THE COMET RENDEZVOUS ASTEROID FLYBY MISSION: David Morrison, NASA Ames Research Center, Moffett Field, CA, Marcia Neugebauer and Paul Weissman, Jet Propulsion Laboratory, Pasadena, CA.

The ultra-fast flybys of Comet Halley in 1986 by the Vega, Suisei, and Giotto spacecraft gave us our first close glimpse of a cometary nucleus and the first in situ measurements of the complex physical and chemical processes occurring in the cometary coma and ionosphere. Many of our basic ideas regarding comets were confirmed, such as the existence of an icy conglomerate nucleus, but many new facts and phenomena were also revealed. For example, the nucleus was found to contain a substantial amount of complex organic material, and hydrocarbon grains were shown to play an important role in the chemical kinetics in the cometary coma. The cometary nucleus was shown to be very dark and highly irregular, but relatively little was learned about its detailed structure, density, and surface morphology.

The Comet Rendezvous Asteroid Flyby (CRAF) mission is designed to answer the many questions raised by the Halley missions by exploring a cometary nucleus in detail, following it around its orbit and studying its changing activity as it moves closer to and then away from the Sun. In addition, on its way to rendezvous with the comet, CRAF will fly by a large, primitive class main belt asteroid and will return valuable data for comparison with the comet results. The selected asteroid is 449 Hamburga with a diameter of 88 km and a surface composition similar to carbonaceous chondrite meteorites, and the expected flyby date is January, 1998.

The present target for CRAF is short-period comet Kopff which orbits the Sun every 6.4 years with a perihelion distance of 1.58 AU. Following launch in August, 1995 and an Earth gravity-assist flyby in 1997, the CRAF spacecraft will rendezvous, that is it will match orbits, with comet Kopff near its aphelion (close to Jupiter's orbit) in August, 2000. During the early stages of the rendezvous when the nucleus is inactive, the CRAF spacecraft will make several slow flybys and then be placed in orbit around the nucleus at an altitude of 30 to 100 km. From this altitude it will image the nucleus surface at a resolution of better than 1 meter/line-pair and produce both infrared and thermal maps of the surface. Sampling instruments onboard the spacecraft will measure the elemental and molecular composition of the outflowing gas and dust particles, and a scanning electron microscope will image individual dust grains at a resolution of 0.04 micrometers. A dust impact counter will provide detailed measurements of the dust flux as well as an onboard warning of dangerously high dust levels. Fields and particles instruments will measure the interaction of the nucleus and its tenuous atmosphere with the solar wind. During this phase the spacecraft will be placed in a very low orbit for several revolutions to precisely determine the comet's mass (and hence, density) and gravitational harmonics.

About a year after rendezvous, the spacecraft will fire an instrumented penetrator into the Kopff nucleus surface from an altitude of 6 to 10 km. The instrument complement on the 1.5-meter long, golf tee-shaped penetrator includes: accelerometers to determine the strength of surface materials and any layering if it exists, a gamma-ray spectrometer for elemental composition measurements, passive and active temperature sensors for measuring thermo-physical properties of the cometary ices, and a differential scanning calorimeter and evolved gas analyzer for determining the molecular composition of the cometary materials. Remote sensing instruments onboard the CRAF orbiter will observe the penetrator impact and compositional instruments will analyze material blown off the nucleus surface. The penetrator will operate on the surface of the Kopff nucleus for about 10 days. The CRAF spacecraft may carry a second penetrator if sufficient launch mass margin exists.

The CRAF spacecraft will continue to make measurements in orbit around the cometary nucleus as they both move closer to the Sun, until the dust and gas hazard becomes unsafe. At that point the spacecraft will move in and out between 50 and 2,500 kilometers to study the inner coma and the cometary ionosphere, and to collect dust and gas samples for onboard analysis. Following perihelion, the spacecraft will make a 50,000 km excursion down the comet's tail, further investigating the solar wind interaction with the cometary atmosphere. The spacecraft will return to the vicinity of the nucleus about four months after perihelion to observe the changes that have taken place. If the spacecraft remains healthy and adequate fuel is still onboard, an extended mission to follow the comet nucleus out to aphelion is anticipated.

The CRAF mission will be the first to employ the Mariner Mark II spacecraft. Mariner Mark II is a new, 3-axis stabilized, Voyager class spacecraft for exploring the outer solar system and small bodies. Its modular design allows it to be readily adapted for a variety of missions while retaining many common spacecraft subsystems and utilizing a common multi-mission ground operations system. The propulsion module for the CRAF spacecraft is provided by the Federal Republic of Germany which also is providing one of the scientific experiments. Current plans are to build a Saturn Orbiter/Titan Probe (Cassini) spacecraft at the same as CRAF, with the European Space Agency providing the Titan Probe and several of the scientific instruments on both the orbiter and the probe. The Cassini mission is expected to be launched in April, 1996 and includes a flyby of asteroid 66 Maja.

The selected scientific investigations on CRAF include 137 researchers from seven countries, with over 25% coming from outside the United States. Additional participating scientists will be selected by NASA to enhance the scientific expertise for key mission phases as asteroid, comet, and cruise science data become available.

CRAF results are expected to shed new light on the composition of the primordial solar nebula, on chemical evolution in the nebula, and on accretionary processes at both microscopic and macroscopic scales. These measurements will help to constrain current solar nebula models, and will provide an important link between astrophysical studies of the interstellar medium and star formation, and planetary studies of these most primitive of solar system bodies. CRAF will provide a fundamental understanding of complex cometary processes, including chemical kinetics in the coma and the solar wind interaction, both of which have important astrophysical applications. In addition, CRAF is expected to provide important data on the role of comets in contributing to the volatile reservoirs on the terrestrial planets and on outer solar system satellites, and in possibly bringing pre-biotic material to the Earth.