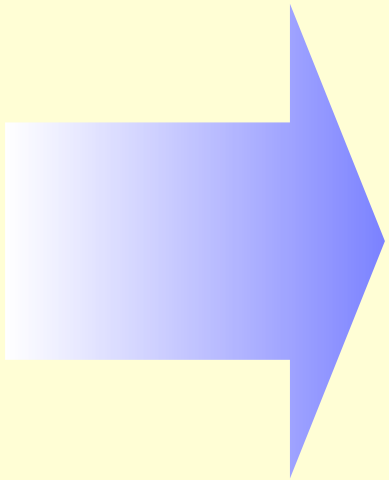
Technological Singularities

A Social Transformation

The 20th Century	The 21st Century
Transportation	Communications
Cars, planes, trains	Computers, networks
Energy, materials	Knowledge, bits
Nation-states	Nationalism
Public Policy	Markets



The Key Themes of the Digital Age

- The changing ways that we handle data, information, and knowledge.
- The pervasive character of digital technology (the Internet).
- The relaxation (or obliteration) of the conventional constraints of space, time, and monopoly.
- The growing important of intellectual capital relative to physical or financial capital in the “new economy”.
- The exponential pace of the evolution of technology (particularly info/bio/nano technology).

A Technological Singularity

John von Neumann once speculated that:

"The ever accelerating progress of technology and changes in the mode of human life gives the appearance of approaching an essential singularity in the history of the race beyond which human affairs, as we know them, could neither be predicted nor possibly even continue."

Bill Joy*

"Accustomed to living with almost routine scientific breakthroughs, we have yet to comes to terms with the fact that the most compelling 21st Century technologies —robotics, genetic engineering, nanotechnology— pose a different threat than the technologies that have come before. Specifically, robots, engineered organisms, and nanobots share a dangerous amplifying factor: They can self-replicate. A bomb is blown up only once—but one 'bot' can become many and quickly get out of control."

*Chief Scientist, Sun Microsystems (inventor of Berkeley Unix and Java)
**B. Eng., U. Michigan, '67

Background

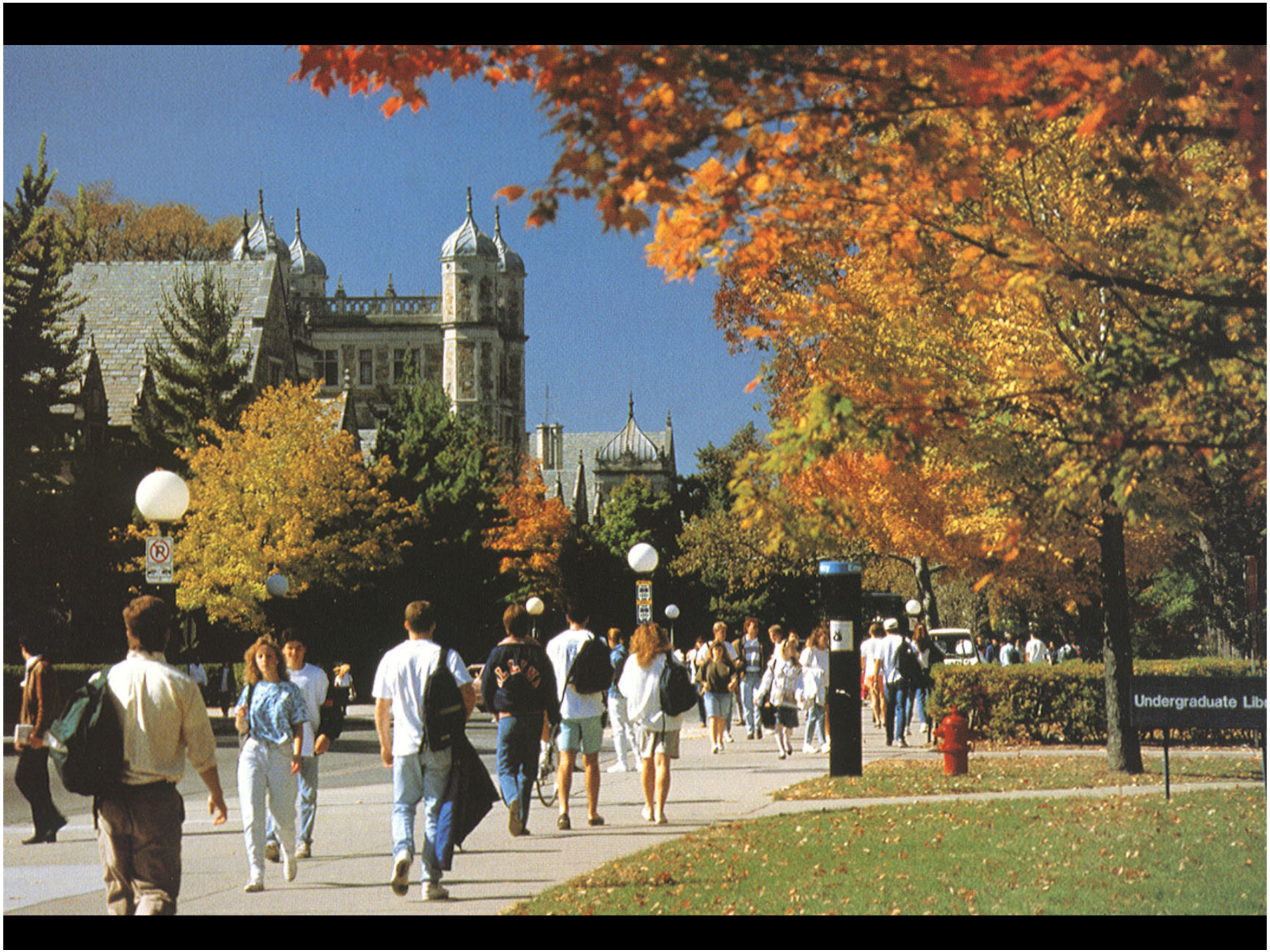
The University of Michigan

University of Michigan

- First public university in United States (1817)
- One of U.S.'s largest universities
  - People: 50,000 students; 3,500 faculty, 25,000 staff
  - Budget: $3.4 billion/year; ($3.9 billion endowment)
  - Facilities: 3 million m^2 of facilities
  - Campuses in Europe, Hong Kong, Korea, Brazil, cyberspace
- One of U.S.'s leading research universities (> $600 million/year)
- Some other features:
  - First university hospital (1 million patients a year, $1.4 billion/year)
  - Key role in developing and managing the Internet (now Internet2)

UM Schools and Colleges

- Architecture
- Art and Design
- Business Administration
- Dentistry
- Education
- Engineering
- Graduate programs
- Information
- Kinesiology
- Law
- Humanities
- Medicine
- Music
- Natural Resources
- Nursing
- Pharmacy
- Public Health
- Public Policy
- Sciences
- Social Work


Undergraduate Lib


UNITED
STATES

THIS FLAG CARRIED ABOARD APOLLO 15 DURING THE FIRST EXTENDED SCIENTIFIC EXPLORATION OF THE MOON. JULY 26 — AUGUST 7, 1971


MICHIGAN
MICHIGAN


MICHIGAN STADIUM
NATIONAL CHAMPIONS
MICHIGAN

More Background

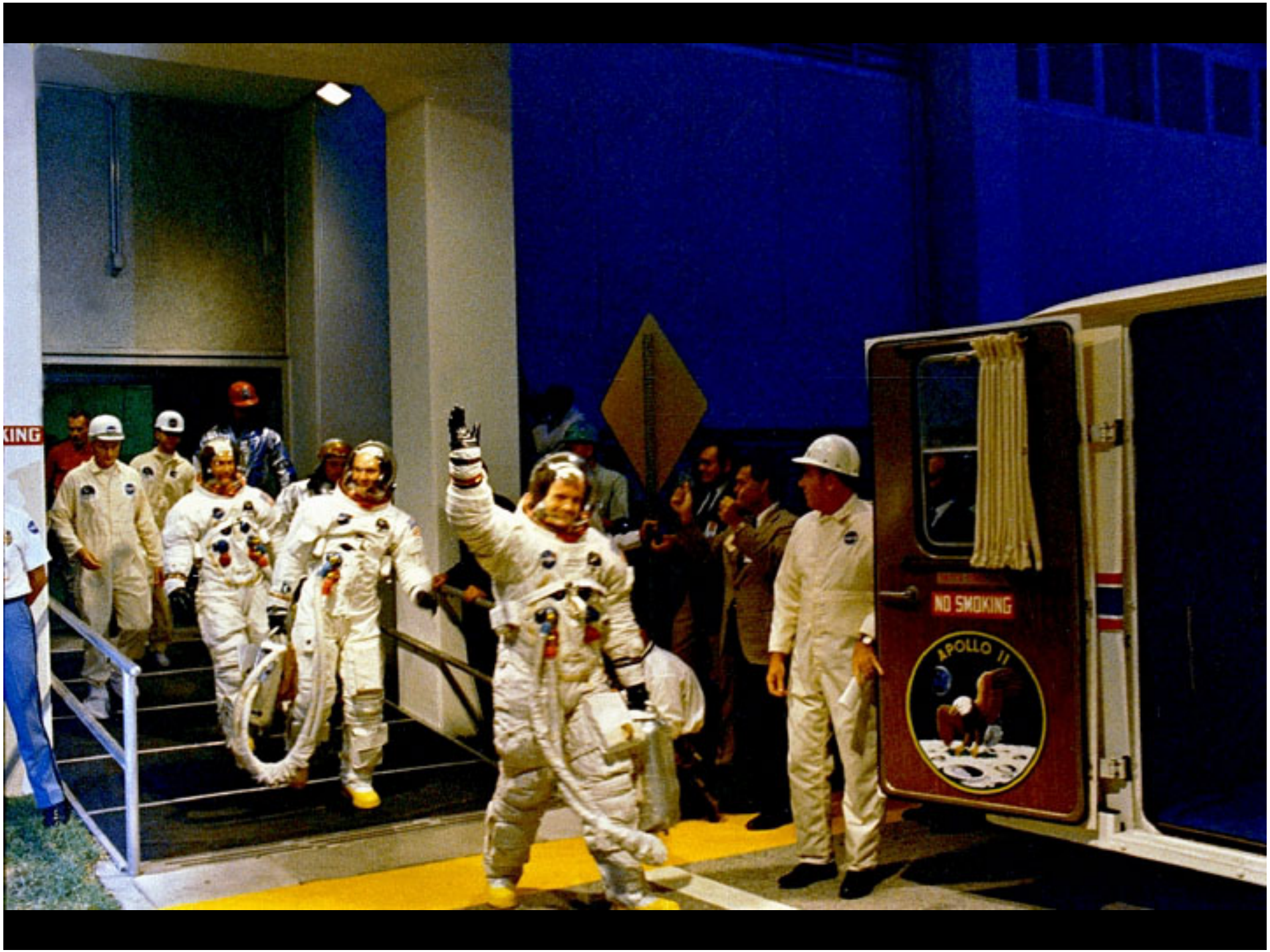
Personal Activities

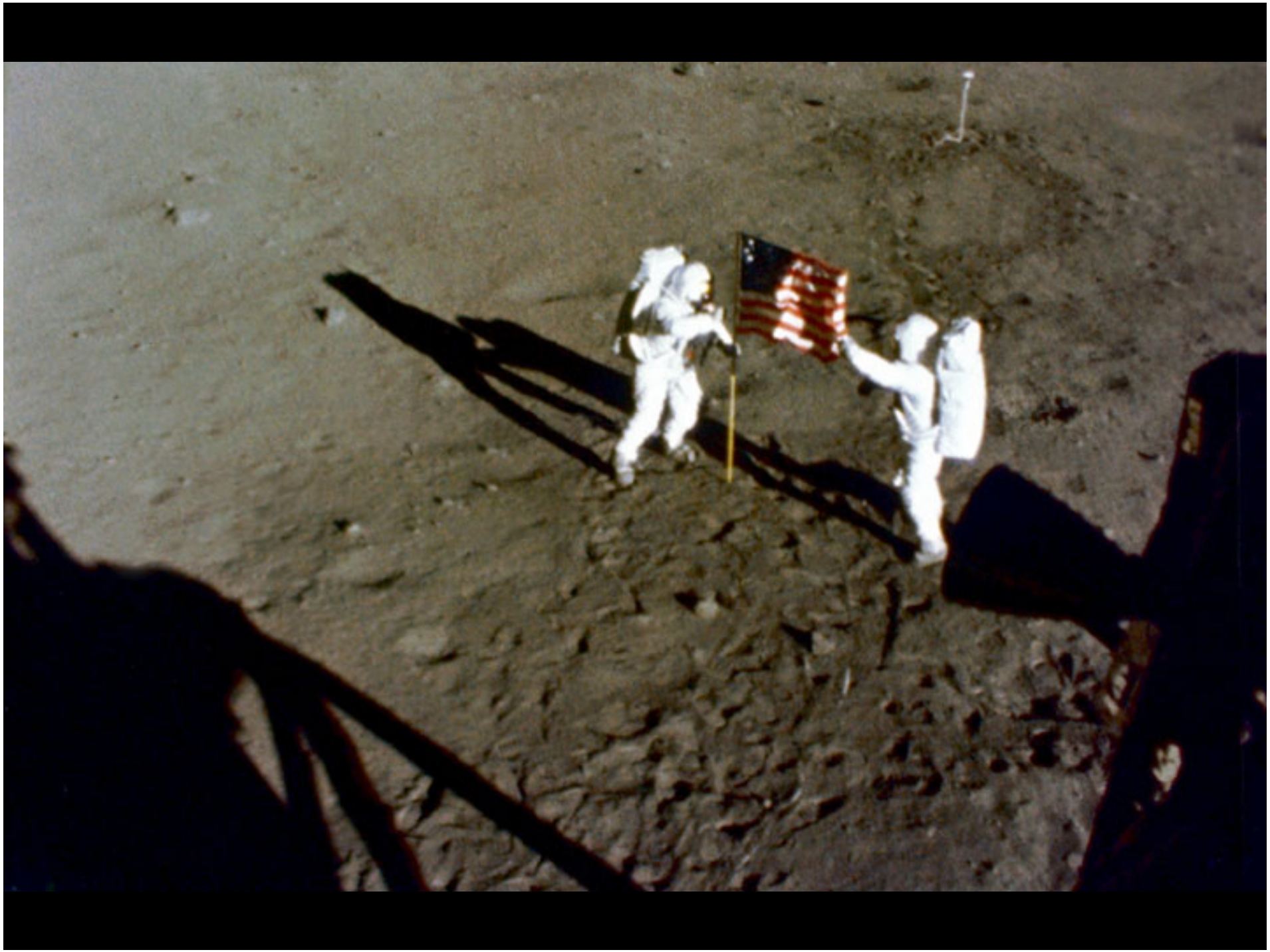
JJD Biography

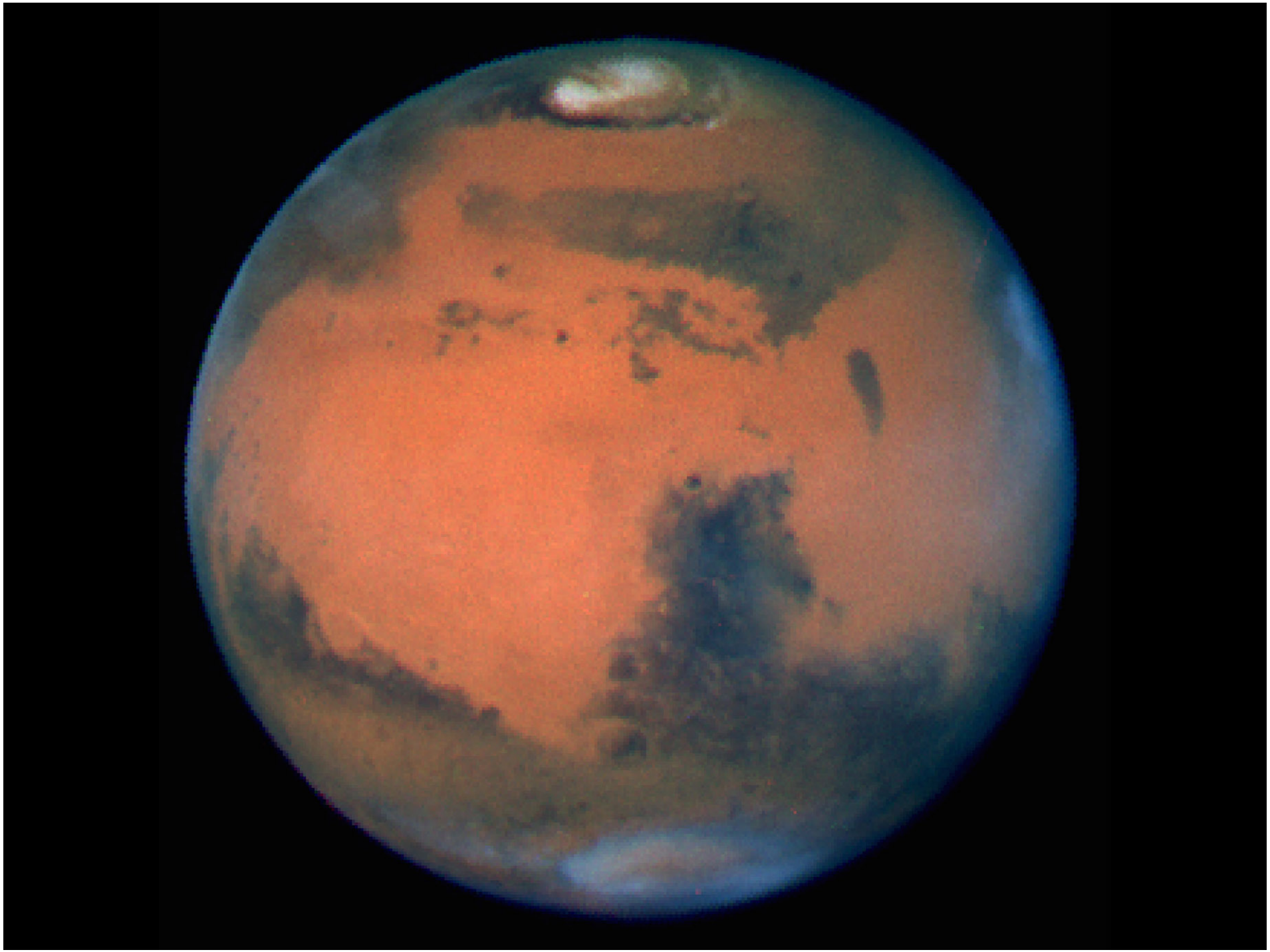
- President *Emeritus* and University Professor of Science and Engineering
- B.S. (Yale '64); Ph.D. (Caltech '67)
- Past UM Assignments: Professor, Dean of Engineering, Provost, President
- National Assignments:
  - Chair, National Science Board
  - Director, National Academy of Engineering
  - Chair, DOE Nuclear Energy Research Advisory Committee
  - Chair, NAS Study on IT and the Future of the University
  - Board of Directors, Unisys Corporation, CMS Energy Corporation
  - Chair, National Research Council, Triana Satellite Study
  - Member, Committee on Science, Engineering, and Public Policy of the National Academies of Science, Engineering, Medicine
- Director, *The Millennium Project*

A long, long time ago…

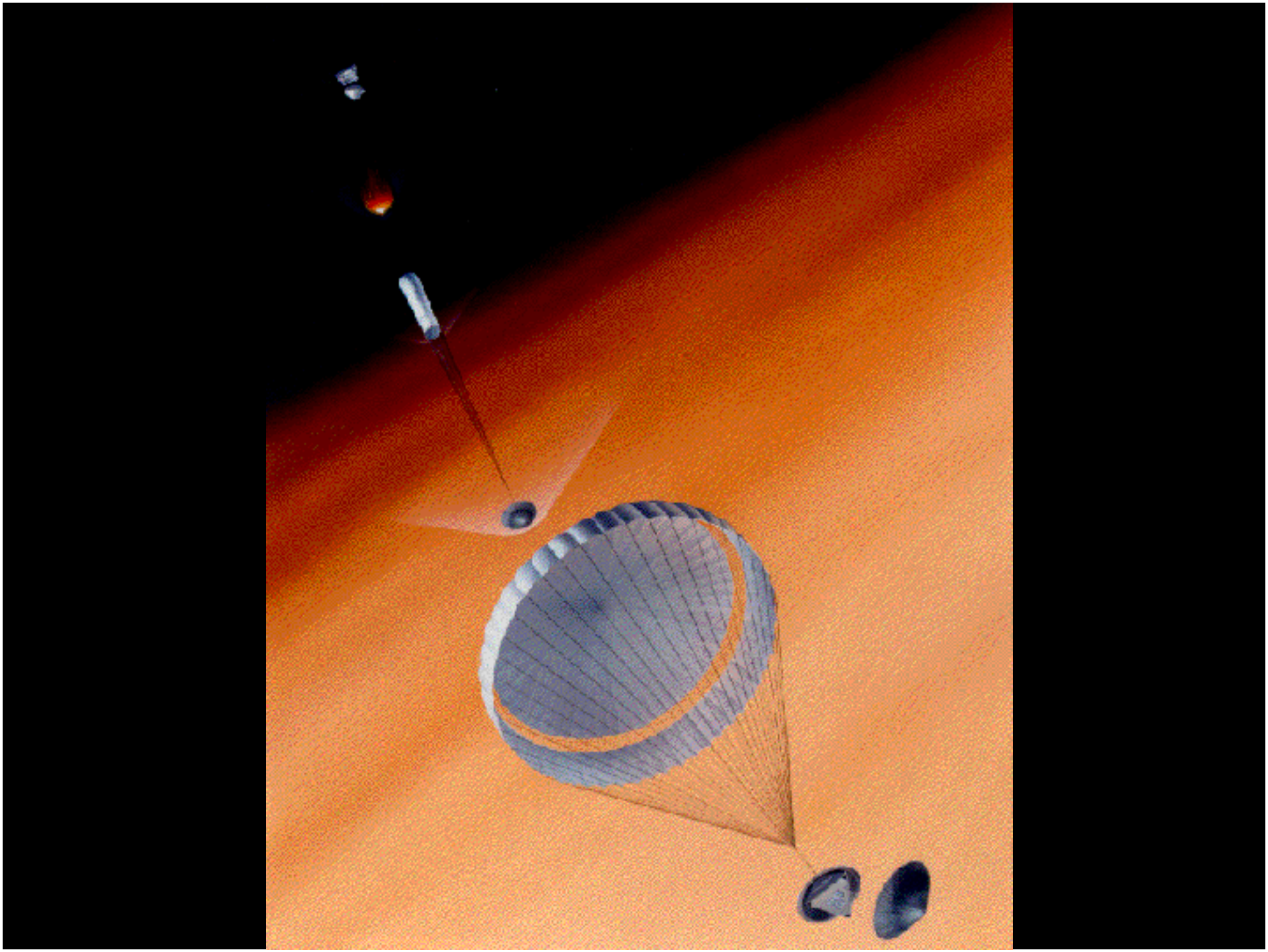
When I graduated from college…

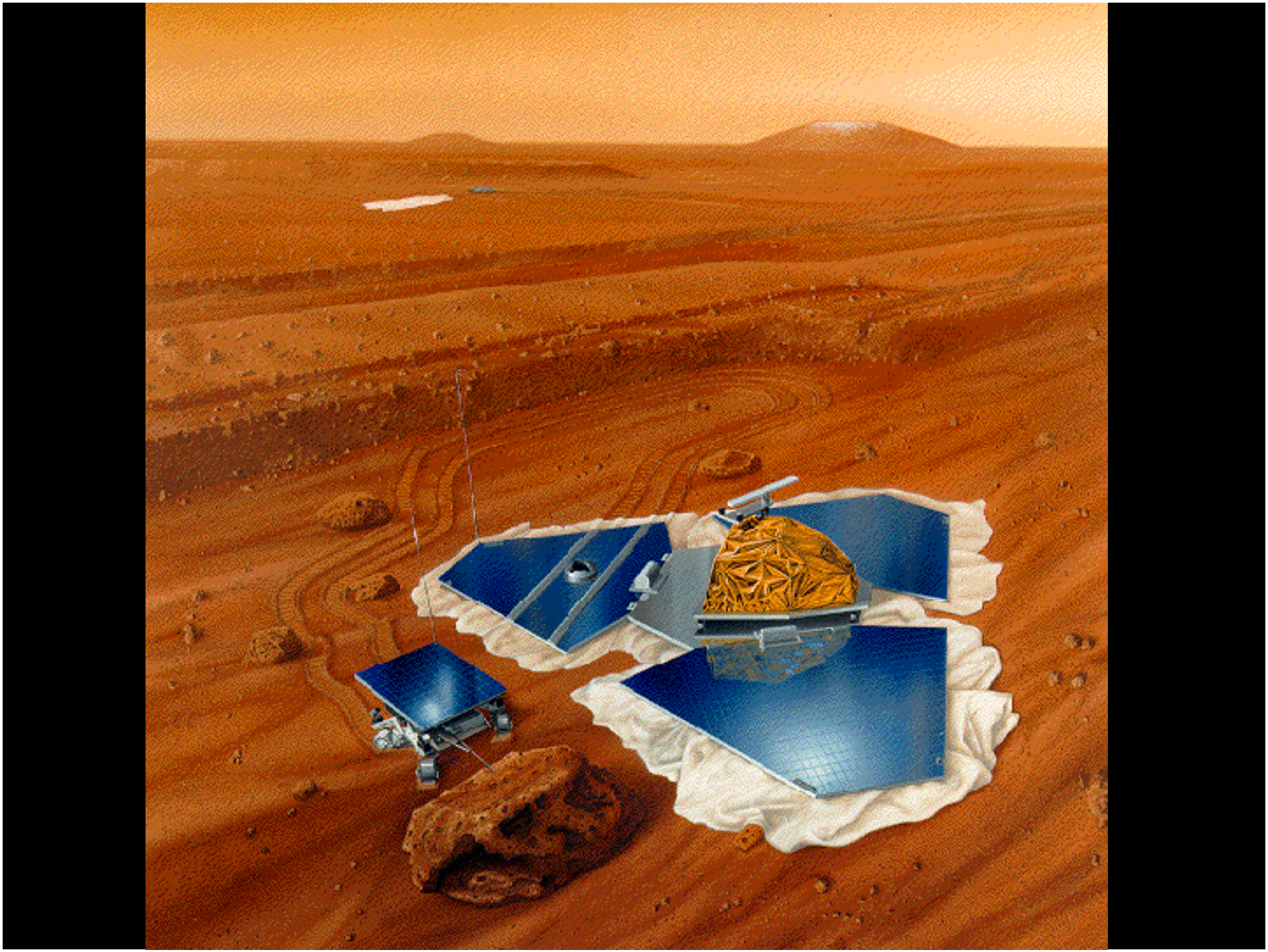

NO SMOKING
APOLLO 11

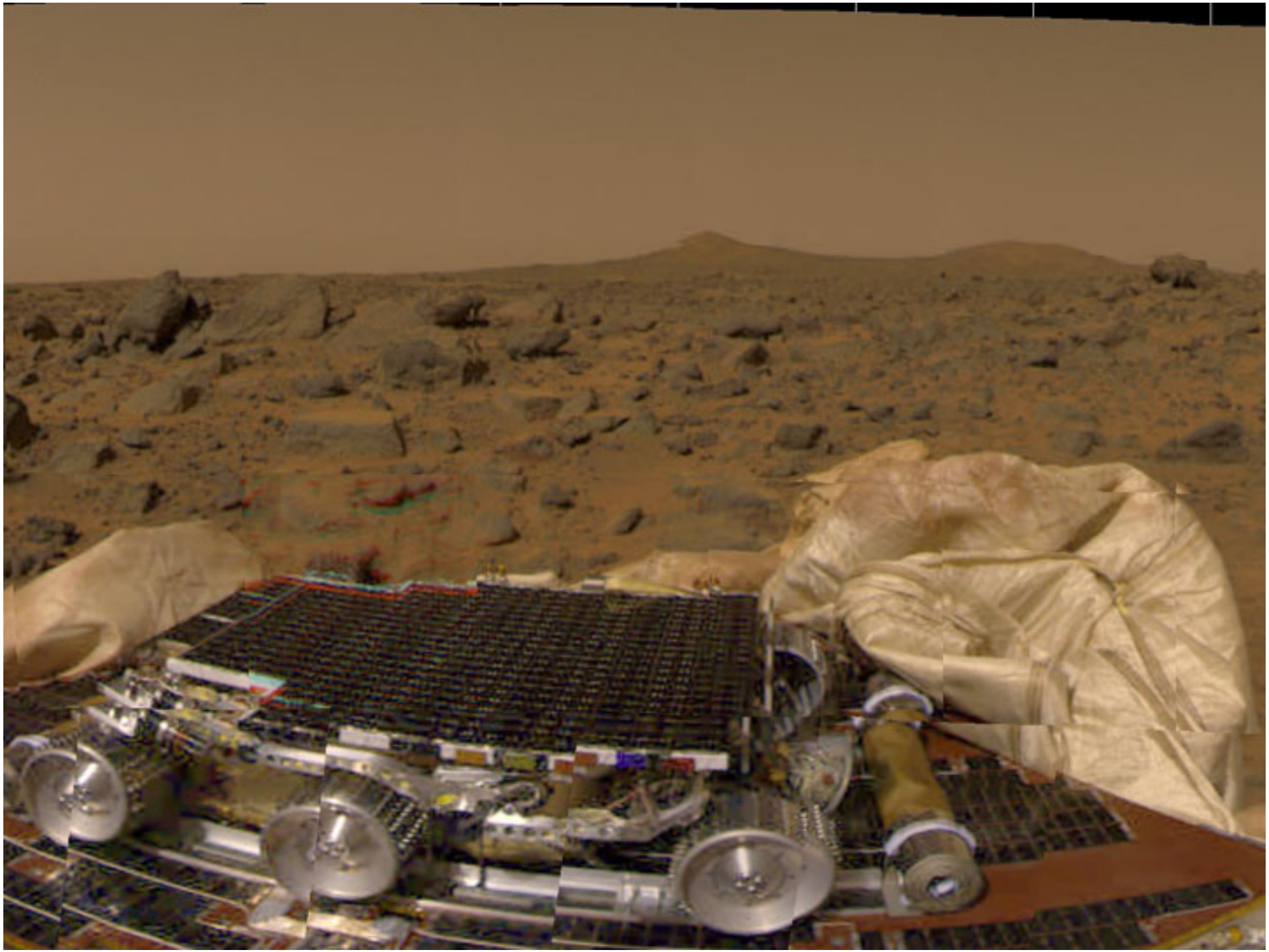


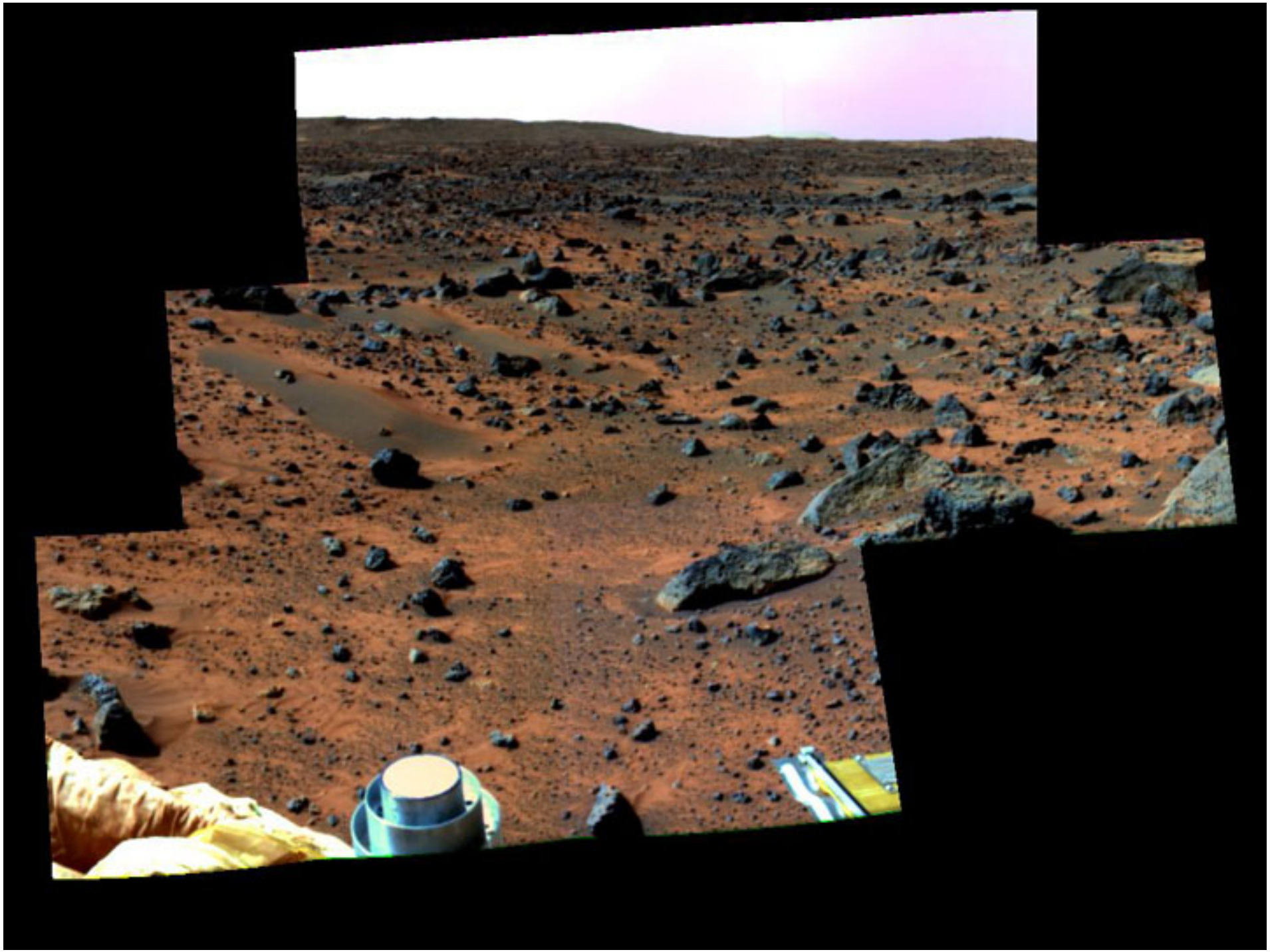



UNITED STATES

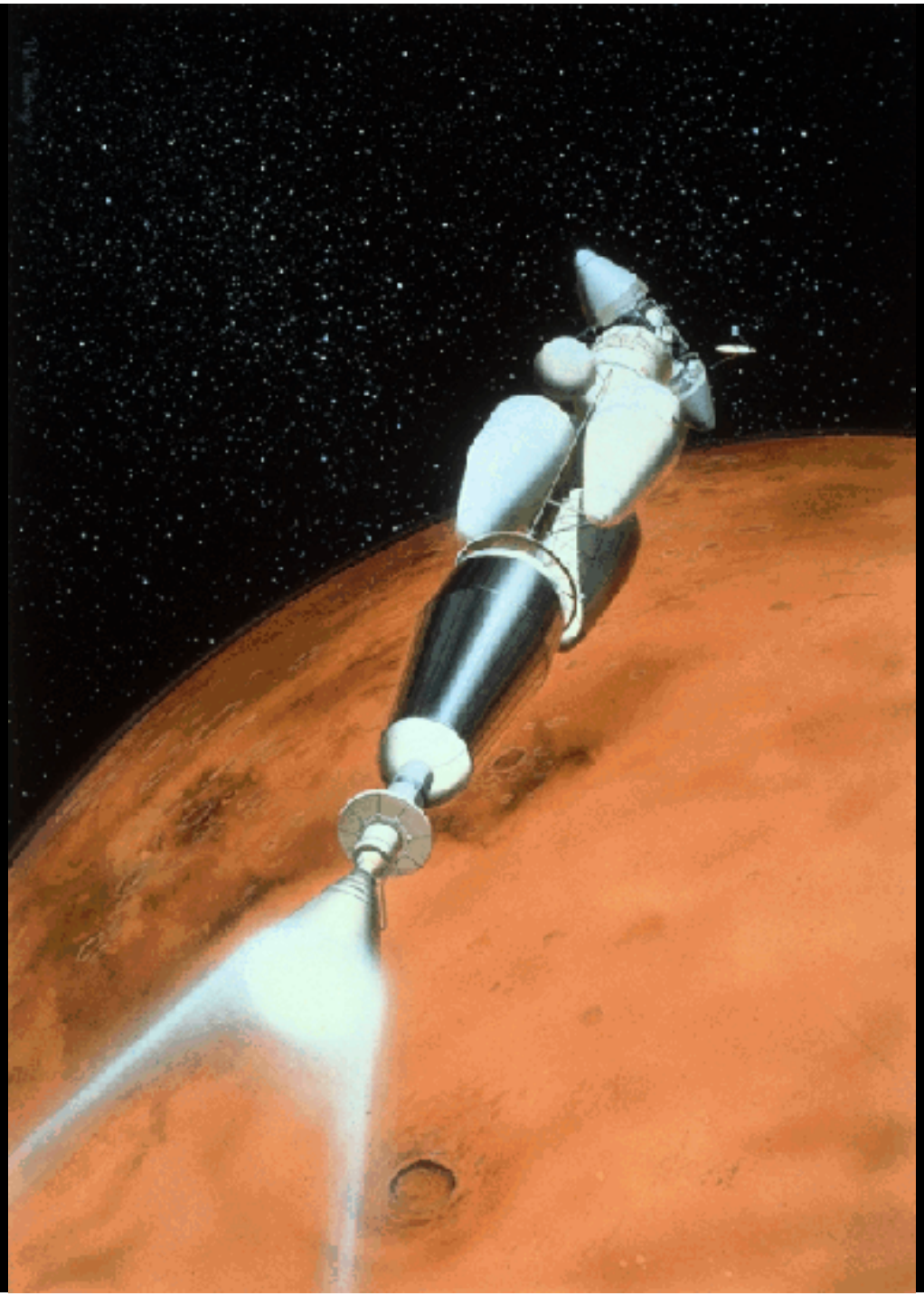


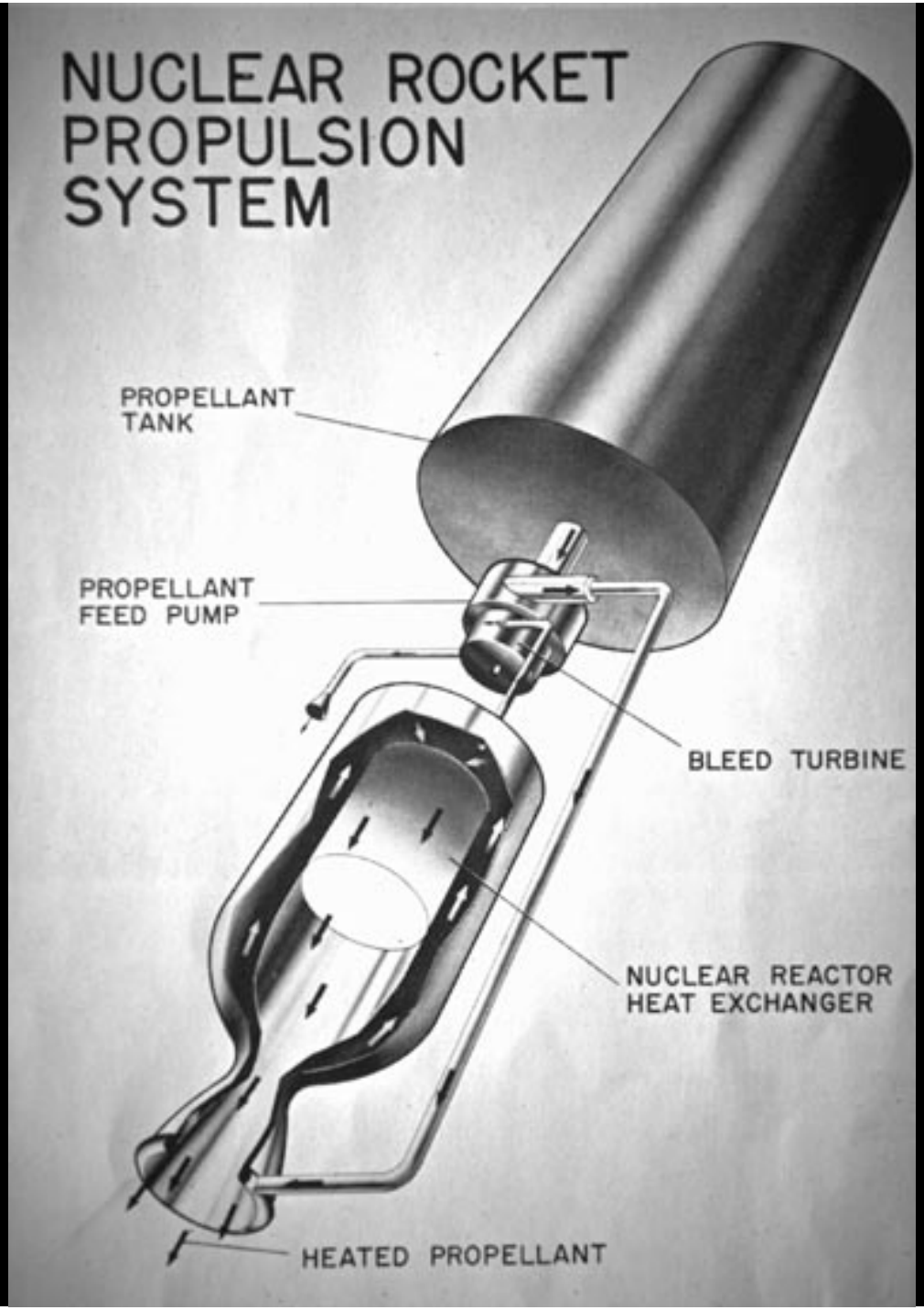


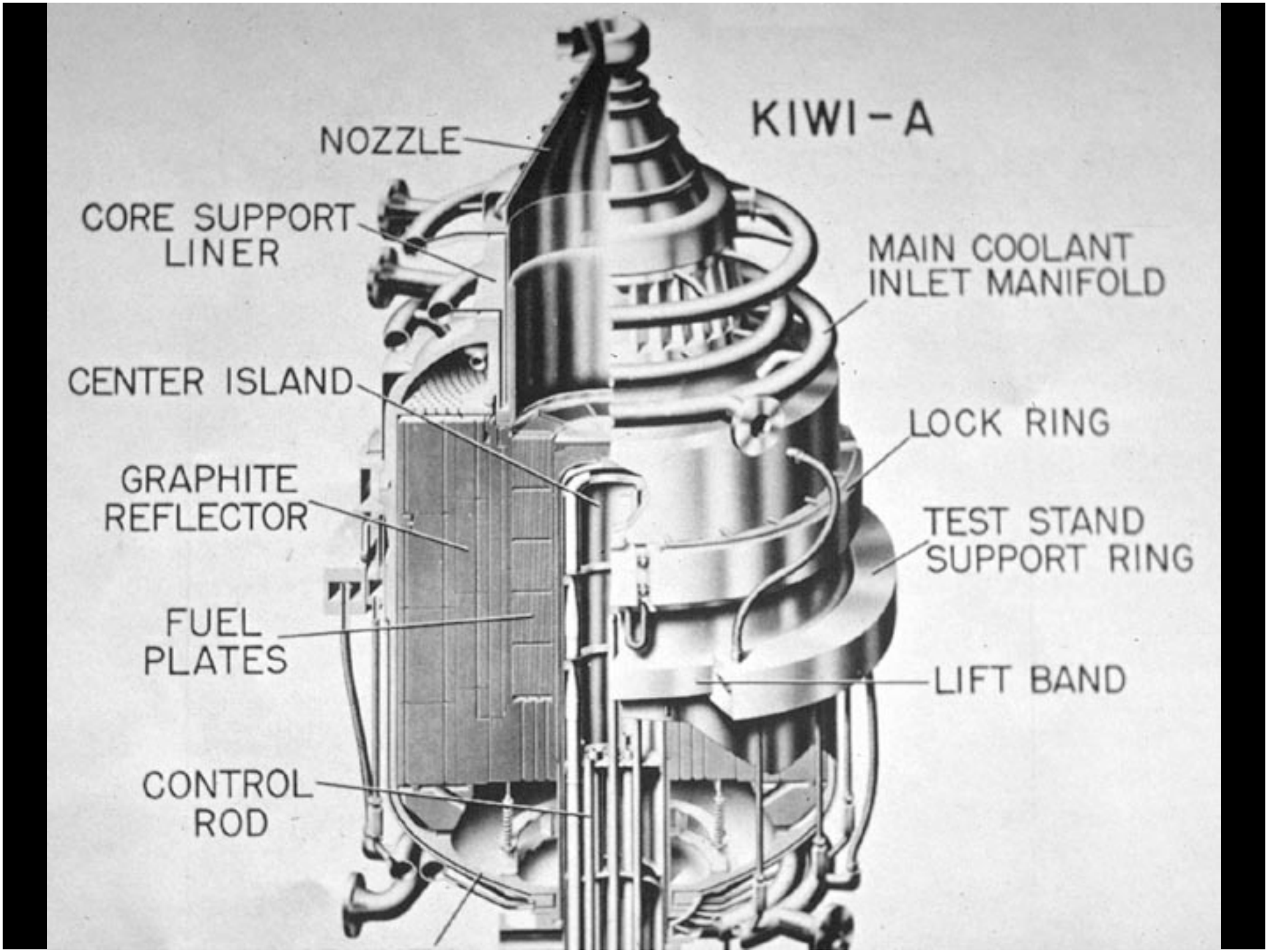


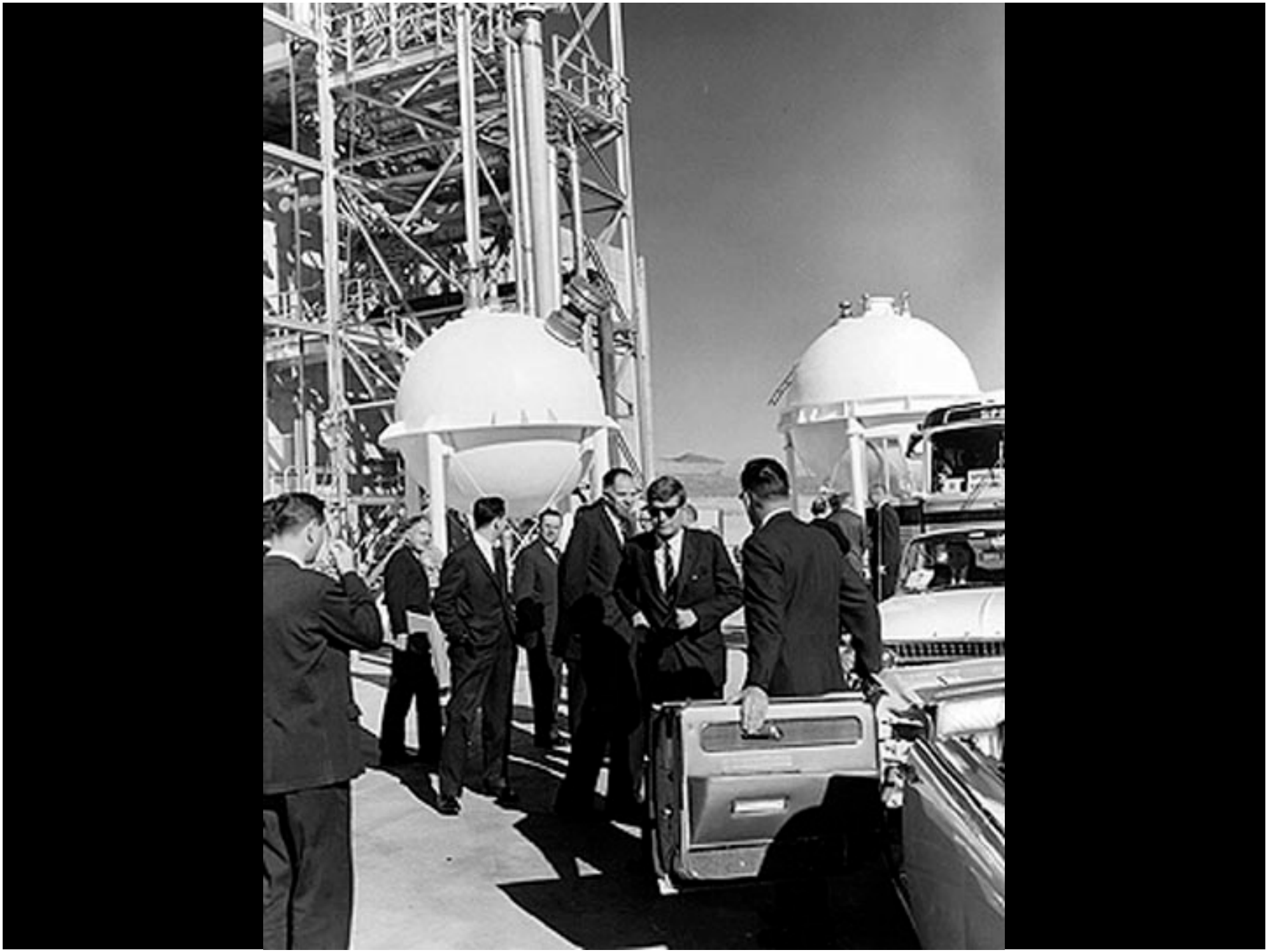


Project Rover

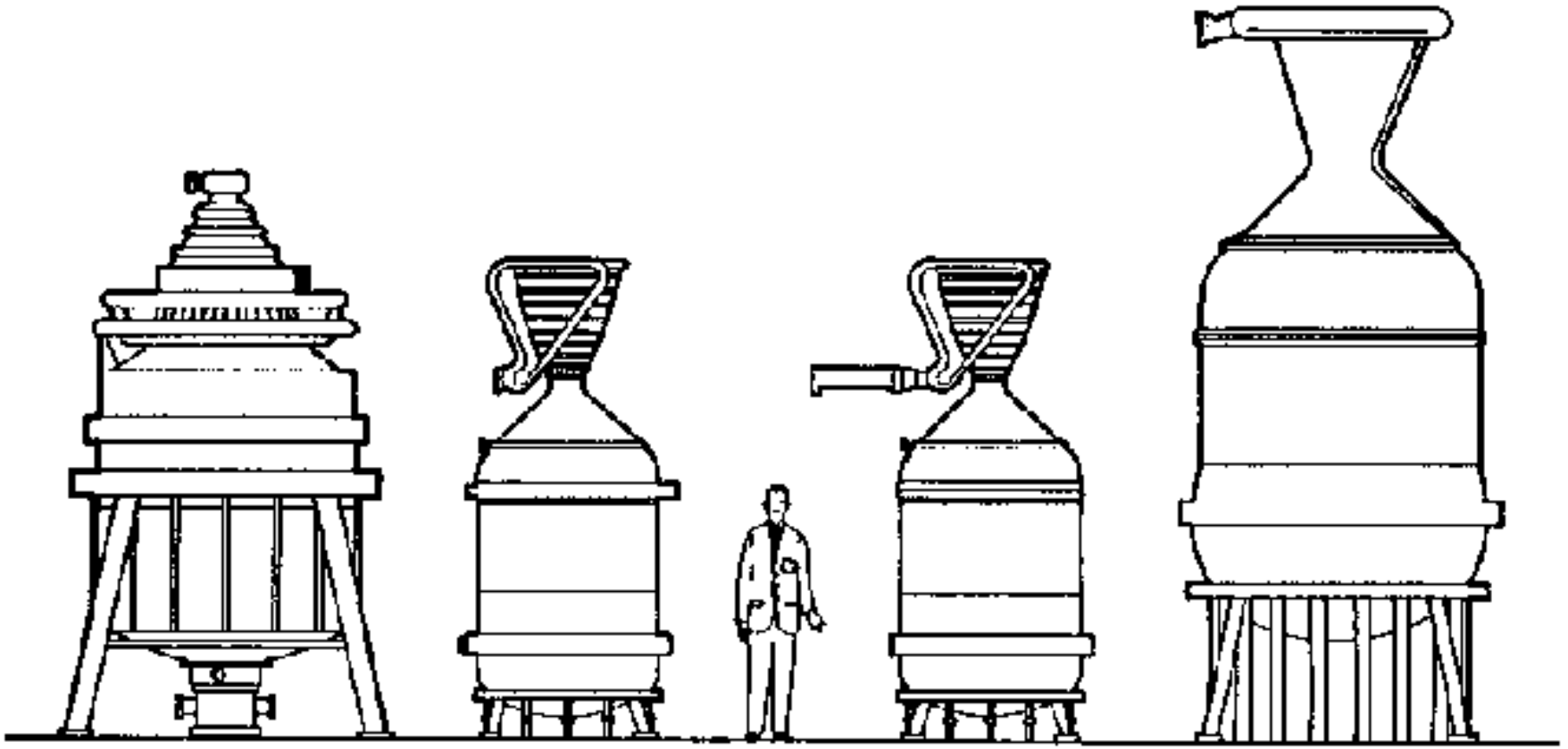



NUCLEAR ROCKET PROPULSION SYSTEM
PROPELLANT TANK
PROPELLANT FEED PUMP
BLEED TURBINE
NUCLEAR REACTOR HEAT EXCHANGER
HEATED PROPELLANT

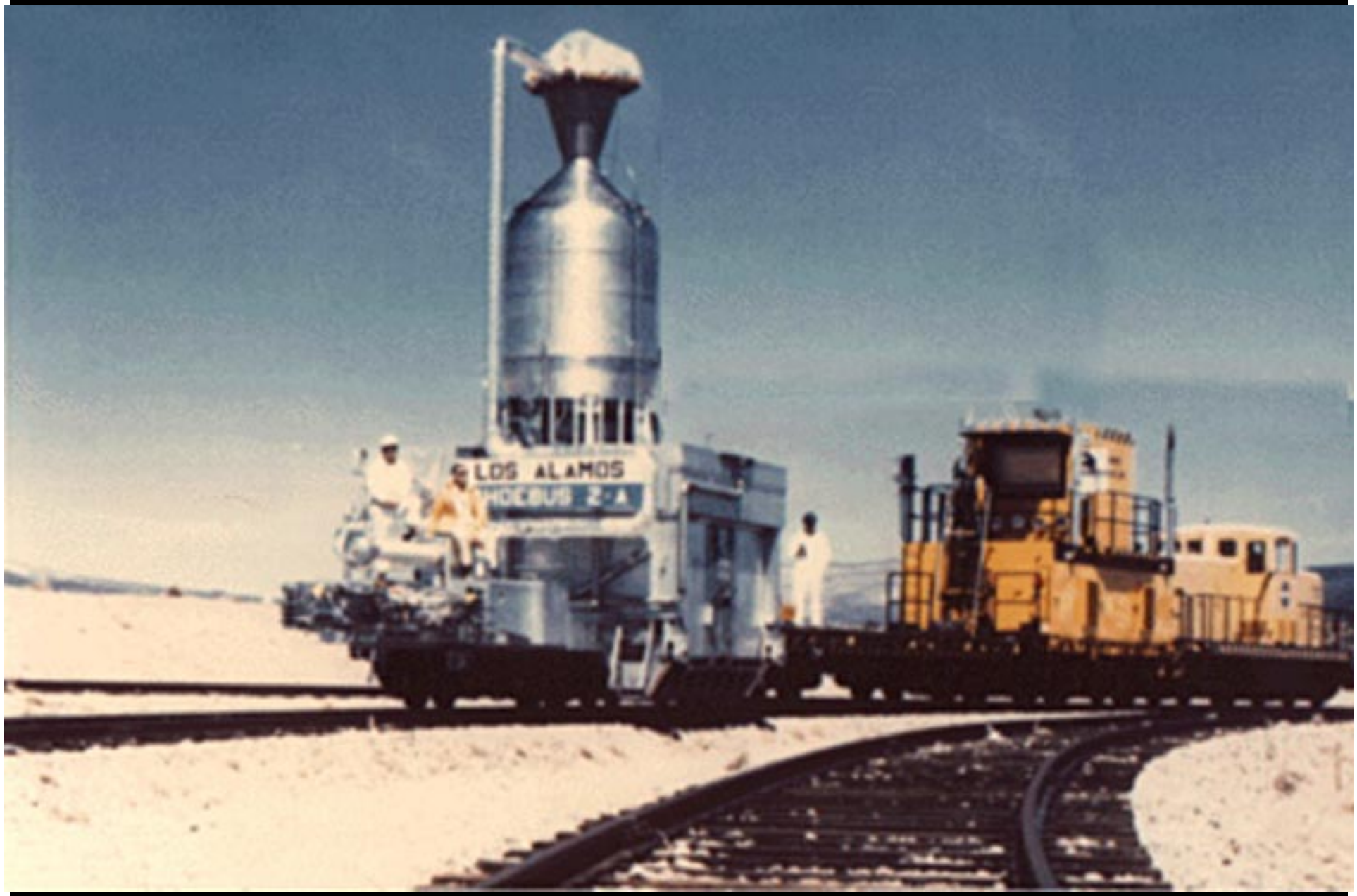

KIWI-A
NOZZLE
CORE SUPPORT LINER
MAIN COOLANT INLET MANIFOLD
CENTER ISLAND
LOCK RING
GRAPHITE REFLECTOR
TEST STAND SUPPORT RING
FUEL PLATES
LIFT BAND
CONTROL ROD

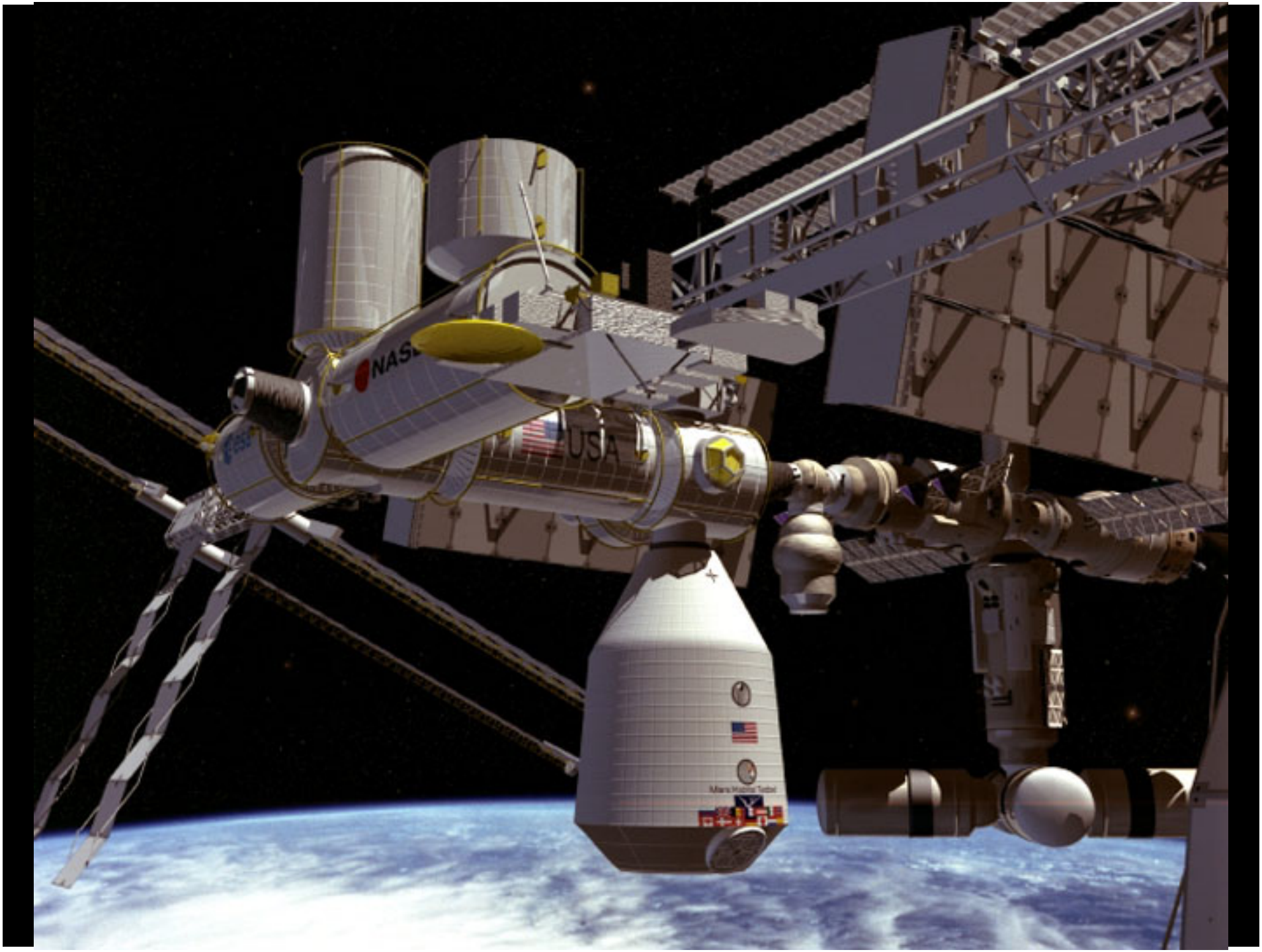


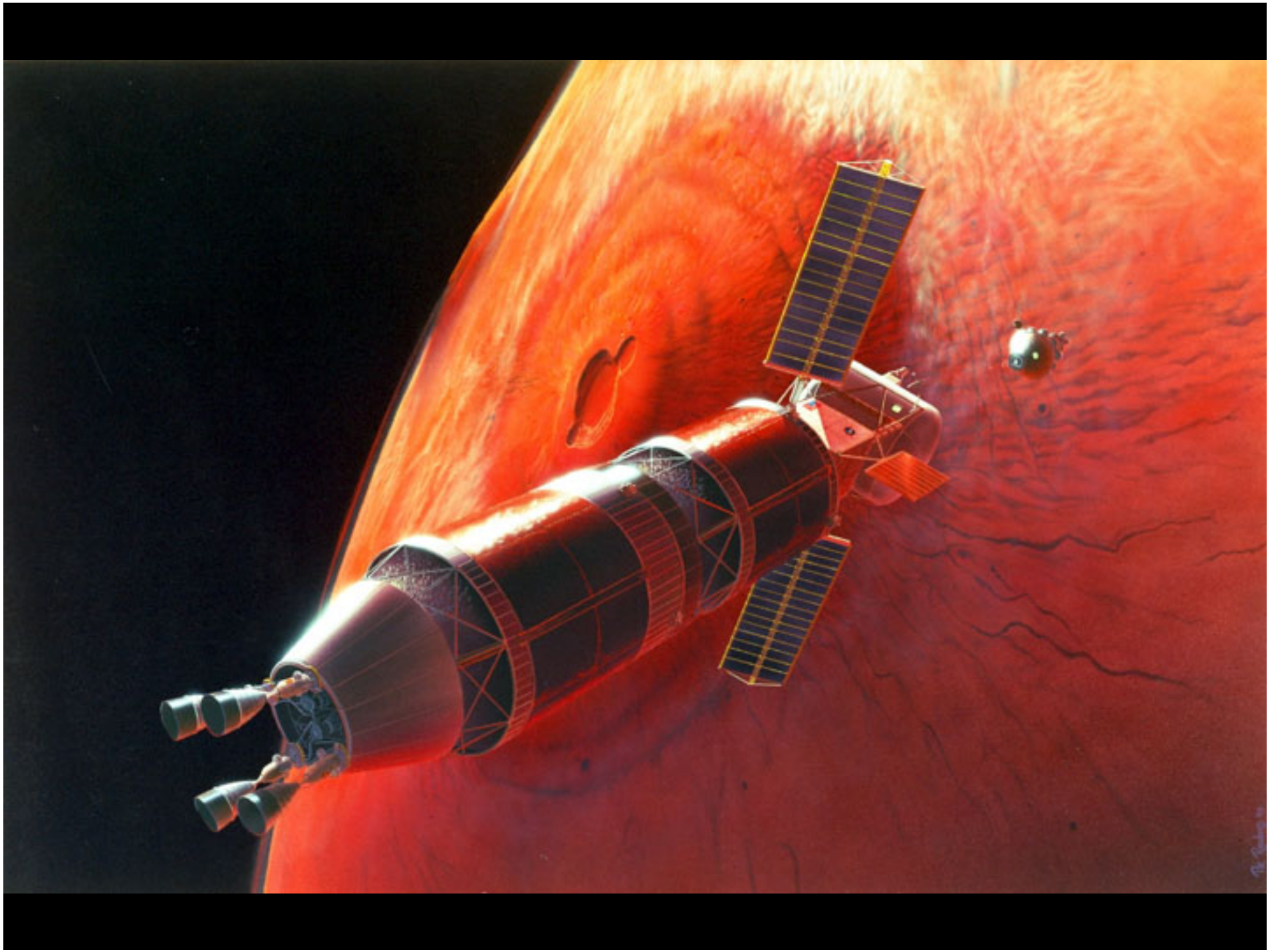
Nuclear Rockets Were Developed to a High State of Readiness in the 1960's

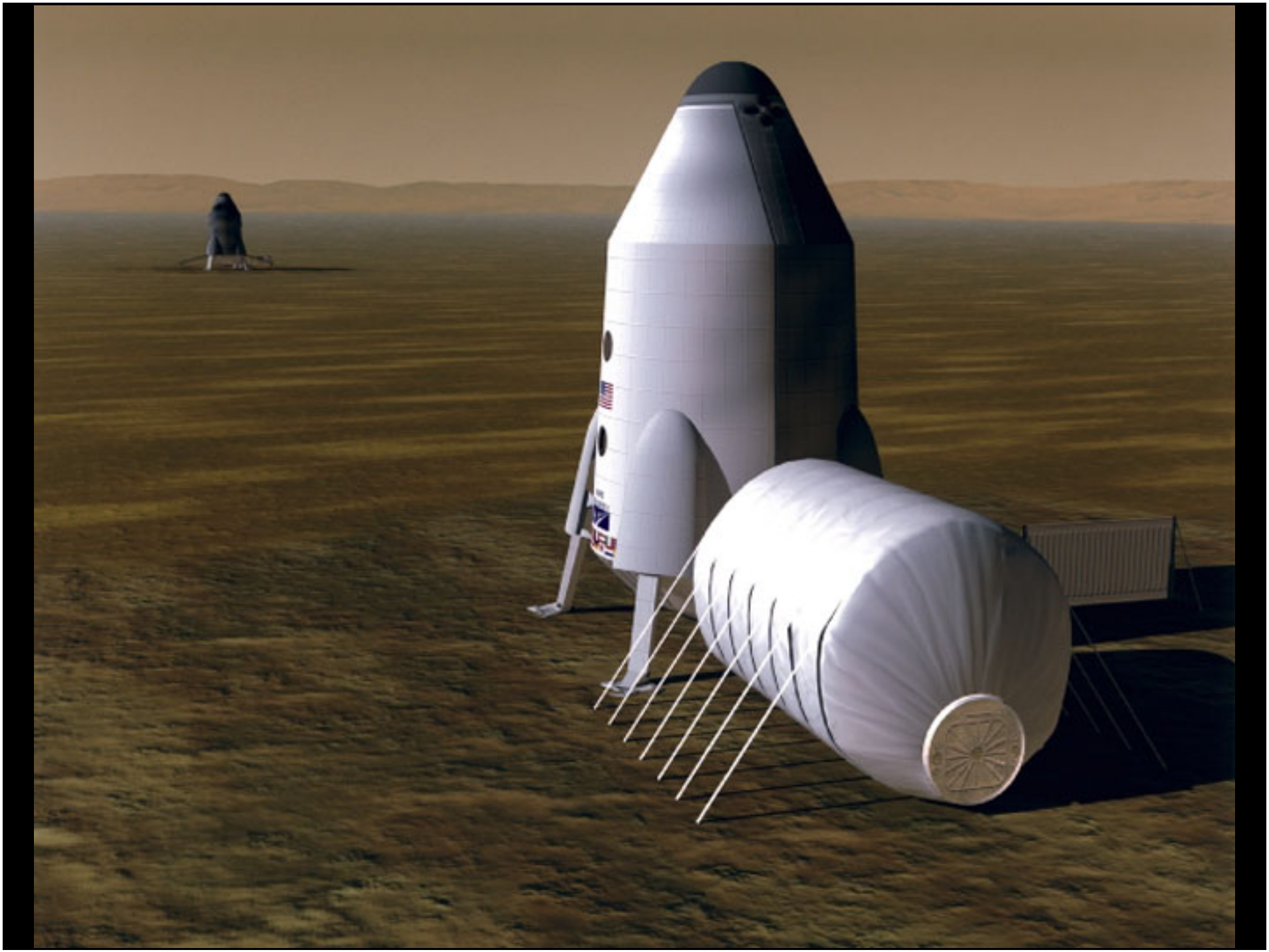


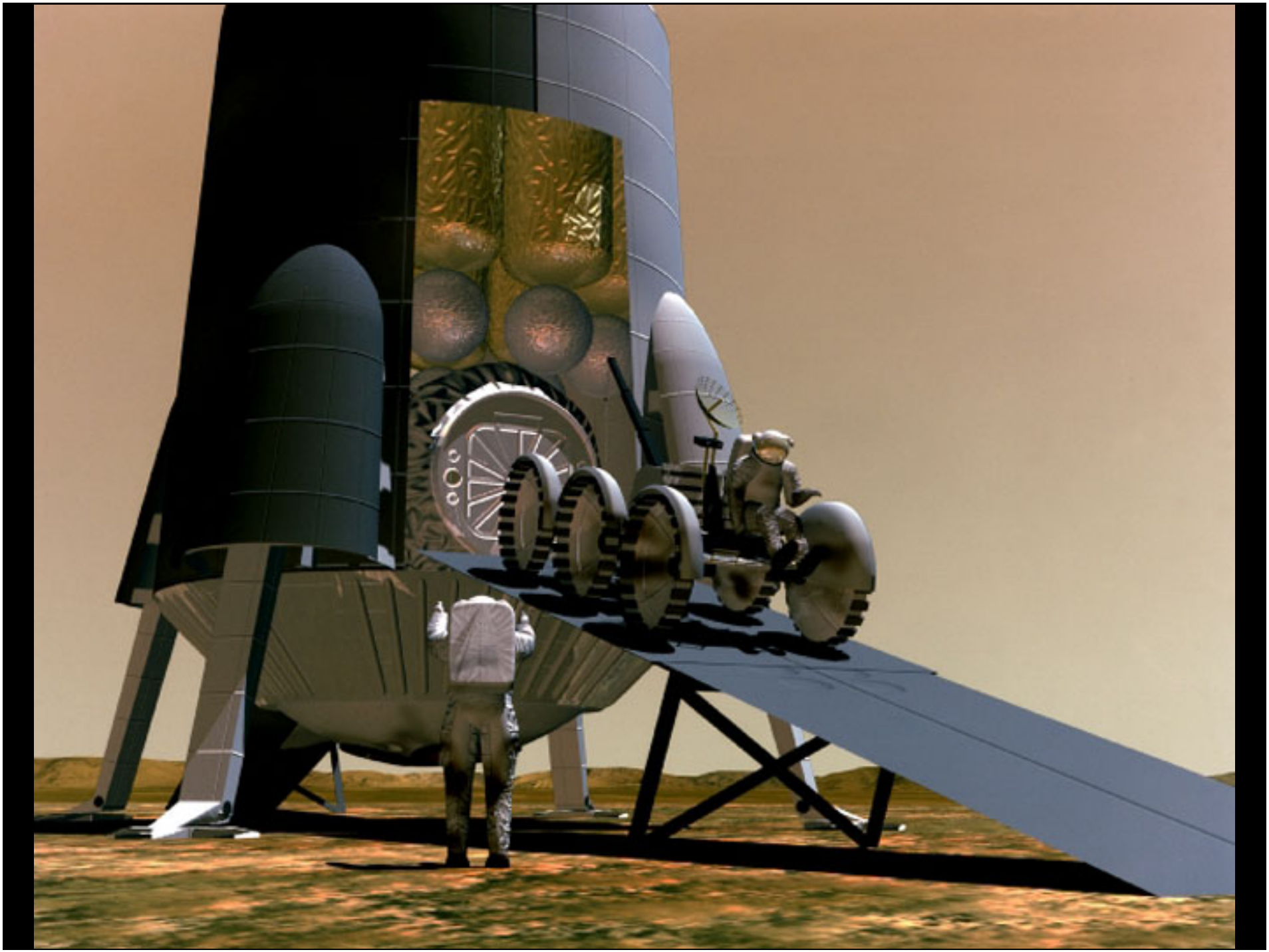
Source: S. V. Gunn, (1989) "Development of Nuclear Rocket Technology", AIAA paper 89-2386

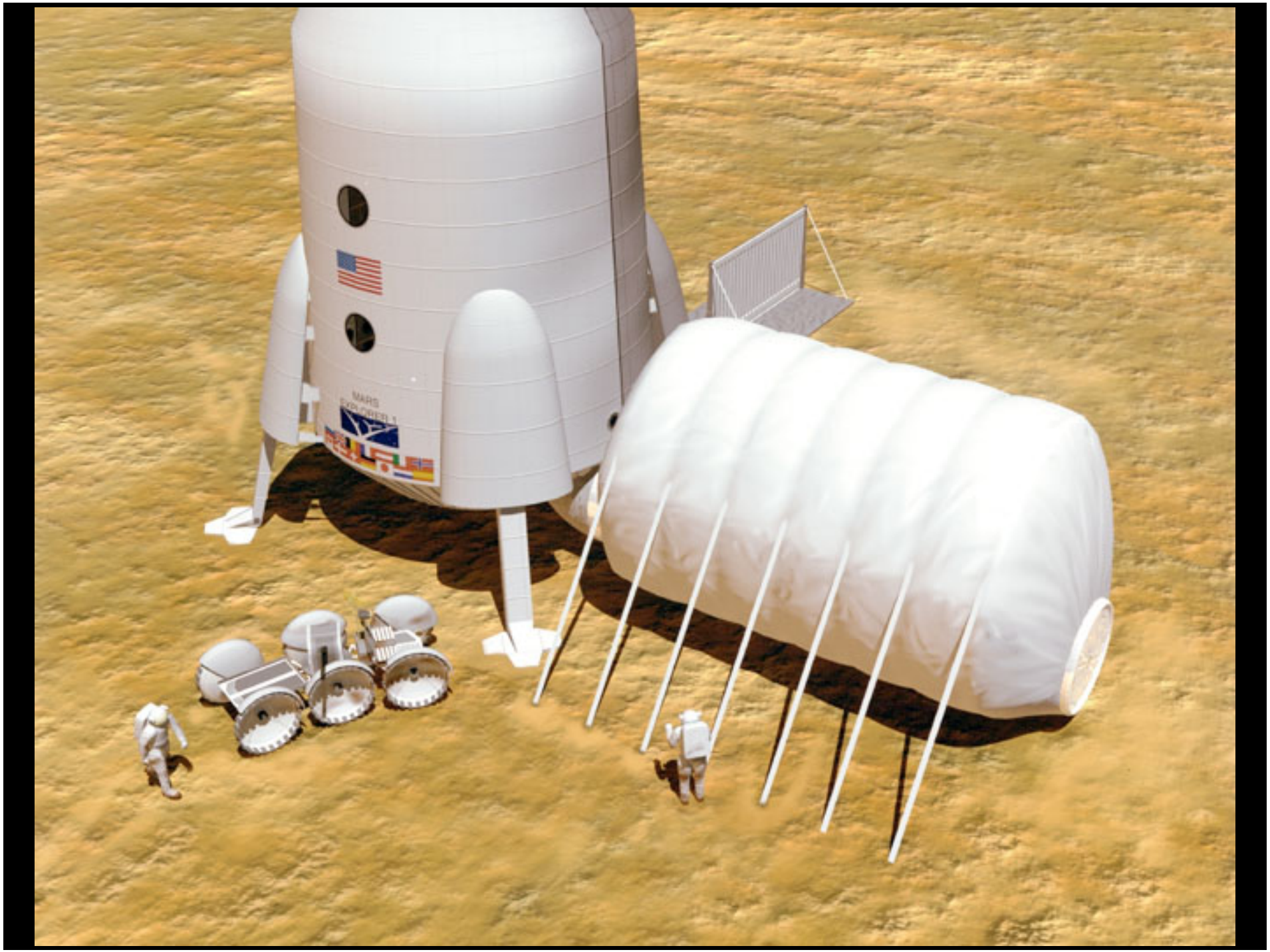

LOS ALAMOS

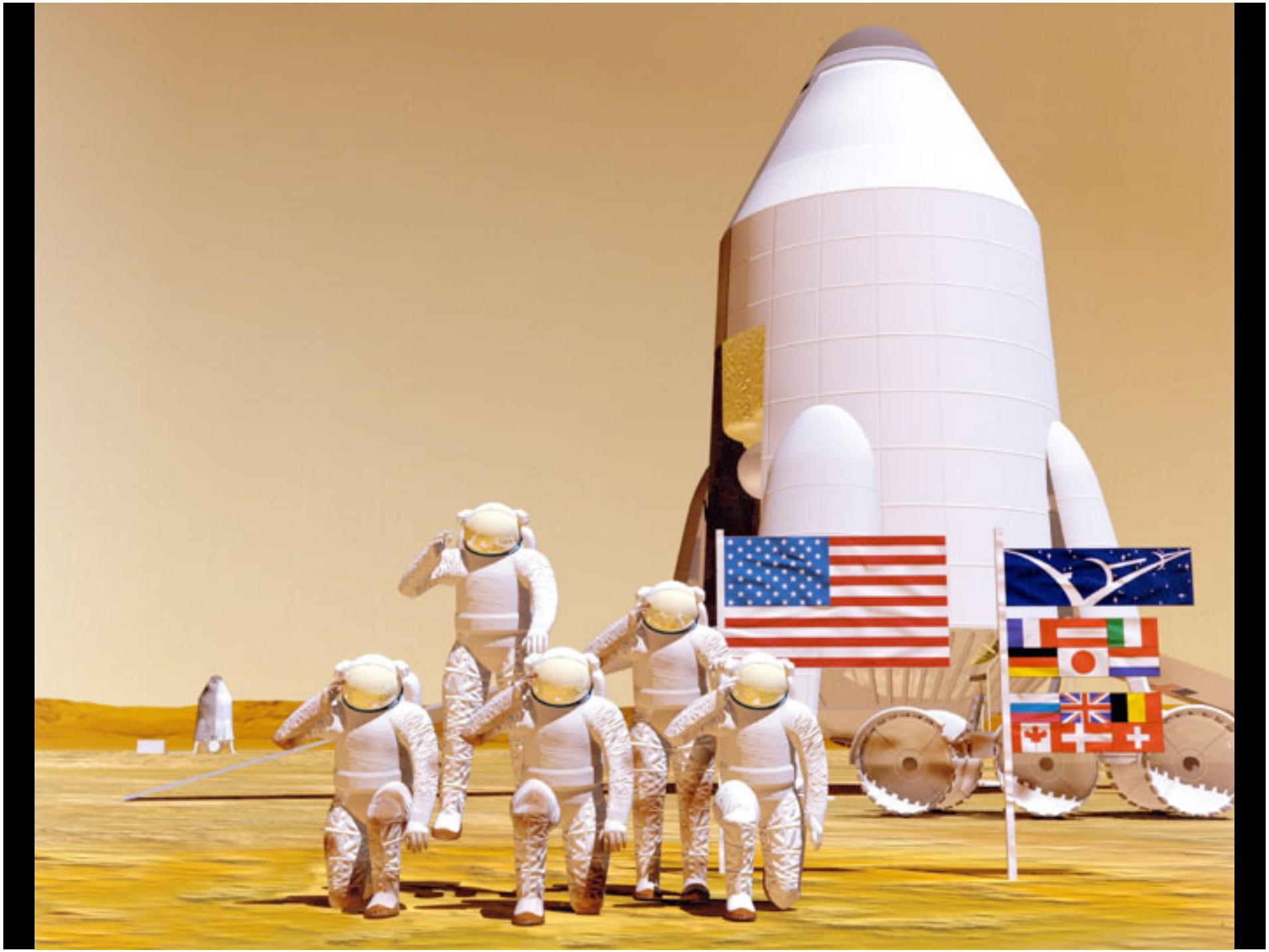

USA



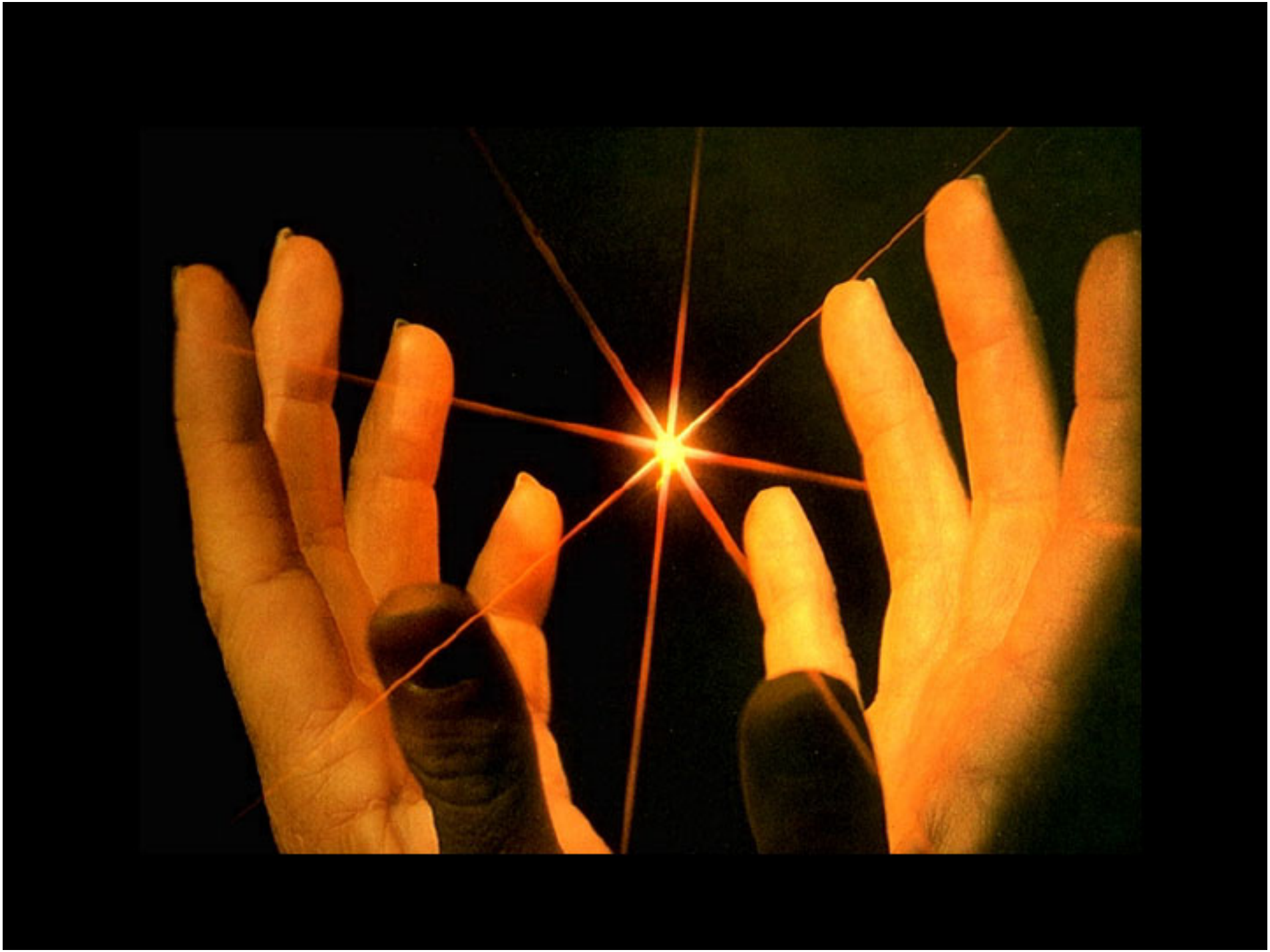


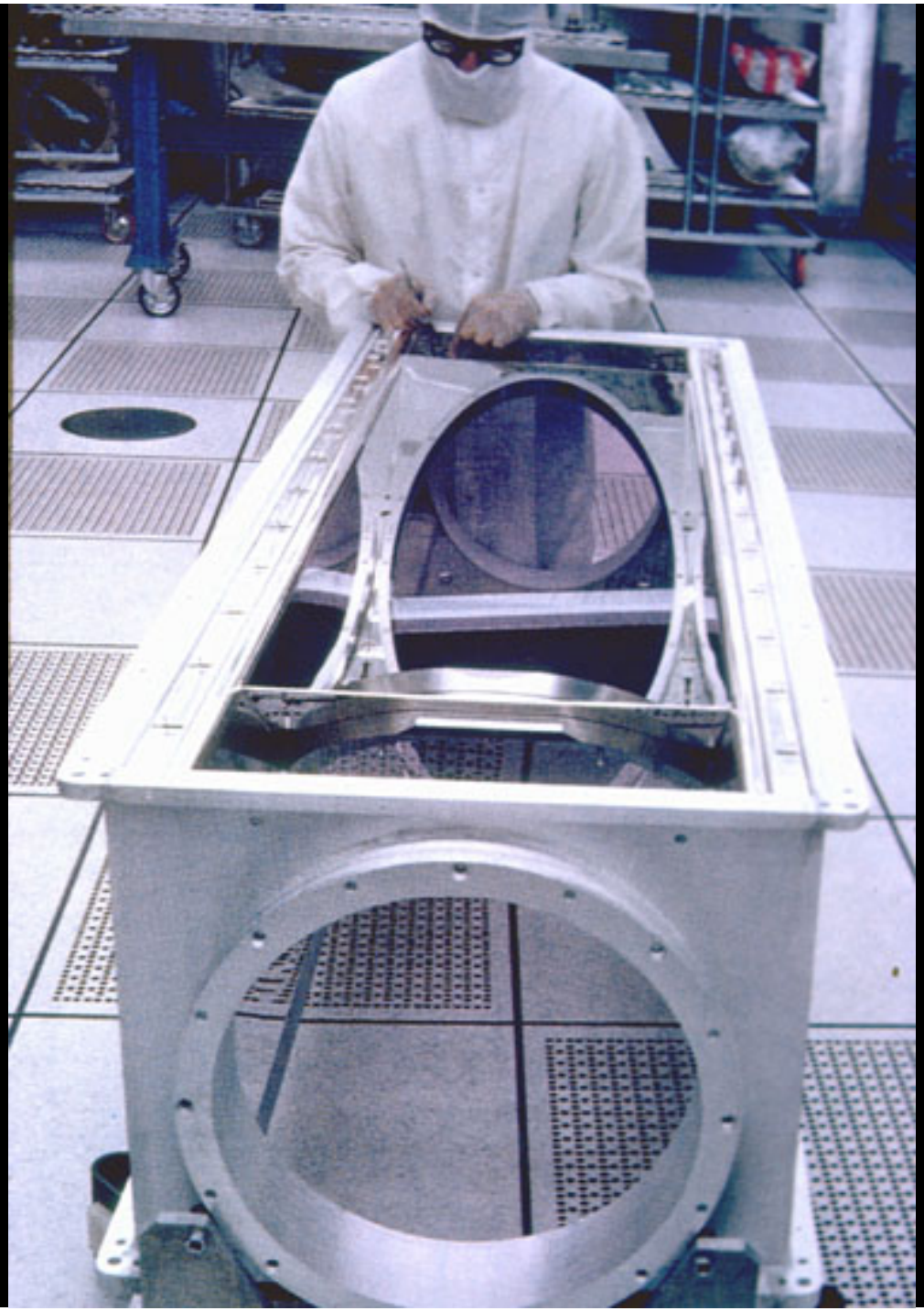


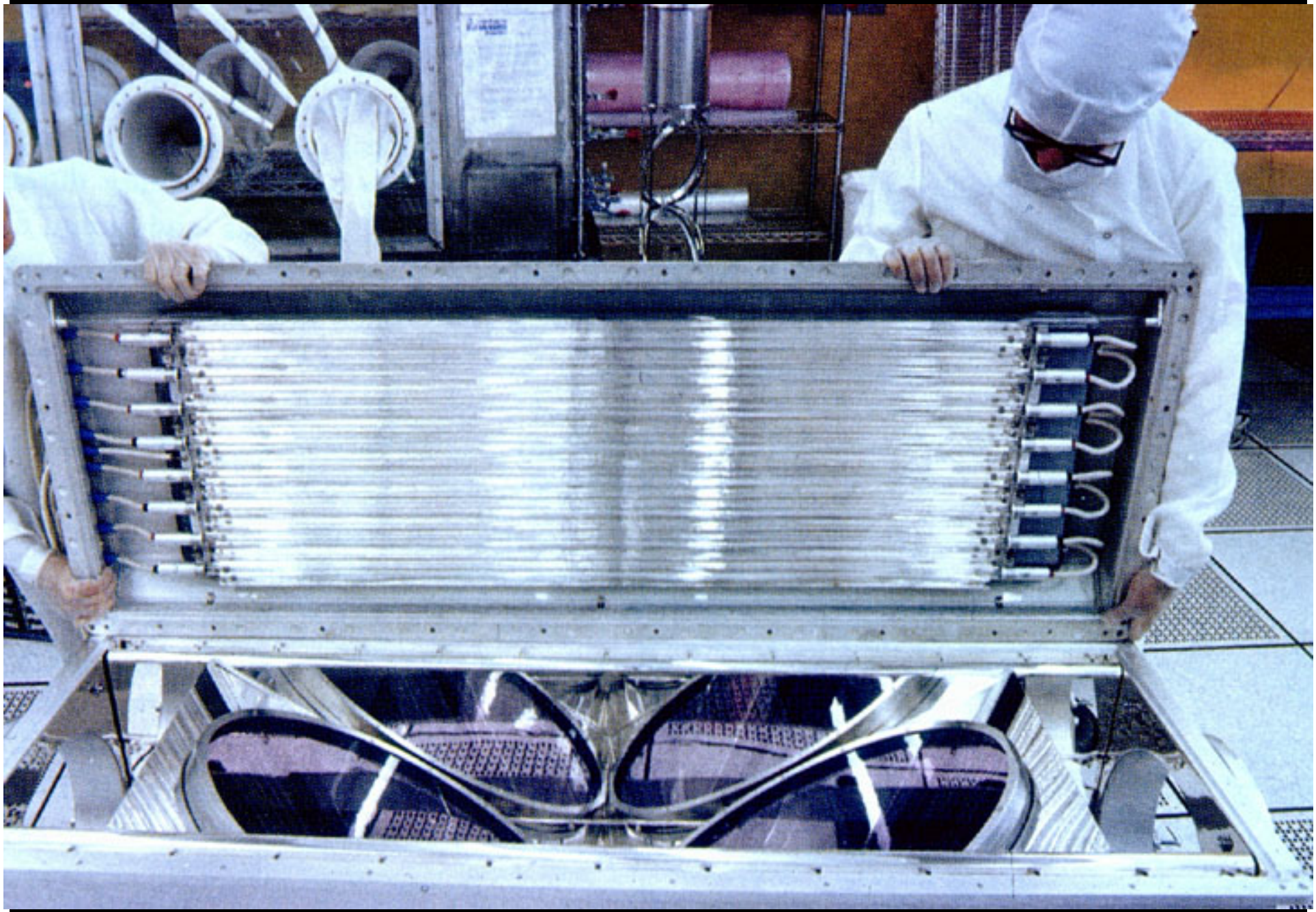


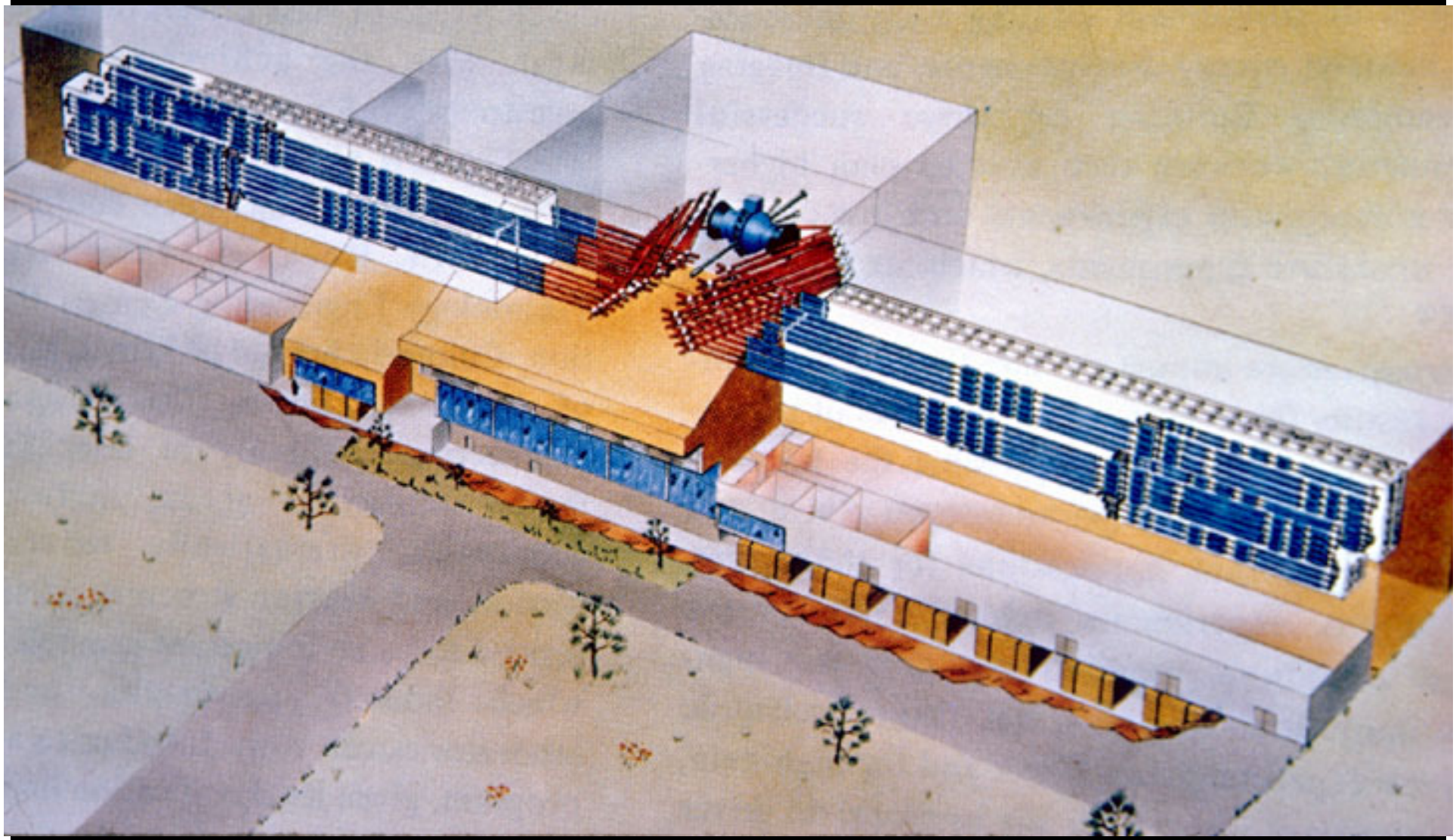


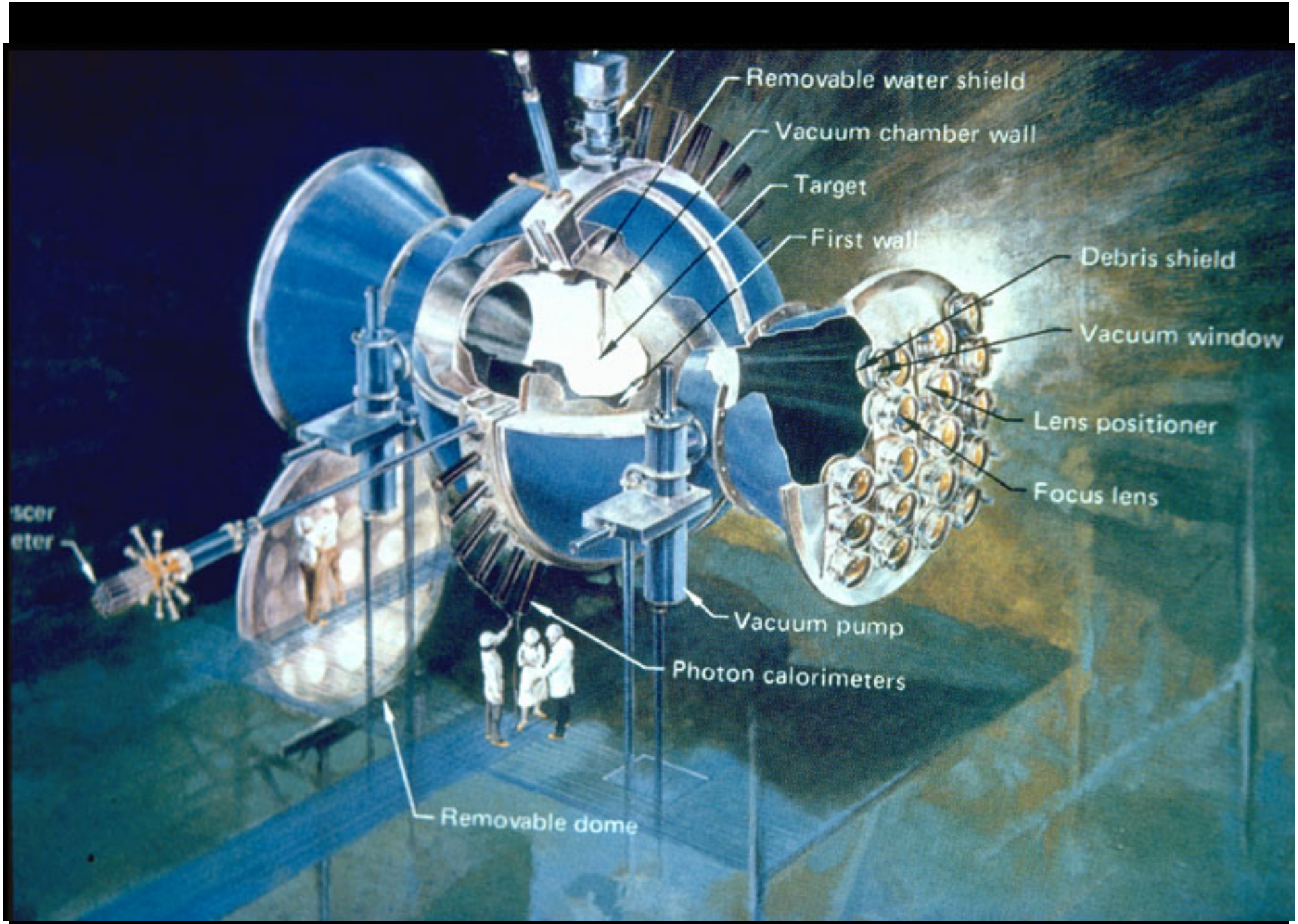
Laser Fusion

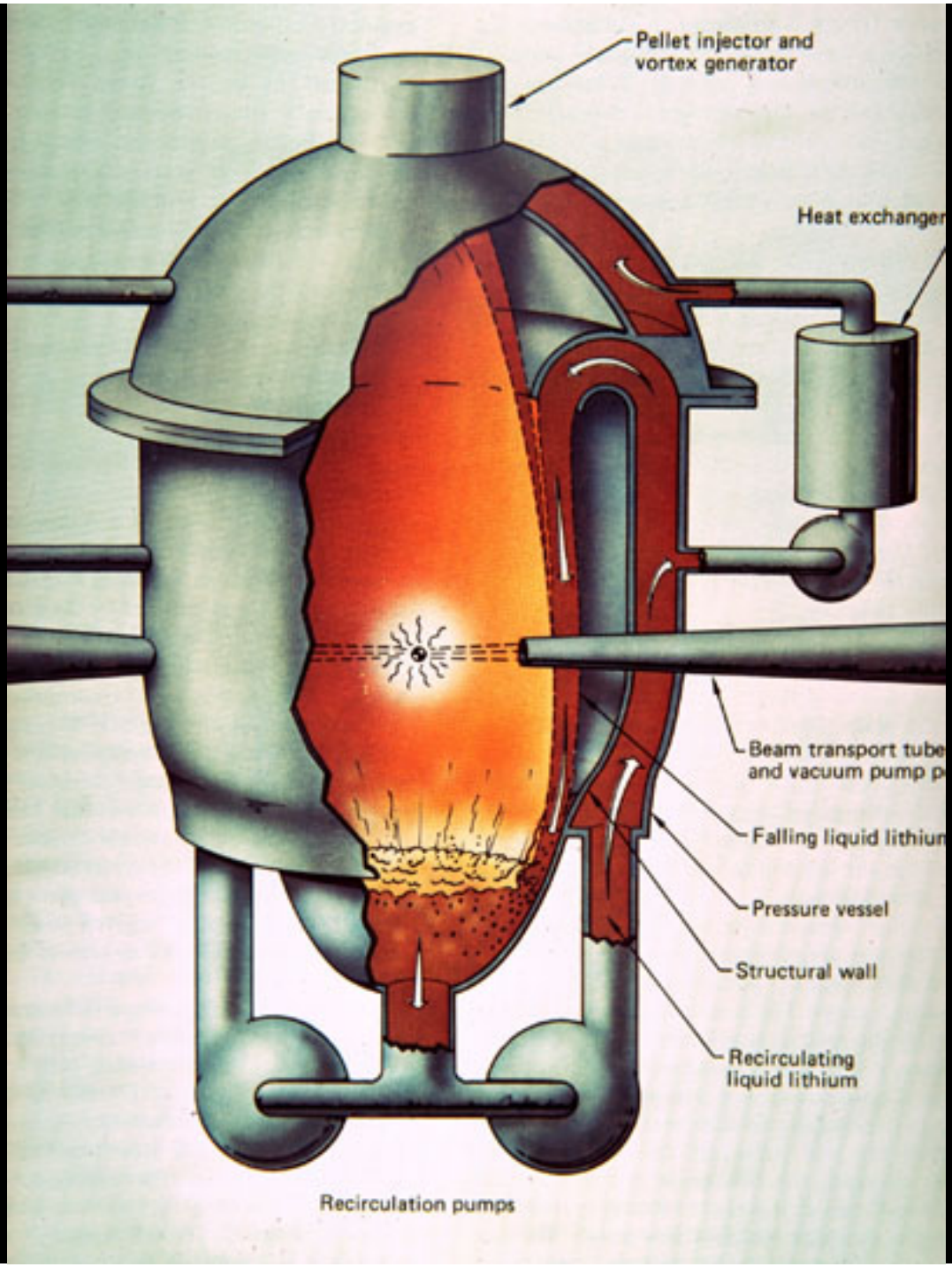


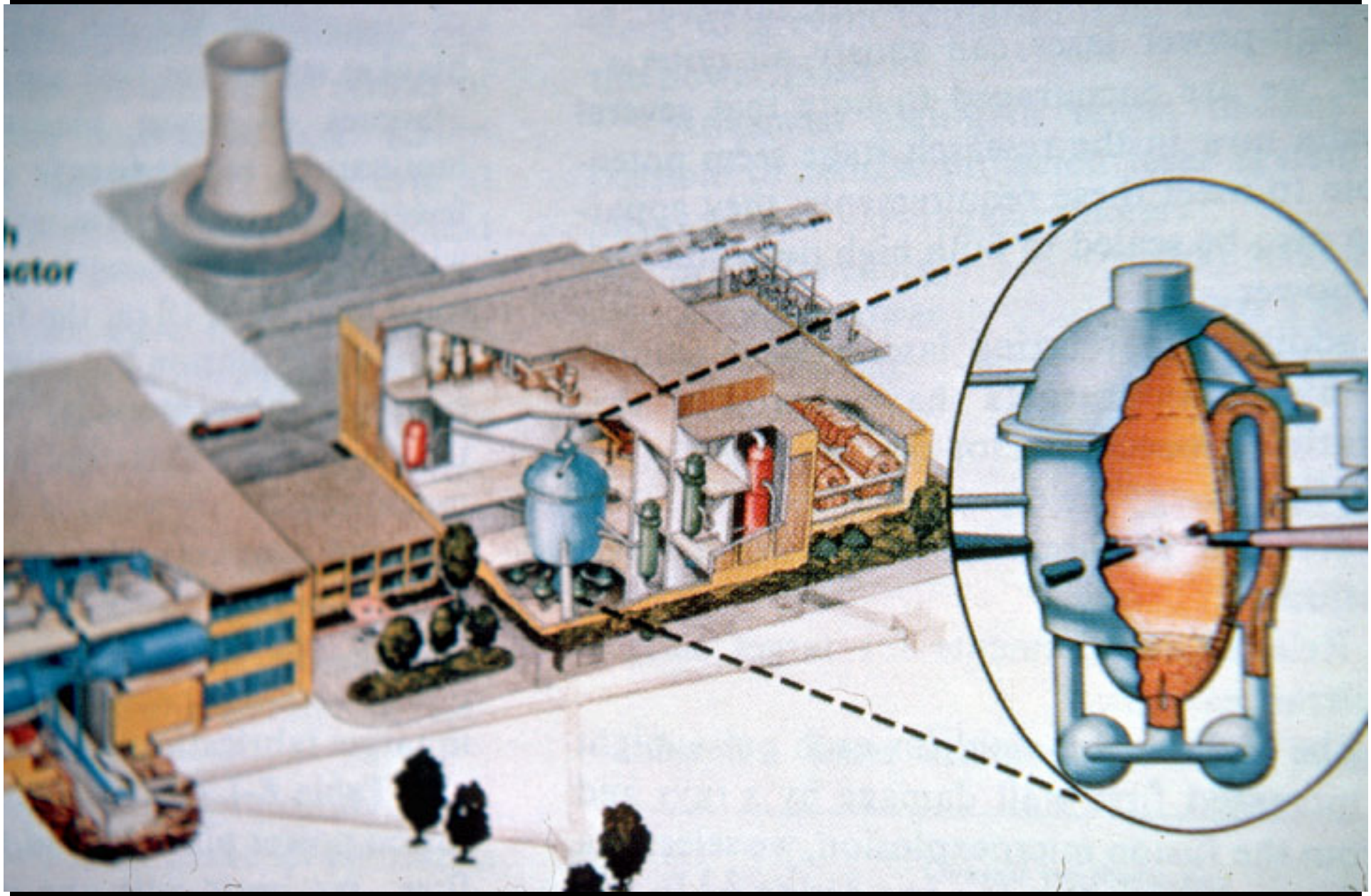


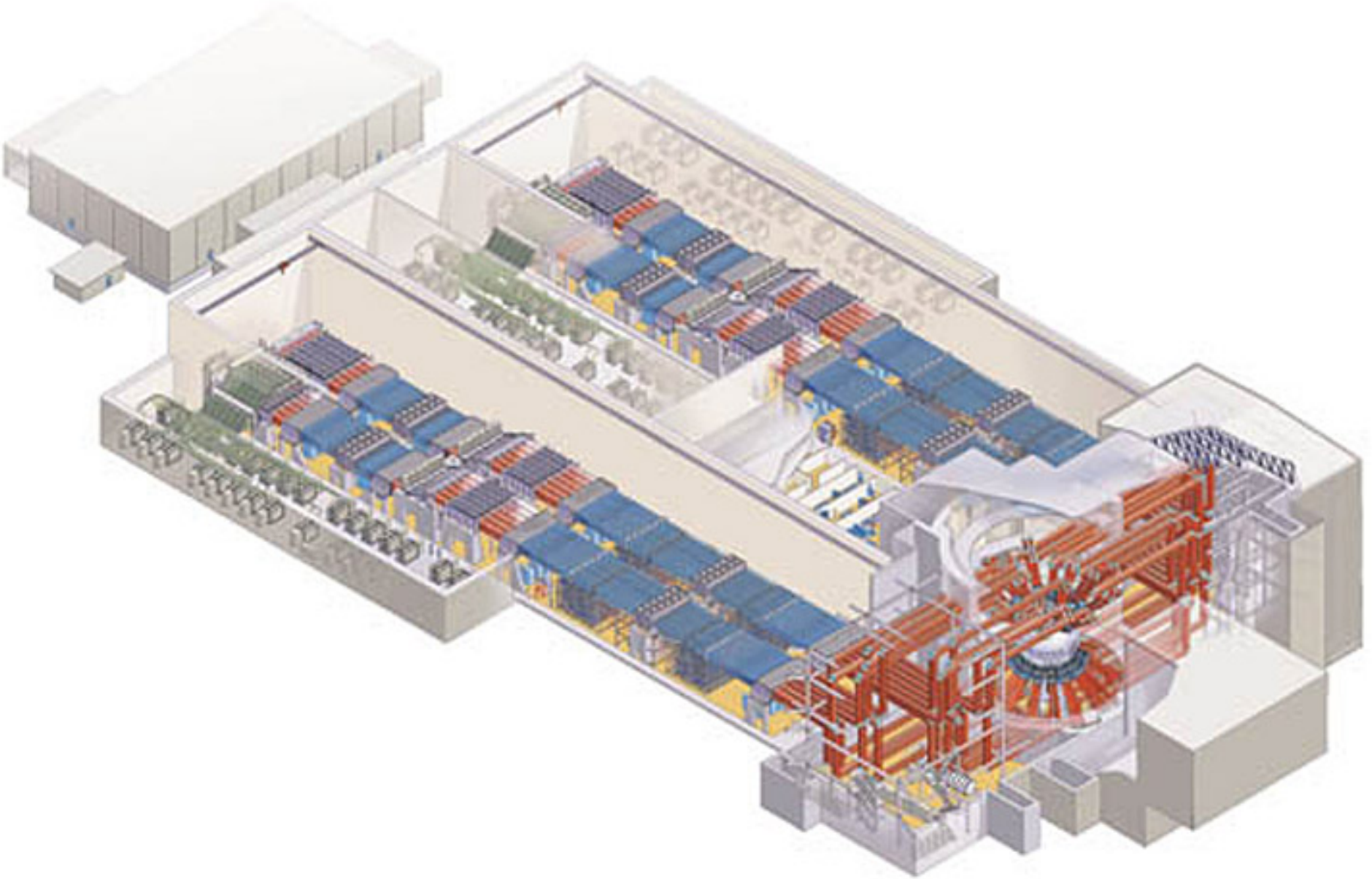


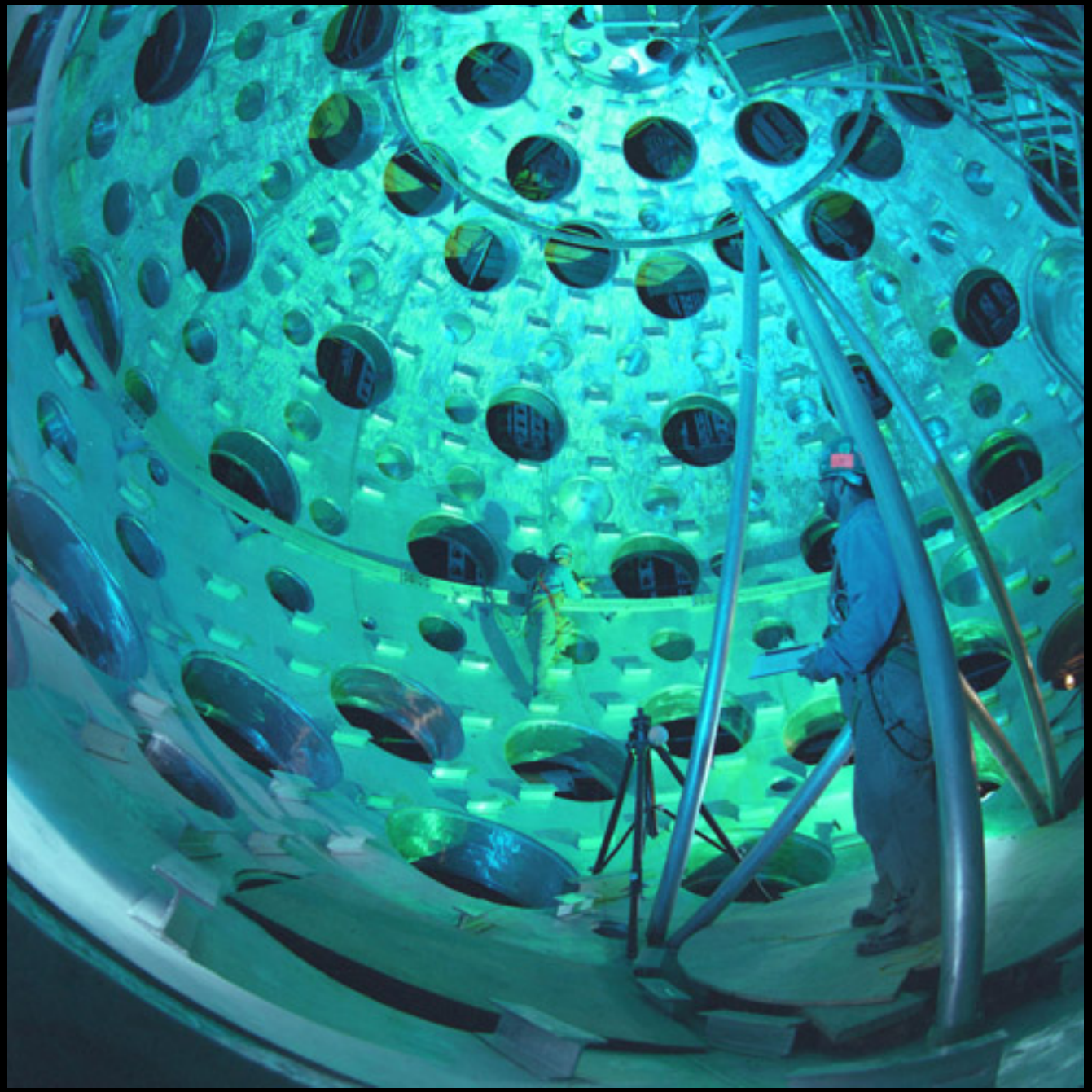


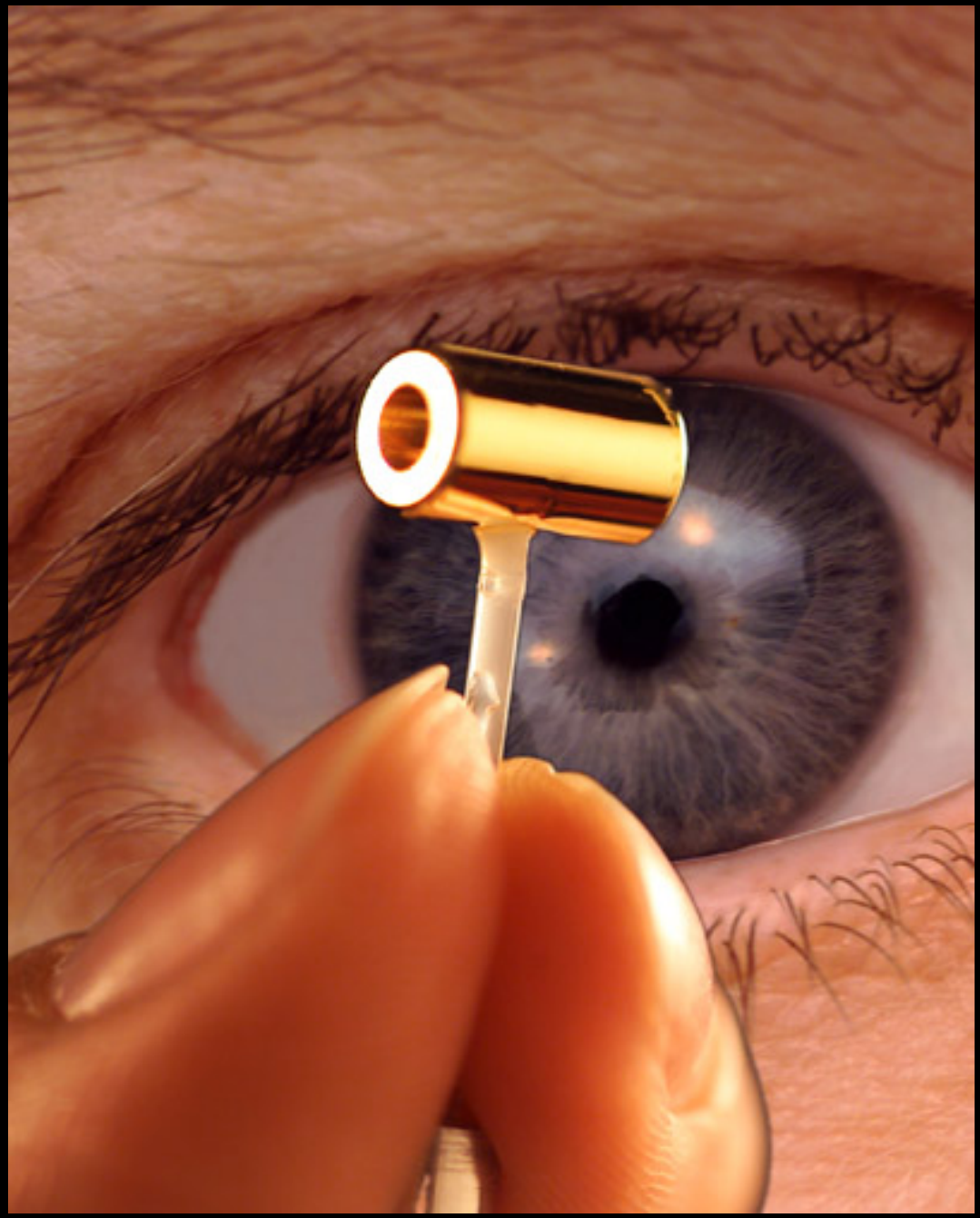

Removable water shield
Vacuum chamber wall
Target
First wall
Debris shield
Vacuum window
Lens positioner
Focus lens
Vacuum pump
Photon calorimeters
Removable dome


Pellet injector and vortex generator
Heat exchanger
Beam transport tube and vacuum pump p
Falling liquid lithium
Pressure vessel
Structural wall
Recirculating liquid lithium
Recirculation pumps



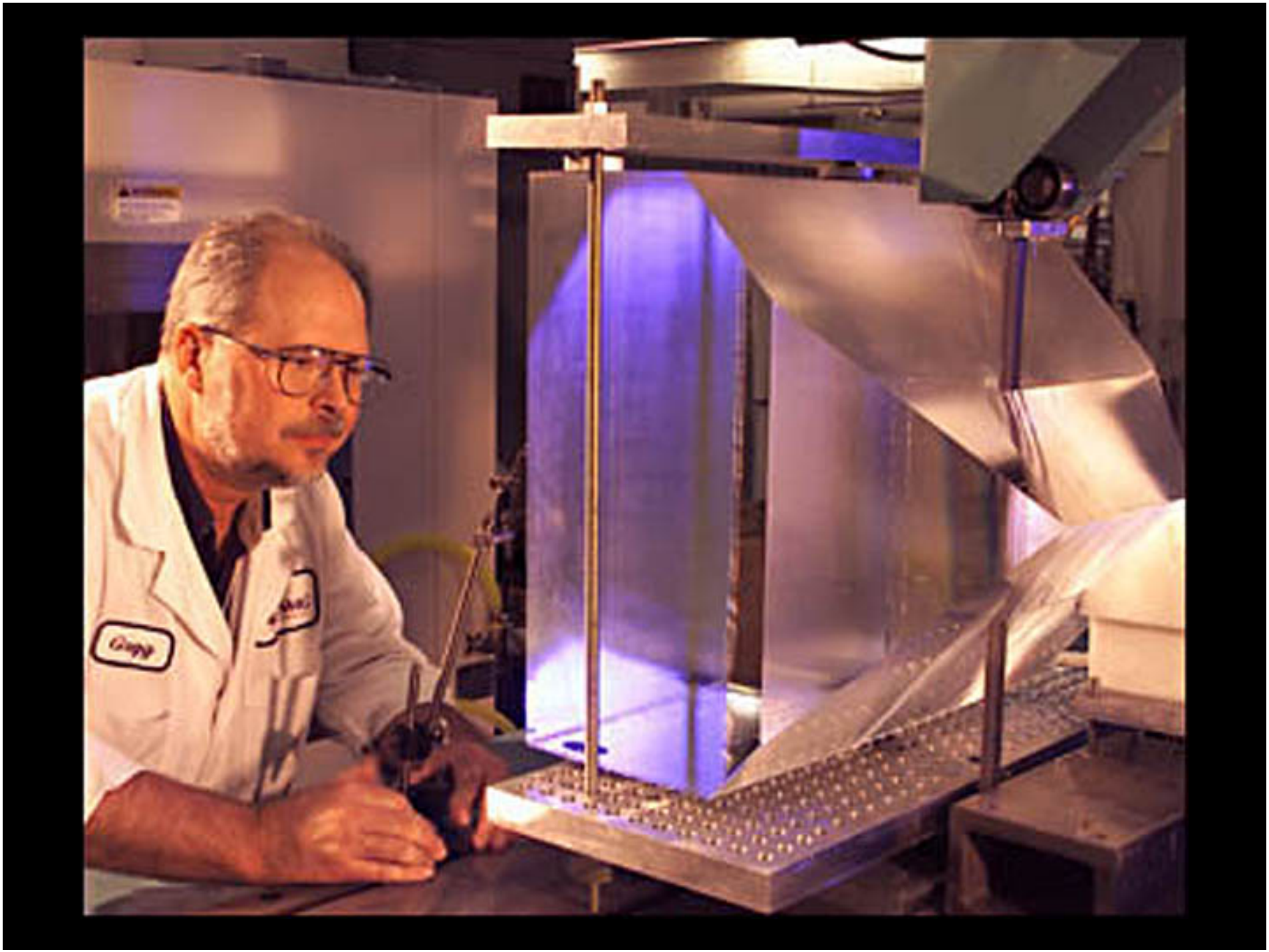


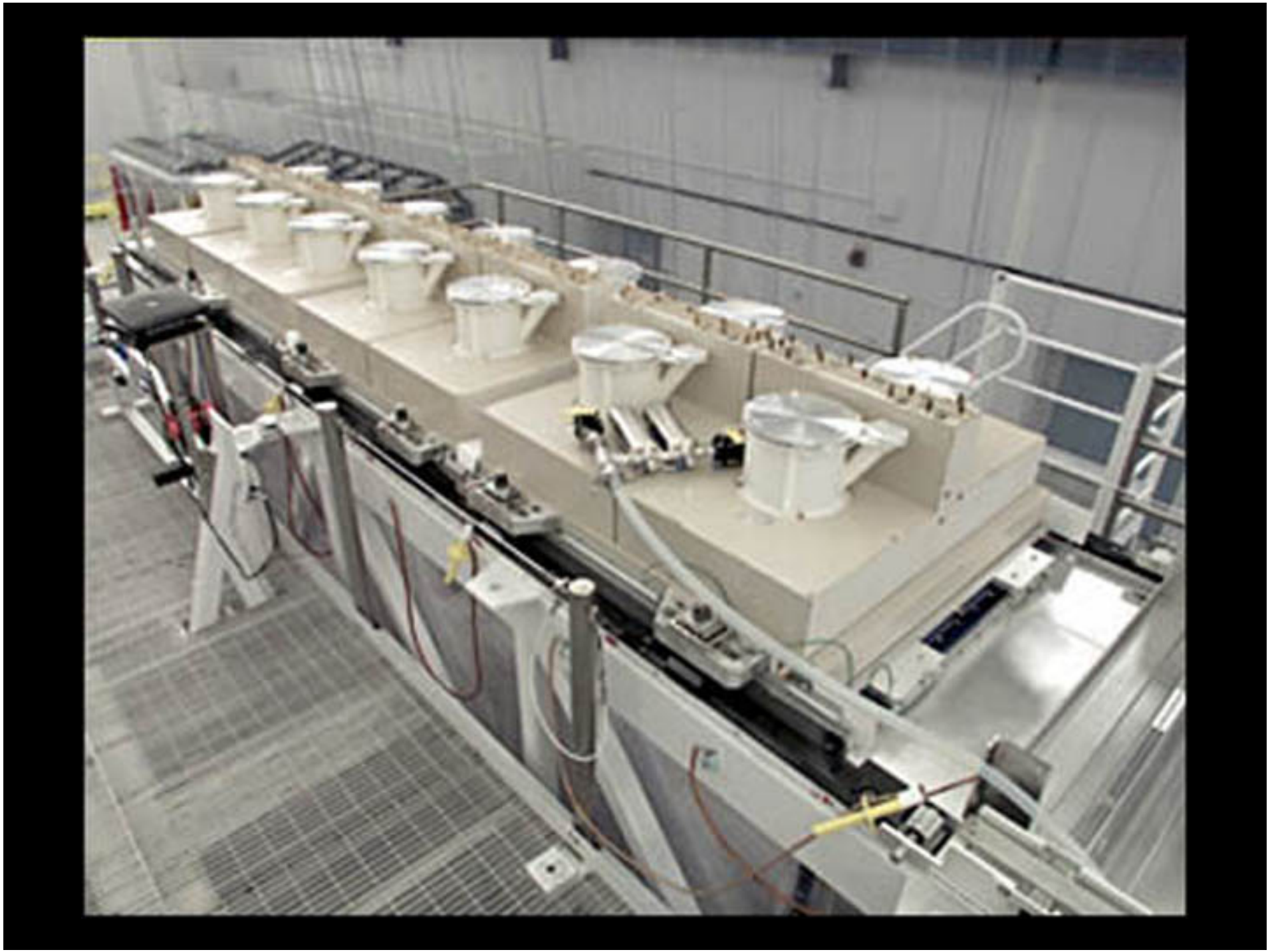




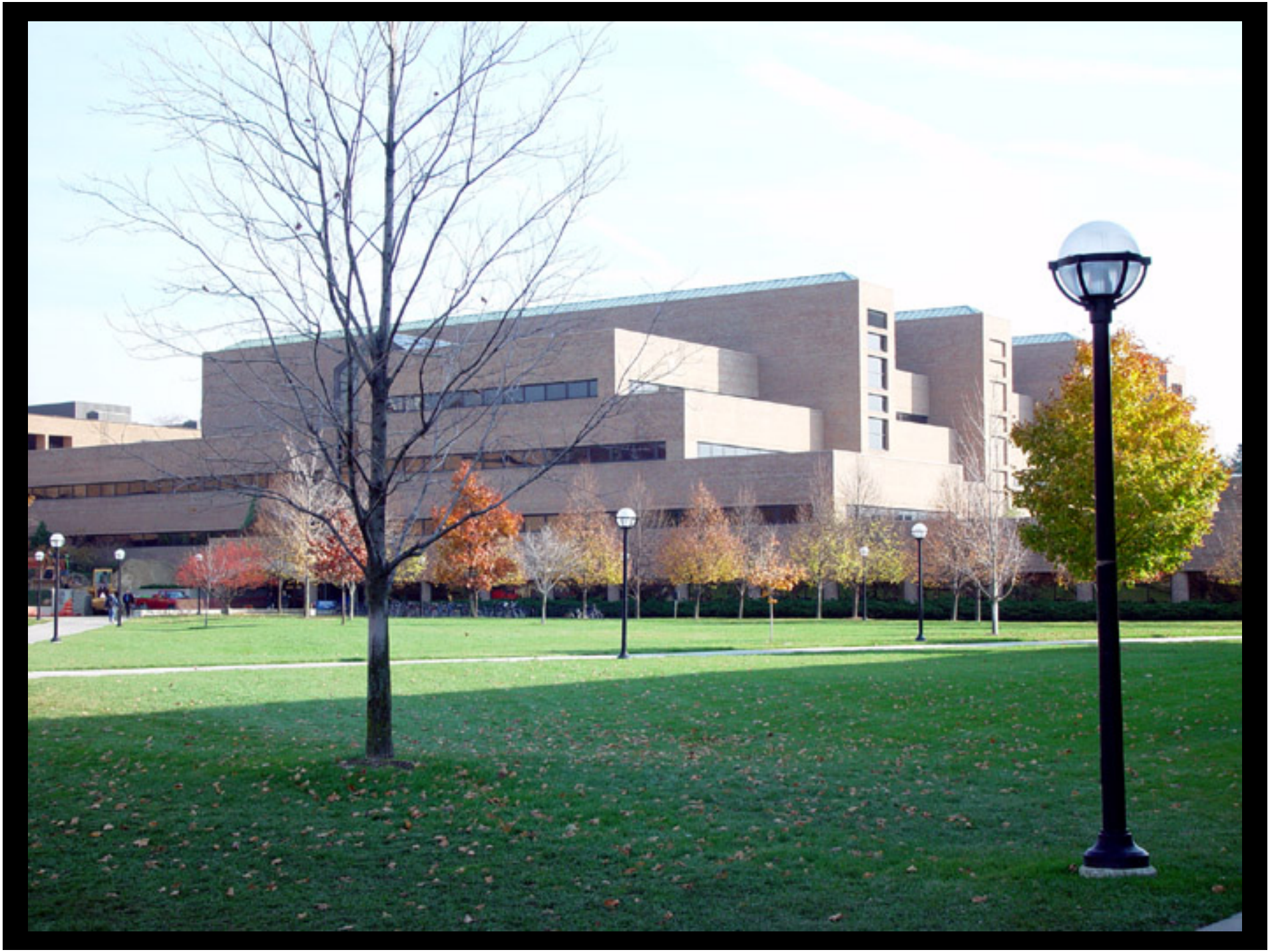

Randy


LG40716-01
LG40811-01
LG40715-02
LG40715-08
LG40716-07
LG40722-06



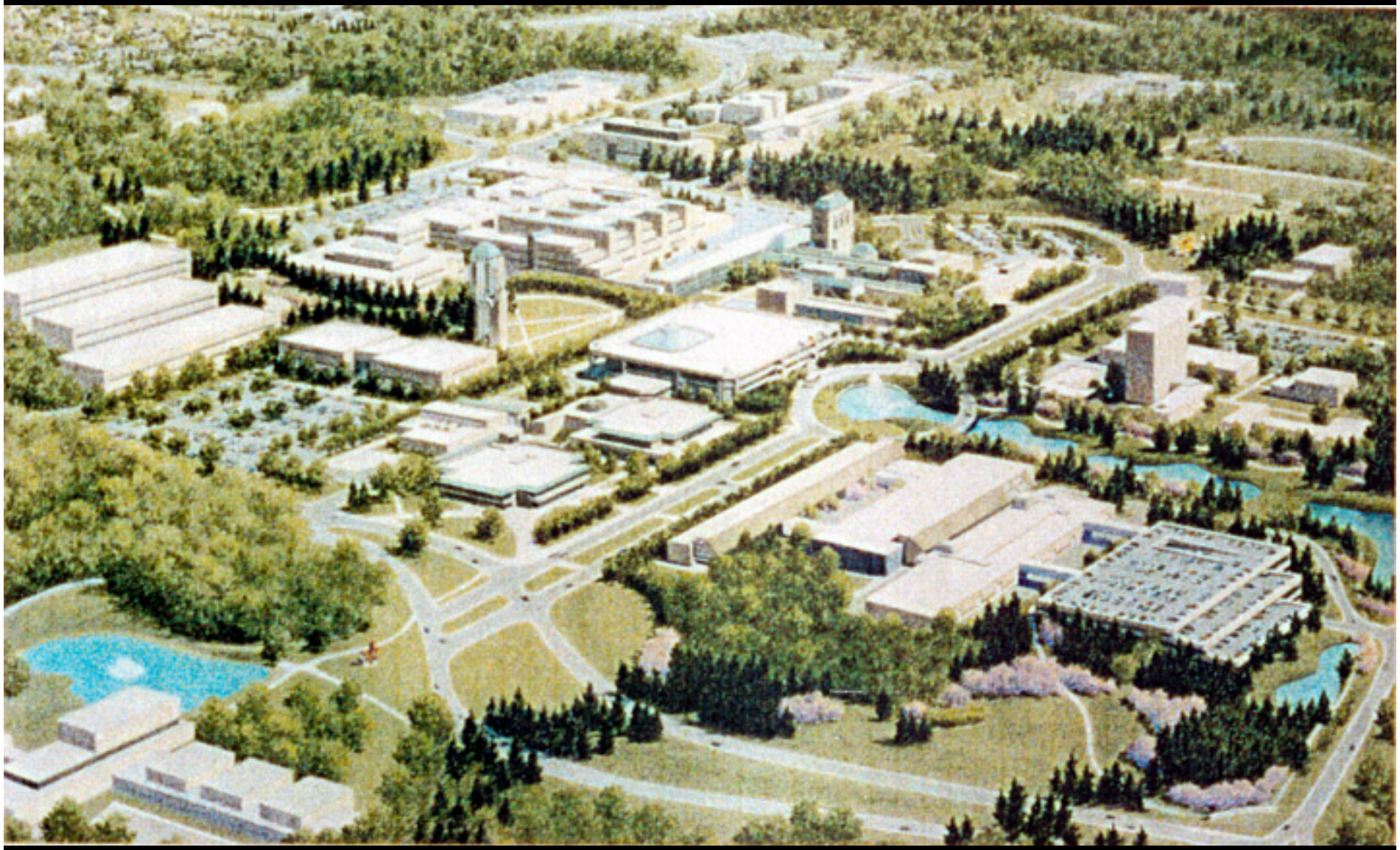


Dean
of
Engineering

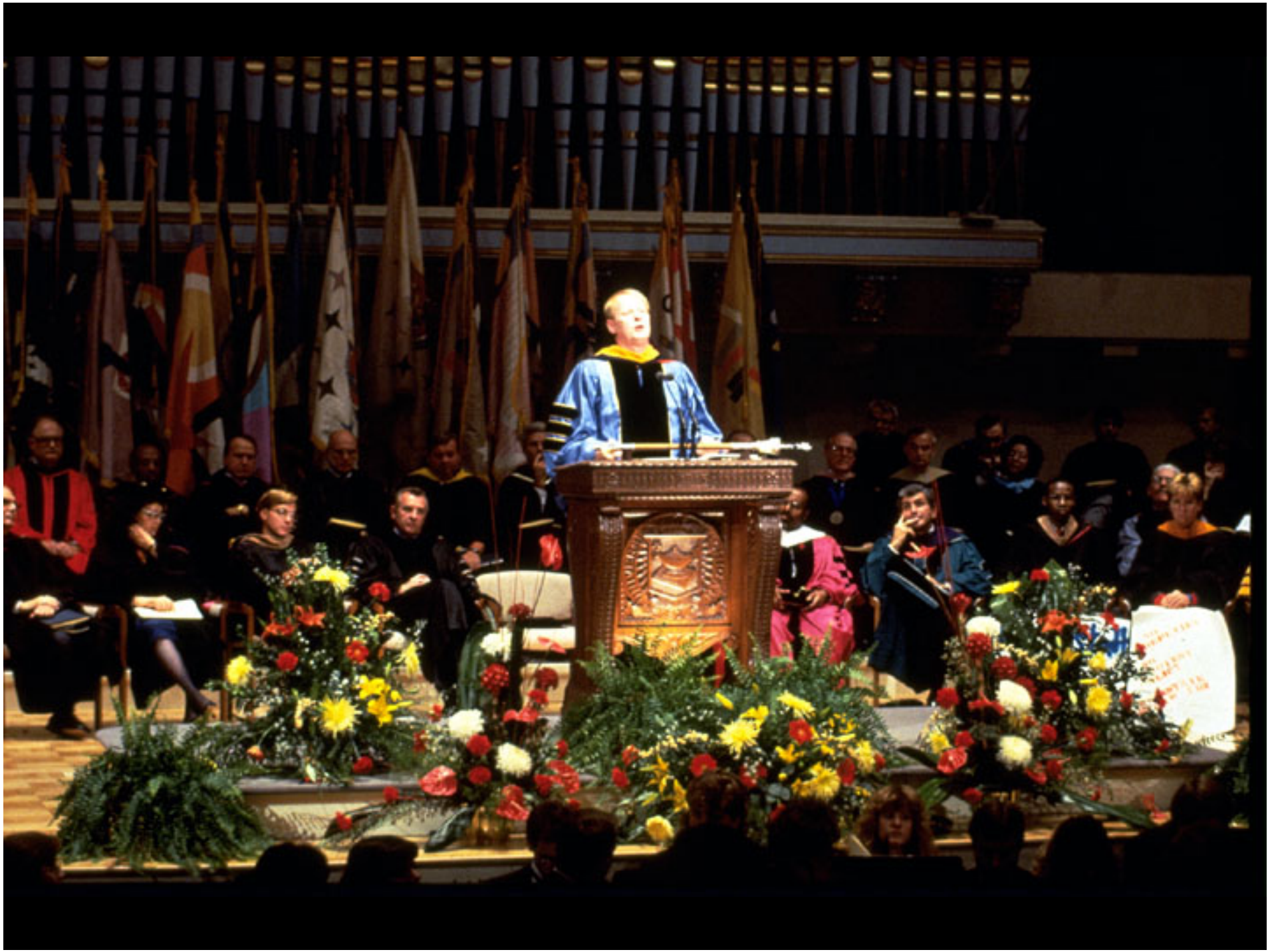



MICHIGAN

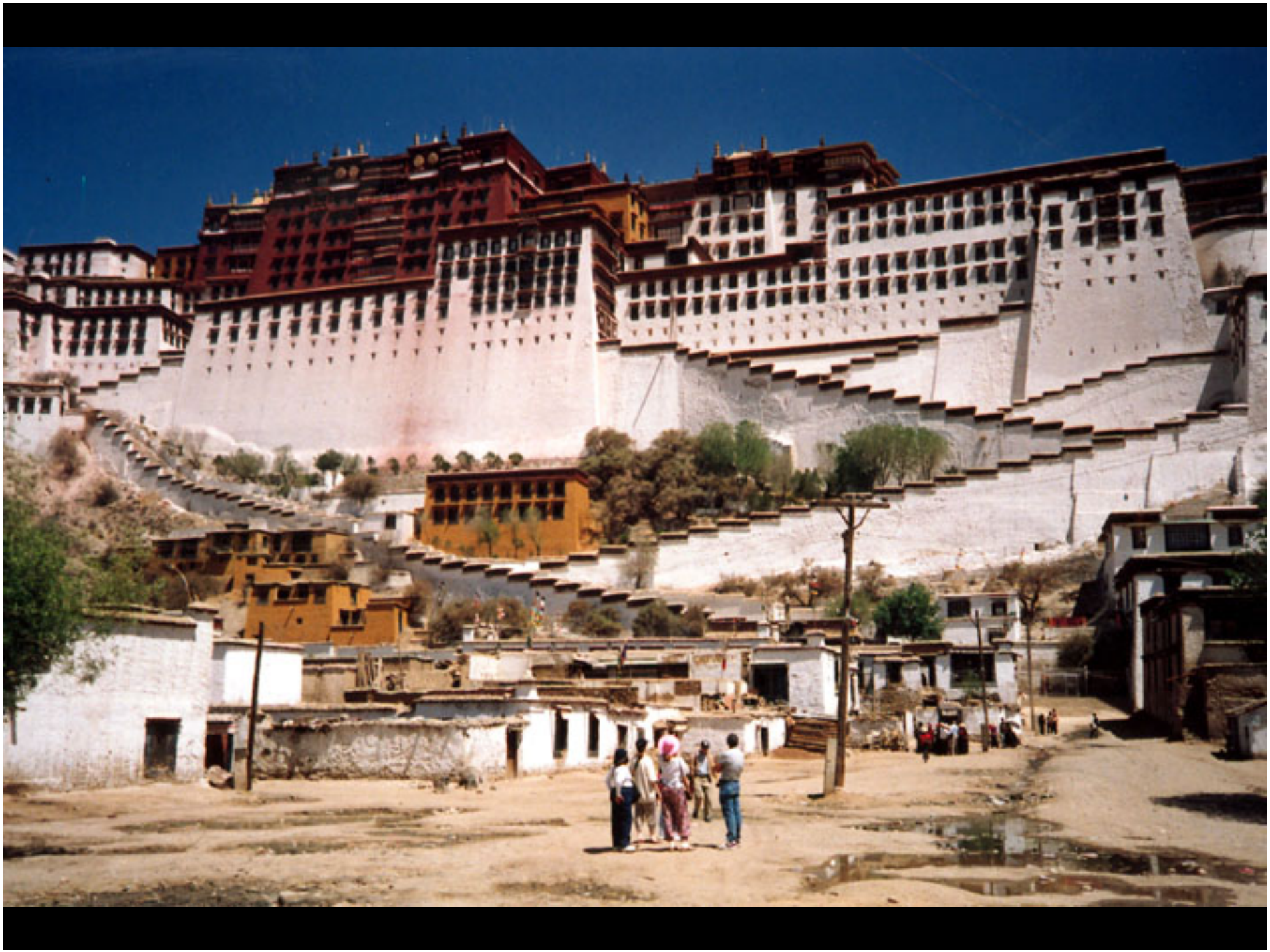

PROFILE



President of the University

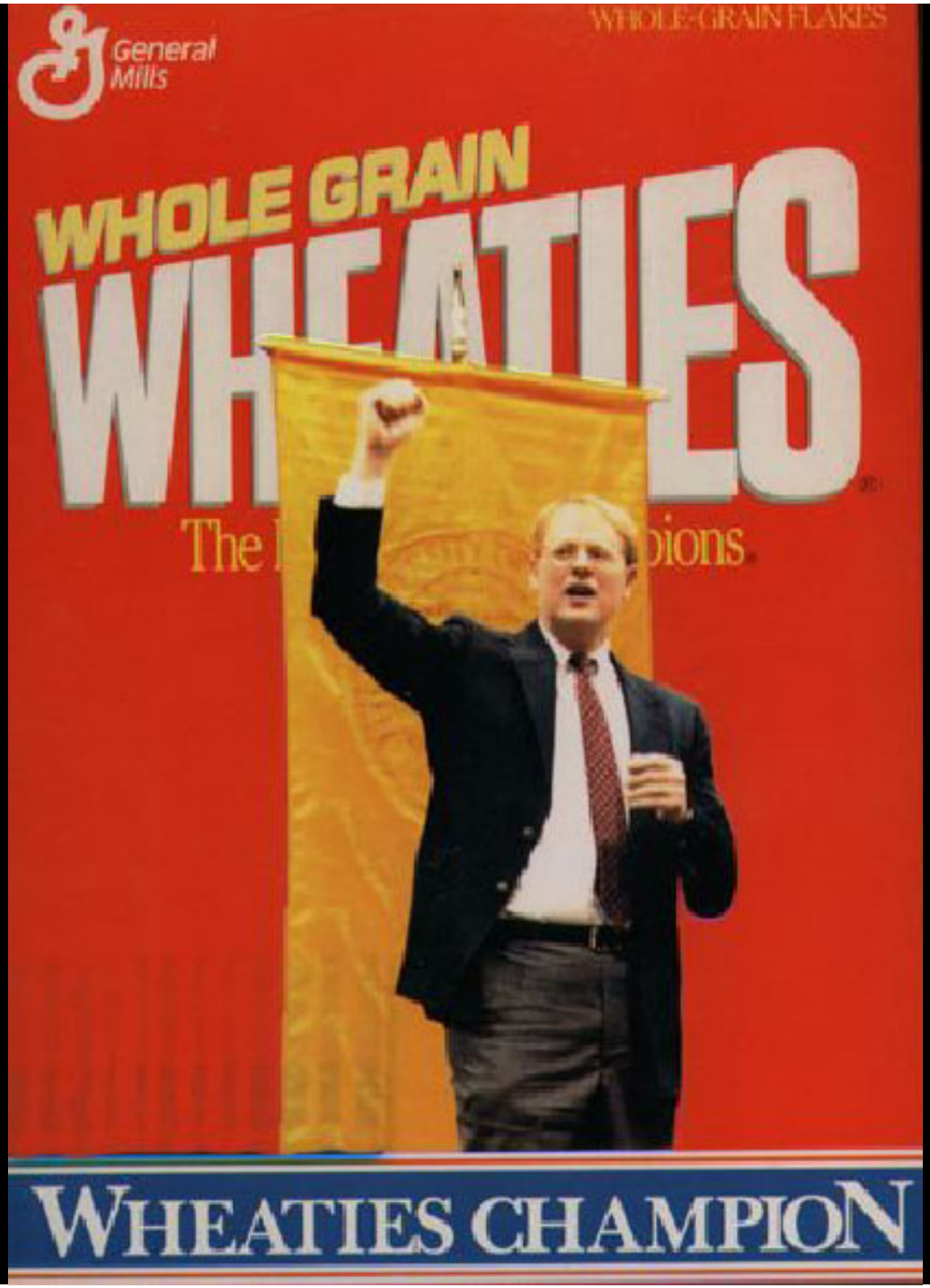



MICHIGAN STADIUM



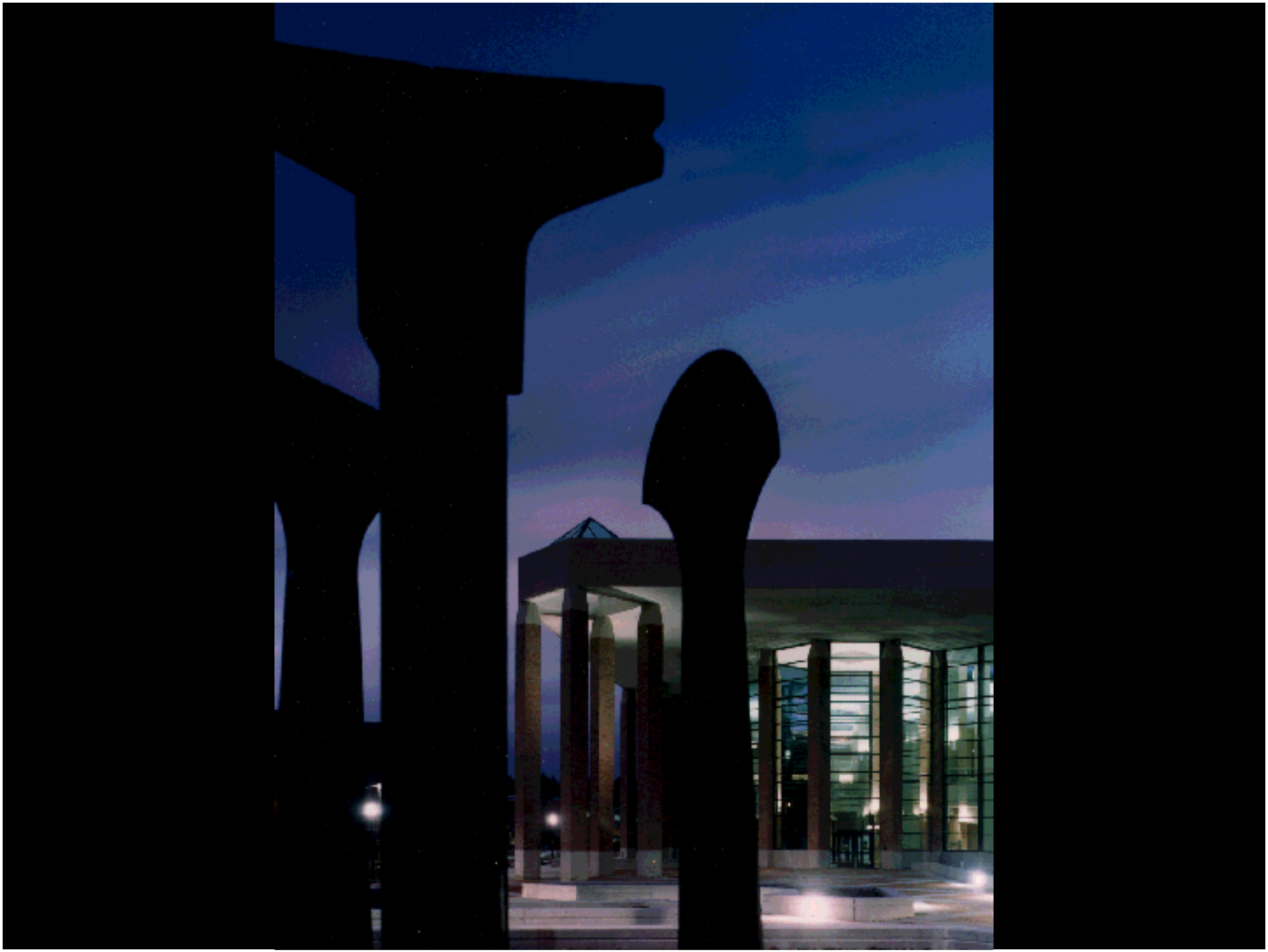

FINAL FOU


MICHIGAN STADIUM
NATIONAL CHAMPIONS
MICHIGAN


General Mills
WHOLE-GRAIN FLAKES
WHOLE GRAIN
WHEATIES
WHEATIES CHAMPION

The Media Union

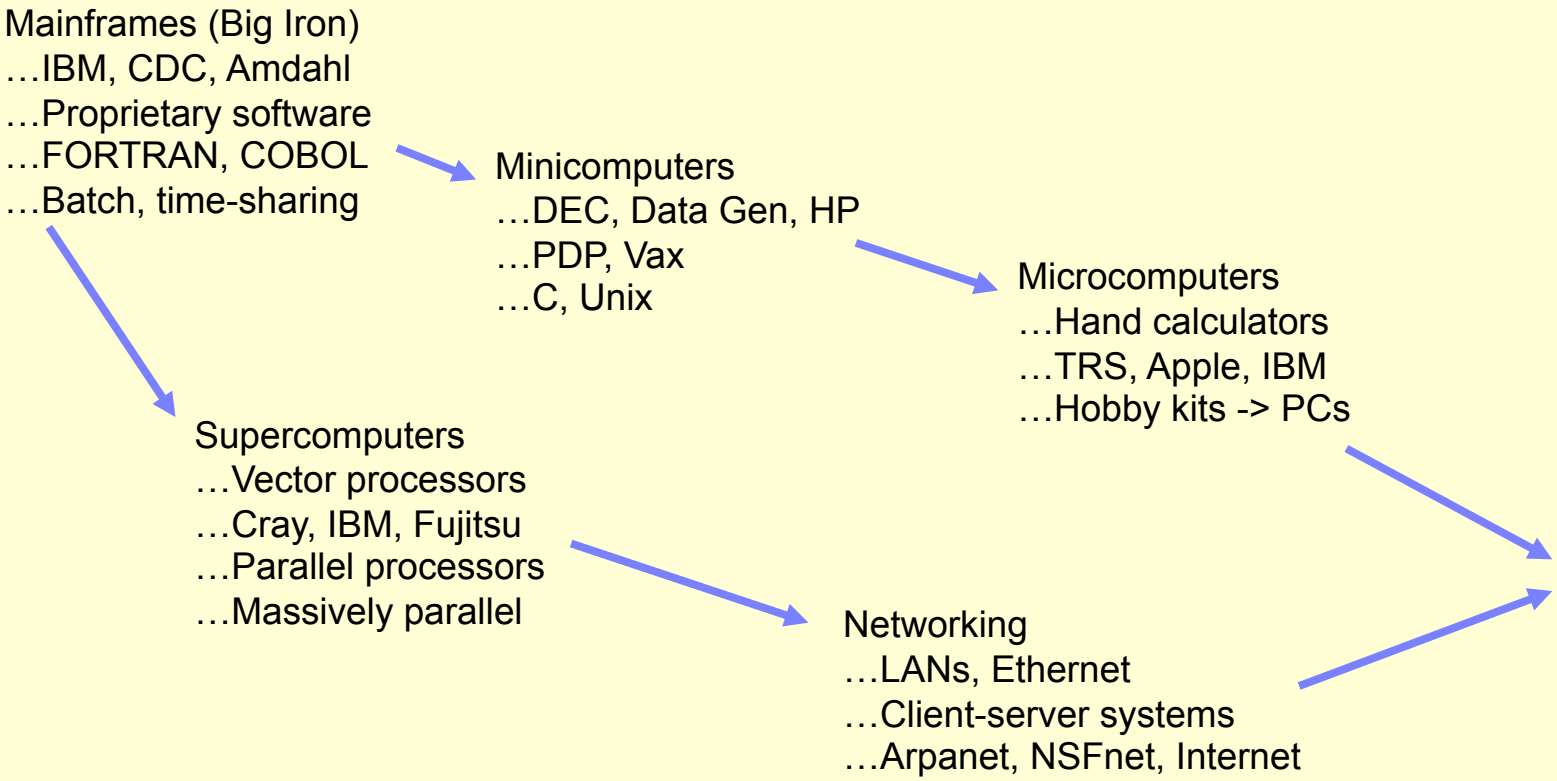
The New Tools for
A Knowledge Society




RESERVES

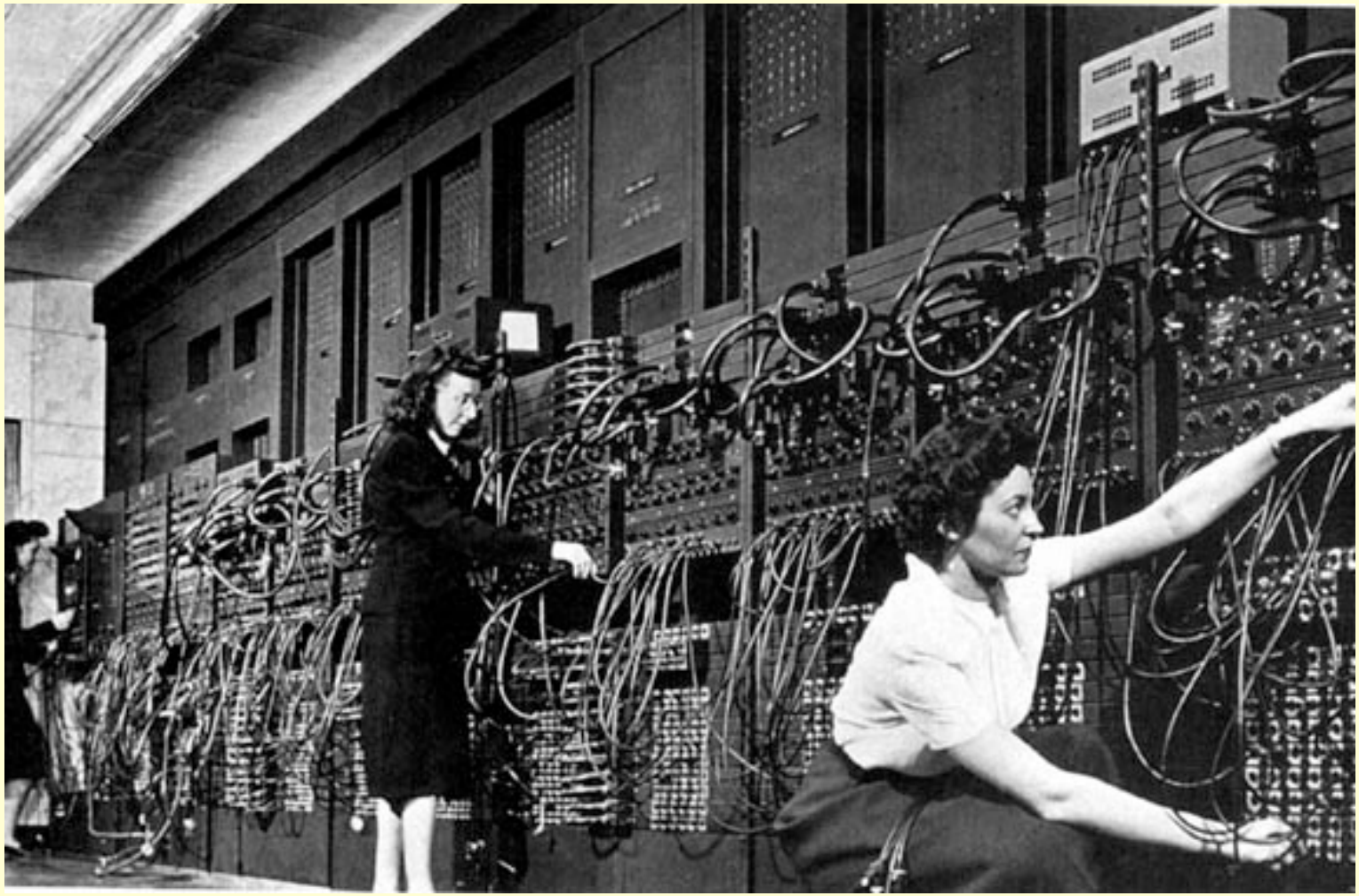
The Evolution of Information Technology

A Detour:
The Evolution of Computers



Batch → Time-sharing → Personal → Collaborative

From Eniac



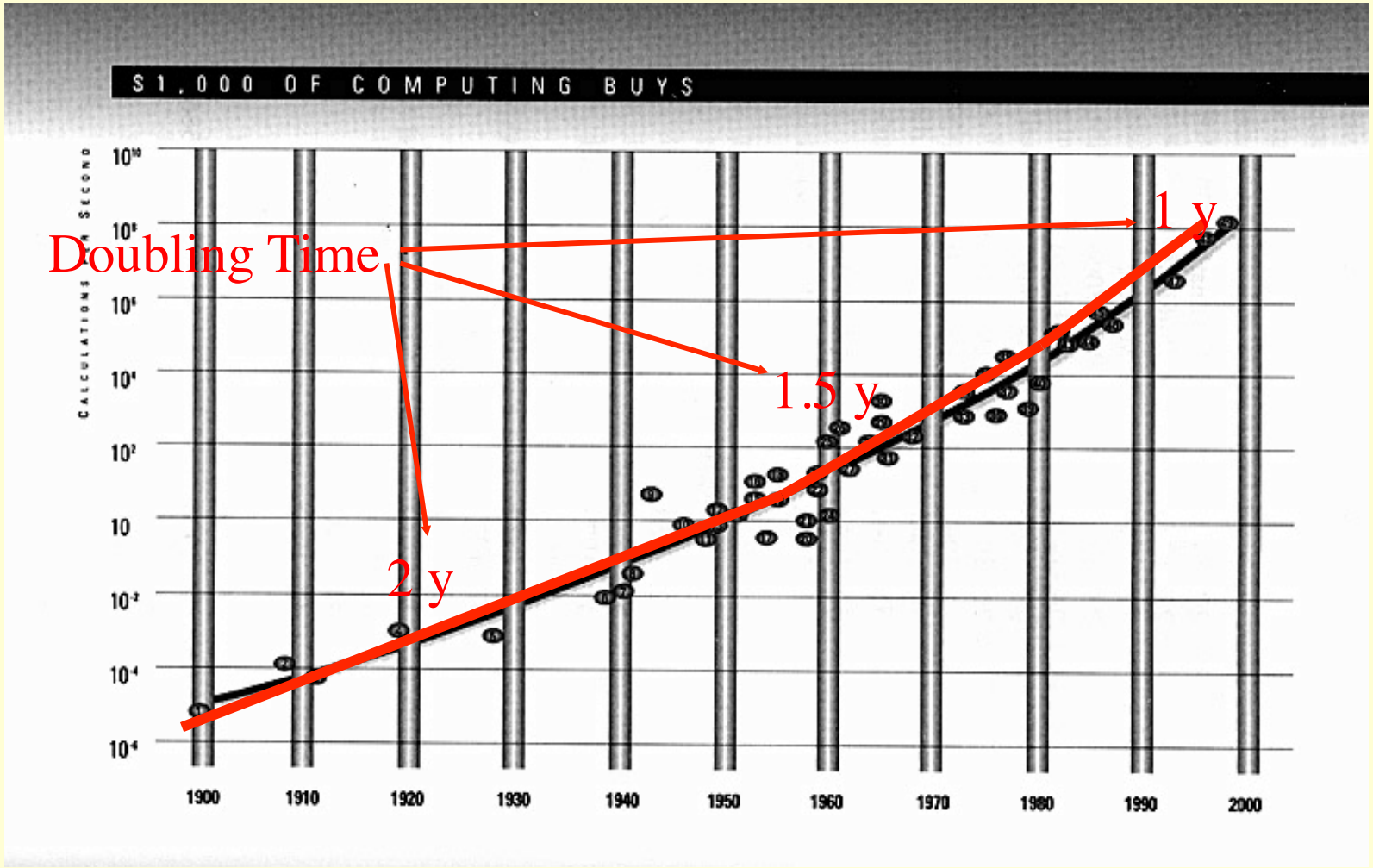
To ASCI White

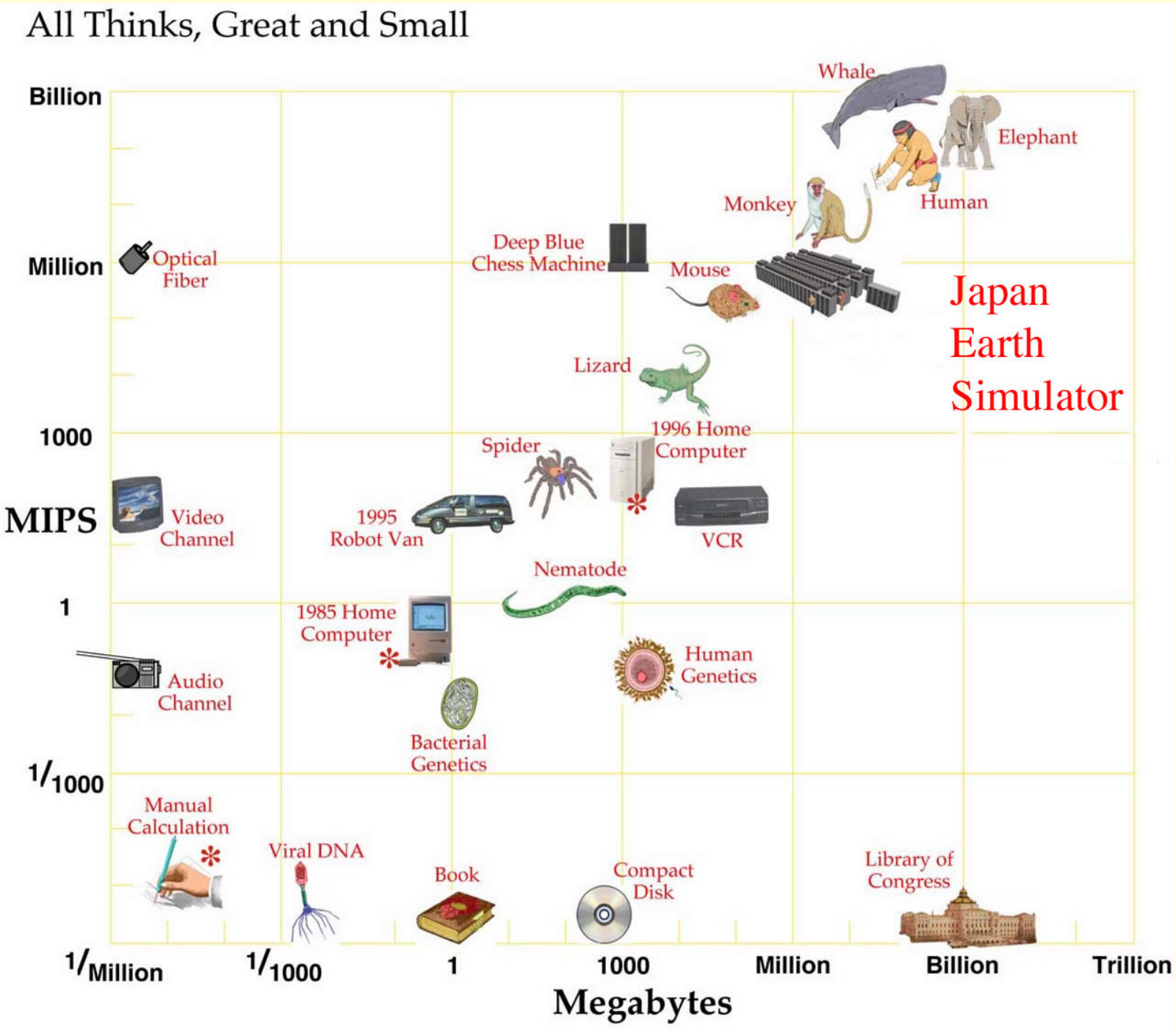

E-11


Japan Earth Simulator


PN-07-12/13
PN-08-08/09
PN-09-14/15

The Evolution of Computing




All Thinks, Great and Small
Billion
Million
1000
MIPS
1
1/1000
1/Million
1/1000
1
1000
Million
Billion
Trillion
Megabytes
Whale
Elephant
Human
Monkey
Deep Blue
Chess Machine
Mouse
Optical
Fiber
Japan
Earth
Simulator
Lizard
1996 Home
Computer
Spider
1995
Robot Van
VCR
Video
Channel
Nematode
1985 Home
Computer
Human
Genetics
Audio
Channel
Bacterial
Genetics
Manual
Calculation
Viral DNA
Book
Compact
Disk
Library of
Congress

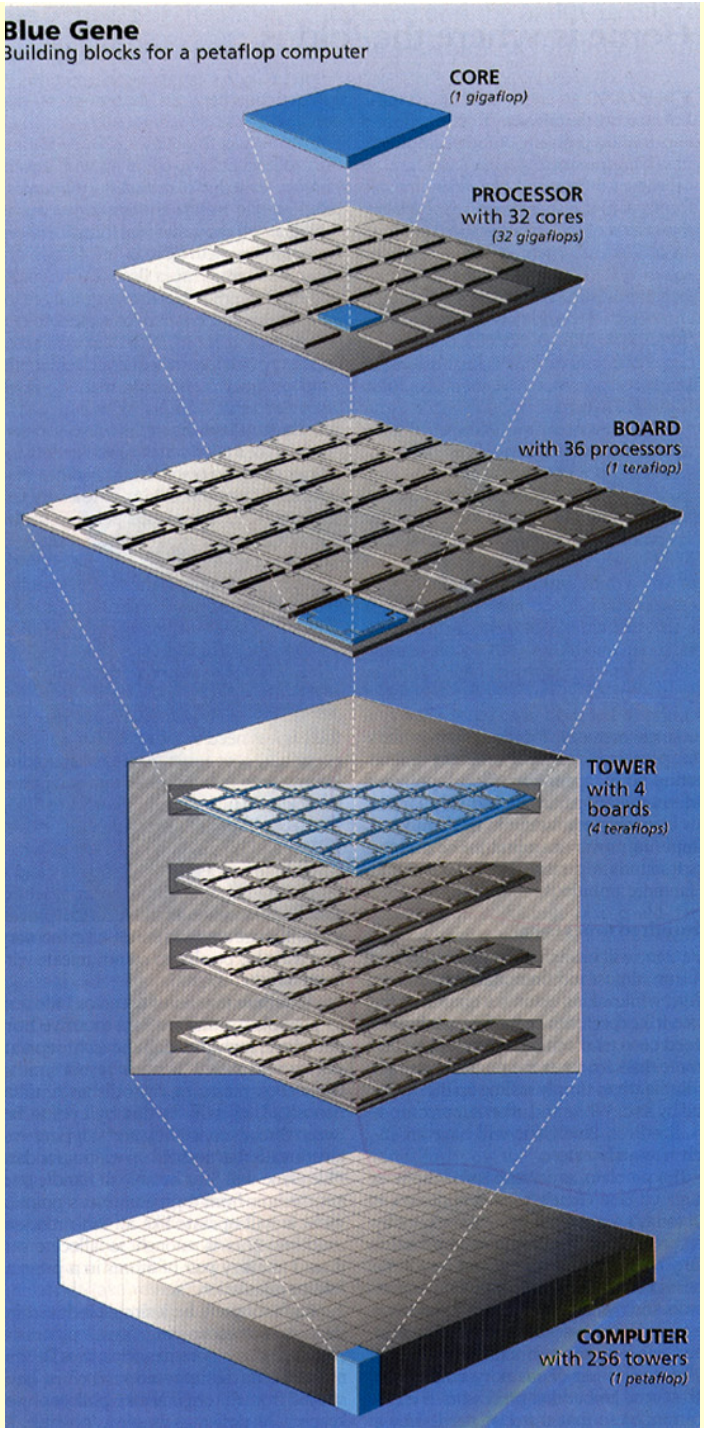
IBM Weather Simulator:

100 TeraFlops

IBM Blue Gene:

1,000 TeraFlops

= 1 PetaFlop



Some Extrapolation of the PC

	2000	2010	2020
Speed	10^9	10^{12}	10^{15}
RAM	10^8	10^{11}	10^{14}
Disk	10^9	10^{12}	10^{15}
LAN	10^8	10^{12}	10^{15}
Wireless	10^6	10^9	10^{12}

Some Examples

- **Speed**
  - MHz to GHz to THz to Peta Hz
- **Memory**
  - MB (RAM) to GB (CD,DVD) to TB (holographic)
- **Bandwidth**
  - Kb/s (modem) to Mb/s (Ethernet) to Gb/s
  - Internet2 (Project Abilene): 10 Gb/s
- **Networks**
  - Copper to fiber to wireless to photonics
  - “Fiber to the forehead…”

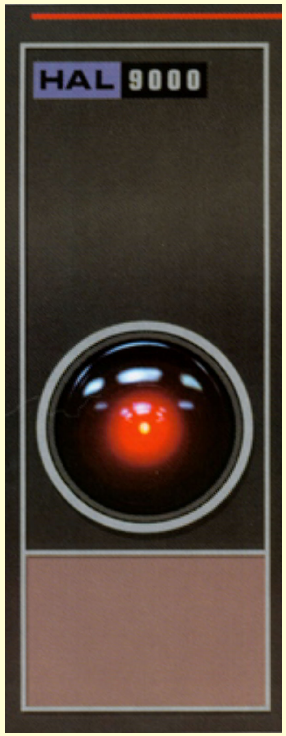
Computer-Mediated Human Interaction

- **1-D (words)**
  - Text, e-mail, chatrooms, telephony
- **2-D (images)**
  - Graphics, video, WWW, multimedia
- **3-D (environments)**
  - Virtual reality, distributed virtual environments
  - Immersive simulations, avatars
  - Virtual communities and organizations
- **And beyond...**
  - Telepresence
  - Neural implants

Evolution of the Net

- Already beyond human comprehension
- Incorporates ideas and mediates interactions among millions of people
- 200 million today; more than 1 billion in 2005
- Internet2, Project Abilene

Some Other Possibilities

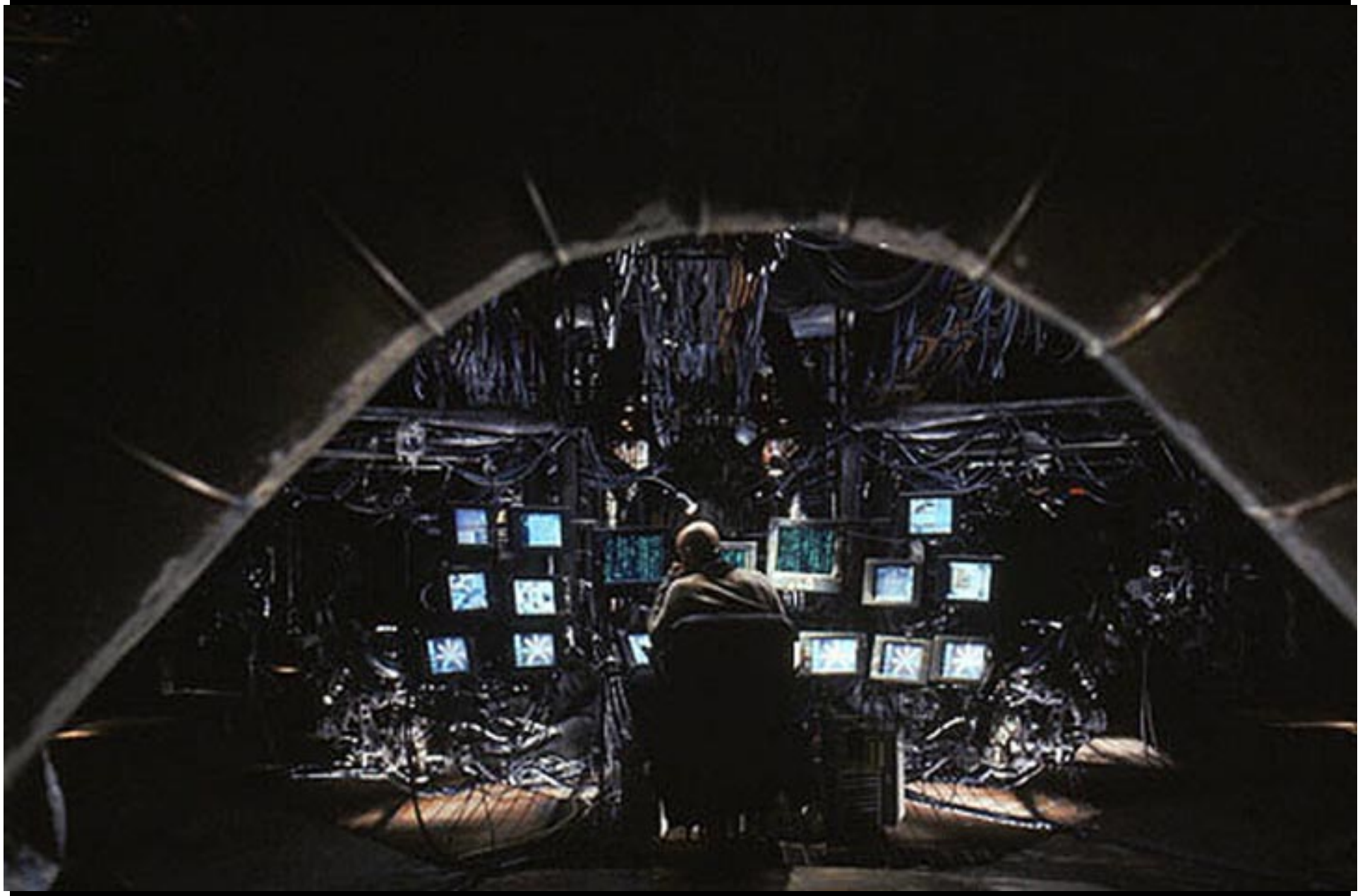


- **Ubiquitous computing?**
  - Computers disappear (just as electricity)
  - Calm technology, bodynets
- **Agents and avatars?**
  - Fusing together physical space and cyberspace
  - Plugging the nervous system into the Net
- **Emergent behavior?**
  - … Self organization
  - … Learning capacity
  - … Consciousness (HAL 9000)

Another Perspective …

The impact of information technology will be even more radical than the harnessing of steam and electricity in the 19th century. Rather it will be more akin to the discovery of fire by early ancestors, since it will prepare the way for a revolutionary leap into a new age that will profoundly transform human culture.

–Jacques Attali, *Millennium*



Technological Singularities

Concerns

Bill Joy, “Why the Future Doesn’t Need Us.” (http://www.wired.com/wired/archive/8.04/joy.html)

Ray Kurzweil, *The Age of Spiritual Machines* (Viking, New York, 1999)

Hans Moravec, *Robot: Mere Machine to Transcendent Mind* (Oxford University Press, New York, 1999)

Kevin Kelly, *Out of Control: The New Biology of Machines, Social Systems and the Economic World* (Addison-Wesley Publishing Company, Reading, Mass, 1994)

Bill Joy*

"Accustomed to living with almost routine scientific breakthroughs, we have yet to comes to terms with the fact that the most compelling 21st Century technologies —robotics, genetic engineering, nanotechnology— pose a different threat than the technologies that have come before. Specifically, robots, engineered organisms, and nanobots share a dangerous amplifying factor: They can self-replicate. A bomb is blown up only once—but one bot can become many and quickly get out of control."

*Chief Scientist, Sun Microsystems (inventor of Berkeley Unix and Java)
**B. Eng., U. Michigan, '67

NBC to GNR

What was different in the 20th Century? Certainly the technologies underlying the weapons of mass destruction (WMD)—nuclear, biological, chemical (NBC) – were powerful, and the weapons an enormous threat. But building nuclear weapons required, at least for a time, access to both rare raw materials and highly protected information; biological and chemical weapons programs also tended to require large-scale activities.

The 21st Century technologies—genetics, nanotechnology, and robotics (GNR)—are so powerful that they can spawn whole new classes of accidents and abuses. Most dangerously, for the first time, these accidents and abuses are widely within the reach of individuals or small groups. They will not require large facilities or rare raw material. Knowledge alone will enable the use of them.

Thus we have the possibility not just of weapons of mass destruction but of knowledge-enabled mass destruction (KMD), this destructiveness hugely amplified by the power of self-replication.

What could happen?

We could develop intelligent machines that self-replicate and evolve beyond the intelligence and control of humankind.

We could genetically engineer new organisms that become a plague destroying natural species.

We could create nanotechnology assemblers that propagate through self-assembly and evolution into a “gray goo” that exhausts the resources of the planet..

20th Century Technologies

NBC: nuclear, biological, chemical

WMD: weapons of mass destruction


STRANGELOVE
OR
HOW I
BOMB


GRAND
FORKS
22
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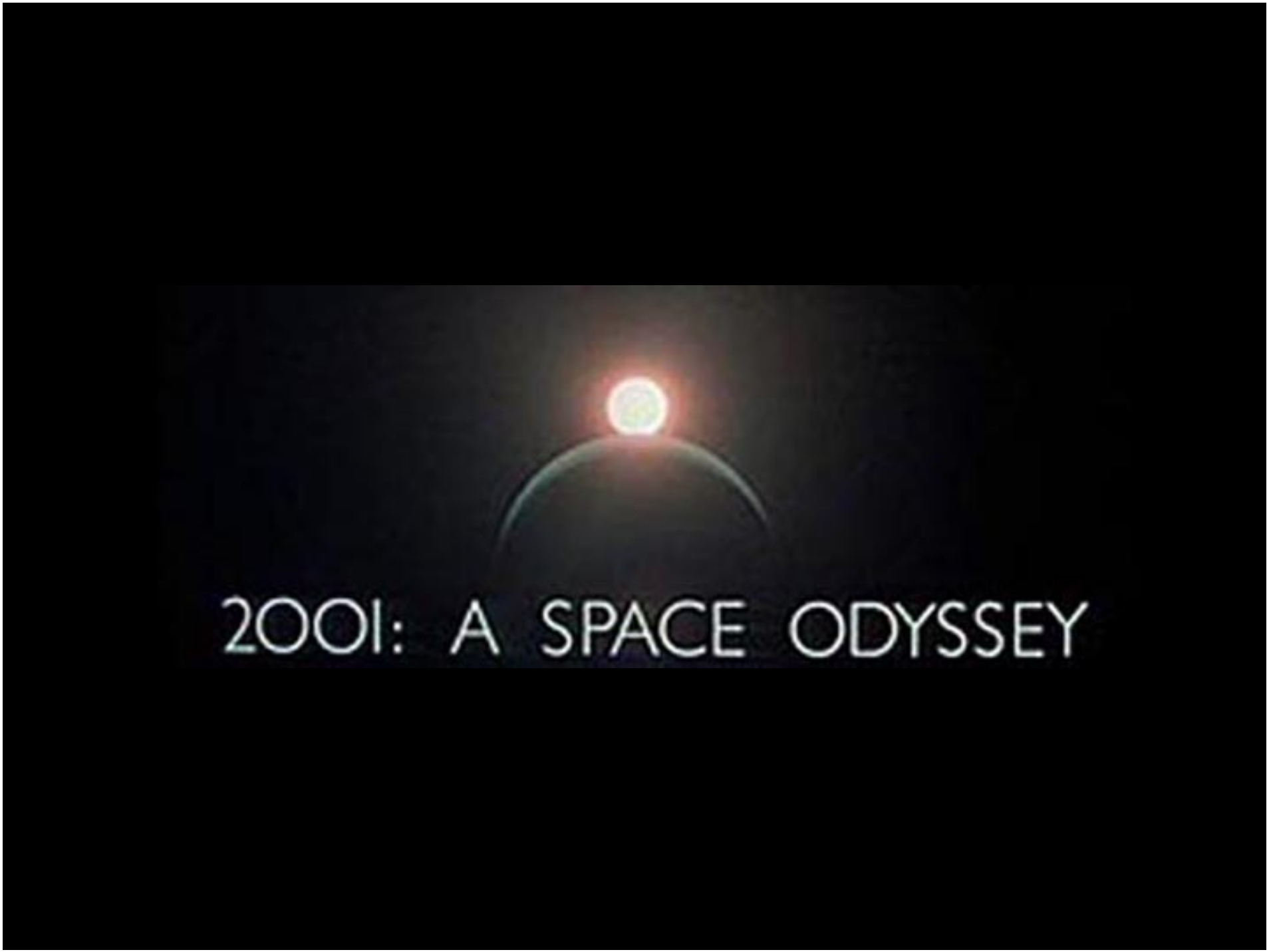
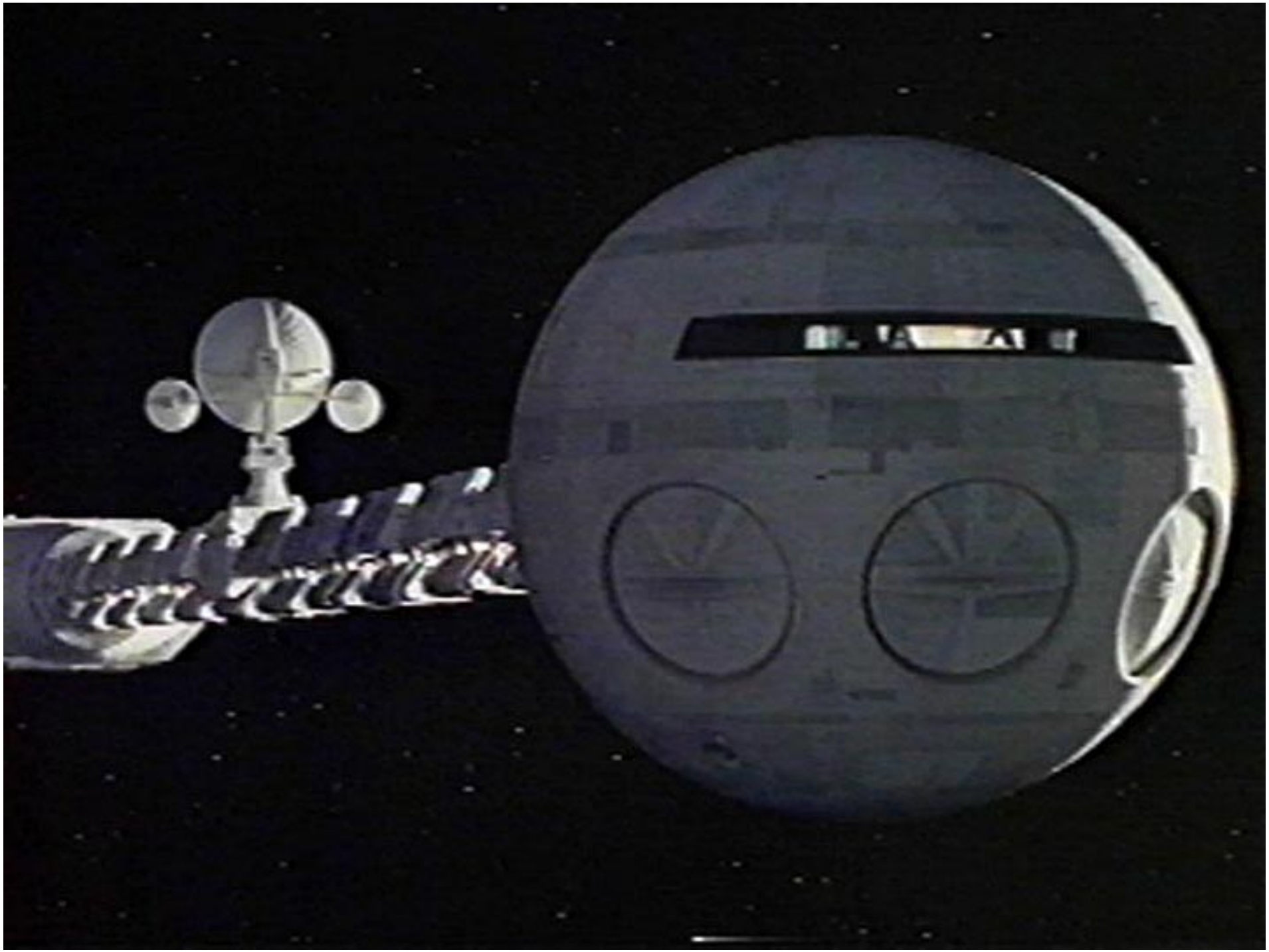
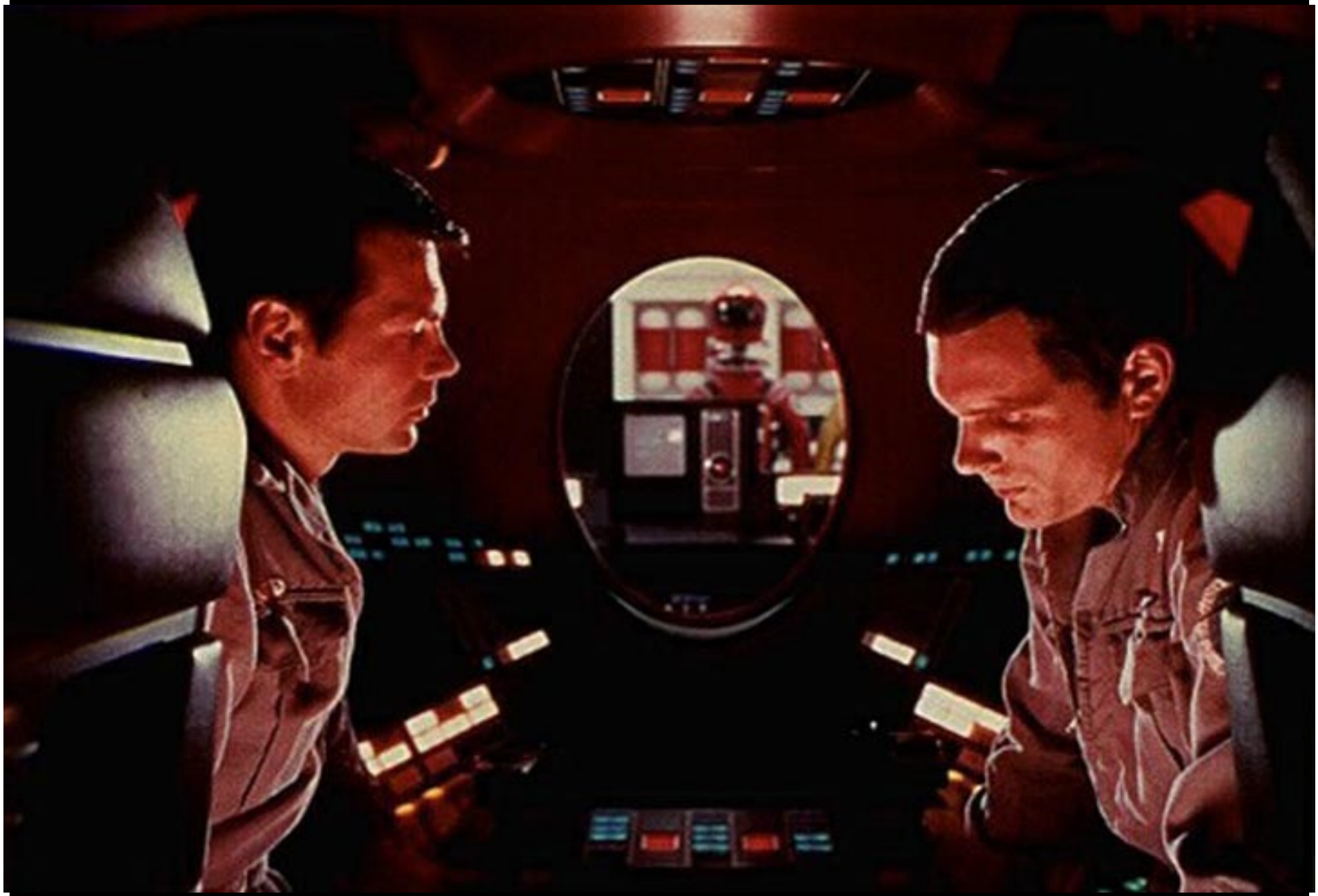
21st Century Technologies

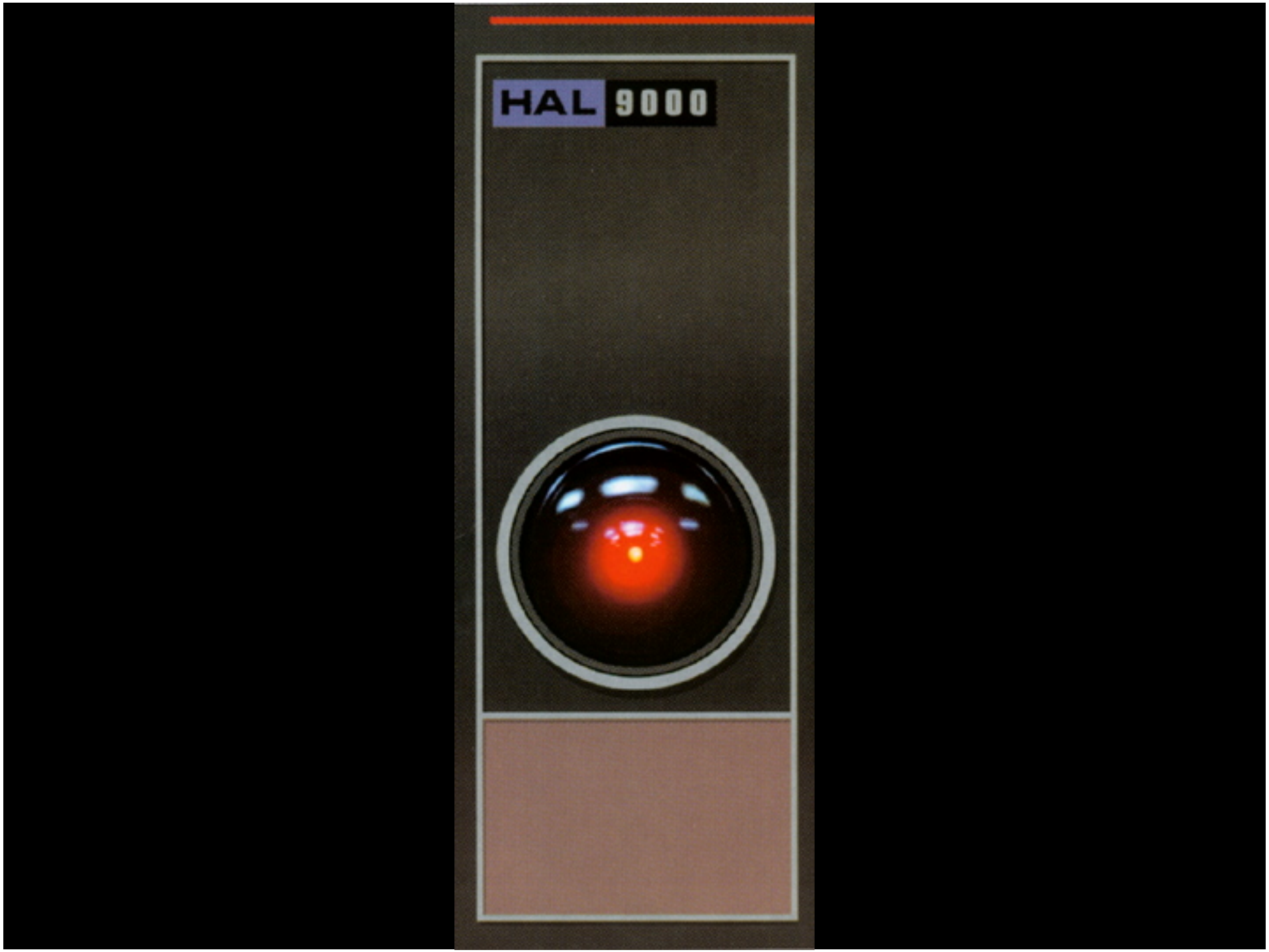
GNR: Genetics, nanotechnology, robotics

KMD: knowledge-enabled mass destruction


2001: A SPACE ODYSSEY






HAL 9000

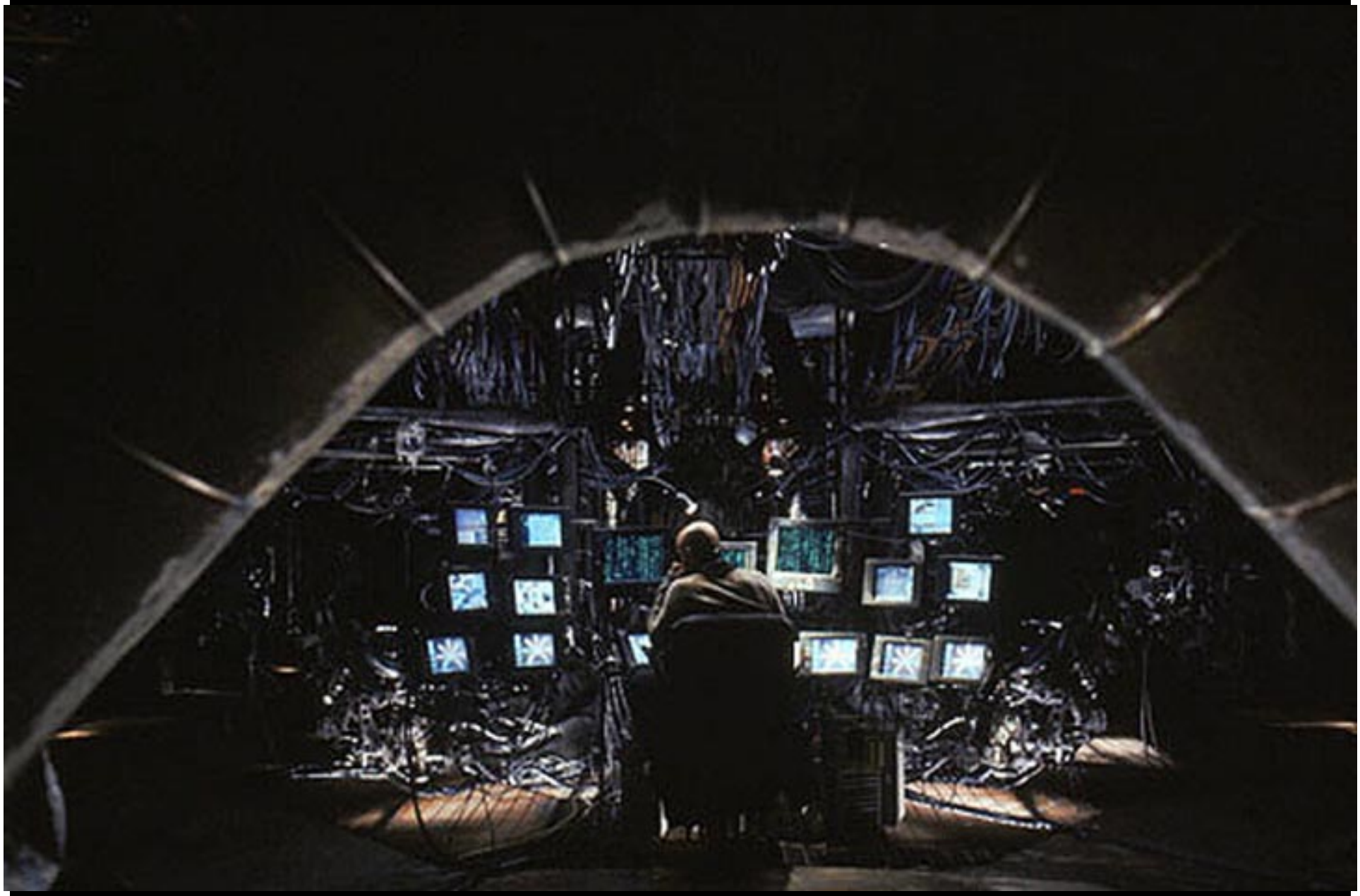

THE
TERMINATOR


TERMINATOR 2
JUDGMENT DAY


G A T T A C A


BLADE
RUNNER


THE
MATRIX



What is the danger?

It is most of all the power of destructive self-replication in genetics, nanotechonology, and robotics that should give us pause. Self-replication is the modus operandi of genetic engineering, which uses the machinery of the cell to replicate its designs, and the prime danger underlying gray goo in nanotechnology.

The nuclear, biological, and chemical technologies used in 20th Century weapons of mass destruction were and are largely military, developed in government labs. In sharp contrast, the 21st Century GNR technologies have clear commercial uses and are being developed almost exclusively by corporate enterprises. We are aggressively pursuing the promises of these new technologies within the non-unchallenged system of global capitalism and its manifold financial incentives and competitive pressures.

What can be done?

The philosopher John Leslie has concluded that the risk of human extinction is at least 30%. Ray Kurzweil believes it closer to 50%.

Joy believes this risk is too high. The only realistic alternative he comes up with is relinquishment: to limit development of the technologies that are too dangerous, by limiting our pursuit of certain kinds of knowledge.

Despite the strong historical precedents, if open access to and unlimited development of knowledge henceforth puts us all in clear danger of extinction, then common sense demands that we reexamine even the basic, long-held beliefs of scholarship.

The new Pandora's boxes of genetics, nanotechnology, and robotics are almost open, yet we seem hardly to have noticed. Ideas cannot be put back in a box; unlike uranium or plutonium, they do not nee to be mined and refined, and they can be freely copied. Once they are out, they are out.

The key questions addressed by this course

Question 1: How serious is this stuff?

Question 2: What role and responsibility do engineers have in the development and control of such technologies?

Question 3: Are there any historical or contemporary precedents that can give us some guidance?

Vinge's Singularity*

The acceleration of technological progress has been the central feature of the past century. Vinge argues that we are on the edge of change comparable to the rise of human life on Earth. The precise cause of this change is the imminent creation by technology of entities with greater than human intelligence. There are several possibilities:

- There may be developed computers that are "awake" and superhumanly intelligent.
- Large computer networks (and their associated users) may "wake up" as a superhumanly intelligent entity.
- Computer/human interfaces may become so intimate that users may reasonably be considered superhumanly intelligent.
- Biological science may provide means to improve natural human intellect.

*Vernor Vinge, "The Coming Technological Singularity: How to Survive in the Post-Human Era"

A Technological Singularity

When greater-than-human intelligence drives progress, that progress will be much more rapid. In fact there seems no reason why progress itself would not involve the creation of still more intelligent entities, on a still shorter timescale.

Vinge calls this a “singularity”, the point where our old models must be discarded and a new reality rules. As we move closer to this point, it will loom vaster and vaster over human affairs until the notion becomes common place. Yet when it finally happens, it may still be a great surprise and a greater unknown.

John von Neumann also speculated that “the ever accelerating progress of technology and changes in the mode of human life gives the appearance of approaching some essential singularity in the history of the race beyond which human affairs, as we know them, could not continue.”

Beyond the Singularity?

Perhaps it was the science-fiction writers who felt the first concrete impact. More and more these writers felt an opaque wall across the future. Once they could put such fantasies millions of years in the future. Now they saw that their most diligent extrapolations resulted in the unknowable…soon. Once, galactic empires might have seemed a post-human domain. Now, sadly, even interplanetary ones are.

Vinge argues that we cannot prevent the singularity, that its coming is an inevitable consequence of human's natural competitiveness and the possibilities inherent in technology. And yet we are the initiators. Even the largest avalanche is triggered by small things. We have the freedom to establish initial conditions, make things happen in ways that are less inimical than others. Of course, as with starting avalanches, it may not be clear what the right guiding nudge really is.

Some Further Speculation

The Age of Spiritual Machines:

When Computers Exceed Human Intelligence

–Ray Kurzweil

2010

- A $1,000 PC delivers Terahertz speeds
- PCs with high resolution visual displays come in a range of sizes, from those small enough to be embedded in clothing and jewelry up to the size of a thin book.
- Cables are disappearing. Communication between components uses wireless technology, as does access to the Web.
- The majority of text is created using continuous speech recognition. Also ubiquitous are language user interfaces.
- Most routine business transactions (purchases, travel, etc.) take place between a human and a virtual personality. Often the virtual personality includes an animated visual presence that looks like a human face.

2020

- A $1,000 PC is now approximately equal to the computational ability of the human brain.
- Computers are now largely invisible and are embedded everywhere–in walls, tables, chairs, desks, clothing, jewelry, and bodies.
- 3-D virtual reality displays, embedded in glasses and contact lenses, as well as auditory “lenses”, are used routinely as primary interfaces for communication with other persons, computers, the Web, and virtual reality.
- Most interaction with computing is through gestures and two-way natural-language spoken communication.

2020(continued)

- Nanoengineered machines are beginning to be applied to manufacturing and process control.
- High-resolution, 3-D visual and auditory virtual reality and realistic all-encompassing tactile environments enable people to do virtually anything with anybody, regardless of physical proximity.
- Paper books or documents are rarely used and most learning is conducted through intelligent, simulated software-based teachers.
- The vast majority of transactions include a simulated person.
- Automated driving systems are now installed in most roads.

2020 (continued)

- People are beginning to have relationships with automated personalities and use them as companions, teachers, caretakers, and lovers.
- There are widespread reports of computers passing the Turing Test, although these tests do not meet the criteria established by knowledgeable observers.

2030

- A $1,000 unit of computation now has the computation capacity of roughly 1,000 human brains.
- Permanent removable implants for the eyes and ears are now used to provide input and output between the human user and the worldwide computing network.
- Direct neural pathways have been perfected for high-bandwidth connection to the human brain. A range of neural implants is becoming available to enhance visual and auditory perception and interpretation, memory, and reasoning.
- Automated agents are now learning on their own, and significant knowledge is being crated by machines with little or no human intervention.

2030 (continued)

- Computers have read all available human- and machine-generated literature and multimedia material.
- There is widespread use of all-encompassing visual, auditory, and tactile communication using direct neural connections, allowing virtual reality to take place ("sim-stim")
- The majority of communication does not involve a human; rather it is between a human and a machine.
- There is almost no human employment in production, agriculture, or transportation. Basic life needs are available for the vast majority of the human race.

2030 (continued)

- There is a growing discussion about the legal rights of computers and what constitutes being “human”. Although computers routinely pass apparently valid forms of the Turing Test, controversy persists about whether or not machine intelligence equals human intelligence in all of its diversity.
- Machines claim to be conscious. These claims are largely accepted.

2050

- The common use of nanoproduced food, which has the correct nutritional composition and the same taset and texture of organically produced food, means that the availability of food is no longer affected by limited resources, bad weather, or spoilage.
- Nanobot swarm projections are used to create visual-auditory-tactile projections of people and objects in real reality.
- Picoengineering begins to become practical.

By 2100

- There is a strong trend toward a merger of human thinking with the world of machine intelligence that the human species initially created.
- There is no longer any clear distinction between humans and computers.
- Most conscious entities do not have a permanent physical presence.
- Machine-based intelligences derived from extended models of human intelligence claim to be human, although their brains are not based on carbon-based cellular process, but rather electronic and photonic equivalents. Most of these intelligences are not tied to a specific computational process unit. The number of software-based humans vastly exceeds those still using native neuron-cell-based computation.

By 2100 (continued)

- Even among those human intelligences still using carbon-based neutrons, there is ubiquitous use of neural-implant technology, which provides enormous augmentation of human perceptual and cognitive abilities. Humans who do not utilize such implants are unable to meaningfully participate in dialogues with those who do.
- Because most information is published using standard assimilated knowledge protocols, information can be instantly understood. The goal of education, and of intelligent beings, is discovering new knowledge to learn.
- Life expectancy is no longer a viable term in relation to intelligence beings.

Many Thousands of Years from Now …

Intelligent beings consider the fate of the Universe …