Destination Venus: Science, Technology and Mission Architectures

Overview: Purpose of Workshop

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Outline

- Venus in a historical context
- A Brief History of Robotic Exploration of Venus
- Future Venus Mission Opportunities
- International Collaboration
- Venus Exploration Assessment Group (VEXAG)
- Objectives of this course
- Conclusions

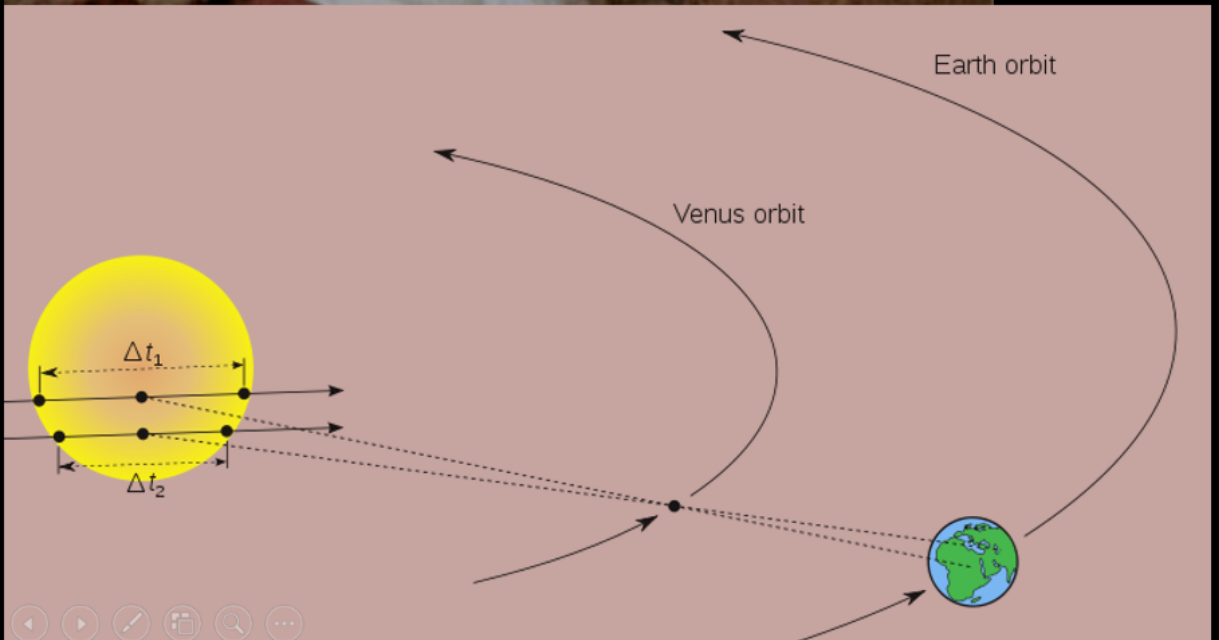
Venus throughout history

- Brightest planet in the sky
  - The morning star
  - The evening star
- Mythology and ancient astronomers
  - Mayan
  - Babylonian
- Age of the telescope
  - Discovery of the first planetary atmosphere
  - Transits of sun – the distance between Earth and Sun

Edmund Halley (1656-1742)

Advocated for using the transit of Venus to estimate the distance between Earth and the sun =

1 Astronomical Unit



(...) « **This sight, which is by far the noblest astronomy affords, like the secular games, is denied to mortals for a whole century**, by the strict laws of motion. It will be afterwards shown, that by this observation alone, the distance of the sun, from the earth, might be determined with the greatest certainty, which, on account of the parallax otherwise quite insensible, has not hitherto been precisely defined. »

Royal Society, **1691** October 3.

Venus in a Historical Context and Popular Culture

SAYS LIFE MAY BE ON VENUS

Cambridge Savant Believes Mars Also Has Essentials for Existence.

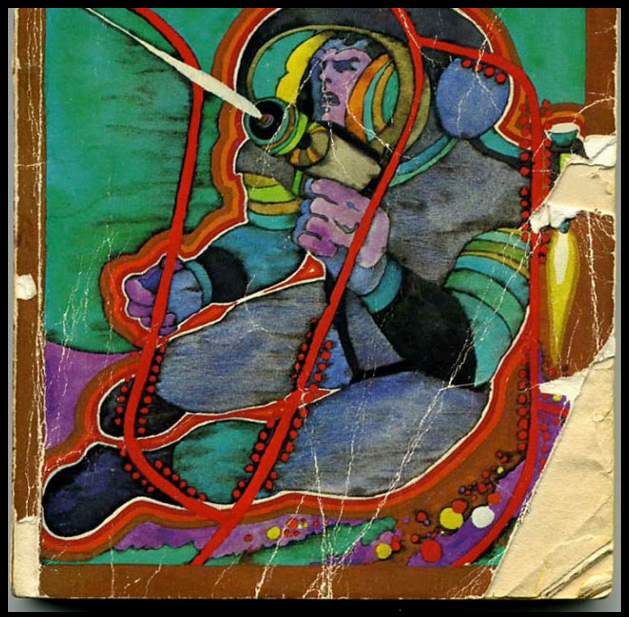
Special Cable to THE NEW YORK TIMES.

LONDON, Nov. 15.—That life may exist on both Venus and Mars is the conclusion reached by Dr. A. S. Eddington, professor of astronomy at Cambridge. In a book to be published tomorrow he says that Venus, so far as is known, would bewell adapted for life similar to ours. The planet is about the same size as the earth, nearer the sun but probably not warmer, and possesses an atmosphere of satisfactory density.

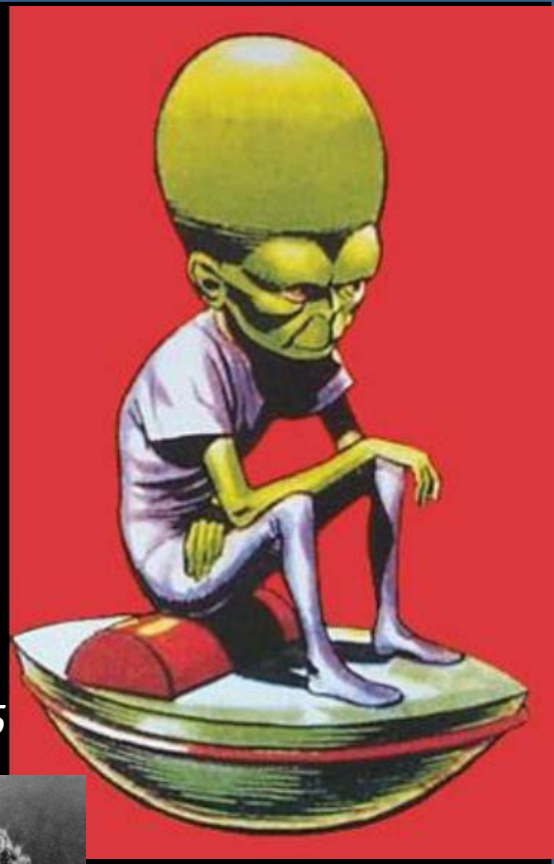
As regards Mars, Professor Eddington says that the two essentials, air and water, are both present but scanty. The Martian atmosphere is thinner than ours, but perhaps adequate. It has been proved to contain oxygen.

If animal life exists on that mysterious planet, he says, it probably is a different form of life from ours, as "Mars has every appearance of being a planet long past its prime."

New York Times
11/16/1928



Lucky Starr and the Oceans of Venus, Juvenile Sci Fi Novel, 1955



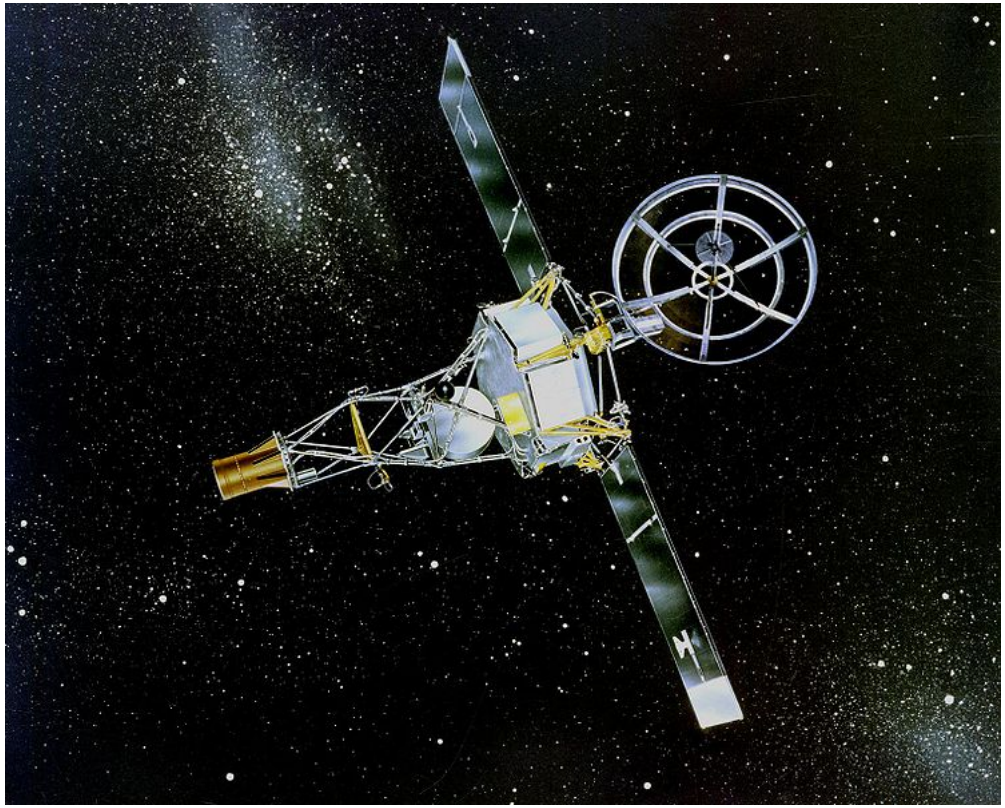
The Mekon Ruler of Venus, British SF Comic Book, 1958

Queen of Outer Space, Movie, 1958 with Zsa Zsa Gabor

A brief history of Venus Robotic Exploration

- The first spacecraft to reach Venus was Mariner 2, a flyby mission in 1962.
- The Soviet Union played the dominant role in Venus Exploration for the next 20 years with a series of orbiters, landers and the VeGa (Venus-Halley) mission in 1985 which also deployed two balloons at Venus.
- From 1989-1994, the NASA Magellan mission produced detailed radar maps of the surface of Venus following earlier less capable US and Soviet radar missions.
- In 2005, the ESA Venus Express mission was launched and for the last decade has investigated the atmosphere of Venus.
- In December 2010, the JAXA Akatsuki mission failed to enter Venus orbit but succeeded in a second attempt in 2015.
- Efforts are underway for further Venus mission in Europe, USA and Russia and other spacefaring nations.

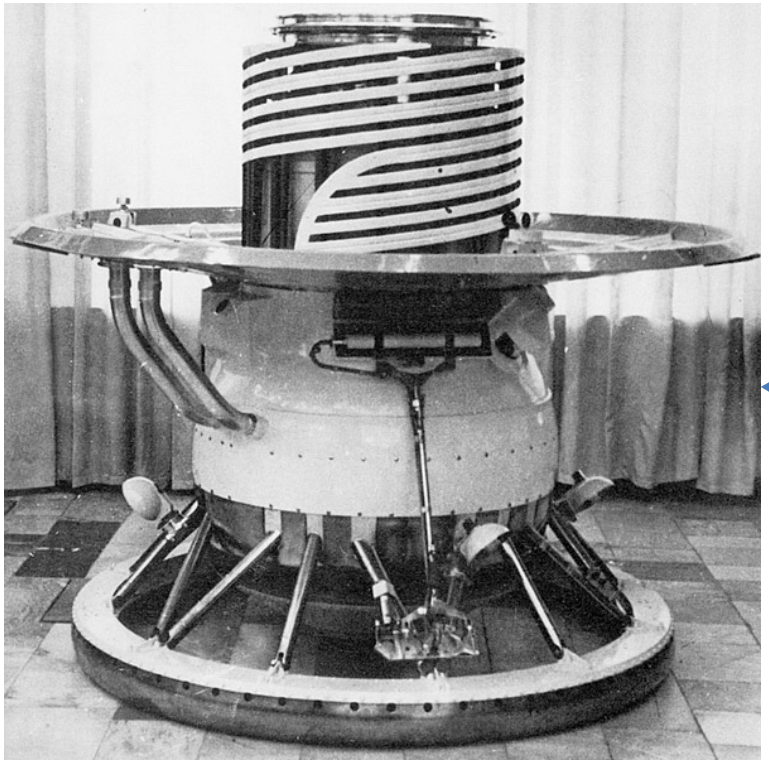
Mariner 2 (1962 and Venera 4(1967)



Mariner 2 flyby spacecraft (200 kg).

Venera 4 flyby + lander (1100 kg).

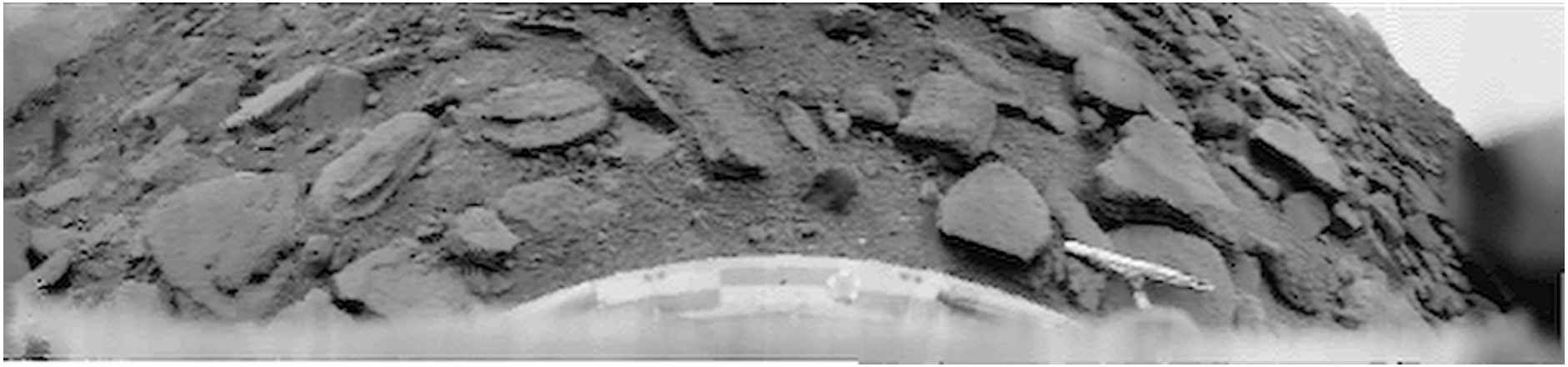
Venera 9 (1975) and Pioneer Venus Multiprobe (1978)



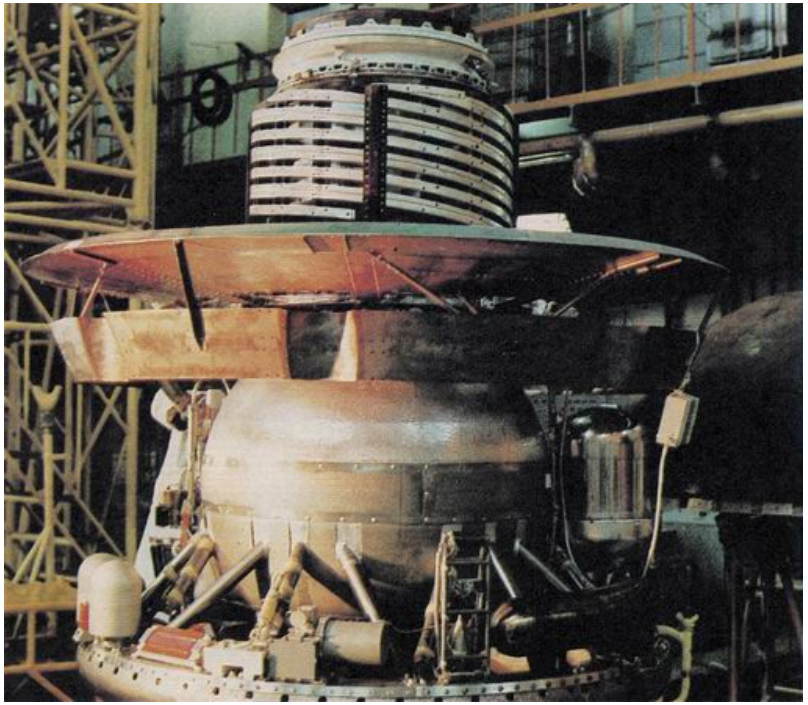
Pioneer Venus Multiprobe (315 kg large, 3x90 kg small)

Venera 9 Lander (660 kg)

Venera 9 Surface Panorama



VEGA (1985)

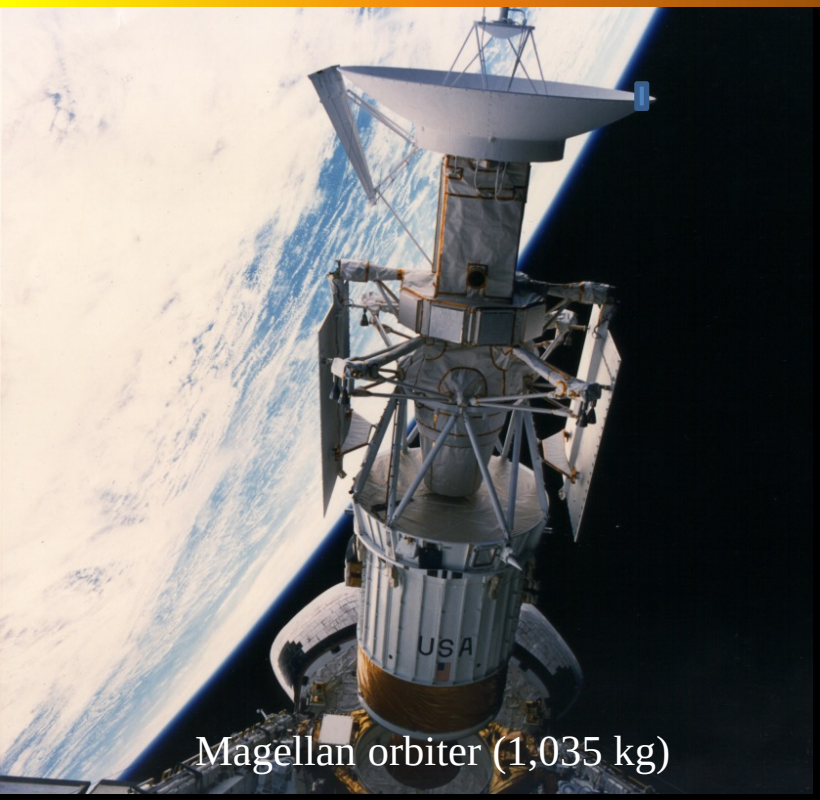


VEGA balloon
(22 kg)

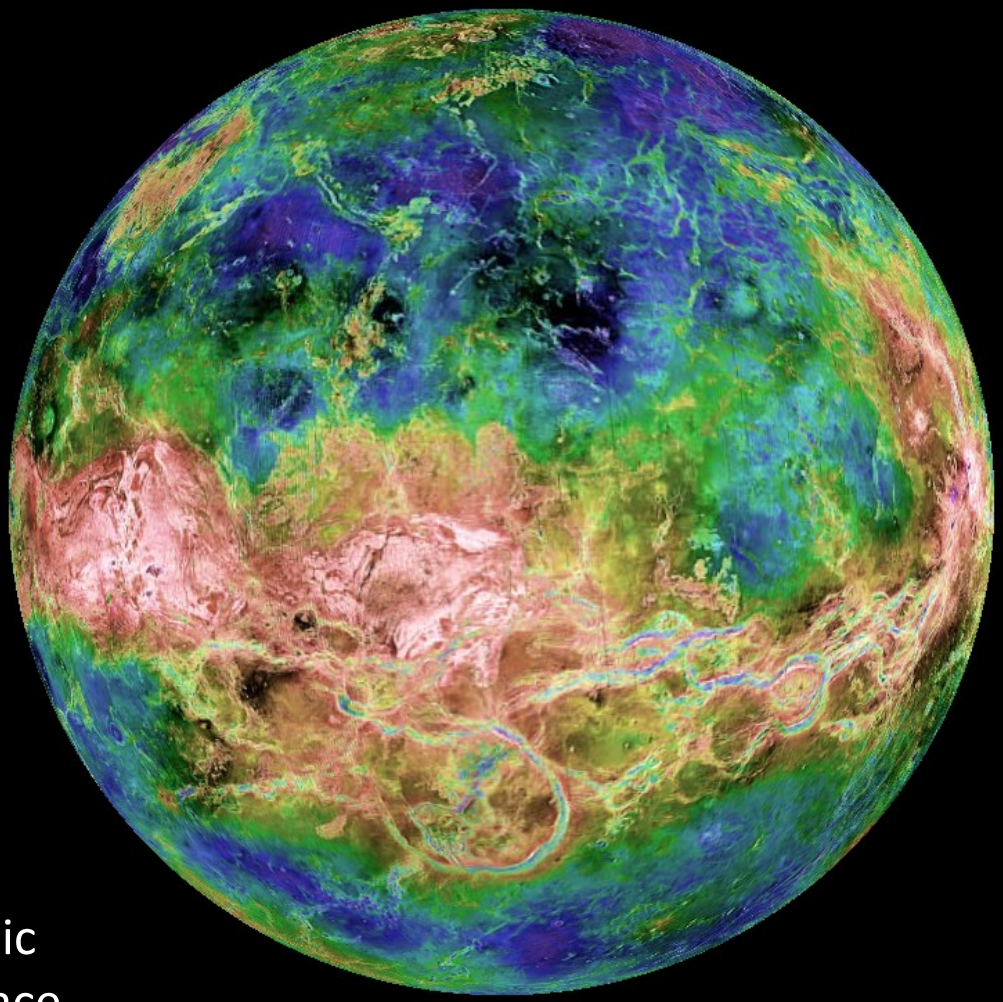
VEGA lander
(750 kg)

Venera 13
lander images

Magellan Orbiter (1989 to 1994)

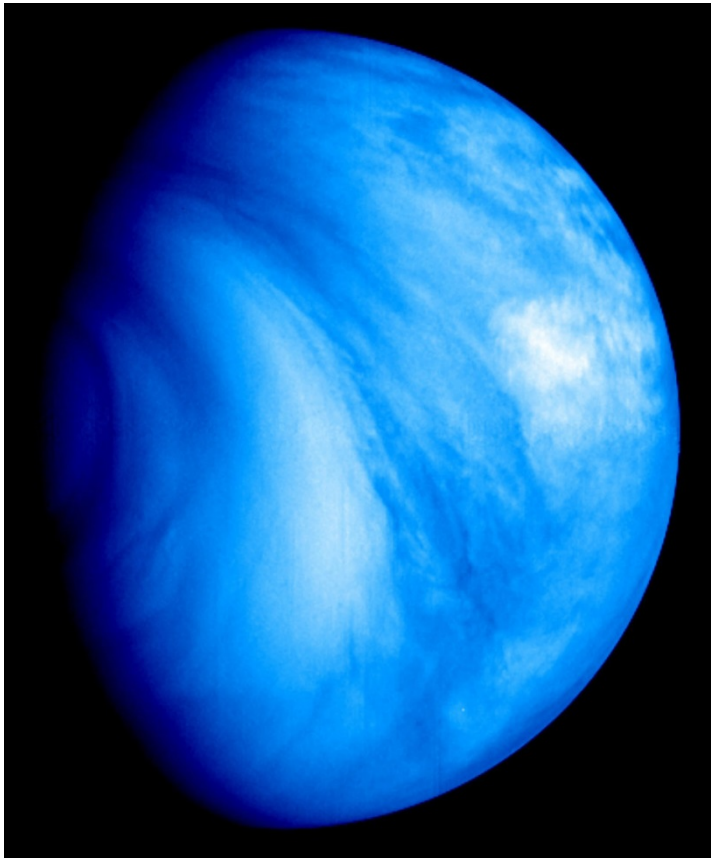


Magellan orbiter (1,035 kg)



Global map of Venus with Synthetic aperture Radar revealed the surface of Venus as we currently know it

Venus Express (Launched 2005)

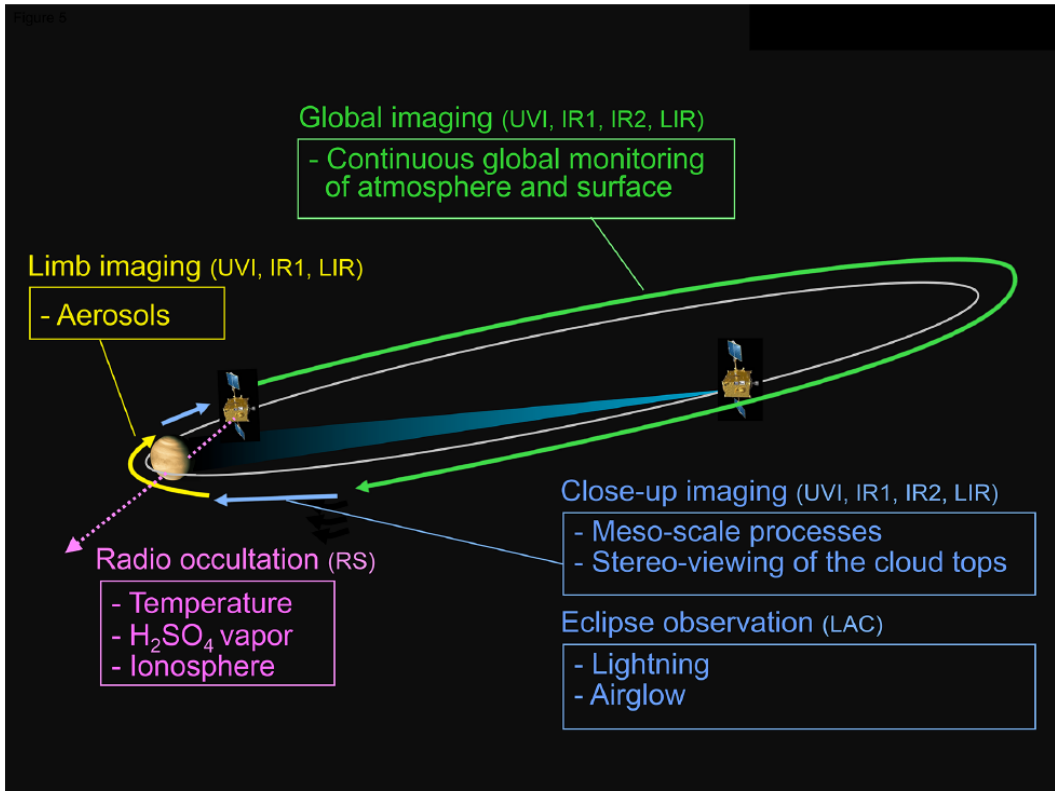


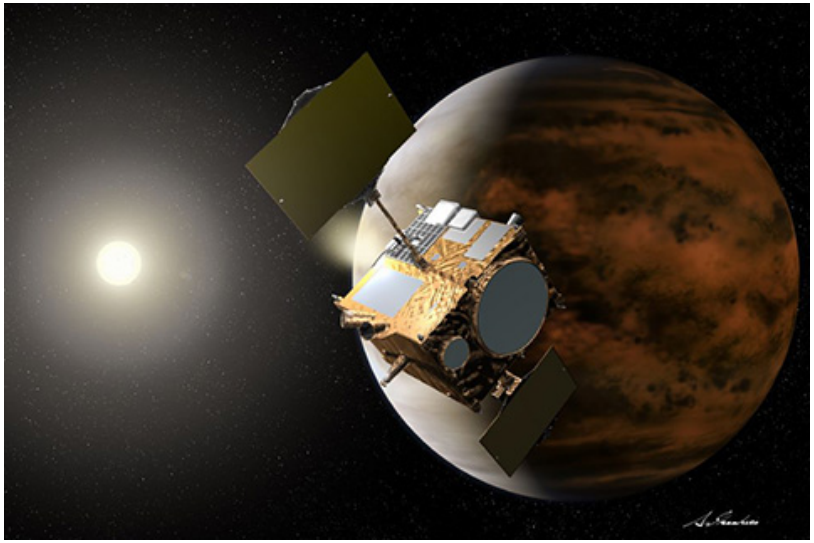
- Key results:
  - Measurement of upper atmosphere winds
  - Detailed mapping of cloud structure
  - Confirmation of lightning on Venus
  - First large scale temperature maps of the surface

ESA's Venus Express concluded its mission in December 2014

Akatsuki - orbited Venus Dec 2010

- Akatsuki is Japan's first scientific mission to Venus.
- It's main propulsion system failed when it attempted to enter Venus orbit in **December 2010.**
- Successfully entered Venus orbit at a second attempt in 2015.
- Now planning on a five year mission extending to 2020.





Akatsuki: The 500 kg spacecraft is based on the design of the Mars spacecraft Nozomi

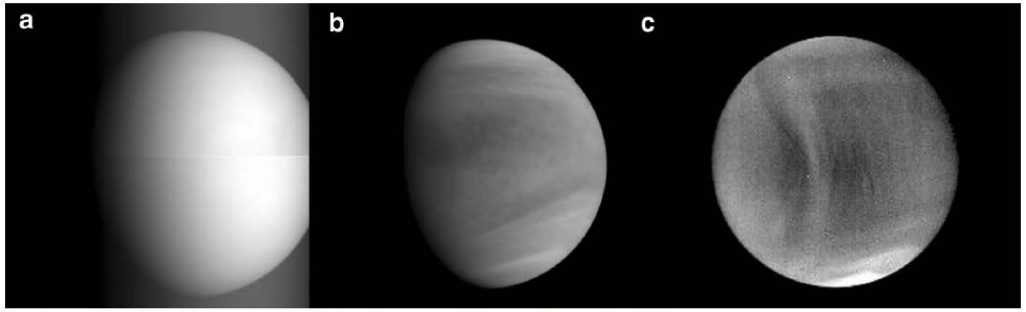


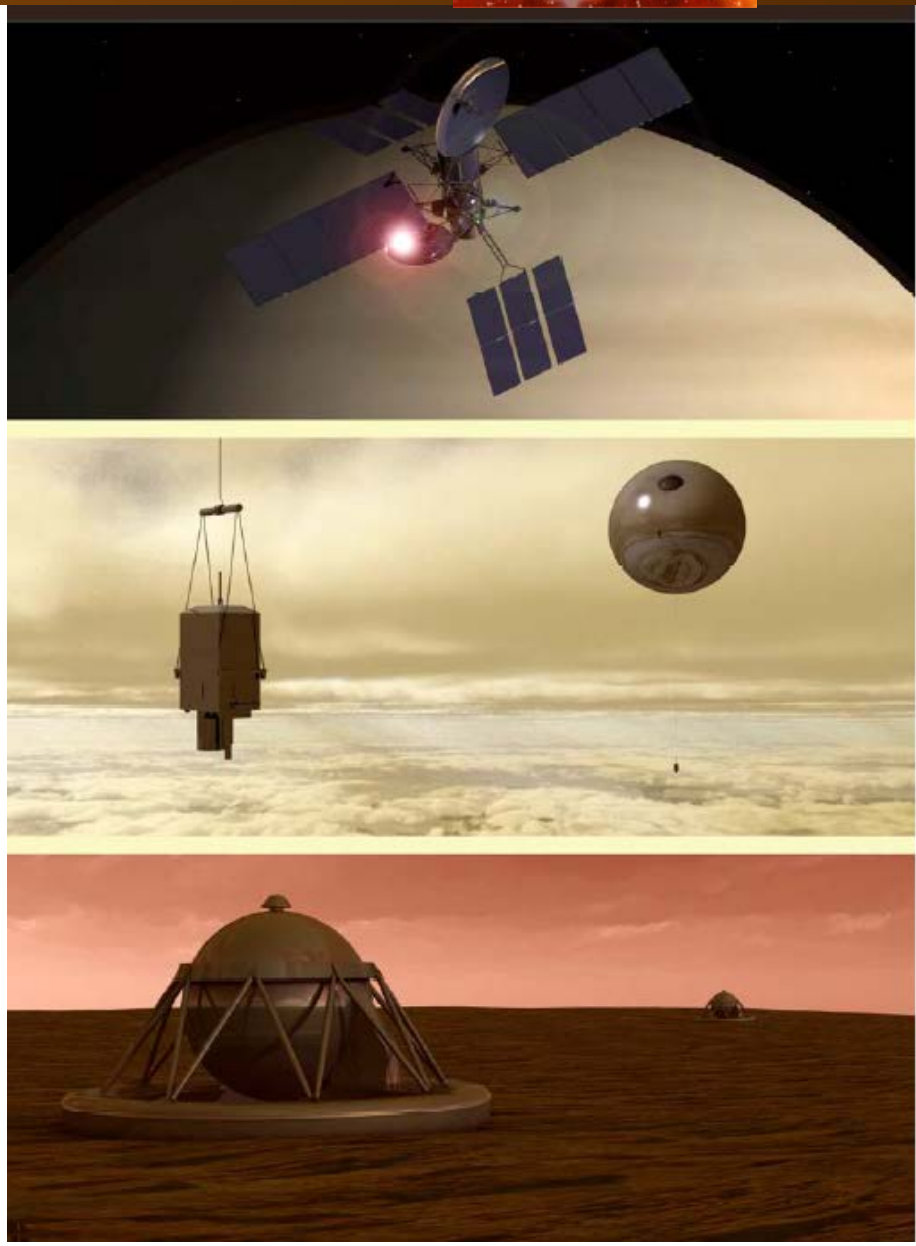
Fig. 6 First memorial images taken by the **a** IR1, **b** UVI, and **c** LIR on "the AKATSUKI satellite" of Venus

First pictures taken by Akatsuki

JAXA's Akatsuki is the only spacecraft currently operating at Venus

Venus Flagship Mission – NASA Study

- A NASA sponsored study completed in April 2009 (see http://vfm.jpl.nasa.gov.
- Key elements were:
  - A capable long lived orbiter with high resolution radar imaging and topography
  - 2 instrumented balloons at 55 km altitude and 1 month lifetime
  - 2 landers with extended surface life of 5 hours
- This study has influenced many subsequent studies including the Venus Climate Mission advocated by NASA's Planetary Science Decadal Survey in 2011
- NASA is also inviting proposal for a New Frontiers Class – Venus In Situ Explorer (VISE) which would last on the surface for several hours



Venera-D – Proposed Russian Mission

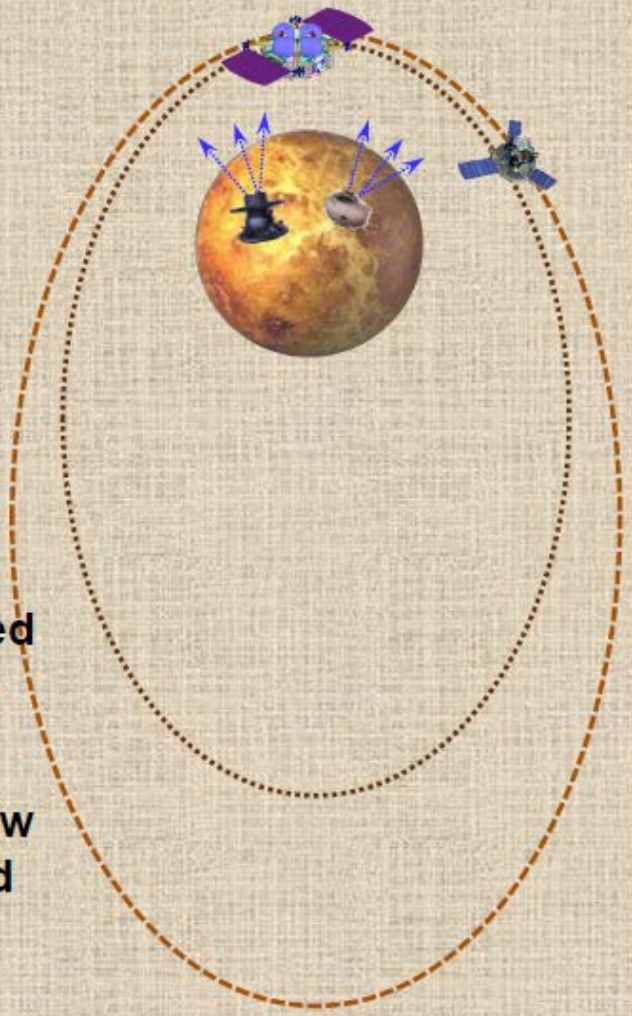
Orbiter
on the polar 24 hours orbit ,
lifetime > 3 years

Lander (VEGA-type, updated)
2 – 3 hours on the surface

Long living station
24 hours on the surface

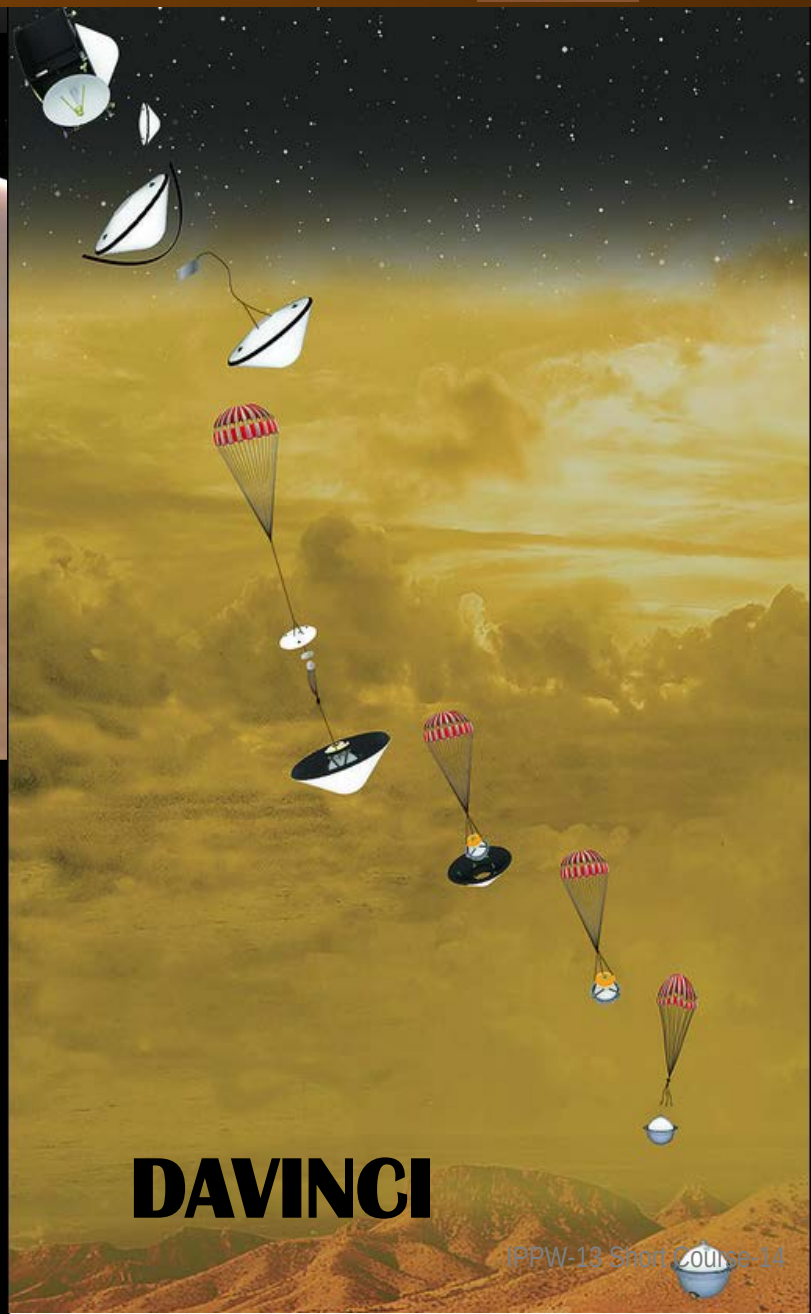
Sub-satellite
orbits with 48, 24, 12 hours are studied

Also it has been studied:
two balloons, in the clouds and below the clouds, and mini probes, dropped from the lower balloon



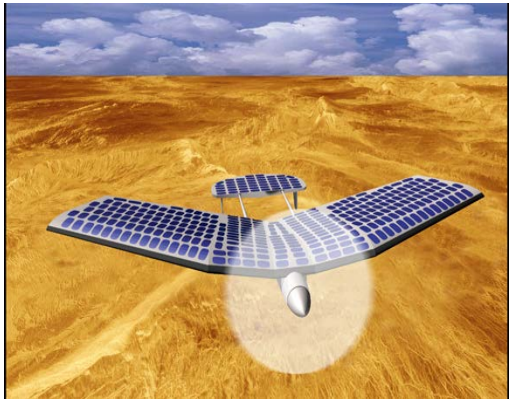
NASA began a partnership with Russia on the scientific goals for Venera D in January 2014.

Proposed Venus Missions 2016

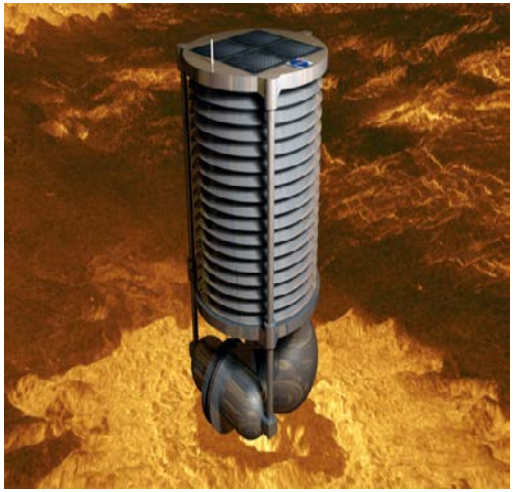


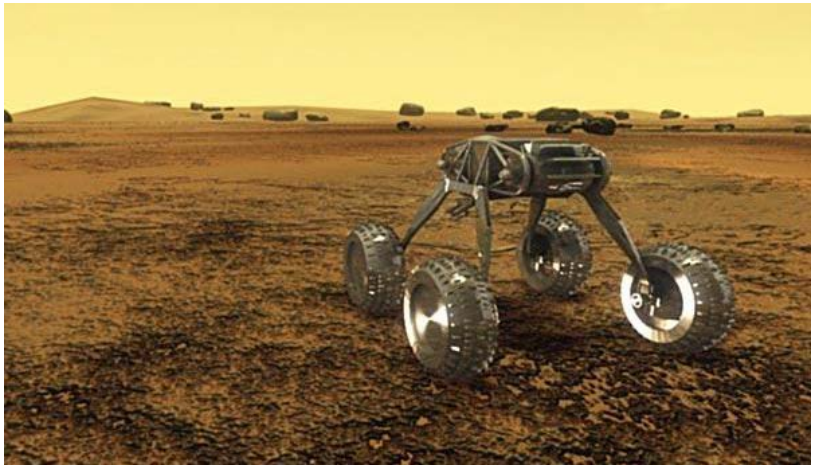
Long Range Vision for Venus Exploration

Concepts for above the clouds



Concepts for below the clouds and on the surface





Human Exploration

Orbital missions with human control of surface or aerial robots?

International Collaboration at Venus

- Who are the potential collaborators?
  - Established planetary explorers – Europe, Japan, Russia and the U.S.
  - Emerging planetary explorers – China and India.
  - Aspiring planetary explorers – Latin America and other parts of Asia

- What makes international collaboration so attractive?
  - Accessibility to ground-based and suborbital observations
  - Ease of spacecraft access – proximity to Earth
  - Rich scientific opportunities for all
  - Technical challenges for established explorers

- What kinds of missions can be expected in the future?
  - Scientifically capable orbiter missions are feasible with existing technology
  - Advances in technology will be needed to enable long-term atmospheric flight and long duration surface and near surface operations

Venus Exploration Assessment Group (VEXAG)

- Established by NASA in July 2005 to identify scientific priorities and strategy for exploration of Venus. Currently, chaired by Lori Glaze (NASA GSFC).

- Has always had strong international participation. Includes a focus group that explores opportunities for international collaboration.

- Has been an important forum for U.S. participation in ESA's Venus Express and JAXA's Akatsuki missions through NASA's Participating Scientist Program.

- Completed a set of four guiding documents for Venus exploration which are available on the VEXAG website http://www.lpi.usra.edu/vexag/

Objectives of this Course

- The focus of this course is on in situ exploration with probes, lander and aerial vehicles. However, the critical role of orbiters in proximity communication and providing context for in situ observations will also be covered.

- The course is structured along the following lines
  - Why go to Venus – the scientific motivation?
  - How do I get there – entry descent and landing or flight?
  - How do I survive and operate once I get there?
  - What instruments and experiments can answer my questions?
  - How do the exploration platforms come together in a coherent architecture?

- The course will conclude with a set of problems set for the students which will be addressed collaboratively

Conclusions

- The proximity of Venus and comparative ease of access means that many nations can participate in scientific exploration of the planet from space as well as from ground based and suborbital platforms

- During the last decade ESA's Venus Express has vastly expanded knowledge of the Venus atmosphere. JAXA's Akatsuki which entered Venus orbit at its second attempt, is continuing this work.

- Two Venus missions are now in the competition for the next NASA Discovery mission – DAVINCI a probe mission and VERITAS a radar orbiter. ESA is also pursuing a radar orbiter ENVISION

- Russia has now renewed interest in Venus with Venera-D and is considering a mission with landed, orbital and balloon elements.

- Looking forward, scientifically capable missions are feasible with existing technology but advances in technology will be needed to address questions that can only be answered with long duration in situ operation.