Saguaro Astronomy Club

Metro Phoenix, Arizona

SACNEWS

January 1993 — Issue #192

The Great Moon Race: The Long Road to Success

by Andrew J. LePage

As 1962 was drawing to a close, the situation with the American Moon program looked bleak. The failure of RANGER 5 was NASA's sixth consecutive lunar mission failure in three years. Only seventeen months after President John F. Kennedy committed the United States to landing a man on Earth's Moon with Project APOLLO, it was beginning to look as though the Americans would never make it. If they could not get a simple unmanned probe to the Moon in working order, how could they hope to pull off the much more complicated mission of a manned lunar landing?

Investigations into the failure of the RANGER program started on October 30, 1962. Over the course of the next month, several groups inside NASA and out examined every aspect of the RANGER project in an attempt to pin down the causes of the failures and recommend changes. On November 30, NASA Headquarters released the findings of its inquiry: In brief, the report recommended streamlining management and changing the mission goals to be more in line with the needs of APOLLO. This meant concentrating on lunar imaging and dropping all other experiments on the Block III RANGER.

Sterilization was pinpointed as the cause of many of RANGER's system failures...

The report also called for a thorough re-evaluation of the RANGER design, modifying vulnerable systems and the inclusion of more backup systems. The Jet Propulsion Laboratory (JPL) would be required to use outside contractors to build the three advanced Block IV RANGERs then being contemplated, instead of in-house as was the case with the first three Blocks. More extensive testing of systems and better quality control for components were recommended.

Most of all, the report called for the immediate abandonment of sterilization. Sterilization was pinpointed as the cause of many of RANGER's system failures and it was now felt to be unnecessary, given that the hostile lunar environment was unlikely to harbor any indigenous life forms. Unless these changes were made, the Block III RANGERs were likely to suffer the same fate as its predecessors. With these recommendations in hand, JPL set about redesigning and rebuilding the Block III RANGERs. The scheduled launch of what would be RANGER 6 was delayed until late 1963.

A Change in Plans

As a result of fears that JPL's problems with RANGER could recur in its SURVEYOR program, and because of the continuing development problems with the

Quick Calendar

SAC Meeting
7:30, Friday, January 8

Deep Sky Meeting
Taurus and Auriga
Thursday, January 14

Star Party
Buckeye Hills Recreation Area
Saturday, January 16

SAC Meeting
7:30, Friday, February 5

1993 SAC Officers

President	Bob Dahl	582–5526
Vice President	Tom Polakis	966–2625
Treasurer	Carol Lee	946–9206
Secretary	Susan Morse	934–7496
Properties	Rich Walker	997–0711
SACNEWS Editor	Paul Dickson	841–7044

ATLAS-CENTAUR rocket, NASA Headquarters began to examine possible alternatives to SURVEYOR. Langley Research Center was quietly directed by Headquarters in 1962 to examine the possibility of using a lightweight lunar orbiter launched by the improved ATLAS-AGENA D to perform a photographic mapping mission in place of the heavier SURVEYOR B orbiter. Any more major delays in either the SURVEYOR or ATLAS-CENTAUR programs could severely impact the schedule of the all-important APOLLO program. High resolution photographs of potential landing sites were urgently needed.

The studies conducted indicated that it was feasible to build a small lunar orbiter that would provide the needed lunar photographs. By March of 1963, the basic design for LUNAR ORBITER was completed and the project approved. On August 30, the newly created LUNAR ORBITER Project Office at Langley issued a request for proposals for its new lunar project. The goal was to build an orbiter that could image potential APOLLO landing sites five degrees north and south of the equator between 45 degrees east and west longitude with a resolution of one meter (3.3 feet). The first flight was expected in 1966.

The goal was to build an orbiter that could image potential APOLLO landing sites

NASA had similar concerns about the lander portion of the SURVEYOR program. In 1963, JPL began studies on an ATLAS-AGENA D launched Block V RANGER that would carry a small soft lander built by Northrop. This option, as it turned out, was never exercised and was dropped along with the advanced Block IV RANGER by the end of 1963, partially for budgetary reasons.

With its orbiter mission deleted, JPL's SURVEYOR program continued by concentrating on building a lunar lander. The program's goals were now altered to directly support APOLLO. SURVEYOR would be used as an engineering tool to develop the techniques needed to land on the Moon. At the end of 1963, a total of seven flights were planned. The first four would be test flights, while the last three would be operational. The first SURVEYOR flight was still optimistically targeted for late 1964. Options for additional flights of heavier and more advanced SURVEYOR landers that would incorporate more of the originally planned experiments and possibly a small rover were still being considered. For this it would be required that the usable payload of the launch vehicle could be increased sufficiently.

Progress with SURVEYOR's launch vehicle, the ATLAS-CENTAUR, continued at a steady pace during 1963. The second test launch, ATLAS-CENTAUR 2, finally occurred during the afternoon of November 11 after months of delays. The goal of this flight was to simply get into orbit. No second burn of the CENTAUR's advanced, hydrogen burning RL-10 engines was being considered on this flight. The five-ton (4.5 metric ton) CENTAUR was successfully placed into a lofty 303 by 1,093-mile (488 by 1,759-kilometer) orbit without any major problems. Much work remained to be done to perfect this fickle machine, but at last there seemed to be a light at the end of the tunnel.

The New and Improved RANGER

The improved Block III RANGER was finally ready by the end of 1963. Much had been changed from the previous design. The RANGER hexagon-shaped bus was similar to previous models with some notable exceptions. First, the bus' framework was now made of aluminum due to its better thermal characteristics. A second battery to provide additional backup power was added. The course correction system was enlarged to provide a 135-mile per hour (60-meter per second) velocity change capability; a one-third increase over the Block II RANGER. The sequencer was redesigned to incorporate components which were not heat sterilized. This included features that increased the chances of a successful mission in case of equipment failure. A second, independent attitude control jet system was added for redundancy.

The bus was also fitted with new rectangular-shaped solar panels similar to the ones carried by the MARINER 2 Venus probe in 1962. This design had portions of the panels electrically isolated from each other to avoid a repeat of the total solar panel failure experienced by RANGER 5. All of these changes increased the weight of the Block III RANGER. This prompted the deletion of every instrument except for the television camera package to keep the probe under 810 pounds (368 kilograms).

Two independent chains of RCA-developed slow scan vidicon cameras were enclosed in a five-foot (1.5-meter) tall tower mounted on top of the bus. Clad in polished aluminum for thermal control, the 380-pound (173-kilogram) cylindrical tower tapered from 27 inches (69 centimeters) at its base to 16 inches (41 centimeters) at the top, where the low-gain antenna was mounted. The six cameras viewed the approaching lunar surface through a 13-inch (33-centimeter) square opening on the side of the tower. Their optical axes were canted at a 28-degree angle from the spacecraft's long axis. Also enclosed inside the tower were two independent power supplies, camera sequencers, and batteries; one set for each chain of cameras. Each chain also possessed its own sixty-watt transmitter to independently transmit images in real time back to Earth.

When the time came for the cameras to switch to full power and start returning images, however, only static was received.

The bus still carried its own three-watt transmitter which would now only carry engineering telemetry.

The first camera chain was the full scan or F chain, which consisted of two cameras. One camera was fitted with a 35-millimeter lens, providing a 25-degree field of view, while the other used a 76-millimeter lens with an 8.4-degree field of view. Each camera would scan the entire 1,152-line vidicon once the exposure had been taken. As a set, the F chain returned one image every 2.56 seconds. Normally the camera would be turned on by commands sent from Earth. If this failed, the bus' onboard sequencer would activate the package at a preset time. If this failed, the F chain had its own timer that was activated by the spacecraft's separation from the AGENA B escape stage. After 67 hours and 45 minutes of flight, the F chain would automatically turn on and start transmitting images. In this way, even if both primary systems were to fail, at least a few hundred full scan images would be returned.

Independent of the F chain was a second set of four partial scan vidicon cameras called the P chain. Like the F chain, 35 and 76-millimeter lenses were used, but only three hundred partial lines — about seven percent of the vidicon's face — was read and transmitted back to Earth. This resulted in images with the same resolution as the F chain but covering a smaller area. This was done so that images could be returned at a rate of five images per second in hopes of capturing at least a partial image a couple of tenths of a second before impact. At this altitude of only one or two thousand feet (300 to 600 meters), a resolution of one foot (0.3 meters) or better was possible. If the F chain were to malfunction, the P chain could independently return thousands of images after receiving a command either directly from Earth or from RANGER's central sequencer and timer.

With all these hardware changes, including redundant and more fault tolerant systems as well as five hundred to eight hundred hours of prelaunch testing, the new Block III RANGER was much more likely to reach its target in working order.

The Block III mission profile was very similar to the Block II up until the encounter with the Moon. Since the Block III probe did not have to be concerned with the site and trajectory requirements of a lander, the impact point could be over a much larger range of longitude near the lunar equator. Typically the most easterly aim point was targeted at the beginning of the launch window. The aim point then drifted westward by about thirteen degrees of longitude per day, so that the impact point would have the optimum lighting conditions.

About one hour before impact, the spacecraft would begin its terminal maneuver and reorient itself. This aims the cameras along RANGER's flight path towards approaching lunar surface and the high gain antenna is again pointed towards Earth. Some seventeen minutes before impact, the F chain of cameras is commanded to warm up for ninety seconds. The P chain then takes its turn and warms up. Finally, fourteen minutes before impact at an altitude of about 1,200 miles (1,900 kilometers), the F chain's sixty-watt transmitter starts beaming images back to Earth, followed by the P chain typically 2.5 minutes later. Transmission would continue until the spacecraft impacted the lunar surface at 5,800 miles per hour (2,600 meters per second). If everything worked perfectly, over 4,200 close up television images of the lunar surface would be transmitted.

More Failure

Because of various minor schedule slips, the first modified Block III spacecraft, RANGER A, was ready for launch by the beginning of 1964. Its primary targets were in the smooth equatorial mare regions, which were considered likely APOLLO landing sites. On the first day of the launch window, the site would be a point at 8.5 degrees north and 21.0 degrees east in Mare Tranquillitatis, the Sea of Tranquility. After several short holds, RANGER 6 lifted off on its first attempt on January 30. The launch and injection into a translunar trajectory went perfectly except for a telemetry channel that switched into an un-

Universal Time and Date of Total Lunar Occultations for Phoenix (33.5° Lat., 112.1° Long.)

Date	Time[1]	Time[2]	Mag	Star Information	PH	PA[1]	PA[2]	PS	Elong	MAL	MAZ	SAL	SAL	
01/05	08:43:20	08:44:03	4.5	ZC0599 (37 Tau)	DD	100	110	79	143	35	276	-71	60	
01/19	13:06:41		4.9	ZC2523 (51 Oph)	RD	212		22	321	11	127	-17	103	†
02/02	01:20:49		4.4	ZC0656 (κ Tau)	DD	139		65	117	65	109	-5	253	
02/02	02:28:47		4.4	ZC0660 (υ Tau)	DD	9		65	118	77	142	-19	262	‡
02/28	01:54:29		4.5	ZC0465 (δ Ari)	DD	163		40	73	63	247	-7	265	§
03/13	10:42:44	10:42:03	2.5	ZC2290 (δ Sco)	DB	103	113	63	247	32	158	-37	65	
03/13	12:10:10	12:09:41	2.5	ZC2290 (δ Sco)	RD	280	275	62	248	35	181	-19	80	
04/19	15:11:59	15:10:49	-4.4	Venus	DB	39	23	14	334	45	120	28	95	
04/19	16:30:04	16:30:07	-4.4	Venus	RD	251	269	14	335	58	144	44	109	
06/12	08:13:33		4.9	ZC3453 (κ Psc)	RD	244		49	272	10	95	-32	13	
11/03	09:36:08	09:35:13	3.0	ZC0847 (ζ Tau)	DB	104	102	73	229	75	143	-52	70	
11/03	11:09:10	11:08:25	3.0	ZC0847 (ζ Tau)	RD	268	263	72	230	73	227	-33	86	
11/04	08:43:26	08:43:02	4.1	ZC0995 (ν Gem)	RD	293	298	66	240	57	104	-62	55	
11/20	02:34:19	02:31:52	4.5	ZC3093 (ν Aqr)	DD	30	10	46	83	38	216	-27	264	
11/23	01:22:46	01:21:35	4.9	ZC3453 (κ Psc)	DD	73	58	64	115	53	145	-13	254	
12/04	09:16:23	09:15:40	4.3	ZC1341 (α Cnc)	RD	321	315	63	246	52	116	-61	74	

NOTES:

Subtract 7 hours for correct Mountain Standard Time and Day.

Time[1] = Hrs:Min (Std Sta NM)

Time[2] = Hrs:Min (Std Sta LA)

PH = Phenomenon, i.e. RD = (R)eappearance on (D)ark Limb

PA[1] = Position Angle of star from north point of moon (90=East) (NM Std Sta)

PA[2] = Position Angle of star from north point of moon (90=East) (LA Std Sta)

PS = Percent Sunlit

Elong = Elongation of moon from sun (180 = full; 270 = 3rd Qtr)

MAL = Moon Altitude in degrees (90 = directly overhead)

MAZ = Moon Azimuth (90 = East)

SAL; SAZ = Sun Altitude; Azimuth

Blanks = Not Listed at Standard Station

Compiled by Brian K. Vorndam, for more info call him at 602–344–9841.

† Southern limit graze southwest of Phoenix (total for Phoenix)

‡ Northern limit graze north of Phoenix (total for Phoenix)

§ Graze line not shown in Observer's Handbook.

scheduled mode for 67 seconds when the booster engines separated from the ATLAS.

Initial tracking of RANGER 6 indicated that it would miss the Moon by about 600 miles (965 kilometers). More refined calculations later indicated a miss of only 495 miles (796 kilometers) that was corrected by a one minute, seven second burn of the course correction motor about sixteen hours and 41 minutes after launch. This 92.2-mile per hour (41.2-meter per second) change of velocity placed RANGER 6 on course for an impact on the western edge of Mare Tranquillitatis 40 miles (65 kilometers) south of the crater called Ross.

On February 2, as RANGER 6 passed the 1,290-mile (2,076-kilometer) altitude mark moving at 4,471 miles per hour (1,998 meters per second), the television cameras were switched into warm up mode with all systems functioning normally. When the time came for the cameras to switch to full power and start returning images, however, only static was received. Quickly a series of emergency commands were sent from Earth, but to no avail. RANGER 6 crashed into the lunar surface at 9.39 degrees north, 21.51 degrees east at a speed of 5,946 miles per hour (2,658 meters per second) without returning a single picture.

The completely redundant camera system was found not to be perfectly so.

RANGER 6 was definitely a very successful engineering test. With the exception of the cameras, all systems worked perfectly. In addition, the navigation accuracy was the best ever attained; the spacecraft impacted the Moon only 19 miles (31 kilometers) from its aim point and only 0.3 seconds before its post-mid-course maneuver predicted impact time. Still, from the science community's and public's point of view, this was NASA's seventh consecutive lunar mission failure. NASA Headquarters formed another board of inquiry to investigate this mishap. The March launch of RANGER B was postponed pending the outcome of this new investigation. The pressure was on NASA and JPL was fighting for its life.

After a self-imposed hiatus, the Soviets began anew their attempts to reach the Moon. In contrast to their early successes, this new generation of LUNA spacecraft suffered even more failures. According to Western intelligence sources, the Soviets first lunar mission since LUNA 4 failed to reach Earth parking orbit due to a launch vehicle malfunction sometime around February or March of 1964. Yet another LUNA was lost around April 20 due to another MOLNIYA launch failure. Possibly as a result of these new failures, the Soviets postponed additional LUNA launch attempts for almost another year while the bugs were worked out of the MOLNIYA.

The NASA investigation into the failure of the RANGER 6 camera package was released on March 17. The 75-page report pinned the problem squarely on the RCA camera package itself. The completely redundant camera system was found not to be perfectly so. There was a single line that carried commands to both camera chains. Somehow a command was sent to the camera package during ascent that turned it on, hence the anomalous telemetry reading during launch. The cameras were turned on and, in the relatively dense atmosphere, both camera power supplies arced and shorted out.

While the source of the errant command was not known at the time, several changes in the RCA camera package were suggested. These included changes to simplify ground testing and in-flight operation, telemetry system modifications to increase failure mode coverage, inclusion of additional noise suppression in the camera command circuitry, and a more rigorous prelaunch inspection of the television circuitry. These changes also included an interlock that would prevent the cameras from being turned on during launch. In addition, the tower temperature would be lowered by twenty degrees Fahrenheit (eleven degrees Celsius).

While these changes would further increase RANGER's chances of success, the blame did not totally lie with RANGER. It was later discovered that the jettisoning of the ATLAS booster engines caused RANGER's cameras to turn on. When the ATLAS dropped its booster engines, about 400 pounds (180 kilograms) of propellant were expelled and ignited by the sustainer. This small detonation had caused some problems during the development of the ATLAS E/F ICBM but was never a problem for the ATLAS D. The detonation wave produced during the flight of RANGER 6 worked its way into a mechanically sealed umbilical door on the AGENA. The umbilical pin that controlled the camera package was 0.25 inches (6 millimeters) from another pin carrying twenty volts. The burning fuel vapor was conductive enough to short the two pins briefly, cause the camera package to turn on prematurely and, as a result, burn out.

Success!

By the summer of 1964, RANGER B had been modified and was ready to be launched during the next launch window in late July. There were some who wanted to target RANGER B close to the impact point of RANGER 6 to observe the crater it produced. Unfortunately the trajectory constraints of this launch window would not allow an impact that far east. Instead, several targets were considered for the first day of the launch period on July 27 along seven degrees west longitude between 21 degrees north and 14 degrees south latitude. The launch on this first day was scrubbed due to problems with the ground-based portion of the guidance system. Finally, on July 28, RANGER 7 successfully lifted off only 7.9 seconds into its launch window aimed at 11 degrees south, 21 degrees west in the northwest portion of Mare Nubium.

With a good injection burn from the AGENA B, it was calculated that RANGER 7 would skim over the leading edge of the Moon and impact on its far side. A fifty-second course correction burn the day after launch brought the predicted impact point within the intended target area. When RANGER 7 was 1,415 miles (2,277 kilometers) above the lunar surface traveling at 4,290 miles per hour (1,917 meters per second), the F chain cameras were placed into the ninety-second warmup mode followed later by the P chain. Much to the relief of JPL and NASA officials, pictures from the F chain cameras started streaming back to Earth seventeen minutes and thirteen seconds before impact, followed three minutes and 33 seconds later by the P chain.

The year 1965 would witness the most intense wave of lunar probes since the beginning of the Space Age.

By the time RANGER 7 plowed into the lunar surface 68 hours, 35 minutes, and 42 seconds after launch, 4,316 pictures had been transmitted back to Earth. The last image, only a portion of which was transmitted before destruction, was made at an altitude of only one thousand feet (three hundred meters), showing features as small as three feet (one meter) across. RANGER 7 had impacted at 10.7 degrees south, 20.7 degrees west, only eight miles (thirteen kilometers) from its aim point. It was the first major American lunar mission success after almost six years of attempts.

The pictures returned by RANGER 7 confirmed that the lunar mare regions are quite smooth and apparently free of major hazards for the APOLLO Lunar Module. Because of the size and shape of the craters and the topography observed during the approach, it seemed unlikely that the lunar surface was coated with a deep dust layer that could bury a lunar lander upon touchdown, as some had feared.

plus2ptWith a solid success under their belts, worked continued on RANGER's followup programs, LUNAR ORBITER and SURVEYOR. On May 10, 1964, Boeing was awarded the contract for the LUNAR ORBITER, beating out a Lockheed bid which had proposed a spacecraft based on its military reconnaissance satellite. The 830-pound (380-kilogram) lunar satellite was planned to be placed into a 575-mile (925-kilometer) high circular orbit for its initial survey of potential APOLLO landing sites. Later the orbit would be adjusted so that LUNAR ORBITER could swoop within 28 miles (45 kilometers) of selected target areas for more detailed inspections. The imaging system that was planned would record images on photographic film, which would be developed automatically onboard, a technique first used by the Soviet Union with the flight of LUNA 3 in 1959. The photographs would then be scanned and transmitted back to Earth over the course of ten days. A total of five flights were planned starting in middle 1966 and continuing at quarterly intervals afterwards.

Substantial advances also continued to be made with the SURVEYOR program. Extensive testing of a prototype had been completed and testing of various systems was proceeding more or less on schedule. The weight estimate for the operational spacecraft was settling around 2,150 pounds (975 kilograms) of which 65 pounds (30 kilograms) would be instrumentation. On the three operational flights, an approach and two surface television cameras would be carried along with an alpha scattering instrument to measure soil composition, a seismograph, micrometeoroid detectors, and a soil dynamics experiment. Minimal instrumentation would be carried on the first four test flights now expected sometime in 1966.

Studies on the SURVEYOR follow on mission, known as Block II, were completed by late 1964. One of the payloads still under consideration for this 2,600 pound (1,200 kilogram) lander was a 150-pound (70-kilogram) rover that could make soil bearing and topographic studies up to two miles (three kilometers) from the lander. In order to lift this much heavier payload, studies indicated that the CENTAUR stage would have to be upgraded and modified to make use of a liquid oxygen/liquid fluorine mixture known as FLOX to replace the normally used liquid oxygen (LOX) oxidizer. The inclusion of highly reactive liquid fluorine in the oxidizer was expected to greatly increase the performance of the CENTAUR. Assuming the program was funded and the FLOXed CENTAUR was available, the first of as many as ten Block II SURVEYOR flights would take place around 1968.

The ATLAS-CENTAUR test program was having mixed results. ATLAS-CENTAUR 3, launched on June 30, 1964, failed to reach Earth orbit, although some tests were conducted with the CENTAUR. ATLAS-CENTAUR 4 was launched on December 11 into a 101 by 107-mile (163 by 172-kilometer) parking orbit carrying a dynamic mass model of SURVEYOR in a flight to test the integrity of the total system. A secondary objective was to test the new upper stage's restart capability for the first time. While the primary objectives were met, the CENTAUR failed to reignite and propel itself into a simulated lunar trajectory. The now inert stage fell out of orbit the following day.

Because of the continued problems with the ATLAS-CENTAUR, the goals of the development program were changed to provide a direct ascent capability for SURVEYOR in 1966. While such a trajectory is less than optimum, it did have the advantage of requiring the CENTAUR to fire only once, thus avoiding the problems encountered developing an in-flight restart capability. The initial flights of SURVEYOR would be light enough and the ATLAS-CENTAUR accurate enough to make such a flight possible. A parking orbit capability would be available later in the year and an increased lift capability would be available in 1967.

The Assault Begins

The year 1965 would witness the most intense wave of lunar probes since the beginning of the Space Age. The first mission of the year started on February 17 with the successful launch of RANGER 8. Like its predecessors, it was targeted for the most promising class of APOLLO landing sites, the smooth equatorial mare regions. For this mission, the selected aim point was 3 degrees north, 24 degrees east in Mare Tranquillitatis about 130 miles (210 kilometers) south of the impact point of RANGER 6.

After injection into a translunar trajectory, tracking indicated that RANGER 8 would miss the Moon by 1,136 miles (1,828 kilometers). This was negated by a 59-second mid-course correction burn at a distance of 99,281 miles (159,743 kilometers). During the burn, however, controllers were alarmed by a loss of telemetry from the receding spacecraft. Concerned about attempting any more maneuvers, it was decided that RANGER 8 would not perform the terminal descent maneuver to align RANGER's cameras with its flight path. While this would smear the last few images returned by the quickly descending probe, it did offer the opportunity to take a swath of images over a wider area that would partially overlap with the early images returned by RANGER 7. Stereo images would also be procured in the process.

The resolution steadily increased to as good as ten inches...

As the probe approached the Moon, the cameras were turned on 23 minutes before impact, almost ten minutes before normally planned. The resolution of these first images was comparable with the best Earth-based telescopic photographs. As RANGER 8 screamed towards its destruction, the robot craft continued returning a stream of pictures which were very similar to those returned by the previous probe. The maria all seemed to have similar topography and presented no major problems for a landing, manned or otherwise. RANGER 8 then crashed into the Moon, producing a 45-foot (14-meter) diameter crater at 2.59 degrees north, 24.77 degrees east, only 14 miles (23 kilometers) southeast from its aim point. RANGER 8 returned a total of 7,137 pictures, the best of which showed features as small as five feet (1.5 meters) across. The American lunar program finally seemed to be on the road to success.

On March 12, only three weeks after RANGER 8 impacted Earth's natural satellite, the Soviet Union launched another lunar lander. Unfortunately the MOLNIYA's escape stage failed to reignite and stranded its payload, now called KOSMOS 60, in a low 125 by 178-mile (201 by 287-kilometer) parking orbit. The failed lander's orbit decayed five days later.

Less than nine days later, the last Block III RANGER spacecraft was being prepared for launch. Unlike its sisters, RANGER D was going to be targeted for scientifically more interesting sites. The first two days of the lunar launch window did not offer any promising targets and no launch attempt was made. A launch on March 21 would allow an impact in the crater Alphonsus, which had shown some signs of apparent selenological activity in the recent past. A March 22 launch would land in the bright rayed crater Copernicus. March 23 would allow Kepler to be targeted, while a launch on either March 24 or 25 would permit an impact near Schroter's Valley.

As it turned out, RANGER 9 lifted off on its first attempt on March 21, bound for a point at 13 degrees south, 2.5 degrees west, located in the crater Alphonsus. After AGENA 6007 completed its ninety-second injection burn, RANGER 9 was heading for a point only 400 miles (640 kilometers) north of its target. A 31-second burn of the course correction motor 38 hours, 26 minutes after launch added the 40.6 miles per hour (18.1 meters per second) needed to put RANGER 9 back on course.

As the last RANGER was hurtling towards the Moon, the probe aligned its cameras with its flight path. Twenty minutes before impact, controllers sent commands to begin warming the cameras. Starting at an altitude of 1,300 miles (2,100 kilometers), RANGER 9 began transmitting the first of 5,814 pictures. The resolution steadily increased to as good as ten inches (25 centimeters) before the spacecraft slammed into the floor of Alphonsus at 13.3 degrees south, 3.0 degrees west, only four miles (6.5 kilometers) from its target.

Surprisingly, the images returned by RANGER 9 indicated that while the lunar highlands were rougher than the maria, they were still smooth enough to be considered viable landing sites for future landing missions. Tracking of all four Block III RANGERs also indicated that the Moon's geometric center was displaced from its gravitational center. This fact was required to improve the accuracy of future lunar missions. After six years of effort, a total of 267 million dollars in funding (which would be close to one billion of today's dollars), much heartache over six failures, and much relief on three successes, NASA's first major lunar exploration program was ended. Efforts now turned to the other two legs of NASA's unmanned lunar triad, SURVEYOR and LUNAR ORBITER.

To be continued next month...

About the Author:

Andrew J. LePage is a member of the Boston Group for the Study of the Soviet Space Program, Krasnaya Orbita. In addition to his interests in astronomical and space related topics, Andrew has been a serious observer of the Soviet (now C.I.S.) space program for over one decade.

Newsletter Deadline

Mail items at least two weeks before the end of the month. Items arriving too late for an issue will be included in the next newsletter.

Morris' Law of Conferences:

The most interesting paper will be scheduled simultaneously with the second most interesting paper.

Bits and Pieces

Magazines & Discounts

Club members may subscribe to astronomical magazines at reduced rates through the club Treasurer. See the Member Services Form on the back page of this newsletter. Furthermore, club members are encouraged to align their subscriptions with the Jan.–Dec. calendar year. This eases the burden both on the Treasurer and the Publisher by permitting a single Group Renewal to be placed in the autumn for the upcoming calendar year.

Those members who experience problems with their subscriptions to *Astronomy* magazine may call Kalmbach Publishing Customer Service at (800) 446–5489.

Those members who experience problems with their subscriptions to *Sky & Telescope* magazine may call Sky Publishing at (800) 253–0245.

Besides the club discount on *Sky & Telescope* magazine, Sky Publishing offers club members a 10% discount on all other Sky publications. This means books, star atlases, observing aids, Spotlight prints, videos, globes, computer software, and more.

Club members who subscribe to *Sky & Telescope* through the Club Discount Plan may order Sky publications directly, at the above toll-free number, without going through the club Treasurer. Simply mention the Club Discount Plan and give the Saguaro Astronomy Club name to receive the discount. Sky Publishing will check their records to verify that you are eligible to receive the discount.

Deep Sky Meeting

The Deep Sky Group is made up of people that like to observe celestial bodies out past the far reaches of our Solar System. These bodies include stars, nebula and galaxies. If you are interested in sharing your observations, or knowing what they look like in telescopes — then by all means come join us at the next meeting. We will discuss Deep Sky objects in Taurus and Auriga. The meeting will be held at John McGrath's house and the directions will be found elsewhere in the Newsletter.

You don't need to RSVP, we don't extend special invitations to anyone — ourselves included. If you are interested show up, we'd love to have you.

The Deep Sky meeting will take place on Thursday, January 14 at 7:30pm.

Planning continues for the Messier Marathon for March 20 at or near EVAC's Arizona City site.

Comet Comments

by Don Machholz

(916) 346-8963 December 10, 1992

Periodic Comet Swift-Tuttle has disappeared into the evening twilight as it heads south and into regions behind the sun. Meanwhile, Periodic Comet Schaumasse graces our evening sky, it will be well-placed for the first half of 1993. Finally, I have word of a new comet in our morning sky, you might want to get out and see it.

Periodic Comet Swift-Tuttle (1992t)

Date	RA-2000-Dec		Elong	Sky	Mag
12–24	19h55.2m	−15°34′	26°	E	5.1
12–29	20h04.6m	−18°43′	22°	E	5.3
01–03	20h13.6m	−21°36′	18°	E	5.5
01–09	20h22.4m	−24°15′	15°	E	5.7
01–13	20h31.0m	−26°43′	13°	E	6.0

Periodic Comet Schaumasse (1992x)

Date	RA-2000-Dec		Elong	Sky	Mag
12–24	03h44.6m	+19°11′	146°	E	11.1
12–29	03h39.1m	+20°38′	140°	E	10.7
01–03	03h34.9m	+22°12′	134°	E	10.4
01–08	03h32.0m	+23°53′	129°	E	10.1
01–13	03h30.8m	+25°39′	124°	E	9.8
01–18	03h31.4m	+27°31′	119°	E	9.5
01–23	03h33.9m	+29°28′	115°	E	9.2
01–28	03h38.5m	+31°29′	111°	E	9.0
02–02	03h45.3m	+33°32′	108°	E	8.8
02–07	03h54.3m	+35°37′	105°	E	8.6
02–12	04h05.6m	+37°42′	103°	E	8.4

Comet Ohshita (1992a_1): Discovered by Ohshita of Japan on Nov. 24 in the morning sky, this comet is slowly moving away from the sun. As it does it approaches to within 0.6 AU of the earth in late December. The ephemeris, printed below, should be accurate to within a degree, the magnitude is uncertain.

The possibility exists that this comet will produce a meteor shower on Jan. 29, plus or minus a day. At that time the earth passes 1.7 million miles outside the point that the comet was at Dec. 7. The Southern Hemisphere is favored but I'm not sure at this if it would be in the morning or evening sky.

Comet Ohshita (1992a_1)

Date	RA-2000-Dec		Elong	Sky	Mag
12–24	12h12.6m	+27°30′	100°	M	10.7
12–29	11h48.9m	+42°24′	113°	M	10.8
01–03	11h05.8m	+57°17′	123°	M	11.1
01–08	09h42.8m	+63°39′	129°	M	11.5
01–13	07h30.6m	+73°25′	128°	E	12.1
01–18	05h34.6m	+72°08′	124°	E	12.6
01–23	04h30.9m	+69°46′	120°	E	13.1

E-Mail Roster

Still yet another update to the e-mail addresses of SAC members. The Compuserve addresses are given in the Internet format: `nnnnn.nnn@compuserve.com` are really in the format `nnnnn,nnn` within Compuserve. BIX and GEnie addresses aren't currently addressable from the outside world (the Internet), but their addresses are given as `@bix` and `@genie` to specify which host. All other hosts are directly accessible from the Internet.

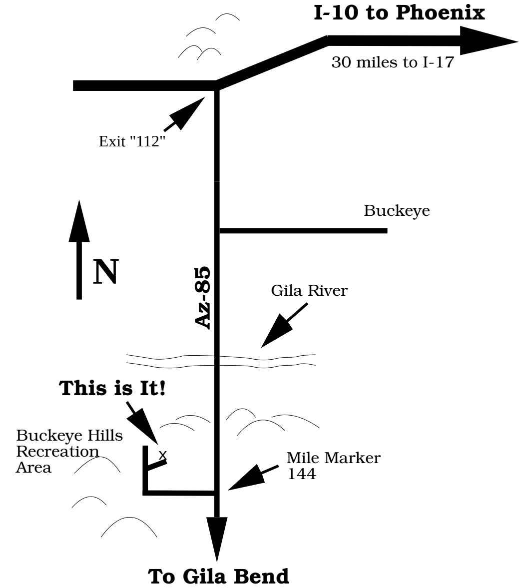
Bob Bryant	`Bob_Bryant@poncho.phx.sectel.mot.com`
Steve Coe	`74040.2071@compuserve.com`
A J Crayon	`a.crayon@az05.bull.com`
Paul Dickson	`p.dickson@az05.bull.com` `pdickson@bix`
Carol Lee	`71361.3541@compuserve.com`
Tim Lee	`71361.3541@compuserve.com`
Paul Lind	`plind@sedona.intel.com`
Pete Manly	`petemanly@bix`
Paul Maxson	`maxson@gc.maricopa.edu`
Tom McGrath	`mcgrath@phyast.la.asu.edu`
Tom Polakis	`70413.1543@compuserve.com`
Chris Schur	`72070.2612@compuserve.com`
Brian Skiff	`bas@lowell.edu`
Alex Vrenios	`71024.3024@compuserve.com`
Diane Vrenios	`71024.3024@compuserve.com`
Dan Ward	`72040.3357@compuserve.com`

Mike Willmoth	`76170.1037@compuserve.com`
	`mwillmoth@bix`
	`m.willmoth@genie`

Directions to SAC Events

SAC General Meetings 7:30 PM at Grand Canyon University, Fleming Building, Room 105 — 1 mile west of Interstate 17 on Camelback Rd., north on 33rd Ave., second building on the right.

SAC Star Parties at Buckeye Hills Recreation Area



Interstate 10 west to Exit 112 (30 miles west of Interstate 17), then south for 10.5 miles, right at entrance to recreation area, one-half mile, on the right. No water and only pit toilets. Please arrive before sunset; allow one hour from central Phoenix.

SAC Deep Sky Subgroup Meeting at John & Tom McGrath's, 11239 N. 75th St., Scottsdale, 998–4661 — Scottsdale Rd. north, Cholla St. east to 75th St., southeast corner.

SAC Meetings

Saguaro Astronomy Club (SAC) was formed in 1977 to promote fellowship and the exchange of scientific information among its members — amateur astronomers. SAC meets monthly for both general meetings and star parties, and regularly conducts and supports public programs on astronomy.

SAC meetings are usually held on the Friday nearest the full moon. This means that over the course of the year, meetings are not held on same week of the month. The same is true of the club's star parties. Star parties at Buckeye Hills are mostly held on the Saturday of the third quarter moon.

1993 SAC Meetings
Jan. 8
Feb. 5
Mar. 5
Apr. 2
May 7
Jun. 4
Jul. 2
Aug. 27
Sep. 24
Oct. 29
Nov. 26
Dec. 18 Party

1993 SAC Star Parties

Date	Sunset	Moonrise
Jan. 16	5:46pm	3:11am
Feb. 13	6:12pm	2:05am
Mar. 20	6:41pm	5:24am
Apr. 17	7:01pm	3:55am
May 15	7:22pm	2:25am
Jun. 12	7:38pm	12:55am
Jul. 17	7:38pm	4:44am
Aug. 14	7:15pm	3:39am
Sep. 11	6:40pm	2:15am
Oct. 9	6:03pm	1:04am
Nov. 6	5:33pm	11:57pm
Dec. 11	5:22pm	6:35am

January 1993

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1	**2**
Quadrantid meteor shower Mars closest approach **3**	**4**	**5**	**6**	Mars at opposition **7**	**SAC Meeting** Full Moon 5:37 a.m. MST **8**	**9**
10	**11**	**12**	**13**	**Deep Sky Meeting** **14**	**15**	**SAC Star Party** Buckeye Hills (members & guests) **16**
17	**18**	**19**	**20**	**PAS Meeting** **21**	New Moon 11:27 a.m. MST **22**	**23**
24/31	**25**	**26**	**27**	**28**	**29**	**30**

Mars at opposition

This is from the January Sky Calendar. It is available for $6 *per year from Sky Calendar, Abrams Planetarium, Michigan State University, East Lansing, MI 48824.*

Mars reaches opposition on January 7, which places it about 180^o from the Sun in our sky and above the horizon all night.

Oppositions of Mars recur at intervals of 25 to 27 months, as Earth passes between Mars and the Sun. The Jan. 1993 approach of Mars, at a distance of 58 million miles, is not unusually close. Still Mars attains magnitude -1.5 early in the month, equalling Sirius, the brightest star. At its next approach in February 1995, Mars will be even farther away at 63 million miles. Thereafter, Mars will come a little a little closer at each successive opposition until August 2003, when it will be within 35 million miles of Earth and gleam at magnitude -2.9, quadrupling this months's peak brilliance.

Whenever a planet is near opposition, it appears to *retrograde,* or move backward or westward against the starry backdrop. On Jan. 1 Mars appears 4^o SW of Pollux. Mars moves to nearly 15^o of Pollux by Feb. 15, when it turns and begins eastward motion.

To understand why planets retrograde, imagine the following experiment. (Wear warm clothes if you actually perform it!) Outdoors around midnight on the night of Mars' opposition, Jan. 7–8, when Mars is nearly overhead, lie on your back, facing upward with your feet toward the south. Since Earth passes between Mars and Sun tonight, as you look up at Mars the Sun is almost directly below you.

In 24 hours, the orbital revolution of Earth will carry you 1.6 million miles to your east (left). Meanwhile Mars moves only 1.2 million miles in the same direction.

Because of the *difference* of these two motions, as seen from Earth, Mars appears to shift to your *right* (*west*) against the background of Gemini. This apparent motion is called *retrograde.*