

The background of the slide is a composite image. The top half shows a close-up of the Moon's cratered surface against a dark blue space background with a few stars. The bottom half shows a large space station with multiple solar panel arrays in orbit above the Earth's blue and white horizon. A smaller satellite is also visible in the distance.

RAPID INNOVATION & OPERATIONALIZATION

THE PRAGMATICS

PRESENTER: DR. STEVE CHAN

BRIEF ABSTRACT:

THE ADVENT OF THE ARTIFICIAL INTELLIGENCE (AI) ERA HAS INDUCED CONTINUAL CYCLES OF ADAPTATION IN A NUMBER OF DOMAINS — CYBER, SOFTWARE DEVELOPMENT, ETC. THE OPERATIONAL TEMPO IS SO FRENETIC THAT ONE OF THE PREVAILING MANTRAS FOR TECHNOLOGY FIRMS IN THE AI SECTOR HAS CENTERED UPON THE NOTION THAT “THE RISK OF UNDERSPENDING IS FAR GREATER THAN THE RISK OF OVERSPENDING” (E.G., DUE TO COMPETITIVE DYNAMICS, AI TALENT SHORTAGE, ETC.). THE CURRENT RACE FOR FRONTIER MODEL DEVELOPMENT CAN, FOR SOME FACETS, BE COMPARED TO THE SPACE RACE. PERTINENT HISTORICAL CASE STUDIES WILL BE REVIEWED, AND IT TURNS OUT THAT “RAPID INNOVATION & OPERATIONALIZATION” IS A COMMON THEMATIC AT THE FRONTIER AND INFRASTRUCTURAL LEVELS.

BRIEF BIO:

DR. STEVE CHAN IS AN INVENTOR WITH 14 GRANTED INTERNATIONAL AND U.S. PATENTS. HE IS THE AUTHOR OF 92 PEER-REVIEWED BOOK CHAPTERS, JOURNAL ARTICLES, AND CONFERENCE PAPERS, WHICH INCLUDE 38 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE) PAPERS. FOR 65 OF THE REFEREED PUBLICATIONS, HE WAS FIRST AUTHOR, AND 21 OF THESE RECEIVED BEST PAPER/BEST PRESENTATION. OVER THE YEARS, HE HAS SERVED AS A REVIEWER FOR 51 PEER-REVIEWED PUBLICATIONS, WHICH INCLUDE 10 IEEE/IET JOURNALS AND 7 IEEE CONFERENCE PROCEEDINGS. HE HAS ALSO SERVED AS CHIEF SCIENTIST/PRINCIPAL INVESTIGATOR FOR DOZENS OF GOVERNMENTAL/INTERGOVERNMENTAL REPORTS (E.G., U.S. GOVERNMENT, ASEAN MEMBER STATES, UNITED NATIONS).

SPACE PEN HISTORY

The background of the slide is a composite image. The top half shows a view of the Earth from space, with a large, cratered Moon in the upper left. The bottom half shows a large space station, likely the International Space Station, in orbit over the Earth's cloud-covered surface. The station's complex structure, including multiple modules and large solar panel arrays, is clearly visible. The Earth's horizon is a bright blue curve across the middle of the image.

NASA INVESTED MILLIONS OF TAXPAYER DOLLARS DOLLARS IN RESEARCH AND DEVELOPMENT TO CREATE A STATE-OF-THE-ART WRITING TOOL TO WITHSTAND THE HARSH CONDITIONS OF SPACE EXPLORATION

SOVIET SPACE PROGRAM RIVAL COUNTERPART
SAVED MONEY BY USING ALTERNATIVE TECHNOLOGY - A PENCIL

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SOVIET

RIVAL COUNTERPARTS SAVED MONEY BY USING ALTERNATIVE TECHNOLOGY - A PENCIL

URBAN MYTH

SPACE PEN HISTORY: **FACT**

FISHER (PAUL C. FISHER) AND HIS COMPANY, THE FISHER PEN COMPANY, REPORTEDLY INVESTED \$1 MILLION TO DEVELOP WHAT IS NOW COMMONLY KNOWN AS THE SPACE PEN. NONE OF THAT FUNDING CAME FROM NASA.

SOURCE: FISHER PEN COMPANY; NASA



▲ U.S. ASTRONAUT WALTER CUNNINGHAM WRITES WITH A FISHER SPACE PEN DURING THE FLIGHT OF APOLLO 7

▼ FISHER ORIGINAL AG7 MODEL, THE VERY FIRST SPACE PEN



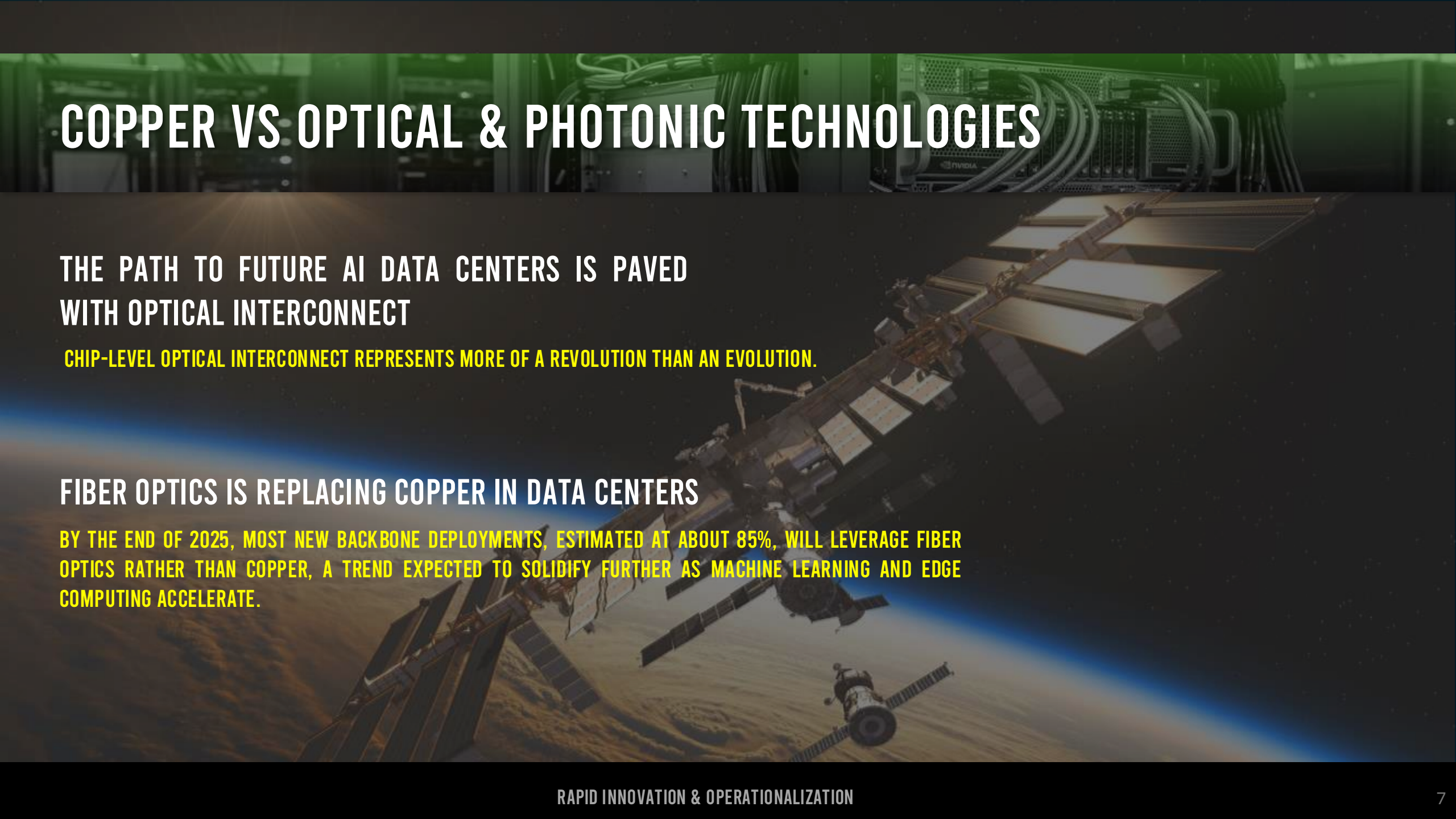
SOURCE: FISHER PEN COMPANY; NASA

FISHER PEN
COMPANY FOUNDER
PAUL FISHER ▶



SOURCE: FISHER PEN COMPANY; NASA

COPPER VS OPTICAL & PHOTONIC TECHNOLOGIES



THE PATH TO FUTURE AI DATA CENTERS IS PAVED
WITH OPTICAL INTERCONNECT

CHIP-LEVEL OPTICAL INTERCONNECT REPRESENTS MORE OF A REVOLUTION THAN AN EVOLUTION.

FIBER OPTICS IS REPLACING COPPER IN DATA CENTERS

BY THE END OF 2025, MOST NEW BACKBONE DEPLOYMENTS, ESTIMATED AT ABOUT 85%, WILL LEVERAGE FIBER OPTICS RATHER THAN COPPER, A TREND EXPECTED TO SOLIDIFY FURTHER AS MACHINE LEARNING AND EDGE COMPUTING ACCELERATE.

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COPPER VS OPTICAL & PHOTONIC TECHNOLOGIES: **FACT**

"I CAN SEE A POINT IN TIME IN THE FUTURE WHEN IT [SILICON PHOTONICS] MATTERS AS THE ONLY WAY TO DO IT [...]. WE ARE NOT QUITE THERE YET."

— HOCK TAN, BROADCOM CEO

THIS SUGGESTS THAT COPPER-BASED INTERCONNECTS REMAIN SIGNIFICANT IN RACK-SCALE AI SYSTEMS BEFORE SILICON PHOTONICS BECOMES NECESSARY.

"THAT'S [USING OPTICAL CONNECTIONS DIRECTLY BETWEEN GPUS] NOT WORTH IT [...]. COPPER IS FAR BETTER."

"WE SHOULD USE COPPER AS MUCH AS WE CAN, FOR AS LONG AS WE CAN, BUT COPPER HAS ITS LIMITS [...] SO YOU USE OPTICS WHEREVER YOU MUST, YOU USE COPPER WHEREVER YOU CAN."

— JENSEN HUANG, NVIDIA CEO

NVIDIA STILL PREFERS COPPER FOR DIRECT GPU-TO-GPU CONNECTIONS DUE TO RELIABILITY CONCERNS.

100-DAY INTERNET GROWTH

“INTERNET TRAFFIC WAS DOUBLING EVERY 100 DAYS. [...] THE RAPIDLY EXPANDING USE OF THE INTERNET HAS BOOSTED INTEREST IN DEVELOPING THIS VEHICLE INTO A THRIVING MARKETPLACE”

—U.S. DEPARTMENT OF COMMERCE IN “THE EMERGING DIGITAL ECONOMY” REPORT
AND ITS CONSUMER BULLETIN NUMBER 13

THIS STATEMENT HELPED FACILITATE THE LARGE-SCALE PRODUCTION AND DEPLOYMENT OF
FIBER-OPTIC CAPACITY DURING THE DOT-COM ERA

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100-DAY INTERNET GROWTH: **FACT**

“INTERNET TRAFFIC IS APPROXIMATELY DOUBLING EACH YEAR. THIS GROWTH RATE APPLIES NOT ONLY TO THE ENTIRE INTERNET, BUT TO A LARGE RANGE OF INDIVIDUAL INSTITUTIONS”

**— K. G. COFFMAN AND A. M. ODLYZKO *ON INTERNET GROWTH:
IS THERE A “MOORE’S LAW” FOR DATA TRAFFIC?***

THIS RATE OF GROWTH IS SLOWER THAN THE FREQUENTLY HEARD CLAIMS OF A DOUBLING OF TRAFFIC EVERY THREE OR FOUR MONTHS

100-DAY INTERNET MYTH: **FROM HYPE TO FIBER OPTIC GLUT**

FIVE YEARS FOLLOWING THE TELECOMMUNICATIONS ACT OF 1996, TELECOMMUNICATIONS COMPANIES SPENT MORE THAN \$500 BILLION ON FIBER OPTIC CABLES, SWITCHES, AND WIRELESS NETWORKS. A MAJOR PORTION OF THIS SPENDING WAS FINANCED WITH DEBT. COMPANIES EXPANDED INFRASTRUCTURE FASTER THAN ACTUAL DEMAND GREW.

WHEN THE DOT-COM BUBBLE BURST, DEMAND FOR FIBER DROPPED SHARPLY, AND MANY OF THE COMPANIES BEHIND THESE NETWORKS COLLAPSED. MANY FIBER COMPANIES WENT BANKRUPT, WHILE THOSE THAT SURVIVED LOST MOST OF THEIR DOT-COM-ERA VALUE.

IN SHORT, COMPANIES TOOK ON SIGNIFICANT DEBT TO BUILD INFRASTRUCTURE AHEAD OF ACTUAL DEMAND; THE UNUSED FIBER BECAME KNOWN AS DARK FIBER.

FROM DARK FIBER TO AI: COULD AI DATA CENTERS CREATE A CAPACITY GLUT?

A CAST AI REPORT FOUND THAT THE AVERAGE GPU UTILIZATION IS ONLY 5% ACROSS THE KUBERNETES CLUSTERS IT ANALYZED, SUGGESTING THAT SOME AI/CLOUD INFRASTRUCTURE MAY BE SIGNIFICANTLY OVERBUILT.

THIS ALLUDES TO THE PARADIGM THAT SOME COMPANIES ARE RESERVING AI COMPUTE CAPACITY AHEAD OF ACTUAL DEMAND.

ZHAO HAIJUN, CO-CHIEF EXECUTIVE OF SEMICONDUCTOR MANUFACTURING INTERNATIONAL CORPORATION (SMIC), WARNED THAT AI DATA CENTERS ARE BEING BUILT AROUND THE WORLD AT A RAPID PACE AND COULD END UP SITTING IDLE, SIMILAR TO THE DATA CENTERS BUILT IN CHINA'S SUBURBS IN THE EARLY 2020S, MANY OF WHICH STILL HAVE NOT FOUND CUSTOMERS.

THE WARNING SUGGESTS THE RISK OF CAPACITY BEING BUILT FASTER THAN ACTUAL DEMAND CAN SUPPORT

ASSESSING AI DATA-CENTER CAPACITY PRAGMATICALLY

AI DATA-CENTER CAPACITY SHOULD BE EXAMINED NOT ONLY AS A TECHNOLOGY OR INVESTMENT ISSUE, BUT ALSO THROUGH ITS IMPACT ON WATER USE, ENERGY DEMAND, ECONOMIC DEVELOPMENT, INFRASTRUCTURE, LOCAL COMMUNITIES, AND GLOBAL PARTNERSHIPS.

THE UNITED NATIONS (UN) SUSTAINABLE DEVELOPMENT GOALS PROVIDE A USEFUL LENS FOR CONSIDERING THE WIDER IMPACTS OF AI DATA-CENTER GROWTH.



ASSESSING AI DATA-CENTER CAPACITY PRAGMATICALLY

8 DECENT WORK AND
ECONOMIC GROWTH



ECONOMIC GROWTH

9 INDUSTRY, INNOVATION
AND INFRASTRUCTURE



INFRASTRUCTURE

7 AFFORDABLE AND
CLEAN ENERGY



ENERGY DEMAND

6 CLEAN WATER
AND SANITATION



WATER USAGE

17 PARTNERSHIPS
FOR THE GOALS



COLLABORATION

11 SUSTAINABLE CITIES
AND COMMUNITIES



CITY AND COMMUNITY

ASSESSING AI DATA-CENTER CAPACITY PRAGMATICALLY

9 INDUSTRY, INNOVATION
AND INFRASTRUCTURE



INFRASTRUCTURE



6 CLEAN WATER
AND SANITATION



WATER USAGE



7 AFFORDABLE AND
CLEAN ENERGY



ENERGY DEMAND



ASSESSING AI DATA-CENTERS: **ENERGY DEMAND ISSUES**

7 AFFORDABLE AND
CLEAN ENERGY



ENERGY DEMAND



**IMPROVE THE
EFFICIENCY OF
THE EXISTING
INFRASTRUCTURE**



**INCREASE
RENEWABLE RESOURCE
INTERMITTENT ENERGY SOURCES**

**BATTERY ENERGY
STORAGE SYSTEM**

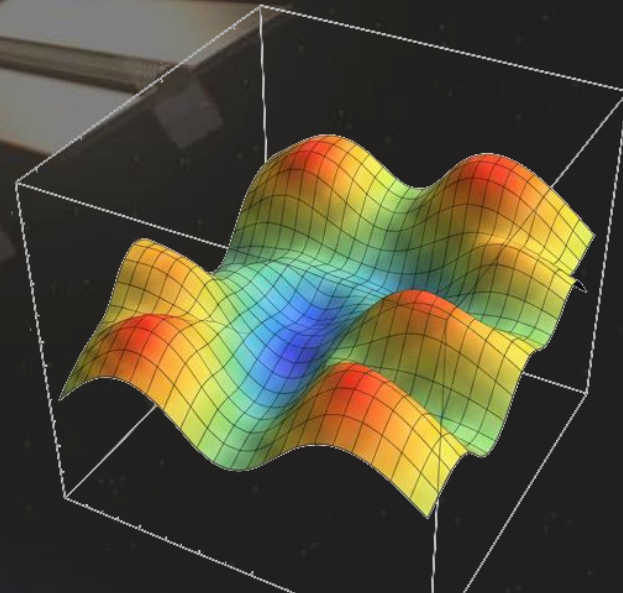
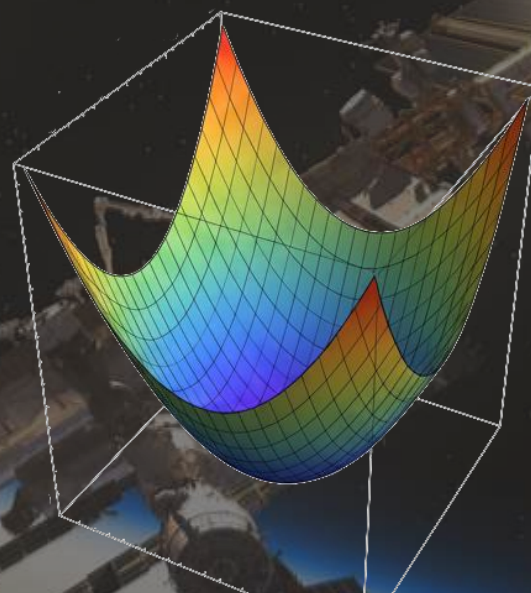


ASSESSING AI DATA-CENTERS: **ENERGY DEMAND ISSUES**

7 AFFORDABLE AND
CLEAN ENERGY



ENERGY DEMAND



BASED ON: ACHIN D. N., "SOLVING FOR OPTIMIZATION PROBLEMS," ANALYTICS VIDHYA ON MEDIUM

ASSESSING AI DATA-CENTERS: **ENERGY WASTE ISSUES**

FLAW BY DESIGN

GUESSING OVER UNCERTAINTY

FAKING IT REWARD SYSTEM

AGENTIC FAILURE

“LANGUAGE MODELS HALLUCINATE BECAUSE THE TRAINING AND EVALUATION PROCEDURES REWARD GUESSING OVER ACKNOWLEDGING UNCERTAINTY” — OPENAI

THE RESEARCHERS SAY THAT THE PROBLEM MAY COME FROM HOW LLMS ARE TRAINED. THE MODELS LEARN TO GUESS BECAUSE BENCHMARKS OFTEN REWARD CONFIDENT ANSWERS AND PUNISH UNCERTAINTY.

REASONING LOOPS CAN MAKE AI AGENTS REPEAT THE SAME ACTIONS WITHOUT PROGRESS, WASTING COMPUTE AND ENERGY WITHOUT PRODUCING A USEFUL ANSWER.

ASSESSING AI DATA-CENTERS: **ENERGY WASTE MITIGATION**

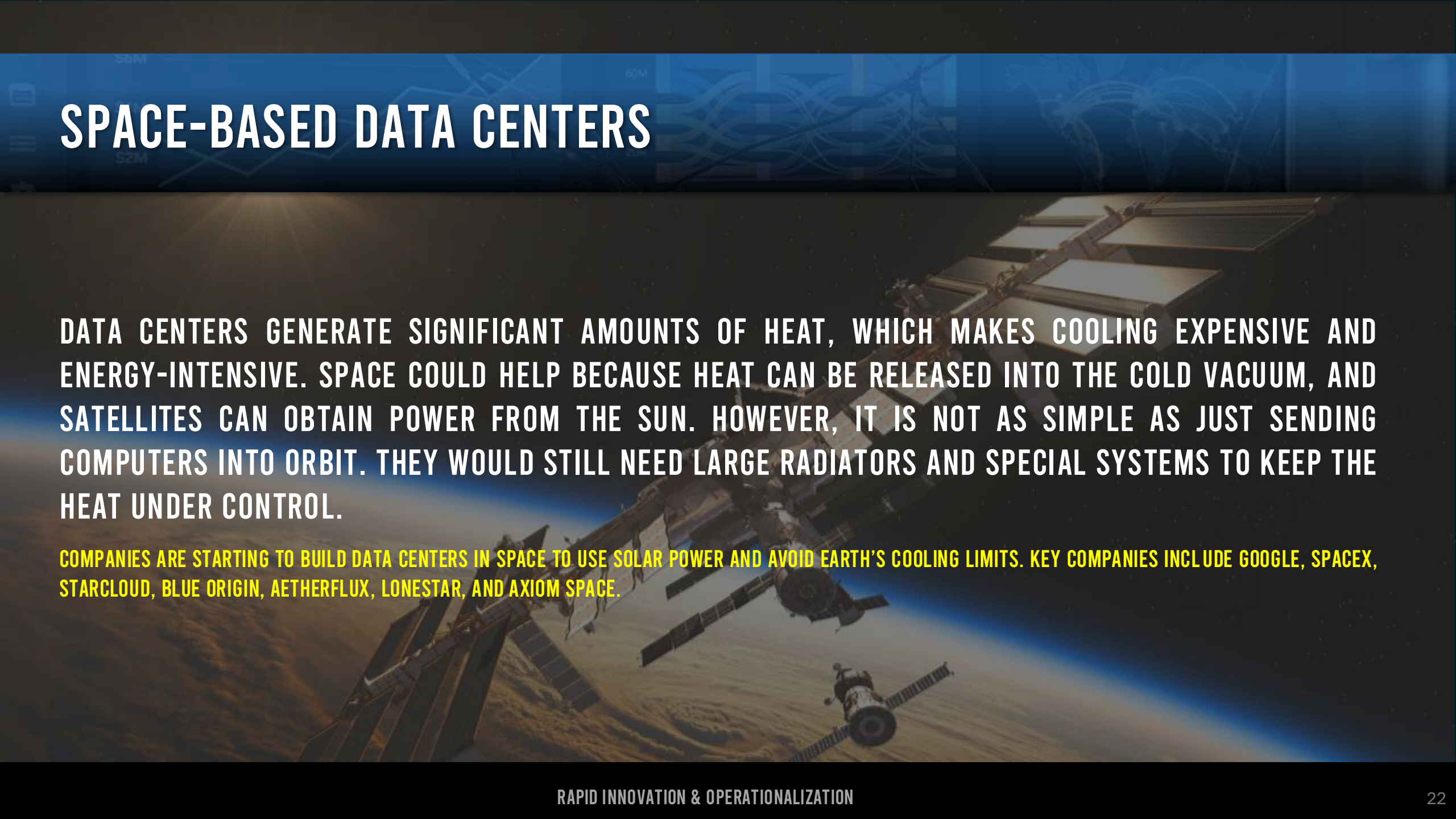
RETRIEVAL-AUGMENTED GENERATION (RAG)

RAG IS A SOFTWARE TECHNIQUE THAT IS USED TO REDUCE AI TENDENCY TO MAKE UP FALSE INFORMATION BY PULLING INFORMATION FROM SPECIALIZED DATABASES, NARROWING THE AI'S FOCUS, AND GROUNDING RESPONSES IN ACTUAL DOCUMENTS.

OPTIMIZE HARDWARE ALLOCATION

IMPLEMENTING SMART OPTIMIZERS THAT MATCH EACH AI MODEL WITH THE MOST ENERGY-EFFICIENT HARDWARE MIX, USING HIGH-POWER GPUS FOR DEMANDING TASKS, AND LOWER-POWER CPUS FOR LIGHTER WORKLOADS.

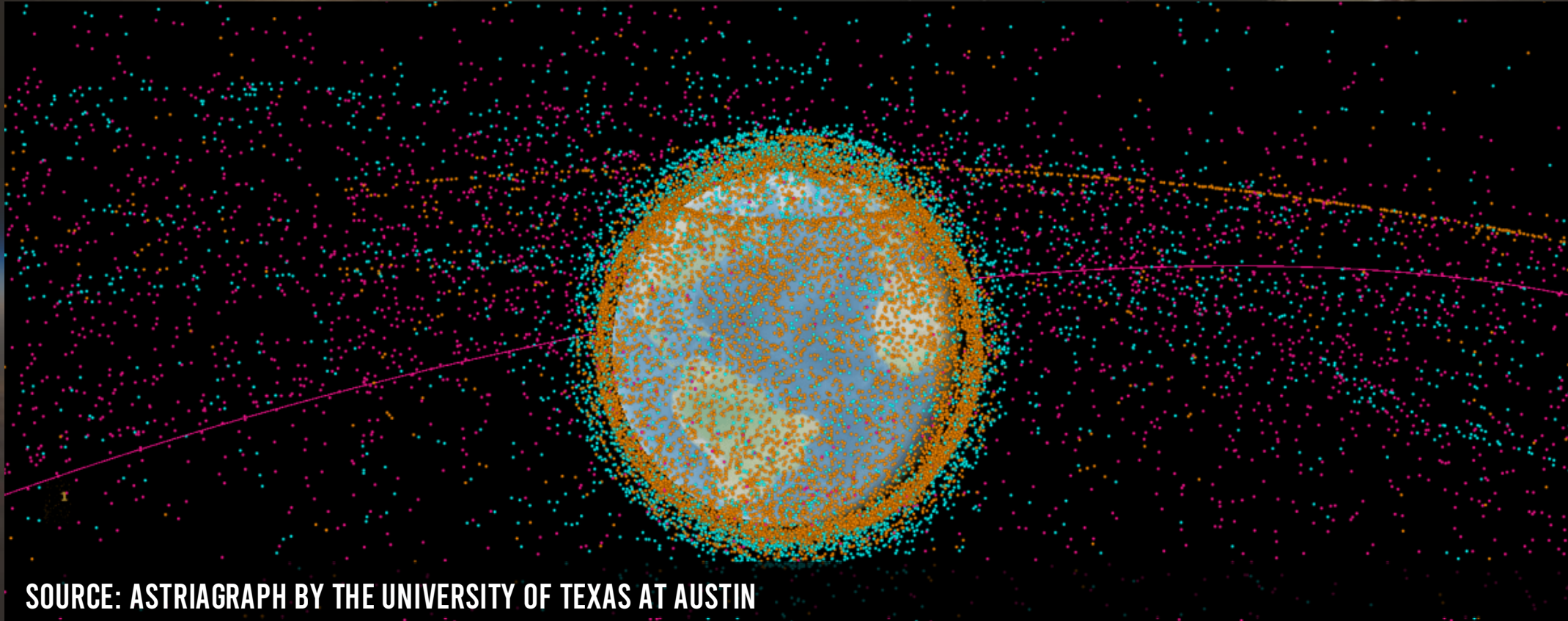
SPACE-BASED DATA CENTERS

A large satellite with multiple solar panel arrays is shown in orbit above the Earth's horizon. The background is a deep blue space with some faint, abstract digital patterns in the upper left corner.

DATA CENTERS GENERATE SIGNIFICANT AMOUNTS OF HEAT, WHICH MAKES COOLING EXPENSIVE AND ENERGY-INTENSIVE. SPACE COULD HELP BECAUSE HEAT CAN BE RELEASED INTO THE COLD VACUUM, AND SATELLITES CAN OBTAIN POWER FROM THE SUN. HOWEVER, IT IS NOT AS SIMPLE AS JUST SENDING COMPUTERS INTO ORBIT. THEY WOULD STILL NEED LARGE RADIATORS AND SPECIAL SYSTEMS TO KEEP THE HEAT UNDER CONTROL.

COMPANIES ARE STARTING TO BUILD DATA CENTERS IN SPACE TO USE SOLAR POWER AND AVOID EARTH'S COOLING LIMITS. KEY COMPANIES INCLUDE GOOGLE, SPACEX, STARCLOUD, BLUE ORIGIN, AETHERFLUX, LONESTAR, AND AXIOM SPACE.

SPACE-BASED DATA CENTERS



◀ A VISUALIZATION
OF ACTIVE AND
INACTIVE
SATELLITES,
DISCARDED ROCKET
BODIES, ORBITAL
DEBRIS, AND OTHER
SPACE OBJECTS
AROUND EARTH

SOURCE: ASTRIAGRAPH BY THE UNIVERSITY OF TEXAS AT AUSTIN

SPACE-BASED DATA CENTERS

SPACE-BASED DATA CENTERS HAVE CERTAIN CHALLENGES AT THIS STAGE. THESE CHALLENGES INCLUDE RADIATION DAMAGE, HIGH LAUNCH COSTS, LIMITED REPAIR OPTIONS, AND POSSIBLE COMMUNICATION DELAYS. THE RECENT BLUE ORIGIN ROCKET EXPLOSION OF 28 MAY 2026 REMINDS US OF THE STATE OF AFFAIRS. THE MOST SERIOUS CONCERN IS THE RISK OF ADDING MORE SPACE DEBRIS, WHICH COULD MAKE THE ORBITS AROUND EARTH EVEN MORE DANGEROUS AND HARDER TO MANAGE.



UNDERSEA DATA CENTERS

UNDERSEA DATA CENTERS ARE BEING CONSIDERED BECAUSE THE OCEAN CAN PROVIDE NATURAL COOLING, WHICH MAY REDUCE THE ENERGY AND COST REQUIRED TO PREVENT SERVERS FROM OVERHEATING. UNDERSEA DATA CENTERS COULD BE PLACED NEAR COASTAL POPULATION CENTERS, WHICH MAY HELP REDUCE LATENCY. EARLY TESTS SUGGEST THAT SEALED UNDERWATER SYSTEMS MAY EXPERIENCE FEWER HARDWARE FAILURES.



SOURCE: SHANGHAI HAILANYUN TECHNOLOGY; SCIENTIFIC AMERICAN



THE UNDERWATER DATA CENTER PICTURED HERE WAS A PILOT PROJECT OFF THE COAST OF HAINAN

UNDERSEA DATA CENTERS

THE MAIN RISKS OF UNDERSEA DATA CENTERS INCLUDE DIFFICULT REPAIRS, POSSIBLE LEAKS AND/OR ENVIRONMENTAL DAMAGE, HIGH INSTALLATION COSTS, AS WELL AS DAMAGE FROM HUMAN ACTIVITY SUCH AS FISHING NETS, SHIP ANCHORS, UNDERWATER CONSTRUCTION, AND/OR VESSEL ACCIDENTS.



SOURCE: SHANGHAI HAILANYUN TECHNOLOGY; SCIENTIFIC AMERICAN

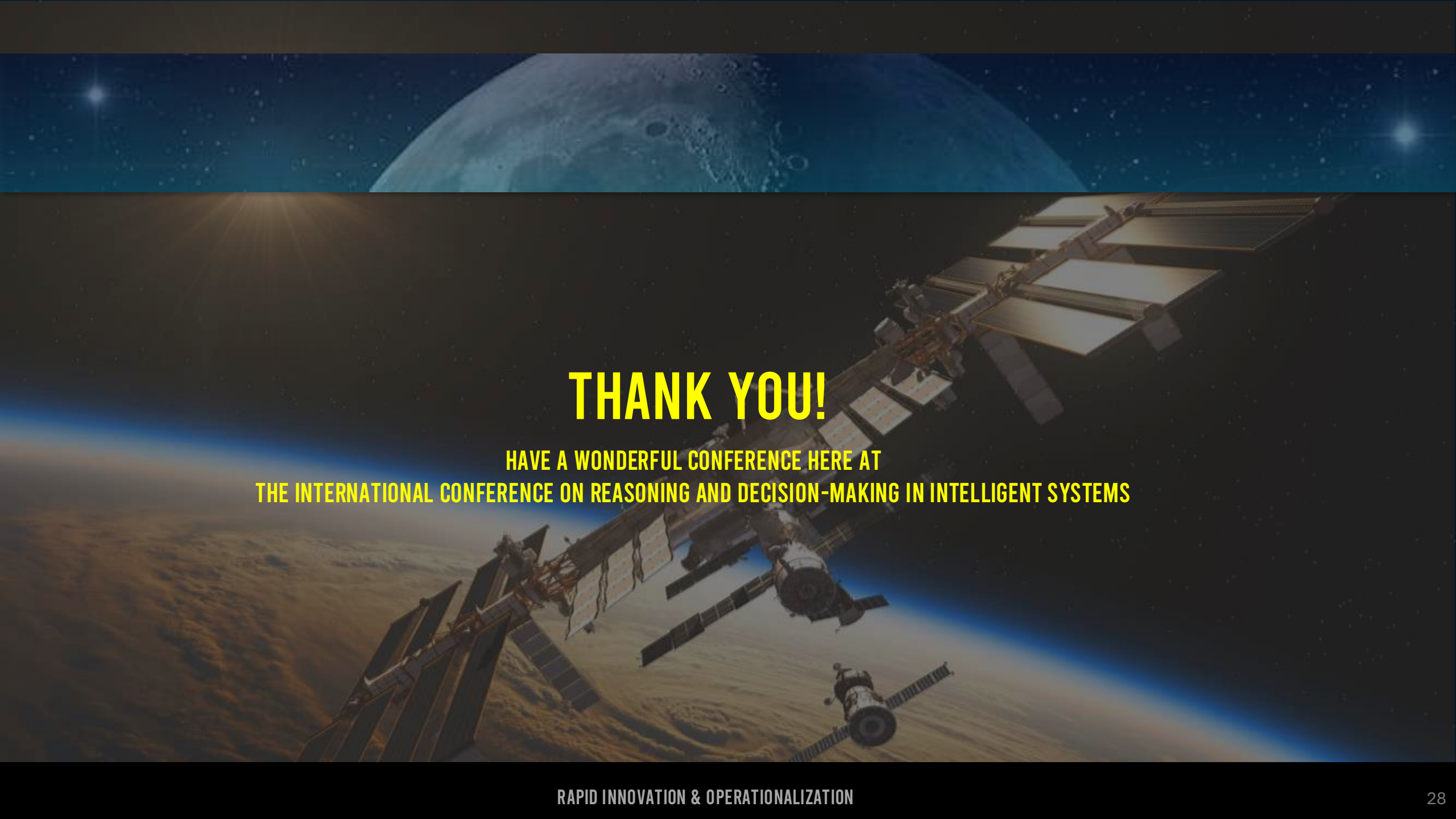


THE UNDERWATER DATA CENTER PICTURED HERE WAS A PILOT PROJECT OFF THE COAST OF HAINAN

MICRO-DATA CENTERS

BOTH UNDERSEA AND SPACE DATA CENTERS ARE DESCRIBED IN THE SOURCES AS MICRO-DATA CENTERS OR SMALLER MODULAR SYSTEMS, RATHER THAN LARGE TRADITIONAL DATA CENTERS. UNDERSEA EXAMPLES ARE DESCRIBED AS SEALED PODS OR CAPSULES, WHILE SPACE EXAMPLES ARE DESCRIBED AS COMPUTATIONAL SATELLITES OR PROTOTYPE SATELLITE MODULES.

BECAUSE THESE SYSTEMS ARE SMALLER AND MORE COMPACT, THEY MAY NOT NEED THE SAME LEVEL OF PHOTONIC OR FIBER-OPTIC INFRASTRUCTURE USED IN LARGE DATA CENTERS, ESPECIALLY FOR SHORT INTERNAL CONNECTIONS. THUS, COPPER REMAINS VITAL IN MICRO-DATA CENTERS SINCE IT SUPPORTS SHORT INTERNAL CONNECTIONS, POWER DELIVERY, GROUNDING, AND HEAT MANAGEMENT, WHILE OPTICAL APPROACHES ARE MAINLY USED FOR LONGER-DISTANCE DATA TRANSMISSION.

A detailed illustration of a space station in orbit above Earth. The station features a central module and several large, rectangular solar panel arrays extending outwards. Below the station, the Earth's surface is visible, showing a mix of blue oceans and brown landmasses. In the upper portion of the image, the large, cratered surface of the Moon is visible against the blackness of space, which is dotted with distant stars. The overall scene is set during a sunset or sunrise, with a warm orange glow on the horizon.

THANK YOU!

HAVE A WONDERFUL CONFERENCE HERE AT
THE INTERNATIONAL CONFERENCE ON REASONING AND DECISION-MAKING IN INTELLIGENT SYSTEMS