Table 1. Timetable of scientific and technical objectives.

	Early
1.	Physics
2.	Geophysics
3.	Meteorology
4.	Minimal moon contact
5.	Experimental communications
6.	Space physiology
	Later
1.	Astronomy
2.	Extensive communications
3.	Biology
4.	Scientific lunar investigation
5.	Minimal planetary contact
6.	Human flight in orbit
	Still later
1.	Automated lunar exploration
2.	Automated planetary exploration
3.	Human lunar exploration and return
	And much later still
	Human planetary exploration

fying camera or telescope is needed to picture the earth's surface in even moderate detail. To the human eye, from 200 miles away, a football stadium would be a barely distinguishable speck. A telescopic camera can do a good deal better depending on its size and complexity. It is certainly feasible to obtain reconnaissance information with a fairly elaborate instrument, information which could be relayed back to the earth by radio.

"Much has been written about space as a future theater of war, raising such suggestions as satellite bombers, military bases on the moon, and so on. For the most part, even the more sober proposals do not hold up well on close examination or appear to be achievable at an early date. Granted that they will become technologically possible, most of these schemes, nevertheless, appear to be clumsy and ineffective ways of doing a job. Take one example, the satellite as a bomb carrier. A satellite cannot simply drop a bomb. An object released from a satellite does not fall. So there is no special advantage in being over the target. Indeed, the only way to 'drop' a bomb directly down from a satellite is to carry out aboard the satellite a rocket launching of the magnitude required for an intercontinental missile. A better scheme is to give the weapon to be launched from the satellite a small push, after which it will spiral in gradually. But that means launching it from a moving platform halfway around the world, with every disadvantage compared to a missile base on the ground. In short, the earth would appear to be, after all, the best weapons carrier. . . ."

Scientific objectives. "The scientific opportunities are so numerous and so inviting that scientists from many countries will certainly want to participate. Perhaps the International Geophysical Year will suggest a model for the international exploration of space in the years and decades to come.

"The timetable [Table 1] . . . suggests the approximate order in which some of the scientific and technical objectives mentioned in this review may be obtained."

Science Advisory Committee members: James R. Killian, Jr., *chairman*; Robert F. Bacher, professor of physics, California Institute of Technology; William O. Baker, vice president (research) Bell Telephone Laboratories; Lloyd V. Berkner, president, Associated Universities, Inc.; Hans A. Bethe, professor of physics, Cornell University; Detlev W. Bronk, president, Rockefeller Institute for Medical Sciences, and president, National Academy of Sciences; James H. Doolittle, vice president, Shell Oil Co.; James B. Fisk, executive vice president, Bell Telephone Laboratories; Caryl P. Haskins, president, Carnegie Institution of Washington; James R. Killian, Jr., chairman, Special Assistant to the President for Science and Technology, the White House; George B. Kistiakowsky, professor of chemistry, Harvard University; Edwin H. Land, president, Polaroid Corporation; Edward M. Purcell, professor of physics, Harvard University; Isidor I. Rabi, professor of physics, Columbia University; H. P. Robertson, professor of physics, California Institute of Technology; Jerome B. Wiesner, director, Research Laboratory of Electronics, Massachusetts Institute of Technology; Herbert York, chief scientist, Advanced Research Projects Agency, Department of Defense; Jerrold R. Zacharias, professor of physics, Massachusetts Institute of Technology; Paul A. Weiss, Rockefeller Institute for Medical Science.

Detection of Nuclear Explosions

American scientists have yet to reach agreement on the scientific question of whether a fool-proof monitoring system for nuclear weapon testing is possible. This first disagreement is at least partially responsible for a second—the policy question of whether the United States should enter into a pact with the Soviet Union to suspend tests. Thus, Edward Teller holds that "disarmament is a lost cause," while Harrison Brown, professor of geochemistry at the California Institute of Technology, charges that Teller is "willfully distorting the realities of the situation."

The scientific arguments in the disagreement have not been fully revealed, but in the March 1958 issue of the *Bulletin of the Atomic Scientists,* Jay Orear, who is assistant professor of physics at Columbia University, discusses four possible methods for detecting nuclear explosions. Orear has been a participant since 1957 in the Columbia Inspection Project, which is a private, unclassified study sponsored by the Columbia University Institute of War and Peace Studies. Orear says that since he has no access to classified material, he is "in the fortunate position of being free to say anything." Following are some excerpts from his discussion.

"An adequate inspection system for a test ban would require the establishment of monitoring stations at various locations deep inside the Soviet Union. About 25 such stations uniformly distributed throughout the Soviet Union should be sufficient. There is hope that such an inspection system would be acceptable to Russia, since it was Soviet delegate Valerian Zorin who proposed in the June 14, 1957 meeting of the U.N. Disarmament Subcommittee that the test-ban agreement 'be implemented by scientific control posts to be set up in the U.S., U.S.S.R., U.K., and Pacific Ocean areas.'

"The main techniques for detection of nuclear weapons testing are detection of: acoustic waves, seismic waves, electromagnetic radiation, radioactivity."

Acoustic waves. "Much of the radiation released in a nuclear explosion gets degraded by atomic processes to kinetic energy of the air molecules. Except in the immediate region of blast effects, this disturbance travels with the speed of sound and can be detected by sensitive microbarometers. This technique accurately gives the location and time of the test, and also gives a measure of the size of the explosion (yield in kilotons of TNT). The general feeling is that except for deep underground explosions, very high altitude tests, and tests of subnominal yield, nuclear tests can be detected at very large distances by this technique. Thus low-yield tests of just a few kilotons TNT equivalent would probably require monitoring stations inside the Soviet Union. Low-yield tests could probably be detected at distances up to a few hundred miles. If we require that every point in the Soviet Union be within 300 miles of a monitoring station, about 22 stations would be needed within the borders of the Soviet Union. This is assuming there are additional stations in the free nations bordering the U.S.S.R. A similar density of stations would be needed in other possible testing areas. In general, the microbarographic technique of detection is the most sensitive and would usually be the most relied upon."

Seismic waves. "In air and surface bursts, considerable blast energy is transferred to the ground. Thus, all tests whether underground or not, give rise to seismic waves which can be detected up to a certain distance by seismographs. For example, the U.S. Pacific tests of 1954 were detected by seismographs in the United States, Australia, Pakistan, Japan, Greece, Sweden, Germany, South Africa, etc. Seismic detection techniques also tell the location and time of the explosion, and can determine the size of an underground explosion.

"As with the acoustic wave, the seismic wave cannot be detected at large distances for sub-nominal tests. For example, the underground Nevada test of September 19, 1957 was not detected in the eastern United States. The U.S. Atomic Energy Commission reported the yield of this test as 1 to 3 kilotons TNT. However, such underground explosions can be detected at distances of 300 miles and the signals can be distinguished from natural earthquakes. [On 11 March 1958 the Atomic Energy Commission confirmed that a small underground atomic explosion in Nevada on 19 September 1957 had been detected on official instruments more than 2000 miles away in Alaska. In a previous announcement the commission had stated that the explosion had not been detected beyond 250 miles.] The initial signal (at distances up to a few hundred miles) of a man-made explosion is a sharp pulse, while the signal from a natural earthquake is of much longer duration. The initial seismic waves from a bomb test are longitudinal and come from a point source, while natural earthquakes initially are predominantly transverse and usually come from a more extended and deeper source.

"For detection of nominal yield bombs at large distances, the acoustic detection appears more sensitive than seismic detection. In the case of deep underground tests one must rely completely on seismic detection since nearly all of the bomb's energy is dissipated underground. A chemical explosion of 0.06 kiloton has been detected by seismograph 240 miles away. . . ."

Electromagnetic radiation. "The high frequency end of the electromagnetic spectrum (x-rays, ultraviolet) is quickly absorbed in the atmosphere and converted to lower frequency electromagnetic energy and molecular energy. Thus an appreciable part of the bomb energy travels in the regions of the electromagnetic spectrum where there is little absorption; namely, as visible light and radio noise.

"Detection of the visible light at distances up to within 300 miles is quite simple. One merely points a photocell at the sky. It doesn't matter whether it is day, night, clear, or cloudy. As long as the test is not deep underground, a very distinctively shaped light pulse will be observed. The same mechanism which gives twilight when the sun (or bomb) is below the horizon will give a glow in the sky due to the nuclear explosion. Because of the large number of photons involved, one can detect light pulses very much smaller in intensity than the steady background intensity. Earth satellites could also be equipped to monitor the electromagnetic radiation emitted by a nuclear explosion. It also appears feasible to detect the light flash of the bomb from the moon. . . .

"The main limitation to electromagnetic radiation detection is the weakness of secondary scatterings. This technique is probably useful up to about 500 miles."

Radioactivity. "According to estimates of United States officials, one should expect that some of the future tests will be '100 percent clean,' and that some current tests have been 96 percent clean. One should keep in mind that '100 percent clean' is a practical impossibility due to neutron-induced activity in the bomb shell and atmosphere. This activity should be equivalent to up to 1 percent fission content, so that if we already have bombs with only 4 percent fission content, there is not much room for improvement.

"Because of the neutron-induced activity, all except the deep underground tests will produce radioactivity which may be detected. For example, the Japanese have detected low-yield Nevada tests by collecting dust from air at sea level.

"Because of the rapid decay, one would expect to obtain maximum sensitivity by collecting dust downstream from the test at high altitudes. The closer to the test, the greater the sensitivity. Collection at high altitudes and within 1000 miles of the test area would require monitor aircraft flying within the Soviet Union, which would require more sacrifice of internal security than fixed ground monitoring stations. Since the fixed monitoring stations at distances of 300 miles give adequate detection, one need not rely on detection of radioactivity. . . ."

Eisenhower on Eniwetok Test

At his news conference on 26 March 1958, President Eisenhower said that the United States will invite foreign scientists, including Russians, to watch a large nuclear explosion at Eniwetok Atoll this summer. One purpose of the explosion will be to demonstrate progress by American scientists in reducing fallout. The President also hinted that in seeking an agreement with the Soviet Union to ban future nuclear tests he might not insist on concurrent suspension of nuclear weapon production. This would represent a change from the Administration's present policy of linking the two items together.

Invitation to watch test. Following are excerpts from the President's comments on the United States invitation to foreign observers:

"In line with what I said to the press on July 3, 1957, the United States will demonstrate the progress our scientists are achieving in reducing radioactive fallout from nuclear explosions.

"To this end, for the first time at any test, we are planning to invite the United Nations to select a group of qualified scientific observers to witness at the Pacific proving ground this summer a large nuclear explosion in which radioactive fallout will be drastically reduced.

"We shall also invite—as we have on occasions in the past—a representative group of United States and foreign news media representatives.

"The United States scientists have been making progress in reducing radioactive fallout from nuclear explosions in the hope and belief that basic advances in both the peaceful and military uses of nuclear energy will thus be achieved. The advantages to mankind of continued progress in this field are obvious.

"The United States has always publicly announced in advance its nuclear testing programs. We trust that the forthcoming tests will provide valuable information to the world."

[At this point the President was asked whether he could specifically say whether observers from Russia and other communist nations would attend the tests.]

"Of course I cannot tell whether they will accept, but we are hopeful that the United Nations will designate the Scientific Committee for Detection, I believe it is, of radioactivity, that's about its name, and on that committee are the U.S.S.R, Czechoslovakia, the United States, the United Kingdom, Canada, and a few others and as a matter of fact Mr. Hagerty can give you also the entire list of nations. [Confers with Mr. Hagerty]. Mr. Hagerty wants me to read the full—the United Nations Scientific Committee on the Effects of Atomic Radiation, that's the name of the committee."

Baghdad Pact Nuclear Training Center

The Baghdad Pact Nuclear Training Center was established in Baghdad, Iraq, in 1956 by the member countries of the Baghdad Pact. W. J. Whitehouse of the Atomic Energy Research Establishment, Harwell, England, was the first director of the center and went there in 1957 with four other members of the Harwell staff. The center was formally opened by