Introduction to Embedded Systems

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Lecture Goals

- Become aware of the *invisible side:* embedded computing.
- Get a glimpse of the challenges in embedded systems.

Introductory Questions

- What is bigger: PC or ES chip market?
- What is an embedded system?

Embedded Systems

... means many things to many people.

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Embedded System Definition I

A general-purpose definition of embedded systems is that they are devices used to control, monitor or assist the operation of equipment, machinery or plant. "Embedded" reflects the fact that they are an integral part of the system. In many cases, their "embeddedness" may be such that their presence is far from obvious to the casual observer. Even the more technically skilled might need to examine the operation of a piece of equipment for some time before being able to conclude that an embedded control system was involved in its functioning.

(Institute of Electrical Engineers)

Embedded System Definition II

The Institute of Electrical & Electronics Engineers (IEEE) considers a computer system and its software embedded, if it is an integral component of a larger system and is used to control and/or directly monitor that system by using special hardware devices.

(paraphrased from IEEE P1003.13/D2.1)

Embedded System Definition

Loosely defined, it is any device that includes a programmable computer but is not itself intended to be a general-purpose computer.

(W. Wolf. "Computers as Components")

Embedded Systems

- Built for a ***specific purpose***
- ***Interaction*** with the environment and physical processes
- Stringent ***timing and resource requirements***
- Mass-produced, everywhere around us

Where Are They?

Where Are They?

Where Are They?

Where Are They?

- Medical devices
- Avionics
- Aerospace
- Transportation

Where's the Software?

- BMW 745i
  - About 70 processors (53 8-bit, 7 16-bit, 11 32-bit)
  - Multiple networks (2 CAN high, 2 CAN low, serials, ...)
  - 2M lines of code
  - Mix of operating systems

Where's the Software

- F-22 Raptor: 1.7M lines of code
- F-35 Joint Strike Fighter: 5.7M lines of code
- Boeing 787: 6.5M lines of code
- Next gen. premium car: 100M lines of code

Historic Evolution

- Mainframe computing (60-70's)
  - Relationship: $\frac{human}{computer} \approx \infty$
  - Large computers executing big data processing applications
- Personal computing & Internet (80-90's)
  - Relationship: $\frac{human}{computer} \approx 1$
  - Personal computers executing business applications
- Ubiquituous/physical computing (00-10's)
  - Relationship: $\frac{human}{computer} \approx 0$
  - Smart environment (=embedded computing) assists continually

Embedded Software

- Tightly-coupled to the physical world
- Rich in non-functional requirements
- Heterogeneity, networked at extreme scale
- Cost sensitivity
- Sociological and ethical requirements
- Designed for debuggability.

Embedded Software Goals

- Correct, safe, and reliable
- Context- and situation-aware
- Seamless integration
- Validation and certification

Embedded Software

- Assuring high confidence
- Safety-critical computing systems
- Design, testing, certification are very expensive
- Integration of large scale, heterogeneous systems
- Education
- ...

Public Works in Ancient Greek

When an architect accepts the charge of a public work, he has to promise what the cost of it will be. His estimate is handed to the magistrate, and his property is pledged as security until the work is done. When it is finished, if the outlay agrees with his statement, he is complimented by decrees and marks of honour. If no more than a fourth has to be added to his estimate, it is furnished by the treasury and no penalty is inflicted. **But when more than one fourth has to be spent in addition on the work, the money required to finish it is taken from his property.**

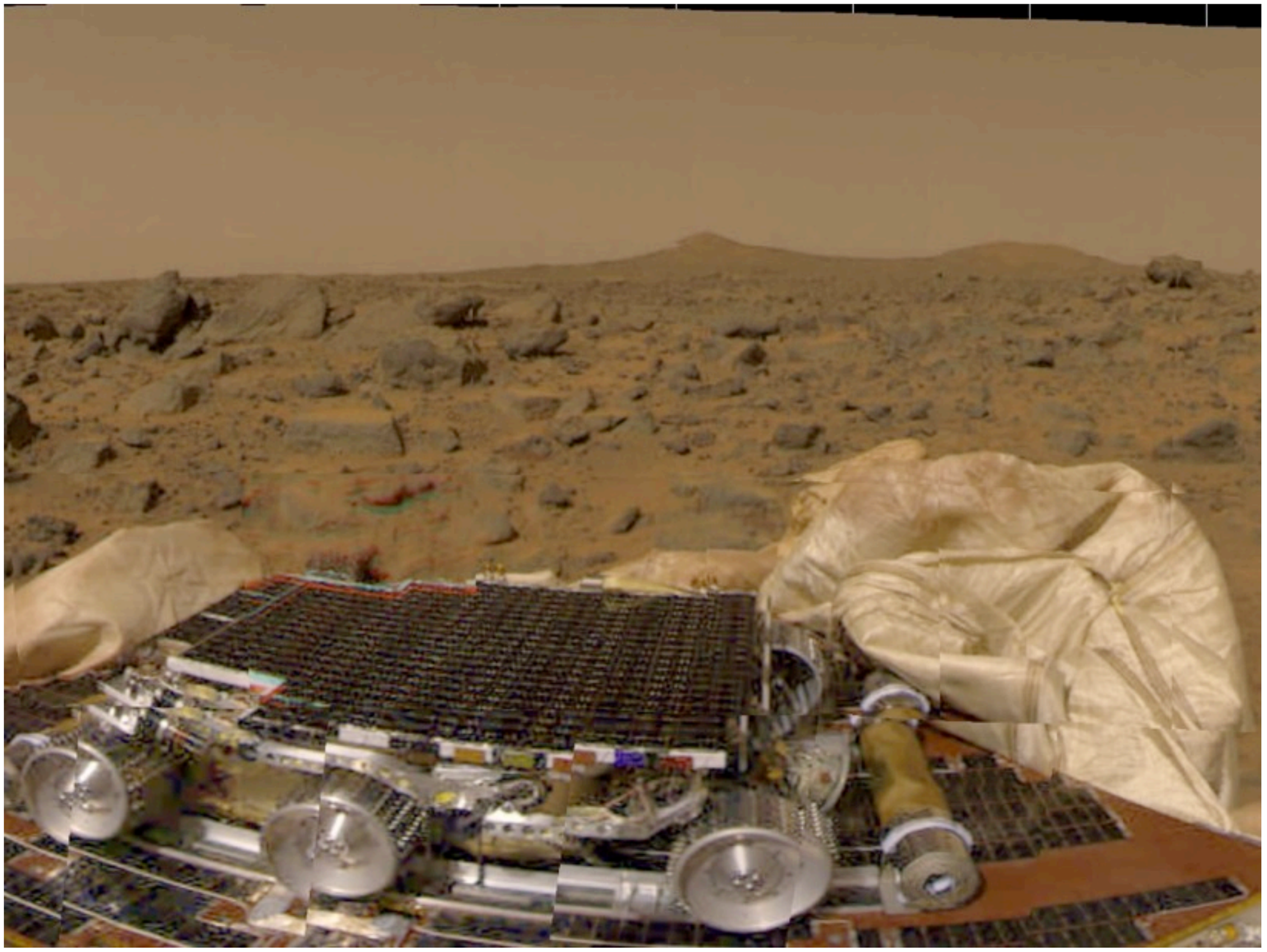
Vitruvius in "The Ten Books on Architecture"

You think it's easy, right?

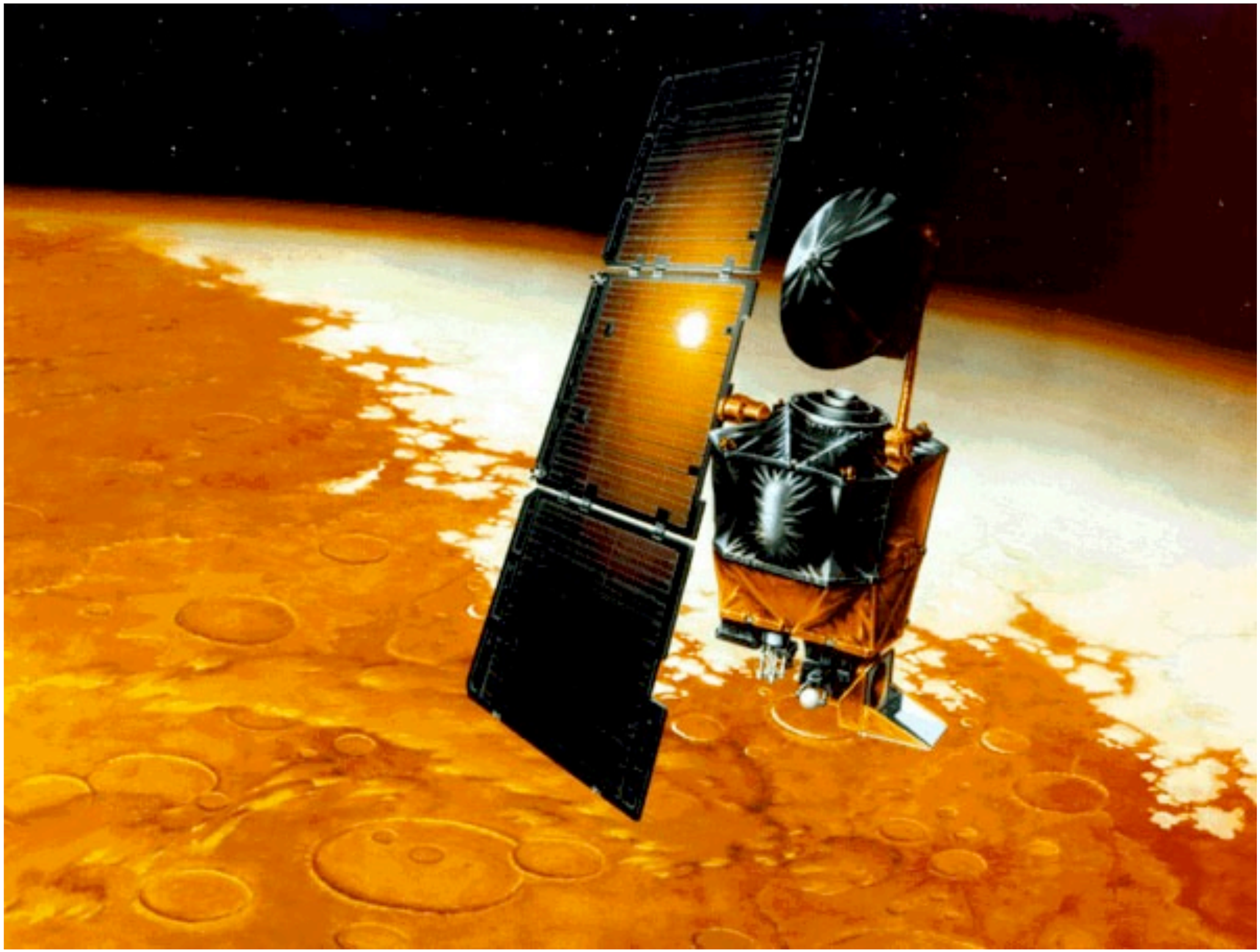
Digital Thermometer

Ariane 5

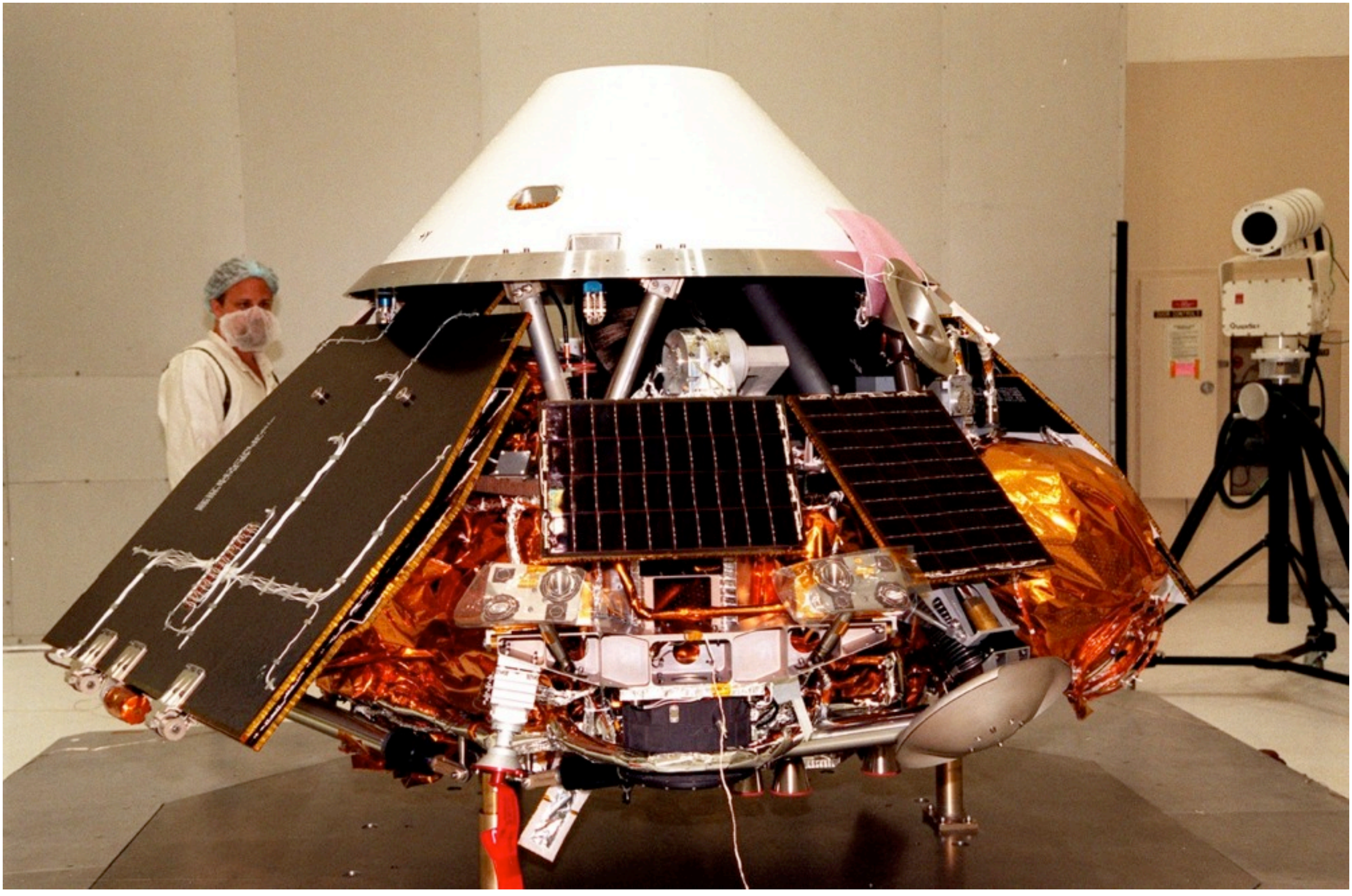
Mars Pathfinder



Mars Climate Orbiter



Mars Polar Lander

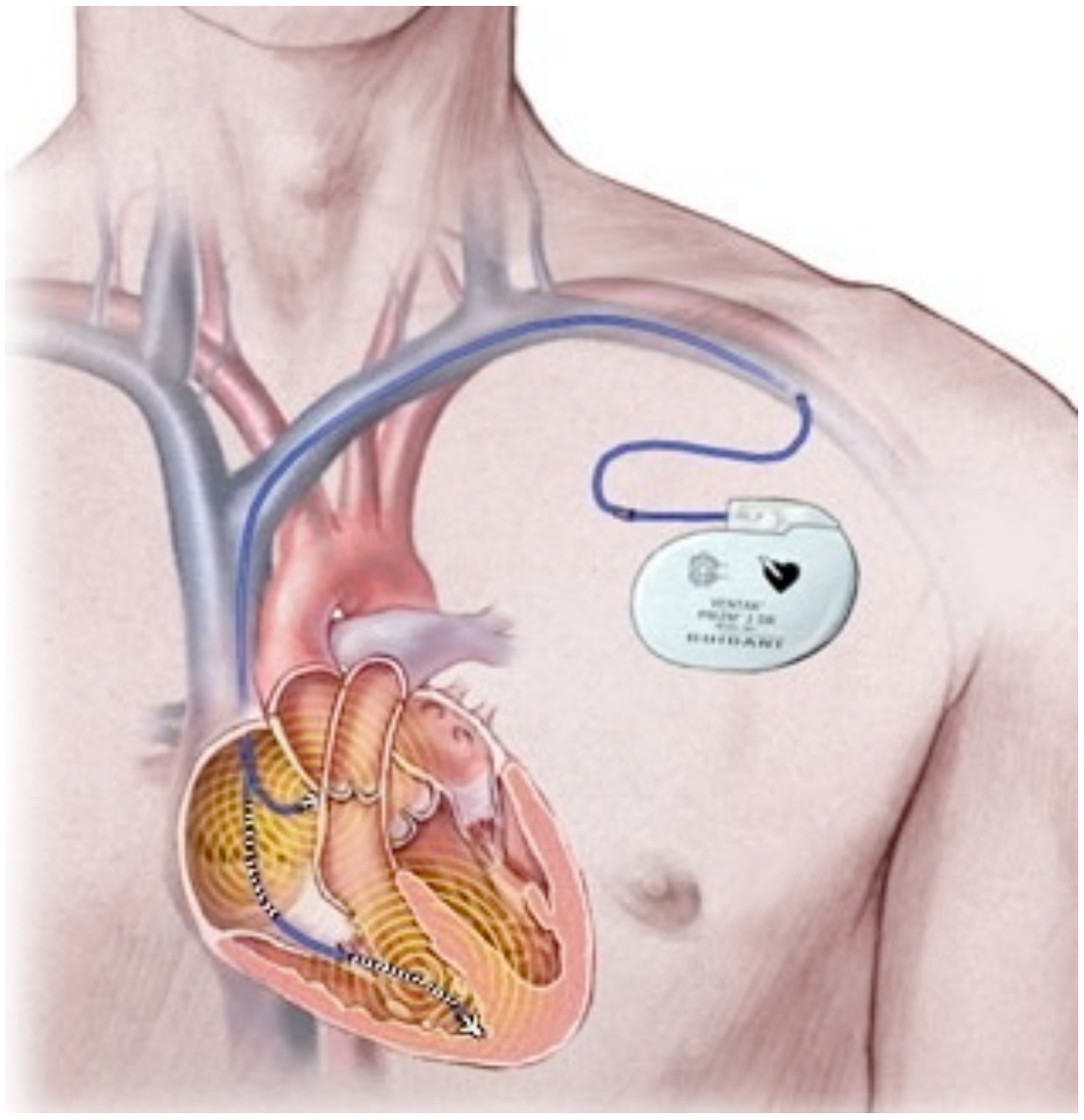


Patriot System

Oerlikon GDF-005

USS Yorktown Smart Ship

Early Pacemakers



Therac 25

PATIENT NAME : TEST
TREATMENT MODE : FIX BEAM TYPE: X ENERGY (MeV): 25

	ACTUAL	PRESCRIBED	
UNIT RATE/MINUTE	0	200	
MONITOR UNITS	50 50	200	
TIME (MIN)	0.27	1.00	
GANTRY ROTATION (DEG)	0.0	0	VERIFIED
COLLIMATOR ROTATION (DEG)	359.2	359	VERIFIED
COLLIMATOR X (CM)	14.2	14.3	VERIFIED
COLLIMATOR Y (CM)	27.2	27.3	VERIFIED
WEDGE NUMBER	1	1	VERIFIED
ACCESSORY NUMBER	0	0	VERIFIED

DATE : 84-OCT-26 SYSTEM : BEAM READY OP. MODE : TREAT AUTO
TIME : 12:55: 8 TREAT : TREAT PAUSE X-RAY 173777
OPR ID : T25V02-R03 REASON : OPERATOR COMMAND:

Lauda Air Flight 004

"The Accident Investigation Committee of the Government of Thailand determines the probable cause of this accident to be uncommanded in-flight deployment of the left engine thrust reverser, which resulted in loss of flight path control. The specific cause of the thrust reverser deployment has not been positively identified."

Qantas 72

Air France Flight 447

Demo: Catapult