Piggy-backing to SAU — examples + lessons from the Past

Virginia Trimble — UCI + LCOGT

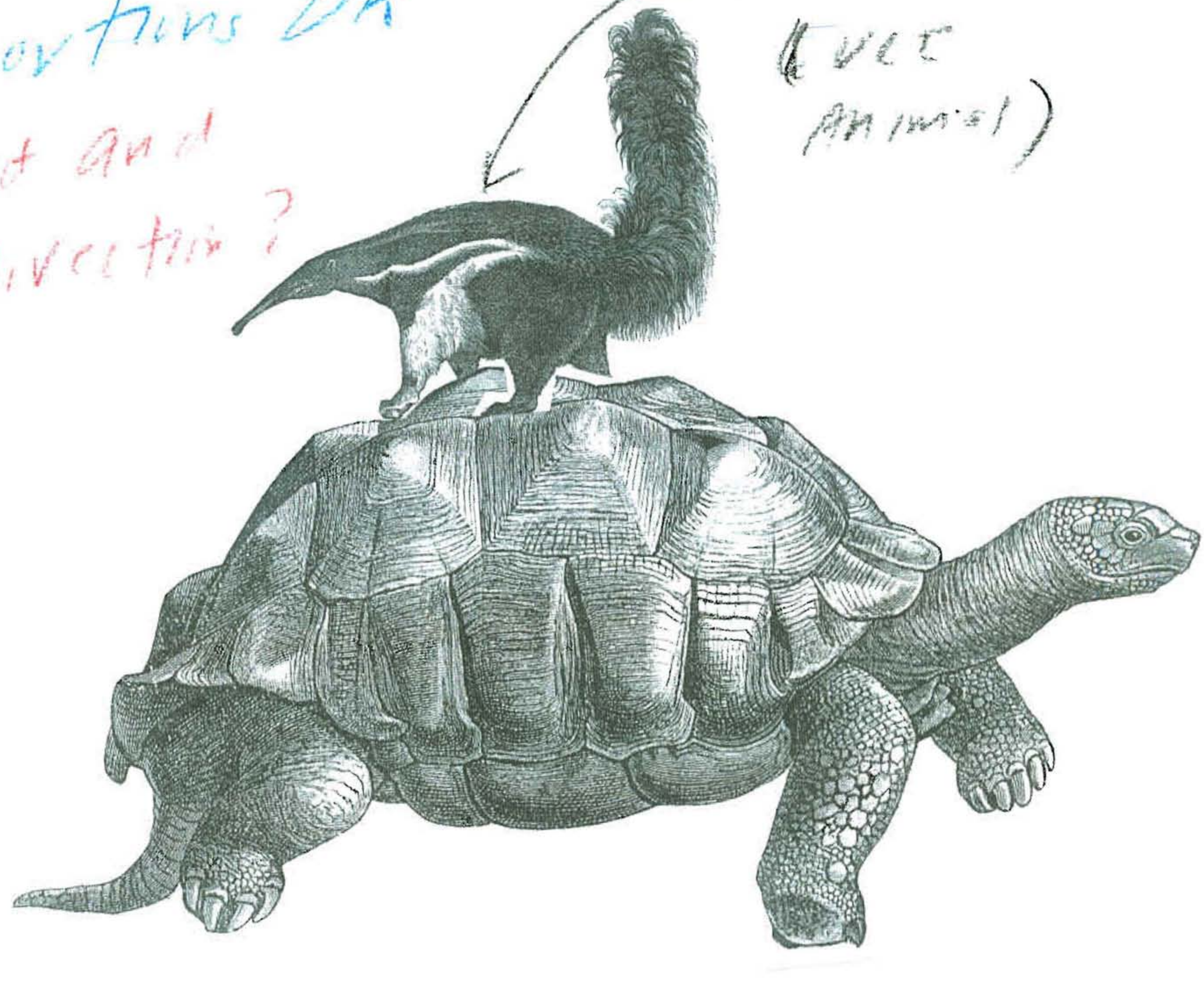
The issue of relative proportion

(relevance of Apollo)

Proportions OK

Speed and Direction?

anteater (Ever Animal)



Proportions, Speed, direction ok

Discovered out Purpose

THE ERA OF SERENDIPITY

Ranger 3, 5 missed moon; gamma ray detectors worked and gave first detection of background (1962 flights; report 1964 Nature, Metzger, Arnold et al). Ranger 4 crashed, 6 transmitter failed, 7 finally sent back moon pictures

1962 rocket flight to look at lunar X-ray fluorescence (finally seen by ROSAT!) finds Sco X-1, X-ray background, Nobel for Giacconi!

1967-73, Kosmos and Vela satellites find gamma ray bursts

1967 OSO-3 meant for solar stuff; saw flares as intended; also upper limits for extra-SS source gammas (Peterson +) and background detection (the "Kraushaar point")

GRB location by triangulation using γ ray monitors on just about everything flown down to present

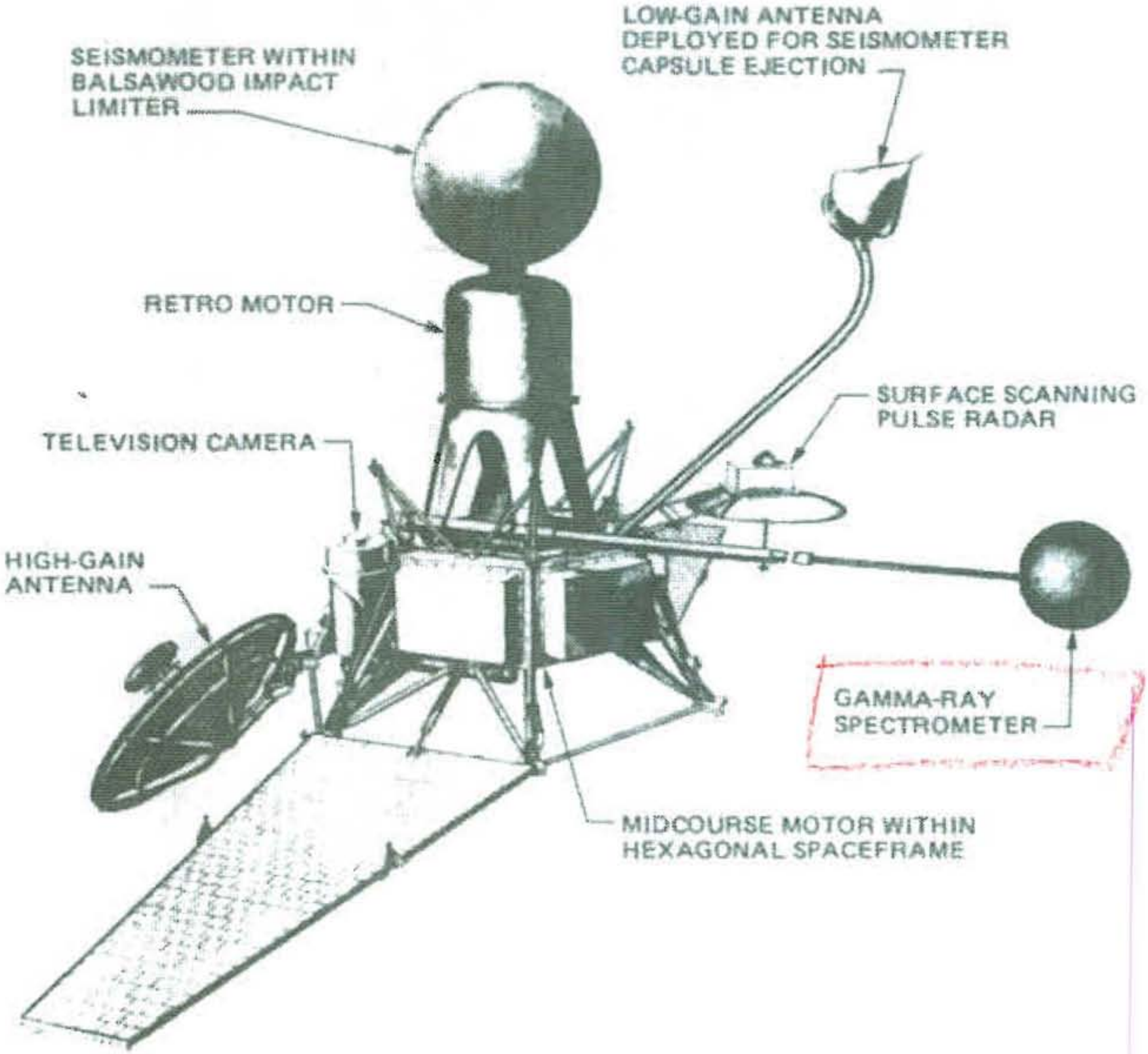


Figure 12-9. Rangers 3 *through* 5 *contained a seismic package (seen at the top of the craft) that was to be hard-landed on the Moon.*

rocket performed well, and after reaching orbit, the Agena fired and sent the Ranger on its way to the Moon. Approximately 38 minutes after leaving the Earth's orbit, electrical power supplied by the probe's solar panels abruptly stopped. The spacecraft automatically switched to its on-board battery, but it only had sufficient power for a few hours of operation. Halfway through the

THE APOLLO ERA

Some deliberate non-SS science on AESEP and ALSEP (12-17) (11)

Most notably the corner reflectors - indeed moon is moving away from earth, but also significant limits on violation of GR

Apollo 16 - some UV imaging, cosmic ray data

Apollo 17 (December 1972, last flight) The sad tale of the Lunar Surface Gravimeter, which would have worked very well where the group had put earlier gravimeters (South Pole for Louis Slichter of UCLA). In fact was as deployed a better seismometer than the real siesmometers, but NASA pulled the plug.

Apollo 18-20 cancelled. Would have included LSG reflight and a good deal more other science.

eace for all mankind.

—From the plaque left on the Moon by the *Apollo 11* astronauts

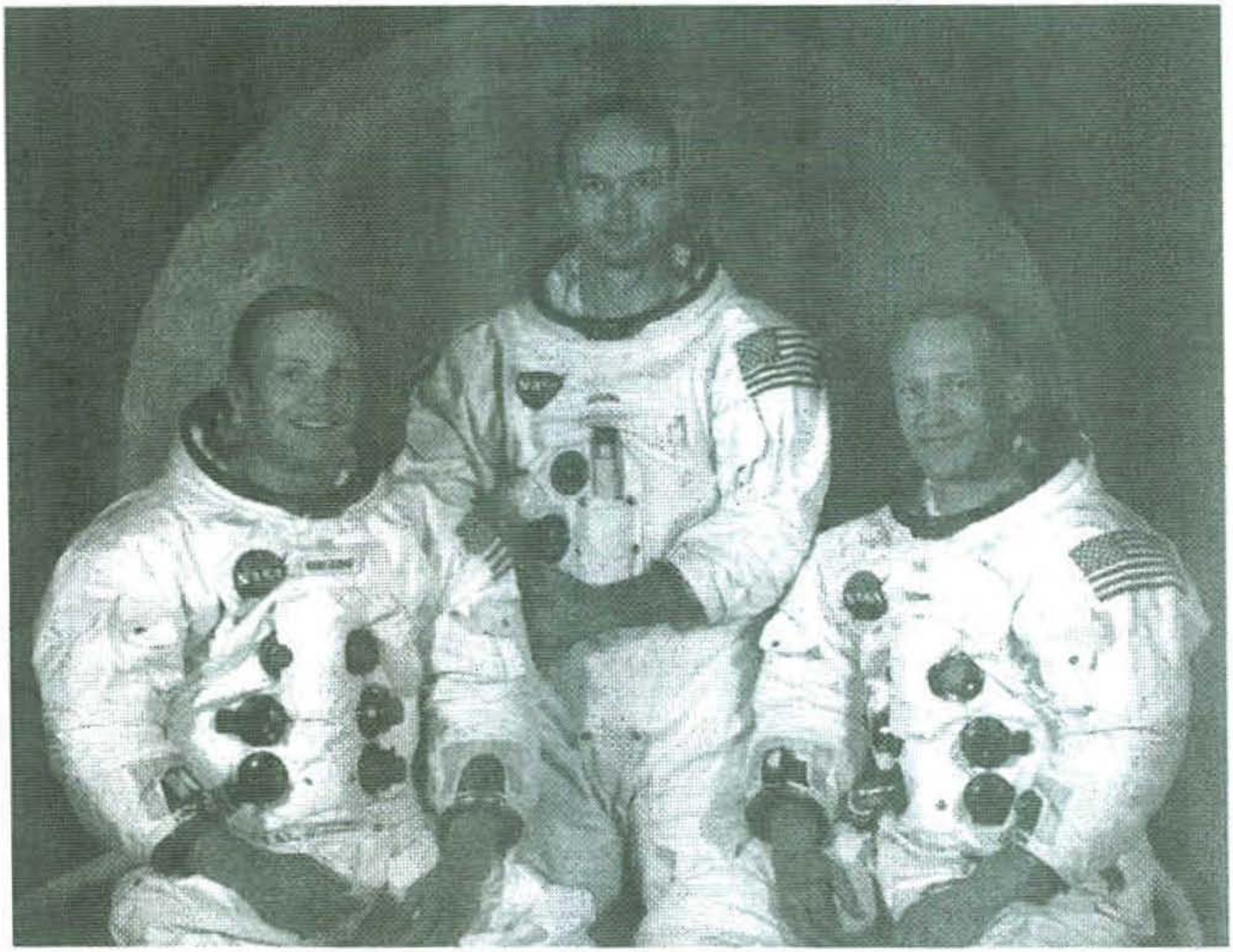


Figure 20-1. Neil Armstrong, commander; Michael Collins, CM pilot; and Edwin Aldrin, Jr., LM pilot.

was finally cleared when *Apollo 10* flew to the Moon and performed all the tasks required for a landing except touching down on the dusty lunar surface.

Despite this careful work, as the nation prepared to

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to radio this information back to Earth. The second experiment was called the Laser Ranging Retro-Reflector Experiment. Once deployed a laser beam would be shot toward it from the

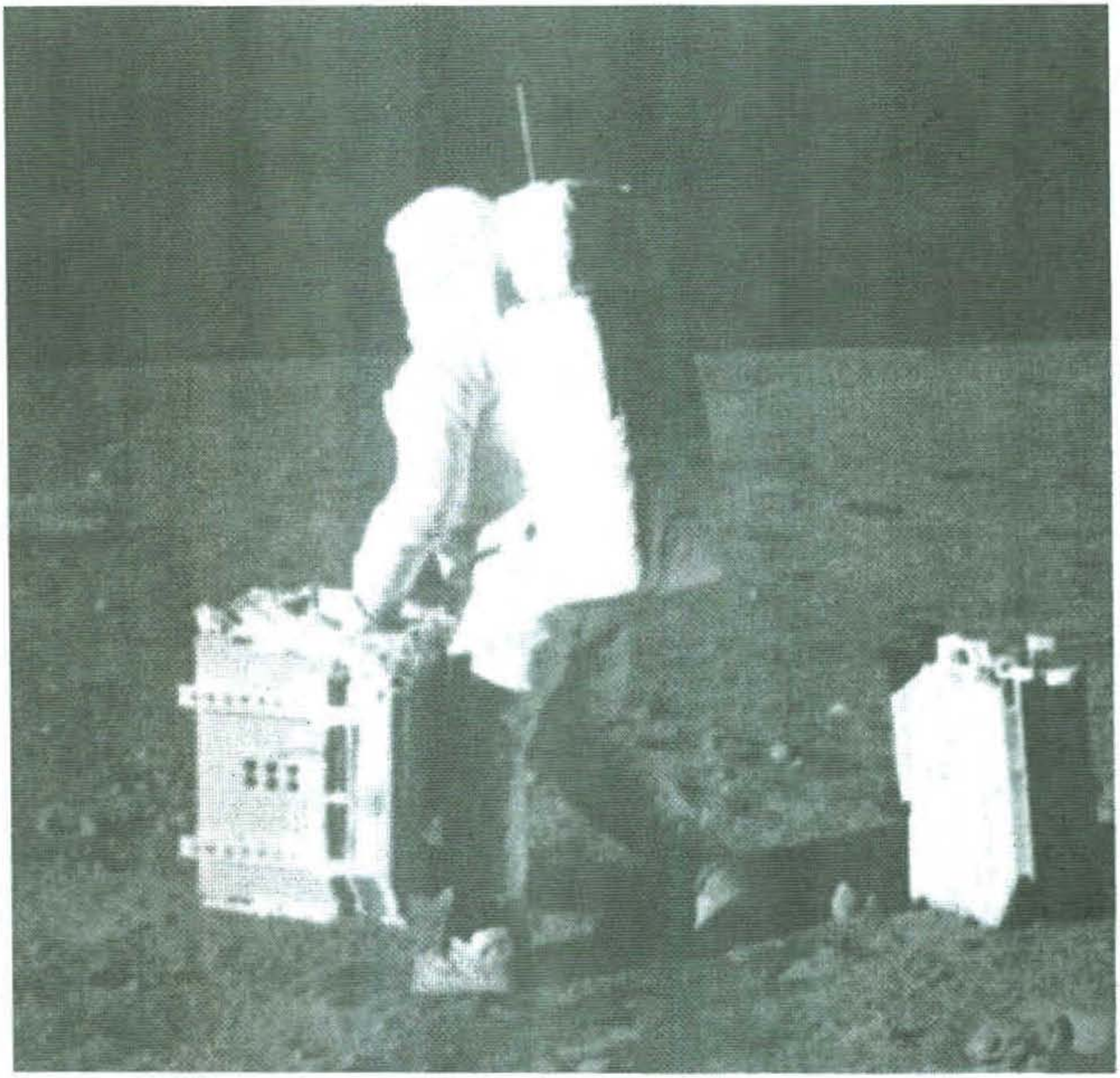
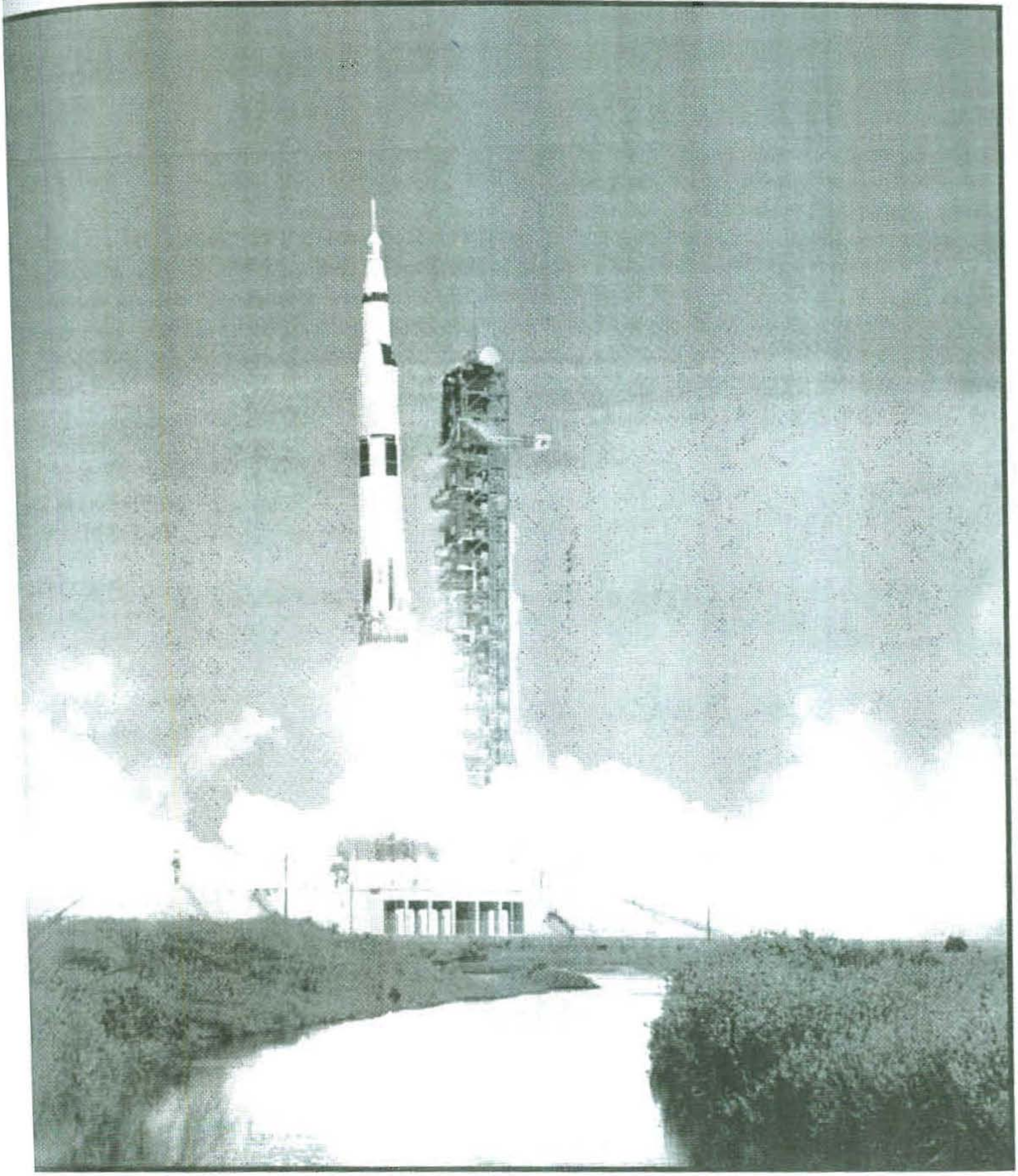


Figure 20-8. Experimental packages were set up on the Moon's surface. Aldrin leaves the laser reflector to set up the seismic experiment.

1st Corner reflectors

also Apollo 14, 15



-foot tall Apollo 15 Saturn V is launched from Pad A, Launch Complex 39, Kennedy Space Center, Florida, July 1, on a lunar landing mission. July 1971

Apollo 17: Lunar Surface Experiments
A18-20 Cancelled (LSG upgrades, other Science)

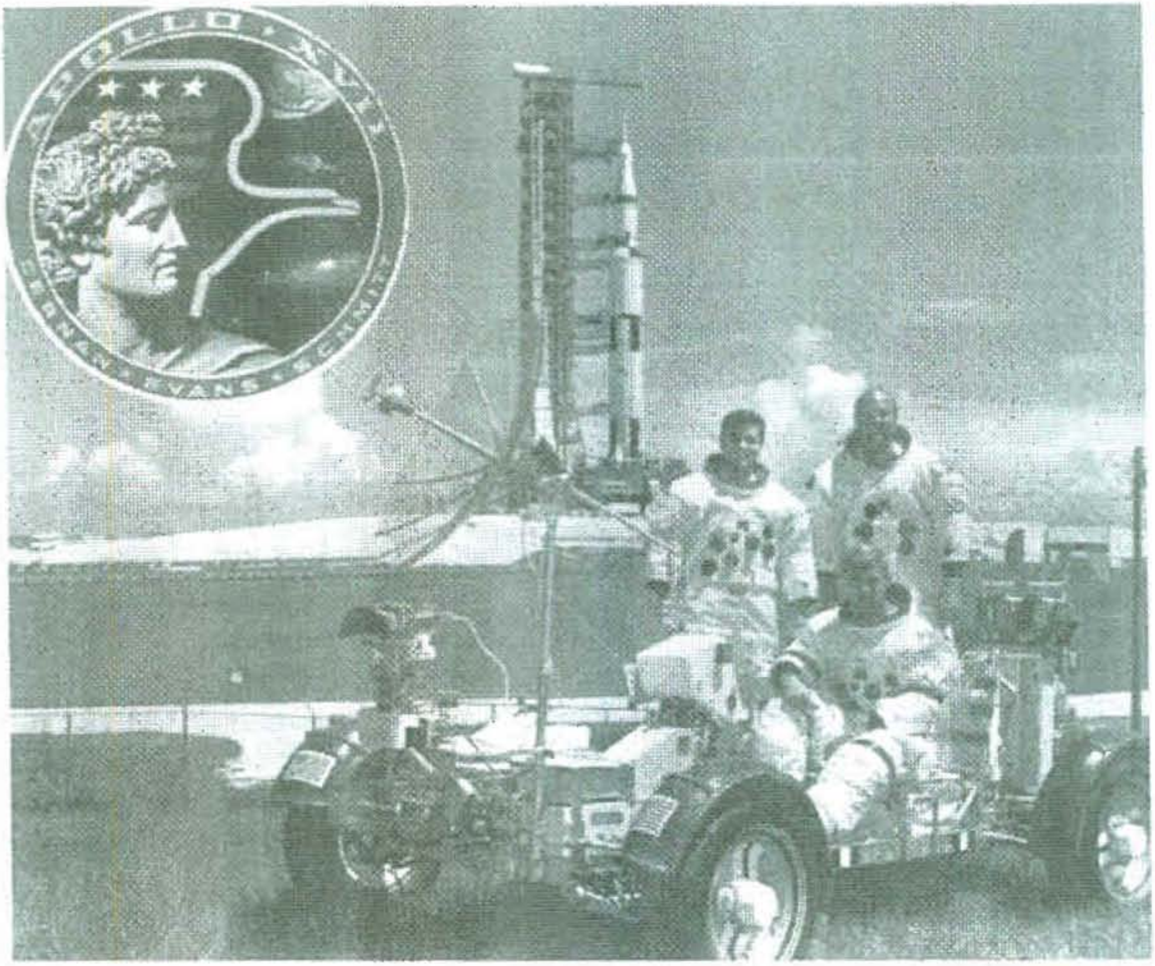


Figure 23-11. The crew of Apollo 17*: (left to right) Harrison Schmitt, Eugene Cernan (sitting), and Ronald Evans.*

Dec 1972

munity had urged NASA to include a scientist on at least one Apollo mission, so he was their standard bearer. Not only did he feel great pressure to meet the expectations of the scientific community, he also had to prove to NASA that a scientist/astronaut could contribute to the flight and landing. He and mission commander Cernan got on well together even though their personalities were quite different. Cernan was among the most talkative of the astronauts, whereas Schmitt was one of the most quiet and introspective.

The third crew member of *Apollo 17* was Ronald Evans

WHAT WERE THE RUSSIANS DOING?

A good deal of space science 1961-65 published in open literature, mostly Doklady, which I have not read. The Salyut/Soyuz era 1971+

Salyut 4, 1974, X-ray observations of the Crab Nebula (but Uhuru launch Dec. 1970)

As for UV competition, OAO-2 = Dec 1968
Copernicus = Aug 1972
TD-1 = March 1972

as the first space station beyond the Earth. The scientific haul

—**Brain Harvey in *The New Russian Space Programme***

What were the Russians doing?

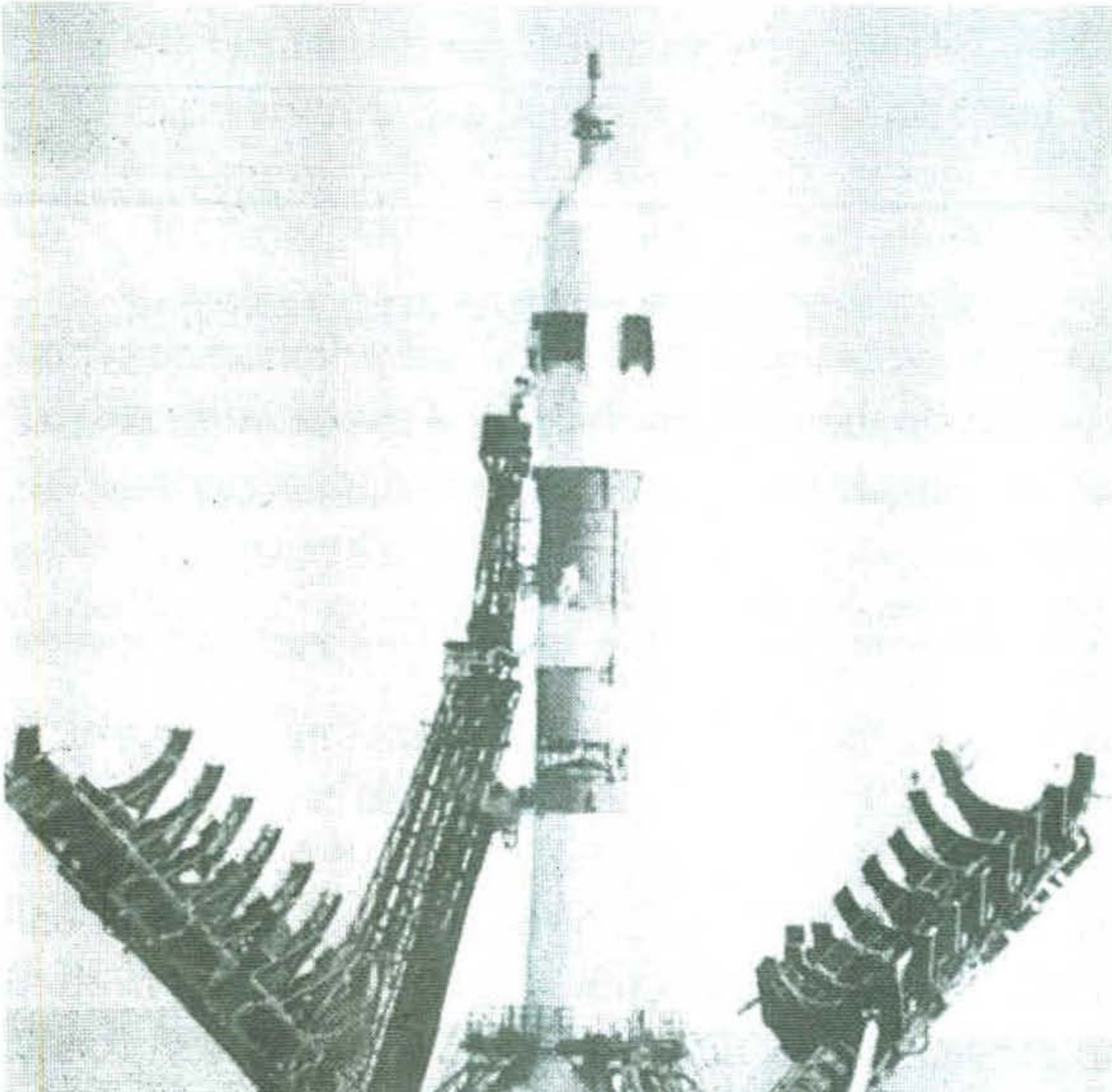


Figure 29-2. The launch of Soyuz 11 *from Baikonur on June 6, 1971.*

module, was pressurized.

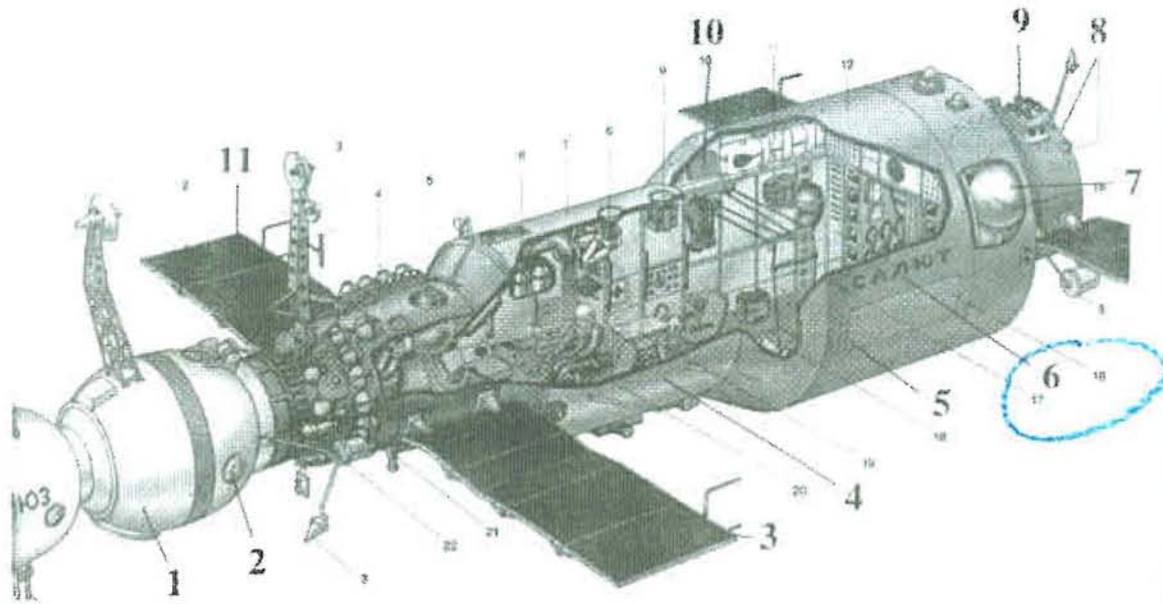
The transfer compartment had dimensions of 6.6 × 9.8 feet with a docking fixture attached to its front. Once a Soyuz was docked, the cosmonauts entered the station through an air-tight hatch. The transfer compartment also housed the station's biology experiments, cameras, and a telescope. This latter instrument, called the Orion stellar telescope (identified as #11 in the Focus Box), was the station's primary optical astronomical instrument. It was designed to obtain ultraviolet stellar spectra in the wavelength range of 2000–3000A. A gamma-ray telescope was also carried by the Salyut that was

A series of pioneering biology experiments to gather new information about the effect of weightlessness on the growth of living organisms was planned as part of the *Salyut 1* mission. Observations would be collected on the growth of frog eggs and other small plants and insects. Genetic changes of short-lived fruit flies would also be collected as well as data about the growth of higher-order plants.

The fourth Salyut compartment, the propulsion unit, was unpressurized and could not be entered by the cosmonauts. It had a length and maximum diameter of about 7.2 feet and contained the station's main rocket, stabilization and

Focus Box: Salyut 1 with Docked Soyuz

1. Docket Soyuz
2. Rendezvous radar
3. Solar panel
4. Main control console
5. Exercise treadmill
6. Scientific instrument bay
7. Main rocket fuel
8. Propulsion unit
9. Attitude thrusters
10. Movie camera porthole
11. Orion telescope



Focus Box: *Soyuz 11* Time-line and Sample Activities

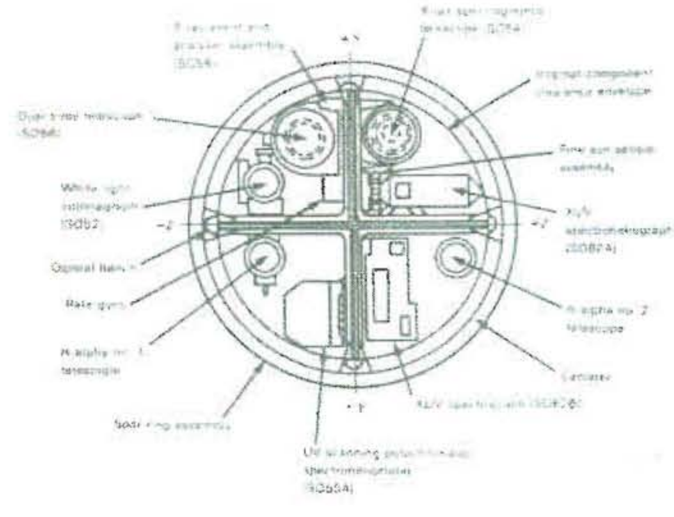
Date	Sample Activities	Date	Sample Activities
June 6	Launch from Tyurtam.	June 18	Orion telescope observations. Television broadcast.
June 7	Docking successful.	June 19	Aerosol content of atmosphere measured. Medical tests. Meteorological observations.
June 8	*Salyut 1* systems activated.	June 20	Television broadcast. Earth photography.
June 9	Salyut engine used to change orbit.	June 21	Orion Telescope studies. Gaama-ray radiation study. Space environment study.
June 10	Physical exercises. Medical tests.	June 22	Polarization of reflected light from Earth. Meteorological study.
June 11	Spectroscopic Earth measurements. Gamma-ray telescope used to measure distribution of celestrial gamma-rays.	June 23	Photography of USSR Engine firings.
June 12	Television broadcast. Medical tests. Photography.	June 24	Space endurance record. Weather observations. Physical exercises. Earth photographs.
June 13	Earth Resources experiments. Measurements of cosmic radiation.	June 25	Experimental program activities. Preparation for return to Earth. Television broadcast.
June 14	Navigation experiment. Coordinated weather observations.	June 26	Micrometeorite measurements. Increased exercises. Preparation for landing.
June 15	Simultaneous space and aircraft photographic studies. Joint Salyut and Meteor satellite cloud cover measurements.	June 27	*Soyuz 11* checks. Television broadcast. Weather observations.
June 16	Salyut systems evaluated. Atmospheric study.	June 28	Medical tests. Soyuz system reactivation.
June 17	Spacecraft antenna tests. Medical tests. Space environment density measurement.	June 29	Departure from *Salyut 1*.

broadcast from the station had made the cosmonauts nearly as well known as Gagarin and Leonov. The joyous reception that had been planned in Moscow was now replaced by yet another somber procession as the cremated remains of the cosmonauts were carried to the Kremlin wall and placed in a position of honor next to their comrades. Tributes flowed in from around the world, and in what seemed like an endless line, grief-stricken Soviet citizens walked by to pay their last respects to a crew they had grown to greatly admire.

Soviet space officials had hoped a successful Salyut mission would relieve some of the pain the nation still felt about the lost Moon race. The tragic end of *Soyuz 11* dashed those hopes and caused a further time-consuming reevaluation of the Soviet manned spaceflight program.

Postflight Changes

After the disaster of *Soyuz 11*, the Soyuz craft was redesigned. It was also decided that on future missions the cos-



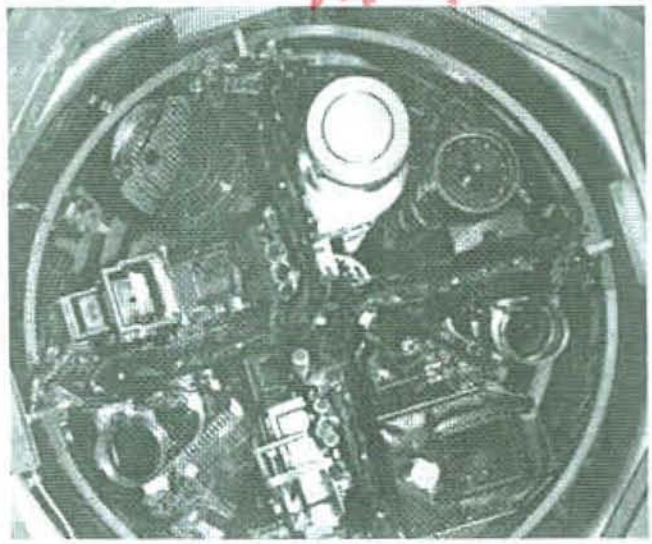


Figure A3.2. (left) Looking down at the telescopes in the Apollo Telescope Mount. In this view, all eight telescopes can be seen. They operated at x-ray to visible wavelengths. (right) Identification of the instruments in the left side panel.

Skylab's Stellar Research Program

Hot stars emit the majority of their light below 3000A and most of this light is absorbed by our atmosphere. Prior to 1973 sounding rockets had been employed to obtain ultraviolet spectra for about thirty stars. Astronomers use these spectra to determine a star's surface temperature and gravity. During its lifetime, Skylab would acquire nearly 400 ultraviolet spectra, increasing the available ultraviolet data on stars by over a factor of ten.

Astronomers use a short-hand notation, called spectral type, when referring to a star's surface temperature. A spectral type consists of one of the letters O, B, A, F, G, K, M followed by a number between 0 and 9. O stars have surface temperatures higher than 25,000°K, whereas M stars have temperatures of around 2,500°K (°K = 273+ °C). Examples of stars with spectral types in between these two extremes are B5, G2, and K9. The surface gravity of a star is designated by a Roman numeral between I and V, which is attached to the spectral type. Large stars which have a luminosity class of I

Focus Box: The Surface Gravity and Temperature of Stars

Skylab ultraviolet spectra included a range of spectral type and luminosity class stars. The strength of the CIV line at 1549A is used as a temperature indicator since its strength dramatically increases when moving from B5 to O6 stars. This same trend is also evident for other luminosity class stars. The luminosity class of the star can be determined from the Si IV lines located at 1394 and 1403A. The strength of these lines increases in moving from luminosity class V to I. The presence of an emission line just to the right of the CIV line indicates that mass is being ejected from the star. Based on the strength of this emission feature, O9.5 II-I stars are losing mass at a rapid rate.

Taken from *Skylab's Astronomy and Space Sciences.*

Earth stuff biomedical Space applications

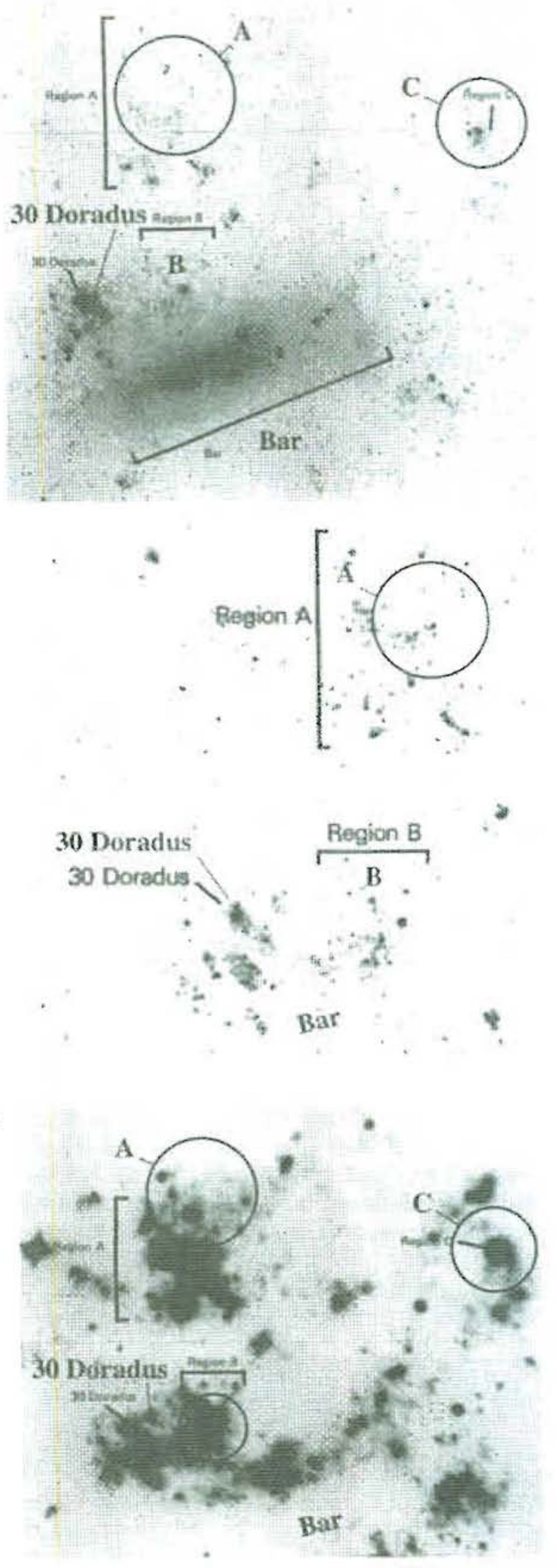


Figure A3-3. (a) An optical image of the Large Magellanic Cloud. (b) An image taken at 2,500A. (c) The same object seen in light with a wavelength of 1,400A.

have low surface gravities. A F2V star has a higher surface gravity than a F2I star but both of these stars have the same surface temperature since their spectral types are F2.

Both the surface temperature and gravity can be determined by the strength of absorption lines in a star's spectrum. By providing ultraviolet spectra, Skylab therefore allowed astronomers to vastly increase the sample for which these values were known (see the Focus Box on page A-22).

Skylab's Galactic Research Program

Galaxies are huge conglomerations of stars. They can be tens of thousands of parsecs in diameter and can contain hundreds of billions of stars. Billions of galaxies exist in our Universe but they have three basic shapes: spiral, elliptical, and irregular. The Large Magellanic Cloud (LMC) is one of the nearest galaxies to the Milky Way. Located at a distance of about 53,000 parsecs (1 parsec = 1.8×10^{13} miles), it contains billions of stars distributed in a chaotic fashion. Gas and dust clouds comprise about 40 percent of its mass and stars are being continuously formed within it. Although the majority of galaxies have either a spiral shape (like our own Milky Way) or an elliptical shape, approximately 25 percent of all galaxies do not have a definable shape, and like the LMC, they are classified as irregular galaxies.

Figure A3-3a shows an image of the LMC taken through a red filter by Dr. Karl Henize. A bar-like structure composed of a red star and a large region of glowing hydrogen gas called 30 Doradus dominates this view. Two faint glowing hydrogen gas clouds (Regions A and C) are located above and to the right of the bar. Figure A3-3b shows a Skylab ultraviolet photograph of the LMC. The emission from Region A remains strong, but the bar-like structure is absent. Figure A3-3c shows a far ultraviolet picture taken from the Moon during the *Apollo 16* mission. Region A is the most prominent feature even though it was barely visible in Figure A3-3a, and a new emission site, Region B, is visible. It is clear that these type of multiwavelength photographs provide dramatically different views that are important for learning about the structure and energetics of galaxies.

The Glowing X-ray Sky

X-rays created in space by energetic objects are absorbed when passing through the Earth's atmosphere. Therefore, before the launch of the Skylab, the x-ray sky had only been explored by unmanned probes. By 1973 about 100 x-ray sources had been discovered, but they possessed a bewildering range of properties. Some appeared to be associated with stars while others covered an extended region of the sky. Some were located within our galaxy, while others were beyond it. Some emitted pulsed x-ray radiation, while others emitted this light in a continuous fashion. In addition to this perplexing picture, the sky itself seemed to be uniformly glowing in soft x-rays.

An important goal of Skylab was to identify the source of this diffuse x-ray emission. The instrument used for this pur-

MORE SERENDIPITY + PLANNED (PASTEUR) CHANCE

The Pioneer effect (uncertain IR radiation recoil more likely?)

The fly-by effect (changes in tracking geometry and antennas used before/after perigeon more likely?) (with thanks to Peter Bender)

Factor of 50 improvement in limit on PPN parameter γ, which comes from Cassini tracking behind Sun and the "Shapiro delay", which says light is slowed down in potential well by amount proportional to $\frac{1}{2}(1 + \gamma)$ where $\gamma = 0$ is GR prediction

Additional improvements on PPN limits can be expected from Beppi-Colombo in a few years (or if you think GR is right, better numbers for J_2 of the sun)

The Pioneer Effect?

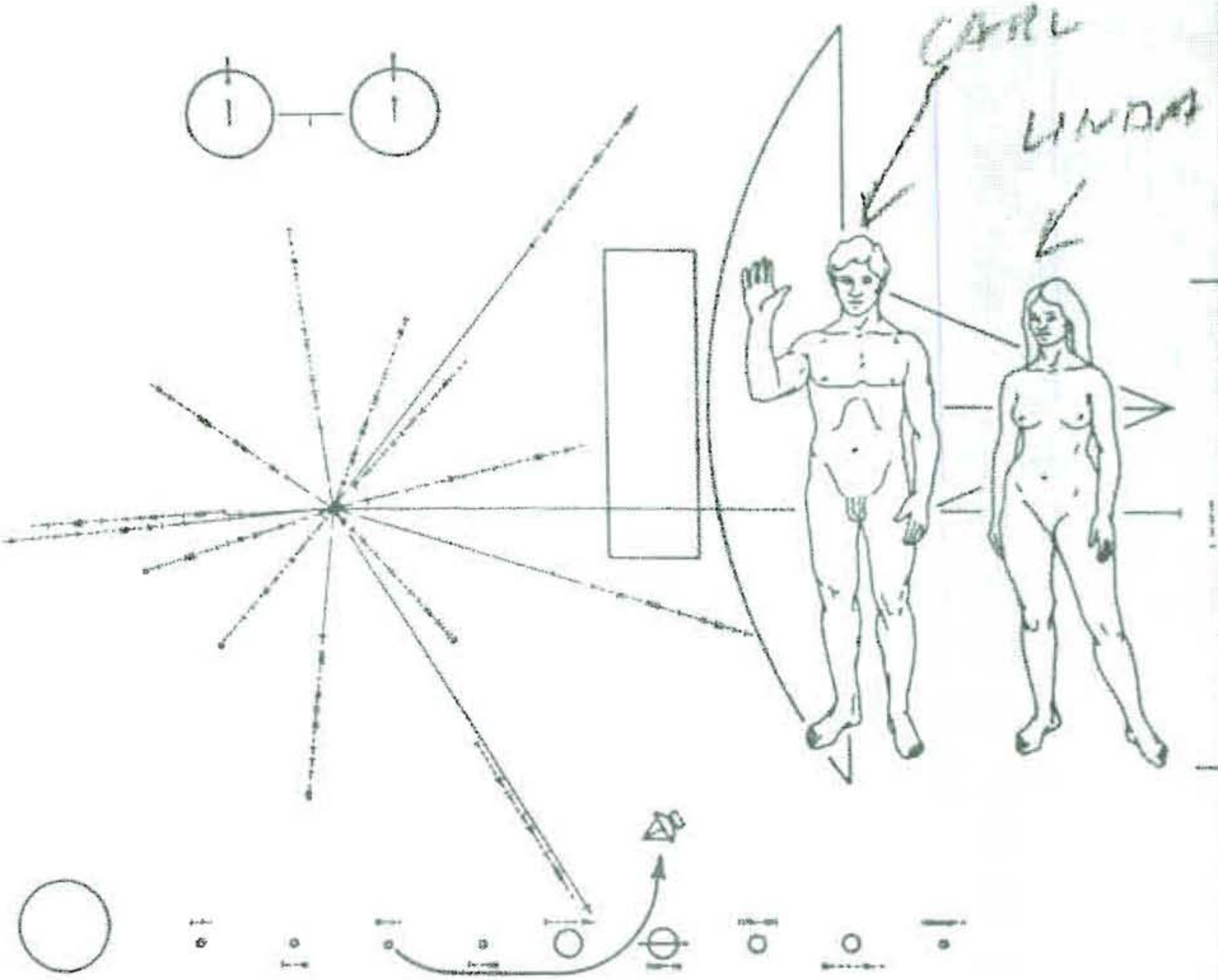
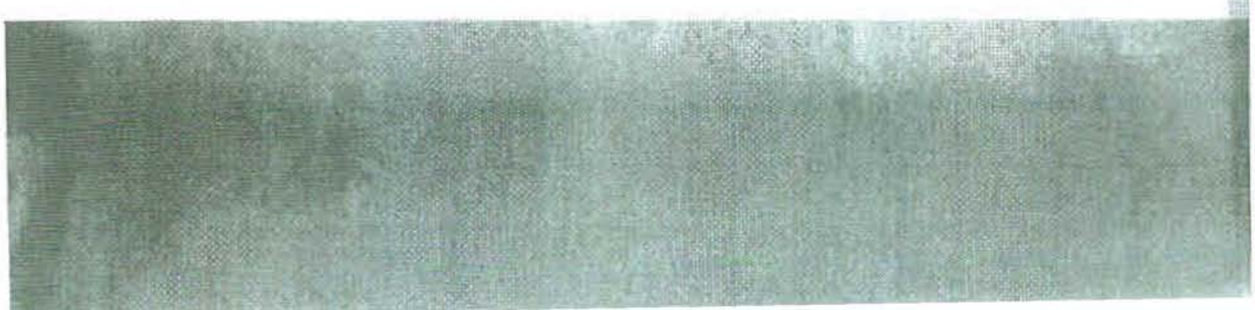


Figure 13.12 Plaque carried out of the Solar System on Pioneer 10 and 11 spacecraft. Short vertical lines and dashes are binary numbers. An extraterrestrial smart enough to catch the spacecraft should be smart enough to understand the numbers. *Courtesy of NASA.*



Ashleigh Brilliant

POT-SHOTS NO. 3877.

THE ONLY REQUIREMENT
FOR EVENTUALLY
GETTING THERE

IS TO KEEP GOING
IN THE RIGHT
DIRECTION.