPC And AI Above the Clouds

SBC-1: Launched on SpaceX CRS-12 on 08/14/2017 -- Flown for 1.8 years
9,562 orbits -- 6,879 SAA Passes -- 53,936 Experiments Completed -- All Successful

First COTS HPC System in Space (1.1TF HPL)



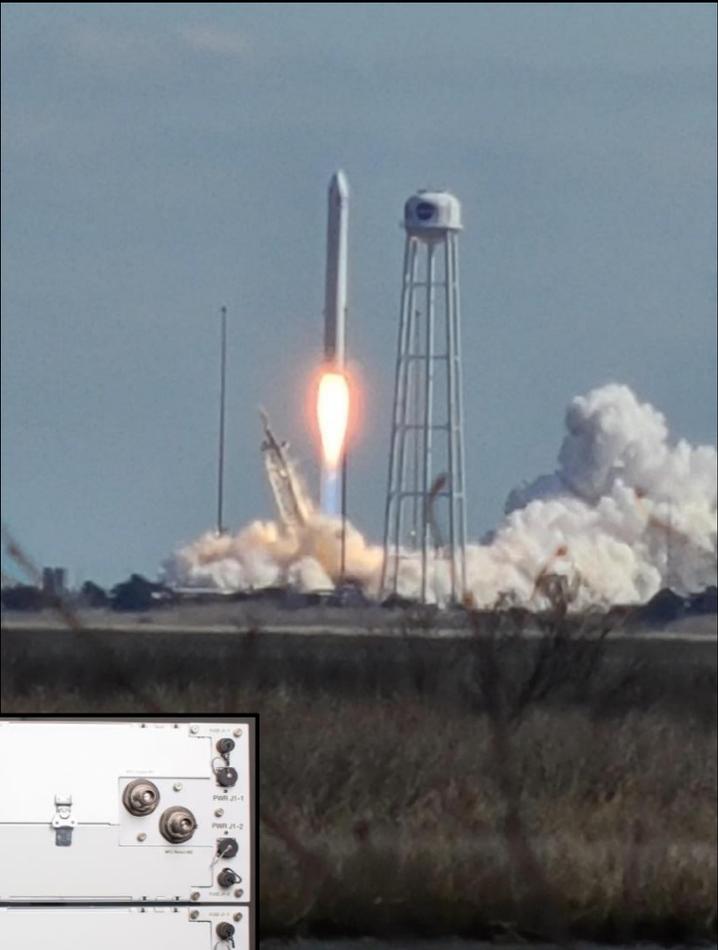
Next Mission: Spaceborne Computer-2

Launched: 20-Feb-2021, Northrop Grumman Resupply Mission to the ISS (NG-15)



Spaceborne Computer-2

Launched: 20-Feb-2021 (aboard the NG-15 SS Katherine Johnson)



Spaceborne Computer-2

Installed: 29-Apr-2021 (in the “overhead” of the Columbus Module)



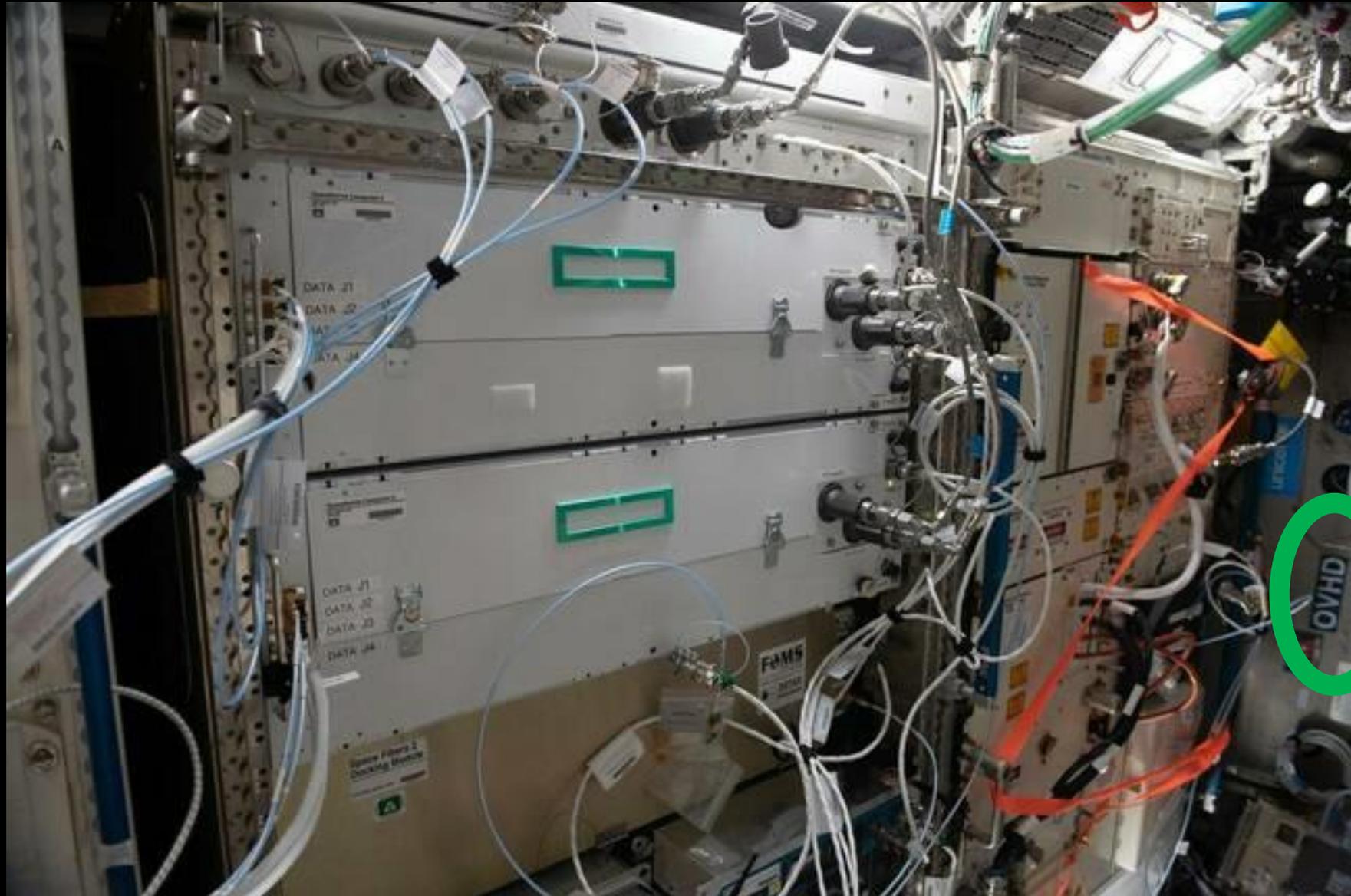
Spaceborne Computer-2

Installed: 29-Apr-2021 (in the “overhead” of the Columbus Module)



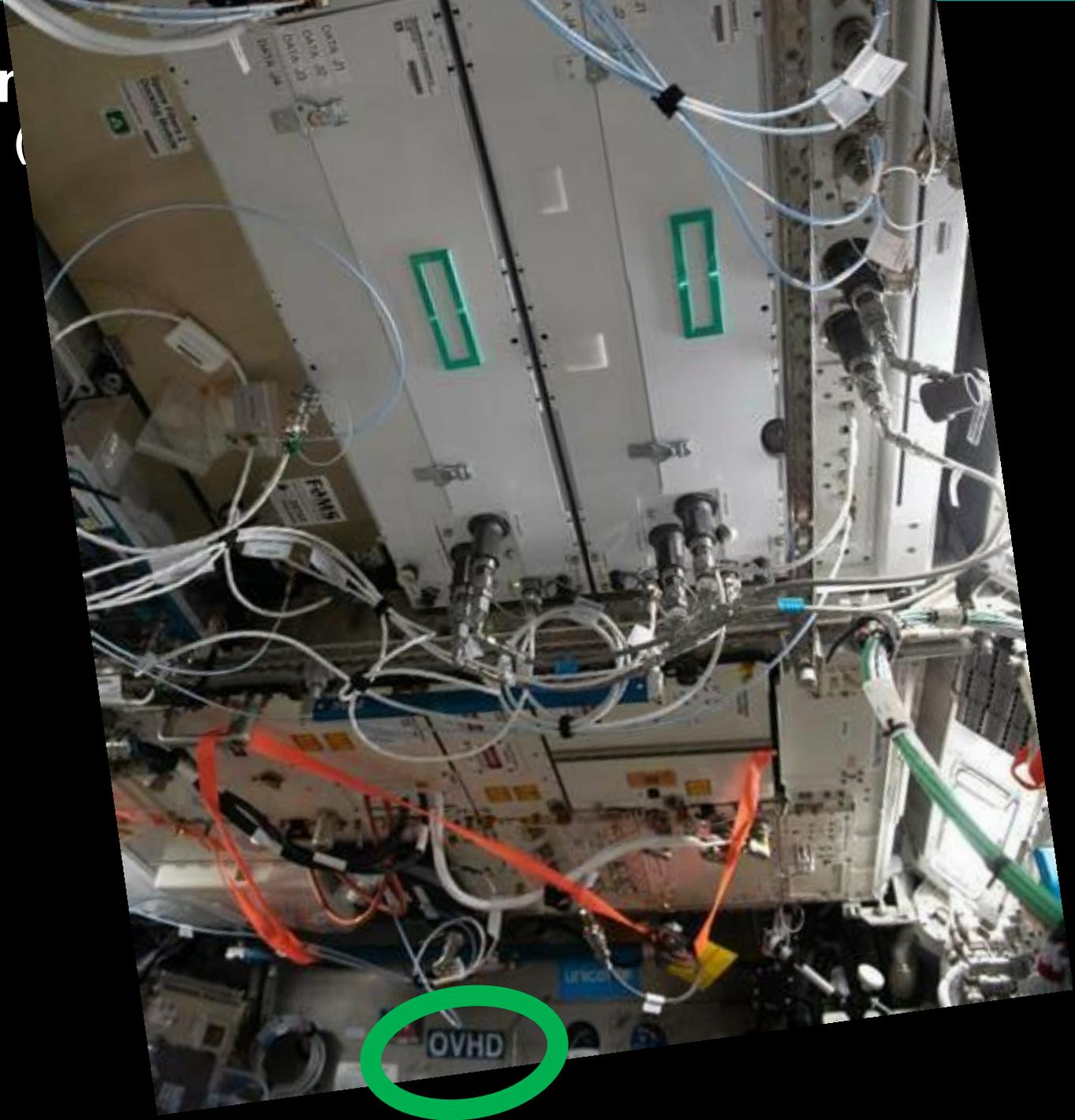
Spaceborne Computer-2

Installed: 29-Apr-2021 (in the “overhead” of the Columbus Module)



Spaceborne Cor

Installed: 29-Apr-2021 (



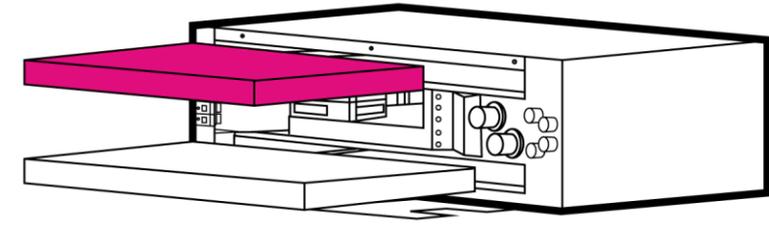


Spaceborne Computer-2: Hardware & Software



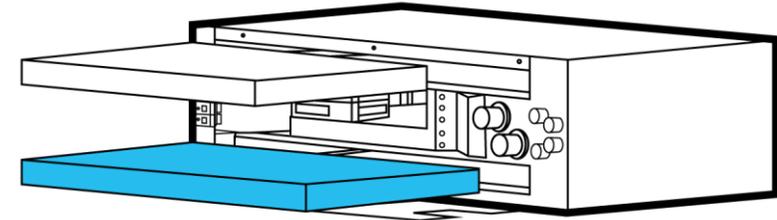
Hardware: HPE Edgeline EL4000
(edge-focused single socket with a single GPU)

- 1 x low wattage x86
- 1 x low wattage GPU
- 64 GB of memory total
- ➔ • **4 x 240GB solid state drives**
- 1 x 10GbE Ethernet adapter



Hardware: HPE DL360 Gen10 server
(traditional 2-socket HPC compute node)

- 2 x low wattage x86 processors
- 192 GB of memory total
- ➔ • **8 x 240GB solid state drives**
- 1 x 10Gb Ethernet Adapter



Software: Red Hat 7.8 Operating System
NASA TReK 5.3.1

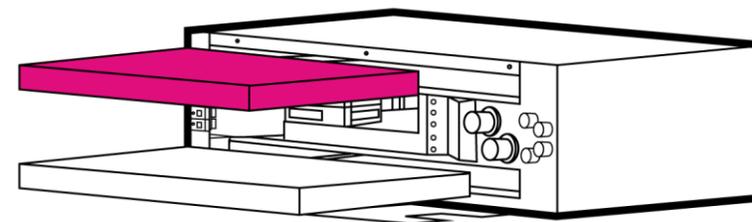
- * Powered from 28Vdc
- * Cooled by AAA & MTL

Spaceborne Computer-2: Hardware & Software Refresh



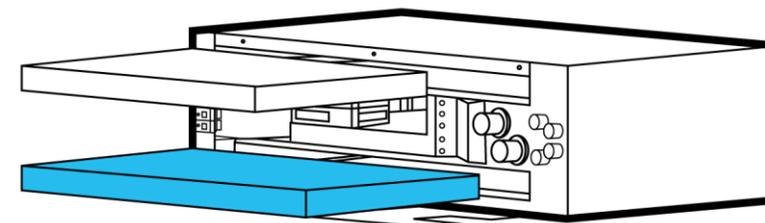
Hardware: HPE Edgeline EL4000
(edge-focused single socket with a single GPU)

- 1 x low wattage x86
- 1 x low wattage GPU
- 64 GB of memory total
- ➔ • **4 x 1024 GB KIOXIA XG6 M.2 SSDs**
- 1 x 10GbE Ethernet adapter



Hardware: HPE DL360 Gen10 server
(traditional 2-socket HPC compute node)

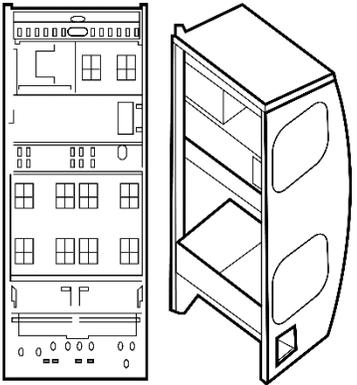
- 2 x low wattage x86 processors
- 192 GB of memory total
- ➔ • **8 x 960 GB KIOXIA RM6 2.5" SSDs**
- 1 x 10Gb Ethernet Adapter



Software: Red Hat 7.8 Operating System
NASA TReK 5.3.1

- * Powered from 28Vdc
- * Cooled by AAA & MTL

Spaceborne: Demonstrating the Value of Edge Storage & Computing

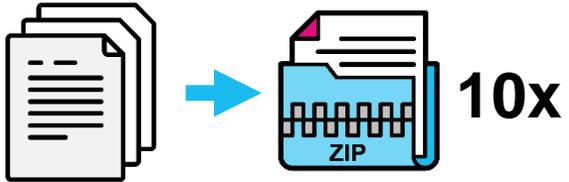
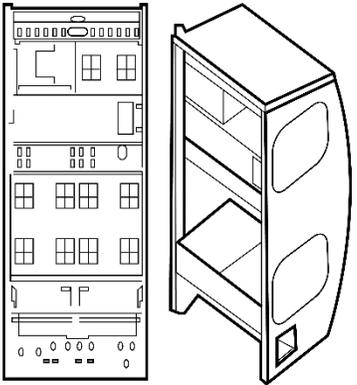


1,873,704 KB
(1.8 GB)
12.2 hours



Proven in Space – Available on Earth™

Spaceborne: Demonstrating the Value of Edge Storage & Computing

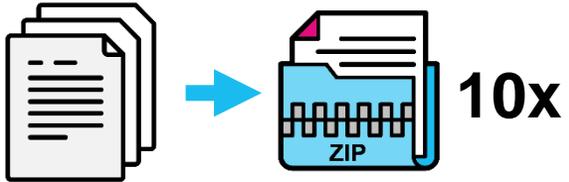
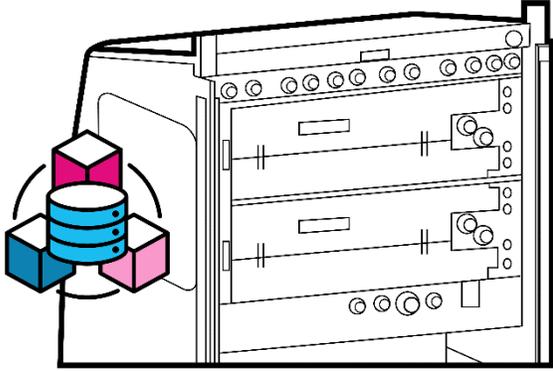
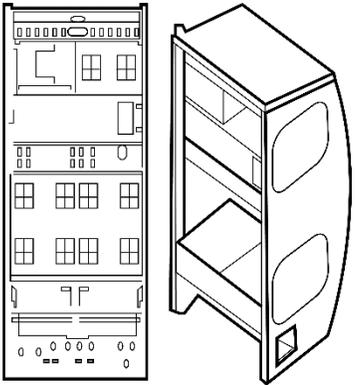


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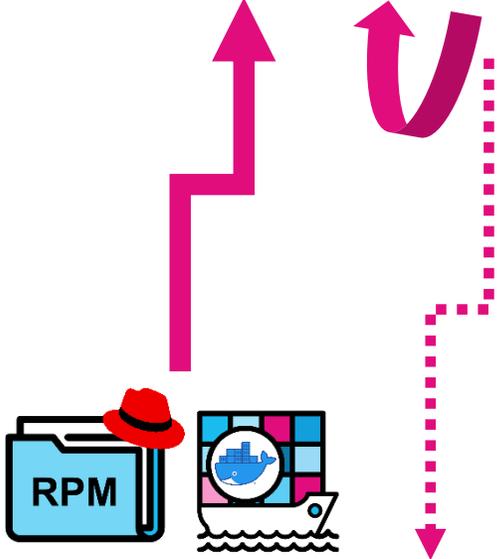


Proven in Space – Available on Earth™

Spaceborne: Demonstrating the Value of Edge Storage & Computing

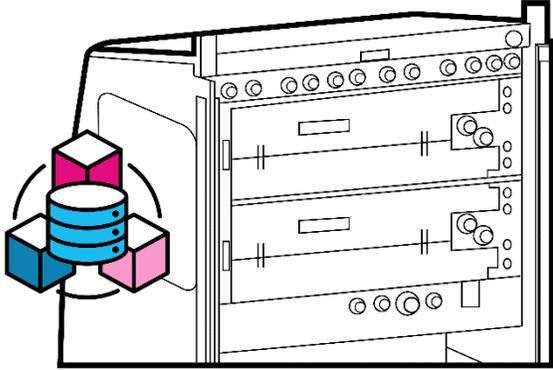
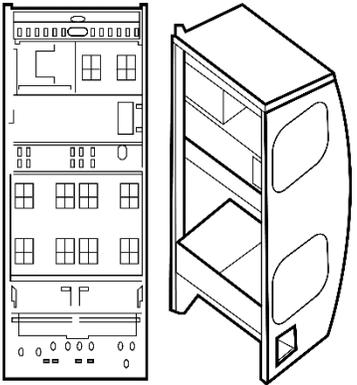


**1,873,704 KB
(1.8 GB)
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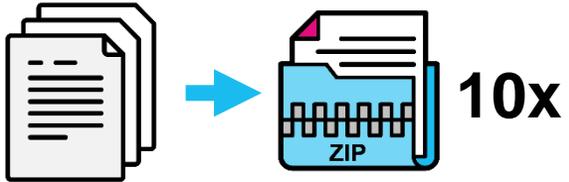


Proven in Space – Available on Earth™

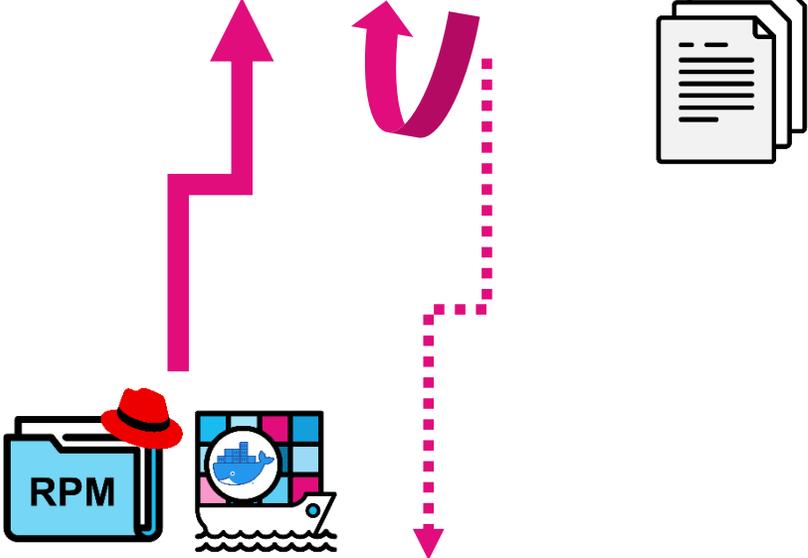
Spaceborne: Demonstrating the Value of Edge Storage & Computing



~6 minutes of Hybrid CPU/GPU processing

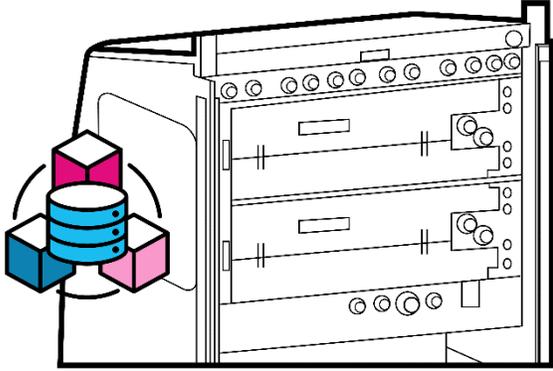
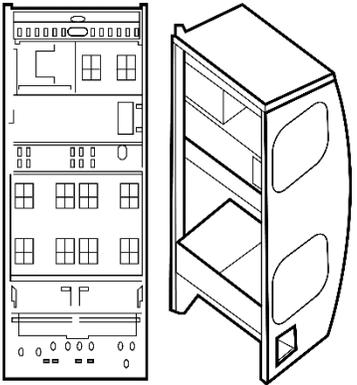


**1,873,704 KB
(1.8 GB)
12.2 hours**

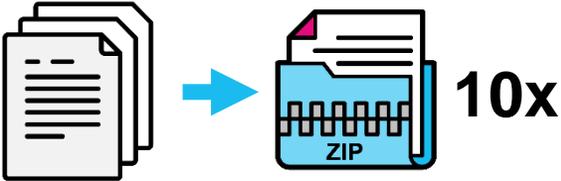


Proven in Space – Available on Earth™

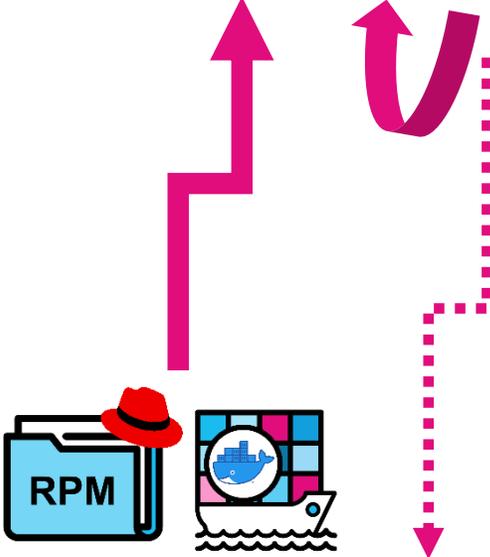
Spaceborne: Demonstrating the Value of Edge Storage & Computing



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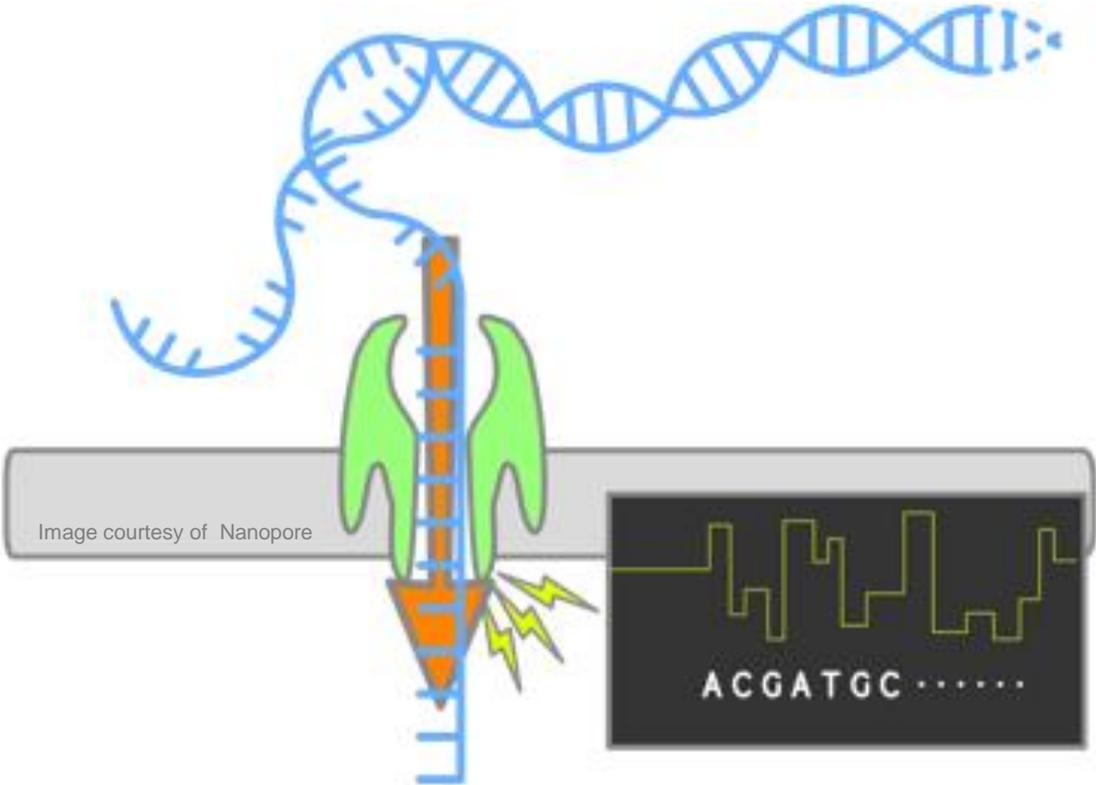
1,873,704 KB
(1.8 GB)
12.2 hours



92 KB
20,000x reduction
2 seconds!

Proven in Space – Available on Earth™

Spaceborne Computer: Mission Success – Life Sciences / Healthcare



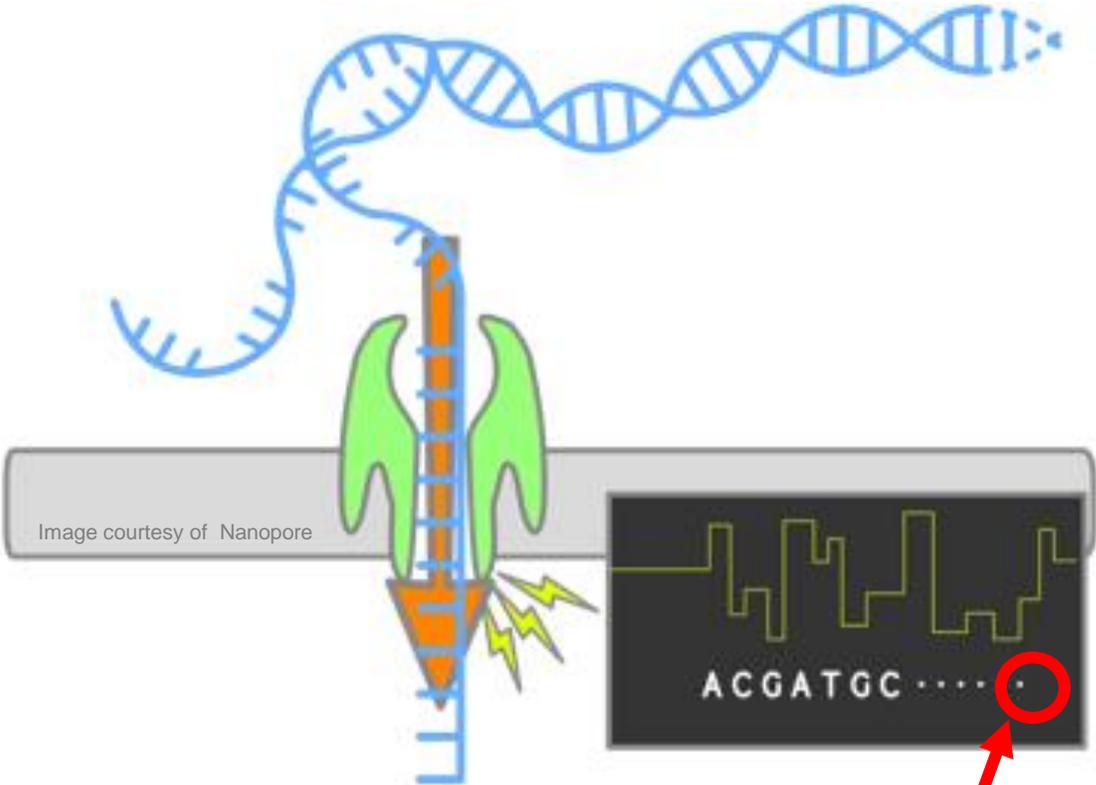
DNA Sequencer onboard the ISS

DNA Sequences are **LARGE**

Today: “about a month to get the data”

Mutations are hopefully non-existent or tiny

Spaceborne Computer: Mission Success – Life Sciences / Healthcare



DNA Sequencer onboard the ISS

DNA Sequences are **LARGE**

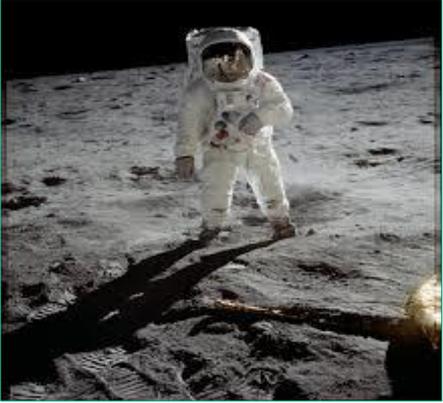
Today: “about a month to get the data”

Mutations are hopefully non-existent or tiny

Mutation

Spaceborne: Demonstrating the Value of Edge Storage & Computing

... Proven 99+% reduction



Today:

- 1 Sample. 1 Month

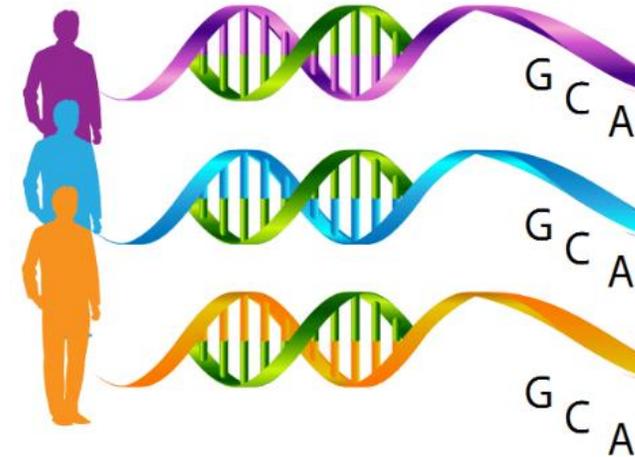


Image courtesy of NASA



With Spaceborne:

- Multiple Samples
- ... in minutes
- Months to minutes



Proven in Space – Available on Earth™



Image courtesy of NASA



Image courtesy of NASA



Image courtesy of NASA



Image courtesy of NASA

Do you want to reduce the size of the images on this message?



Reduce image size



Keep original size



Do you want to reduce the size of the images on this message?

-  Reduce image size
-  Keep original size

Edge Storage & Computing

Image Processing
Feature Extraction
AI / ML

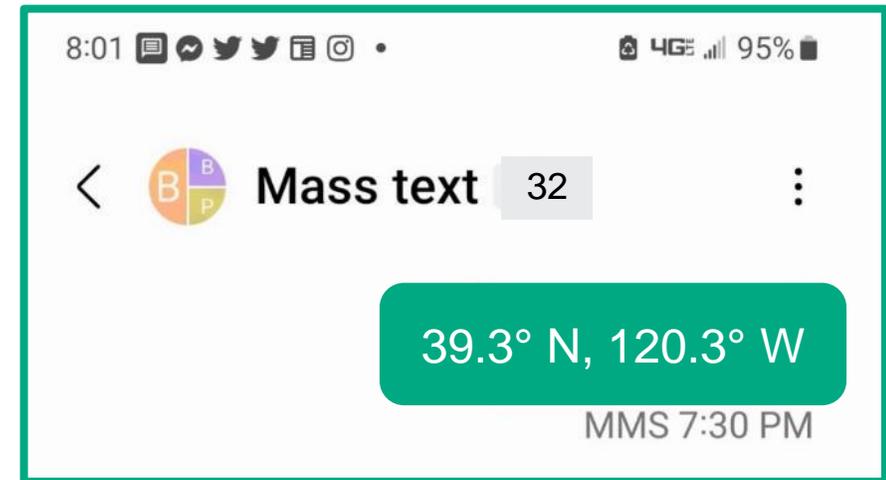




Image courtesy of NASA



Image courtesy of NASA



Image courtesy of SKY News

Do you want to reduce the size of the images on this message?



Reduce image size



Keep original size

Edge Storage & Computing



Image Processing
Feature Extraction
AI / ML

8:01 [message icon] [social icons] [signal strength] 4G [battery icon] 95%



Mass text

32



39.3° N, 120.3° W

MMS 7:30 PM



Do you want to reduce the size of the images on this message?



Reduce image size



Keep original size

Edge Storage & Computing

Image Processing
Feature Extraction
AI / ML

8:01 [message icon] [social icons] 4G [signal strength] 95% [battery icon]

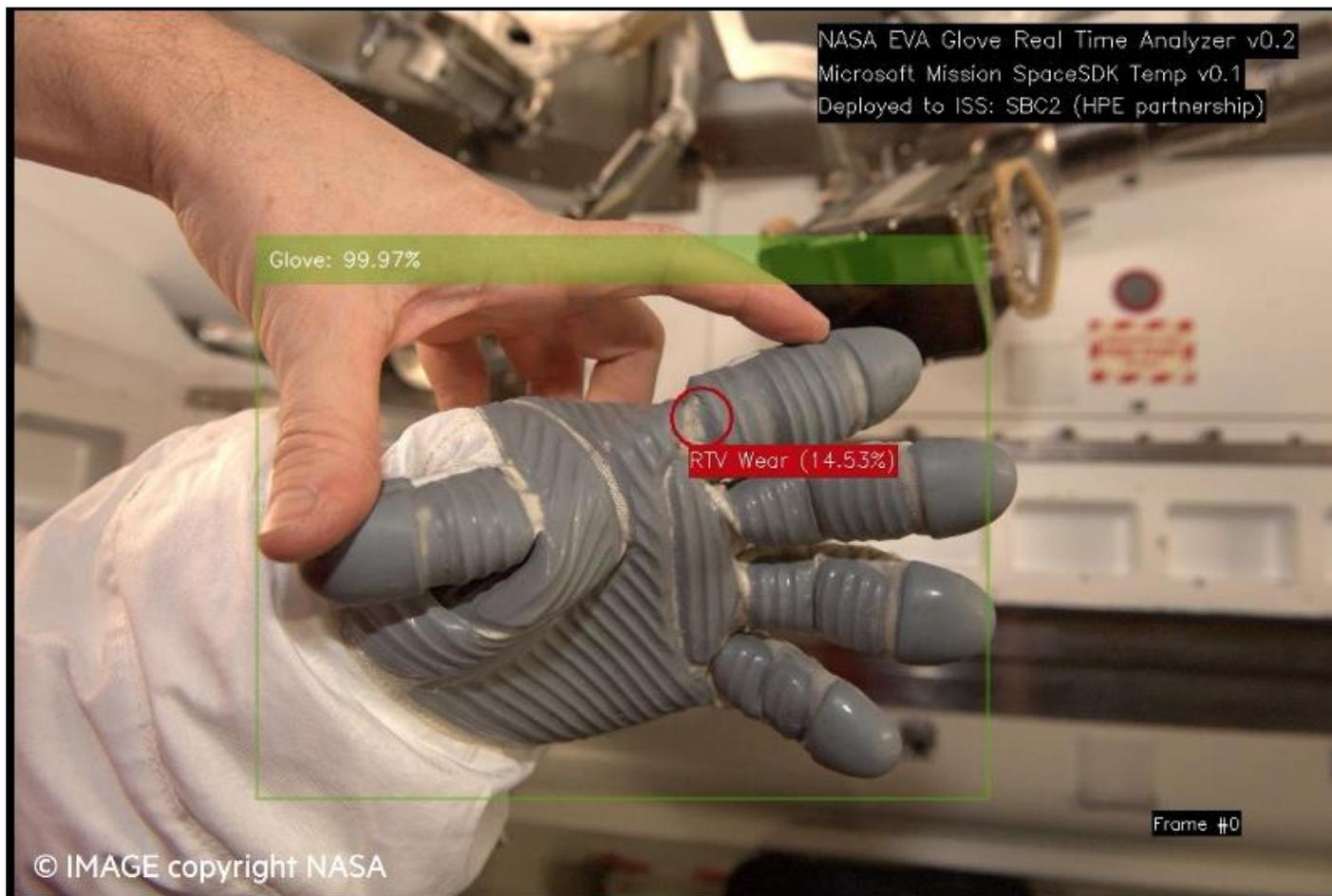
< [B P logo] Mass text 32 [three dots menu]

39.3° N, 120.3° W

MMS 7:30 PM

Spaceborne: Demonstrating the Value of Edge Storage & Computing

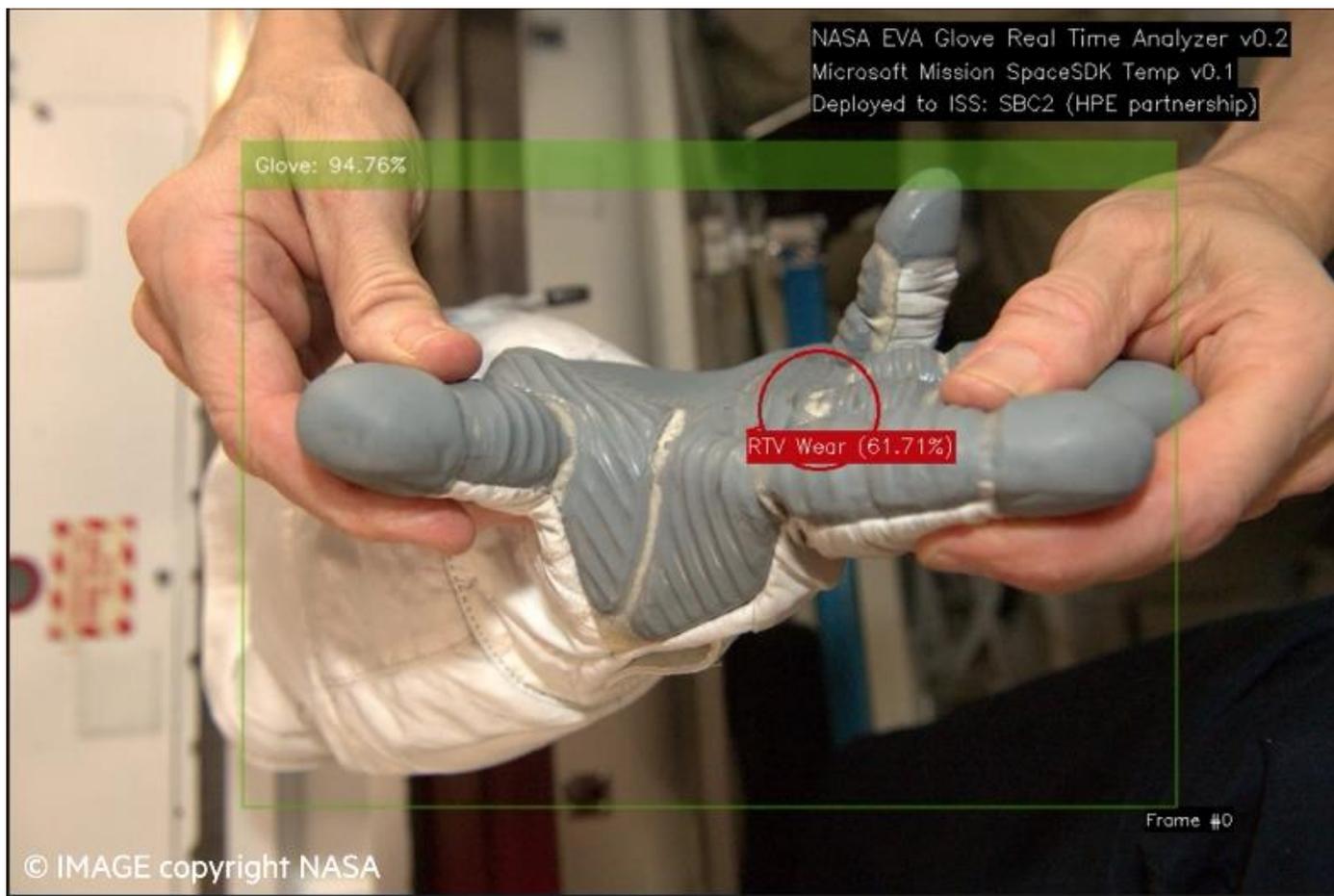
Proven Examples Since the Initial 20,000X Improvement...



Proven in Space – Available on Earth™

Spaceborne: Demonstrating the Value of Edge Storage & Computing

Proven Examples Since the Initial 20,000X Improvement...

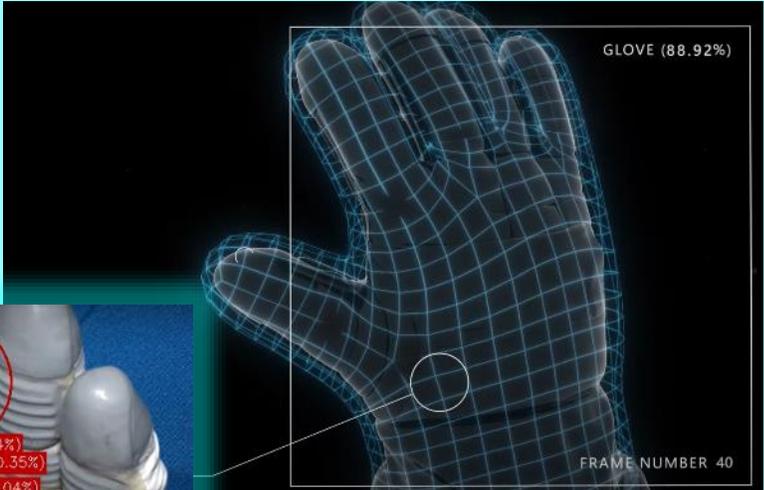


Proven in Space – Available on Earth™

Spaceborne Computer: Mission Success – QA / QC & Safety

24+ Experiments conducted on station thus far in partnership with the international scientific community

An example: AI & ML ‘Glove’ experiment conducted with HPE, Microsoft, NASA – winner NASA 2022 Team Flight Award



Spaceborne: Demonstrating the Value of Edge Storage & Computing

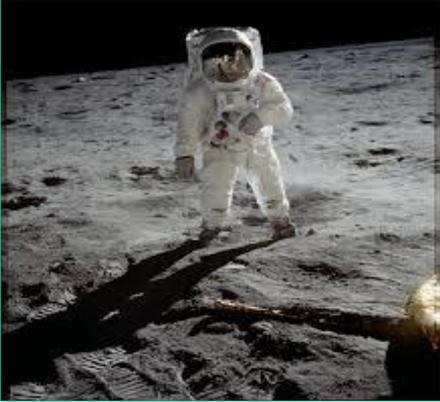
The EVA Glove Inspection process is traditionally performed by a group of individuals and **requires multiple days** to analyze data and develop a recommendation. While on the ISS, the AI/ML model was able to perform and generate a recommendation **in less than 45 seconds**, validating how AI/ML technology can benefit human space flight.



Proven in Space – Available on Earth™

Spaceborne: Demonstrating the Value of Edge Storage & Computing

... Proven 99+% reduction



Today:

- 1 Astronaut. 1 EVA
- ... **multiple days of downtime**

With Spaceborne:

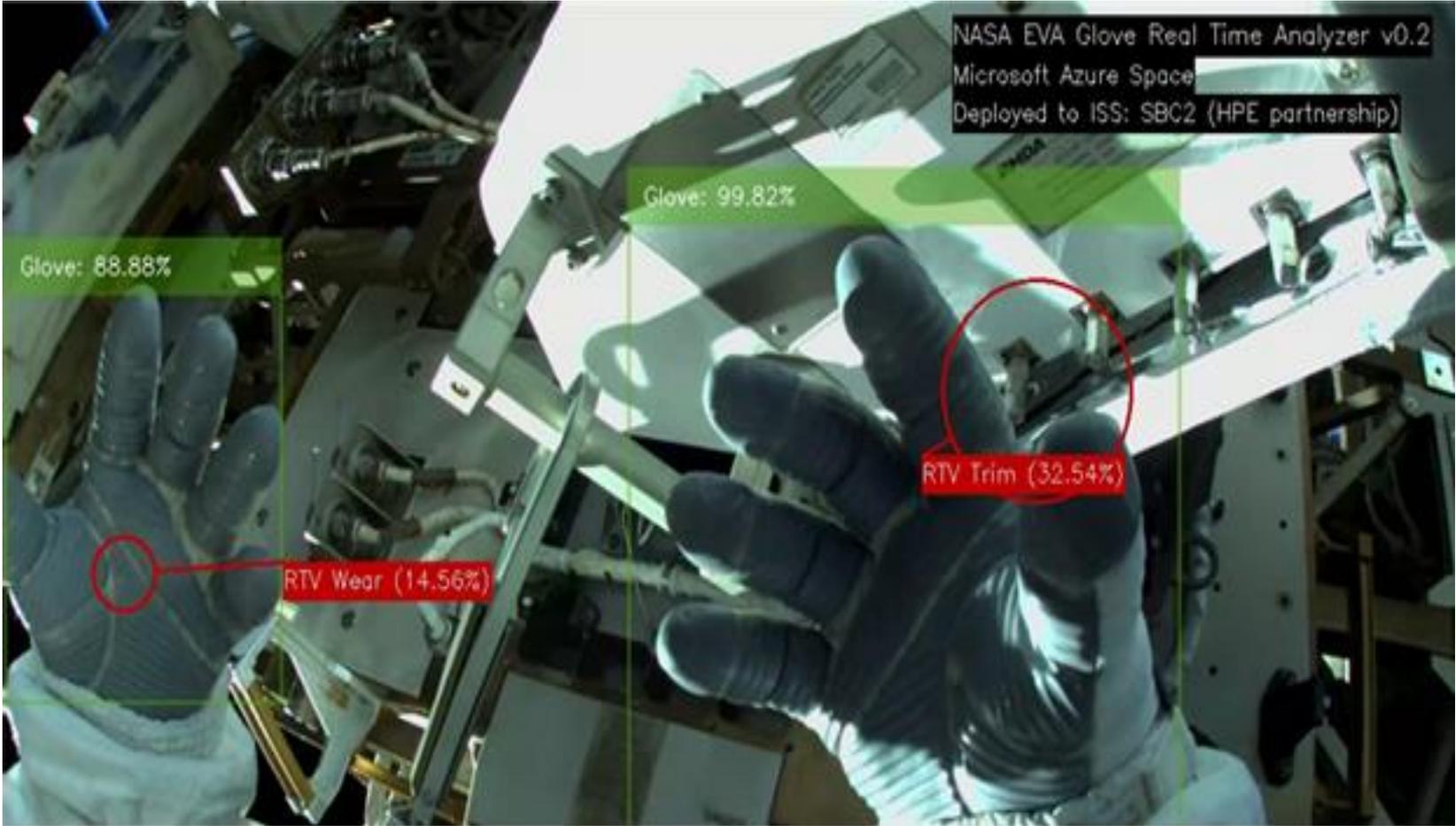
- Multiple Astronauts
- ... **0 days of downtime**
- ... 5 day work week



Proven in Space – Available on Earth™

Spaceborne: Demonstrating the Value of Edge Storage & Computing

... Proven Examples Since the Initial 20,000X Improvement



Proven in Space – Available on Earth™

Spaceborne: Demonstrating the Value of Edge Storage & Computing

SBC-2 ISS Projects		Traditional Collect & Forward		SBC-2 Edge Storage & Computing		
Vertical	Edge Technologies	Raw Data Size	Original Download Time	SBC-2 Download Time	Output / "Insight" Size	Download Size Improvement
Life Sciences	GPU-enabled	2.8 GB 2,816,431 KB	"about 18 hours"	~2 secs	92 KB	30,000X
Life Sciences	Hybrid CPU-GPU multistep workflow	22 GB 22,702,059 KB	"days to weeks"	~11 secs	235 KB	93,000X
Image Processing QA/QC	GPU-enabled AI/ML model	899 MB 898,896 KB	"about a day"	<1 sec	5 KB	179,000X
Image Processing Feature Extraction	AI/ML model	299 Photos 5.5GB of .NEF	"about 6 hours"	~7 minutes	100 MB	98% Reduction
Feature Extraction	Docker Containers (updates)	5GB image (tar.gz)	383 min. (over 6 hours)	~2 secs (upload)	50 KB "patch" (upload)	99% Reduction (upload)

Proven in Space – Available on Earth™

Spaceborne: Demonstrating the Value of Edge Storage & Computing

... requires Data Generated at the Edge to be Stored at the Edge

KIOXIA

Storage Solutions from
the Edge to the Cloud

- ✓ Completed FA on SBC-1 SSDs
- ✓ Design Assistance for Future Missions
- ✓ New SSDs in SBC-2 Locker-1!!!

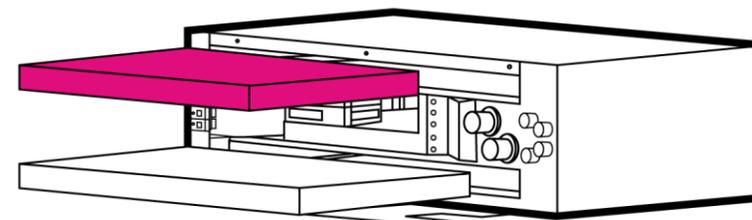
Proven in Space – Available on Earth™

Spaceborne Computer-2: Hardware & Software Refresh



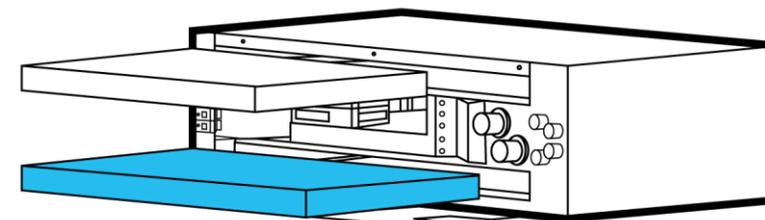
Hardware: HPE Edgeline EL4000
(edge-focused single socket with a single GPU)

- 1 x low wattage x86
- 1 x low wattage GPU
- 64 GB of memory total
- ➔ • **4 x 1024 GB KIOXIA XG6 M.2 SSDs**
- 1 x 10GbE Ethernet adapter



Hardware: HPE DL360 Gen10 server
(traditional 2-socket HPC compute node)

- 2 x low wattage x86 processors
- 192 GB of memory total
- ➔ • **8 x 960 GB KIOXIA RM6 2.5" SSDs**
- 1 x 10Gb Ethernet Adapter



Software: Red Hat 7.8 Operating System
NASA TReK 5.3.1

- * Powered from 28Vdc
- * Cooled by AAA & MTL

Spaceborne Computer-2: Hardware & Software Refresh !



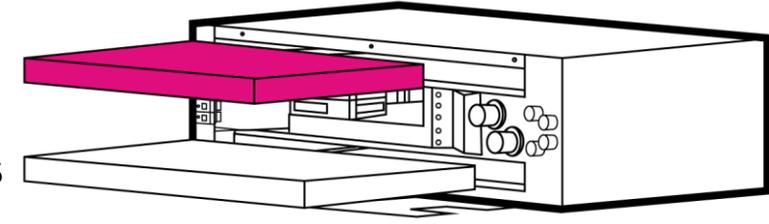
Hardware: HPE Edgeline EL4000
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- 1 x low wattage x86
- 1 x low wattage GPU
- 64 GB of memory total
- ➔ • **4 x 1024 GB KIOXIA XG6 M.2 SSDs**
- 1 x 10GbE Ethernet adapter

Hardware: HPE DL360 Gen10 server
(traditional 2-socket HPC compute node)

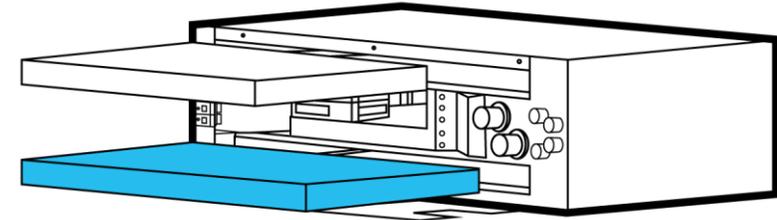
- 2 x low wattage x86 processors
- 192 GB of memory total
- ➔ • **4 x 960 GB KIOXIA RM6 2.5" SSDs**
- ➔ • **4 x 30.72 TB KIOXIA PM6 2.5" SSDs**
- 1 x 10Gb Ethernet Adapter

* Software: Red Hat 7.8 Operating System
NASA TReK 5.3.1



Upgraded with:

- **4 x KIOXIA PM6
30.72 TB SSDs**
- **> 120TB storage**



* Powered from 28Vdc
* Cooled by AAA & MTL

Spaceborne: Demonstrating the Value of Edge Storage & Computing

... requires Data Generated at the Edge to be Stored at the Edge



The banner features a dark space background on the left and a teal geometric pattern on the right. The ISSSRDC logo, a colorful hexagon, is positioned on the left. The text 'ISSSRDC' is written in large white letters. Below the logo are the ISS National Laboratory, NASA, and American Astronautical Society logos. The right side of the banner contains the event details: 'SAVE THE DATE', 'July 31 - August 3, 2023', and 'Seattle, WA | Hyatt Regency Seattle'.

ISSSRDC

SAVE THE DATE

July 31 - August 3, 2023

Seattle, WA | Hyatt Regency Seattle

ISS NATIONAL LABORATORY

NASA

American Astronautical Society

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Nanopore Sequencing in Space: The Advancement of *In Situ* Microbiome Analysis for the International Space Station and Beyond

Christian Mena, M.S.
JES Tech.
NASA Johnson Space Center Microbiology Laboratory
christian.g.mena@nasa.gov



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BioMole: Onboard Data Analysis

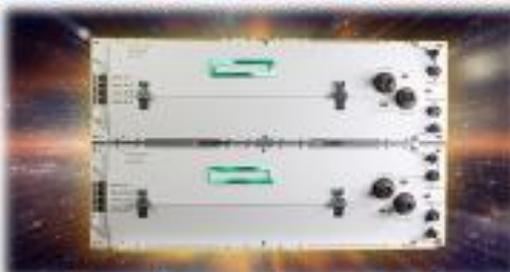


- Collaboration with HPE, IBM, and ISSNL
- Utilize the IBM Open Data and AI Edge software platform on Spaceborne Computer-2 (SBC-2)
- Results perfectly paralleled the downlinked data analyzed on the ground
- 24 hours from swabbing to final data (as the data is not processed in real-time by the SSC)
- Sample-to-answer is possible, reducing the time from sample collection to result from weeks/months to 24 hours

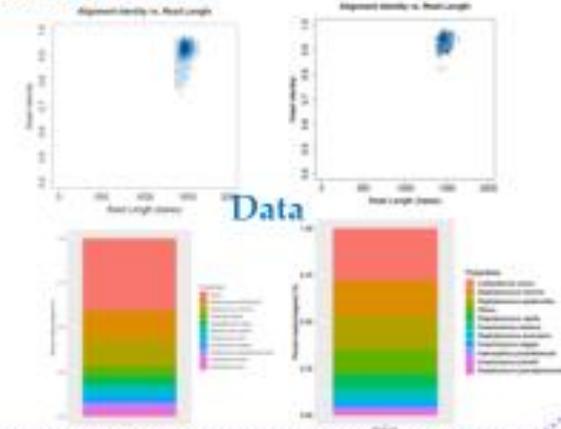
First Sample-to-Answer Microbial Identification onboard the ISS



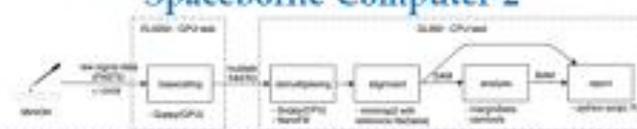
Space Station Computer



Spaceborne Computer-2



Data



```
graph LR; Sample[Sample] --> Sequencing[Sequencing]; Sequencing --> Assembly[Assembly]; Assembly --> Alignment[Alignment]; Alignment --> Analysis[Analysis]; Analysis --> Report[Report];
```

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First Sample-to-Answer Microbial Identification onboard the ISS

The image displays a workflow for microbial identification. It starts with a 'Space Station Computer' (laptop) on the left. In the center is the 'Spaceborne Computer-2' hardware rack. Below it is a flowchart showing the process: 'Sample' -> 'Preprocessing' -> 'Analysis' -> 'Data' -> 'Results'. The 'Data' section shows two heatmaps and two bar charts, with a legend on the right. The number '14' is in the bottom right corner of the slide.

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First Sample-to-Answer Microbial Identification onboard the ISS

The image displays a 'Space Station Computer' (laptop) on the left, a 'Spaceborne Computer-2' hardware rack in the center, and a data analysis interface on the right. The interface includes two heatmaps labeled 'Data' and a flowchart below them. The flowchart shows a process from 'Sample' to 'Analysis' and 'Report'. The heatmaps show 'Approximate number of Reads' vs 'Read Length (bases)' for 'Data' and 'Reference'.

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The Abstract/Bio:

... at the forefront of developing and implementing molecular methods to allow for **in situ** microbiome **analysis**. These ISS-based methods have **changed the** sample return **paradigm** associated with spaceflight.



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KIOXIA

Thank you!

Inquiries to:

mark.r.fernandez@hpe.com

spaceborne@hpe.com

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HPE SBC-2 TeamOfSeven++

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9. Norm Follett, Marketing
10. Nahren Khizeran, Communications
11. Eng Lim Goh, PI SBC