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MARS SURFACE SCIENCE REQUIREMENTS AND PLAN

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ABSTRACT

We analyze the requirements for obtaining geological, geochemical, geophysical, and meteorlogical data on the surface of Mars associated with manned landings. We identifiy specific instruments and estimate their mass and power requirements. A total of 1-5 metric tons, not including masses of drill rigs and surface vehicles, will need to be landed. Power associated only with the scientific instruments is estimated to be 1-2 kWe. We define some requirements for surface rover vehicles and suggest typical exploration traverses during which instruments will be positioned and rock and subsurface core samples obtained.

INTRODUCTION

The purpose of this paper is to present an analysis of desirable physical science activities (geology, geophysics, meteorology) associated with manned Mars landings. The scientific rationale and objectives for Mars investigations are discussed in detail in previous studies (e.g., [1]); differences associated with the manned aspects are discussed in references [2] and [3]. As a context for the plan, we assume a multiple-landing mission scenario that leads to a permanent manned surface base called "Columbus Base"[4]. In this approach, during each of the first three missions a crew of four lands at different sites and performs scientific investigations for about two months. On these first three landings, the crew has the aid of an extra vehicular activity (EVA) rover vehicle with a range of about 10km. On the fourth mission, one of the previously visited sites is selected for development as a base from which more extensive explorations will take place. More capable surface transportation is assumed to be available at this point, namely a shirt sleeve (SS) rover with a range of about 100km. A remotely piloted air-plane of the type suggested by Clarke, et al [5] is also assumed to be available by the fourth landing as an instrument carrier for long range (1000+km) geochemical, geophysical, and atmospheric surveys as well as visual reconnaissance.

We define instrumentation needs and give estimates of power and mass requirements in order to help estimate the total landed payload from which propulsion and other requirements can be calculated. Our mass and power estimates represent upper limits because they are based on present technology. We expect that advances in instrument technology stimulated by mission requirements such as those proposed here will greatly reduce the ultimate payload mass and power values. The main science questions we address here are the composition and structure of the solid planet and the nature of geological and atmospheric processes. As a consequence, we emphasize geologic sampling and geophysical and meteorology observations. We do not discuss life science or operational engineering science requirements.

ROCK COMPOSITION AND PROPERTIES

Samples

Obtaining rock and soil samples will be a primary function of the landing team. We suggest that a total sample mass of 100-500kg should be returned to Earth from each of the first three landing sites. Of these amounts, about 25% should be returned in sealed, refrigerated storage containers so as to retain volatile materials and heat-sensitive structures in as close to a pristine martian environment as possible. Samples will consist of hand-sized rocks, 50-100g soil samples (including special samples to investigate microenvironments), and core samples obtained with the aid of drilling equipment. The surface sampling, cataloging, and documentation procedures will be derived from those developed during the Apollo lunar explorations [6] and are not discussed further here.

We suggest that each landing team take one 100m-long core at the landing site and numerous 10m-long cores at remote sites during rover traverses. These cores will be essential for analysis of near surface physical properties and geologic stratigraphy. The cores will be examined on the surface and portions selected for environmental storage and return. The remaining cores can be studied by the crew while present on the surface and/or stored locally at ambient conditions for future retrieval. Judging from experience on Earth, hole diameters of 15cm and core diameters of 5-10cm seem appropriate. Details of the equipment that will be required to perform these coring operations, including masses and power requirements, are given in reference [7]. It is assumed that the landing craft and rover vehicles will be capable of supporting the respective drilling and sample storage equipment.

Petrology/geochemistry:

The landing craft should have analytic equipment capable of determining rock compositions quickly to help guide the sampling and geologic exploration. These instruments will remain behind on the lander for future use. Instrumentation, with estimated mass and overall power requirements, will include the following:

1. A combined x-ray fluorescence/diffraction instrument (exchangeable anode, with capability of synchronized movement of tube, sample, and detector). This instrument is for major-element chemistry and for mineral analysis. MASS: 70 kg

2. An electron beam instrument optimized for imaging (scanning electron microscope), but equipped for energy-dispersive analysis (microprobe). This instrument is for microfossil exploration and for mineral analysis. MASS: 80 kg

3. A combined thermogravimetric/differential scanning calorimeter instrument for hydrous mineral analysis. MASS: 15 kg

4. Sample powdering, dissolution, and optical analysis equipment. MASS: 40 kg

5. A gas and water analysis system based on one or more of atomic absorption, gas chromatography, laser emission spectroscopy, and mass spectroscopy. MASS: 50 kg

PETROLOGY/GEOCHEMISTRY SYSTEM - TOTAL ESTIMATED MASS: 255 kg
TOTAL ESTIMATED POWER: 2 kw

Rock Physical Properties:

Rock physical properties will be observed directly during rover traverses, in the immediate vicinity of the lander, and remotely by geophysical means (discussed below). Suggested requirements for the direct observations are listed below.

Soil: Core penetrometer and plate bearing tests will be performed automatically at every rover sampling stop. MASS: 10kg

Core holes: Each of the 10m-long core holes will be used for an in situ seismic Q and P-wave velocity measurement by deploying a reusable acoustic probe in the hole and hitting the nearby surface with a spring-loaded or chemically-propelled impacting source.

MASS: 15 kg

POWER: 1 w

To determine basic rock mechanics properties, about ten hand-sized rock samples at each EVA site will be crushed in a simple point load press to obtain strength data under martian conditions. No sample preparation is required for these tests but after crushing, samples can then be used for petrology/geochemistry analysis after further preparation.

MASS: 20 kg

POWER: 1/2 w

Pieces of the 10m core and surface samples will be used to measure dielectric constant under in situ atmospheric conditions in order to interpret radar absorption data.

MASS: 3 kg

POWER: 1 w

SURFACE SCIENCE TELEMETER STATION

Conceptual Design and Requirements

We propose that multiple, long-duration science stations be deployed by a two-man crew operating from a rover vehicle. A number of identical stations, shown schematically in fig. 1, will telemeter their data to the landing base for up-link to the main craft. In the initial landings, a maximum of four stations will be deployed from an EVA-type rover. In later landings, more stations will be deployed at larger ranges using the SS rover. The stations will be powered by radioisotope thermal generators (RTGs) for an operational lifetime of at least 10 years. The stations will have the following instrumentation, consisting of separate functional packages interconnected by cable.

SEISMOMETER:

A 3-axis, broad-band (0.1-50 Hz), high sensitivity seismic unit that will be well coupled to ground by installation in a drilled, cored, and backfilled hole (see fig. 1).

MASS: 1 kg

POWER: 1/2 w

ELECTROMAGNETIC SYSTEM:

A permanent, passive electromagnetic (EM) data acquisition system will be installed at each Surface Science Telemeter Station (SSTS). This equipment will be similar to tensor magnetotelluric (MT) systems widely used in Earth applications. The system we propose consists of a three-

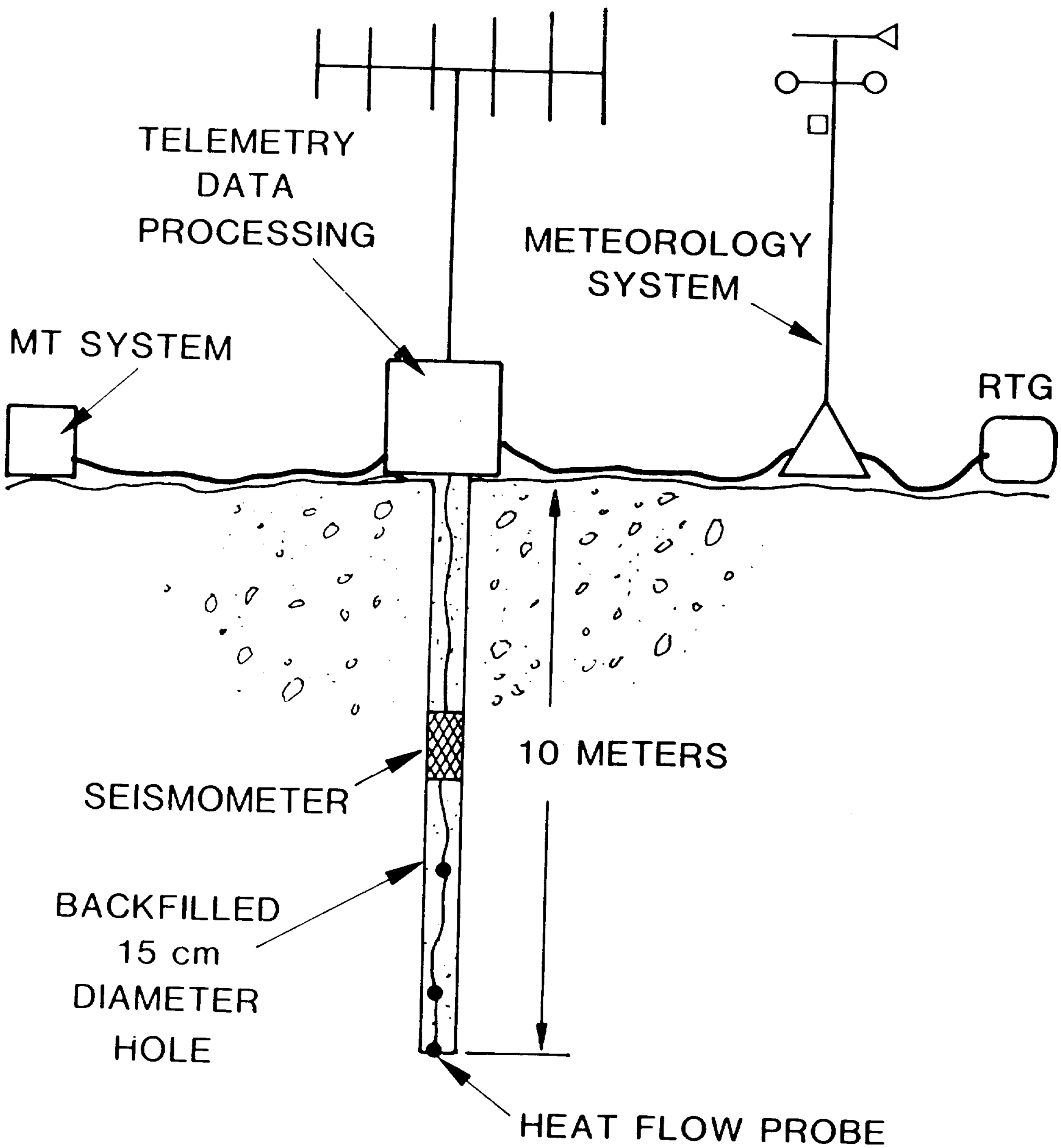

FIGURE 1

Schematic Illustration of the proposed
Surface Science Telemeter Station.
Instrument Modules are explained in the text.

axis fluxgate magnetometer for magnetic (H) field measurements less than 10^{-3}Hz, a three-axis coil magnetometer for H-field measurements from 10^{-3} to 10^{2}Hz, and a two-axis horizontal electric (E) field dipole for measurements from 10^{-3} to 10^{2}Hz. Thus, with this equipment, the martian magnetic spectrum and it's time variations may be studied below 100Hz, and subsurface electrical resistivity estimated to great depths in order to help determine radial structure and thermal state. The presence of the E-field dipoles will permit estimates of the tensor electrical resistivity from 10^{-3} to 10^{2}Hz. Deep magnetic and electric field sounding. DC to 100 Hz: MASS: 100kg

POWER: 1/2 w

METEOROLOGY SYSTEM: Instruments to measure: Temperature, wind speed and direction, barometric pressure, aerosol content (mini-LIDAR?), and composition using a mass spectrometer: MASS: 20 kg

POWER: 10 w

HEAT FLOW PROBE: MASS: 1/4 kg

POWER: 1/2 w

DIGITAL TELEMETRY/DATA PROCESSING SYSTEM - 15 channel (AM) with microVax -equilvalent or better processing capacity: MASS: 15 kg

POWER: 25 w

RTG POWER SUPPLY (50 watts): MASS: 25 kg

TOTAL ESTIMATED SSTS INSTRUMENT MASS, PER STATION - 162 kg

TOTAL ESTIMATED POWER, PER STATION - 37 watts (50 w-class RTG)

EXPLORATION TRAVERSES

Rover surface vehicles

Exploration from the initial three landing sites will consist of about ten one-day-long traverses using the EVA rover out to a range of about 5 km. Primary exploration from the permanent base will consist of four approximately 5-day-long SS rover traverses out to a linear range of 30-40 km. Schematic plan views of rover traverses and typical placements of instrumentation stations and explosive seismic sources are shown in figs. 2 and 3. The EVA rover will carry modules for installation of Surface Science Telemeter Stations (SSTSs, described above) on at least three of the traverses, and explosives (100 kg) for at least two seismic-source stations. The advanced SS rover will carry sufficient modules for

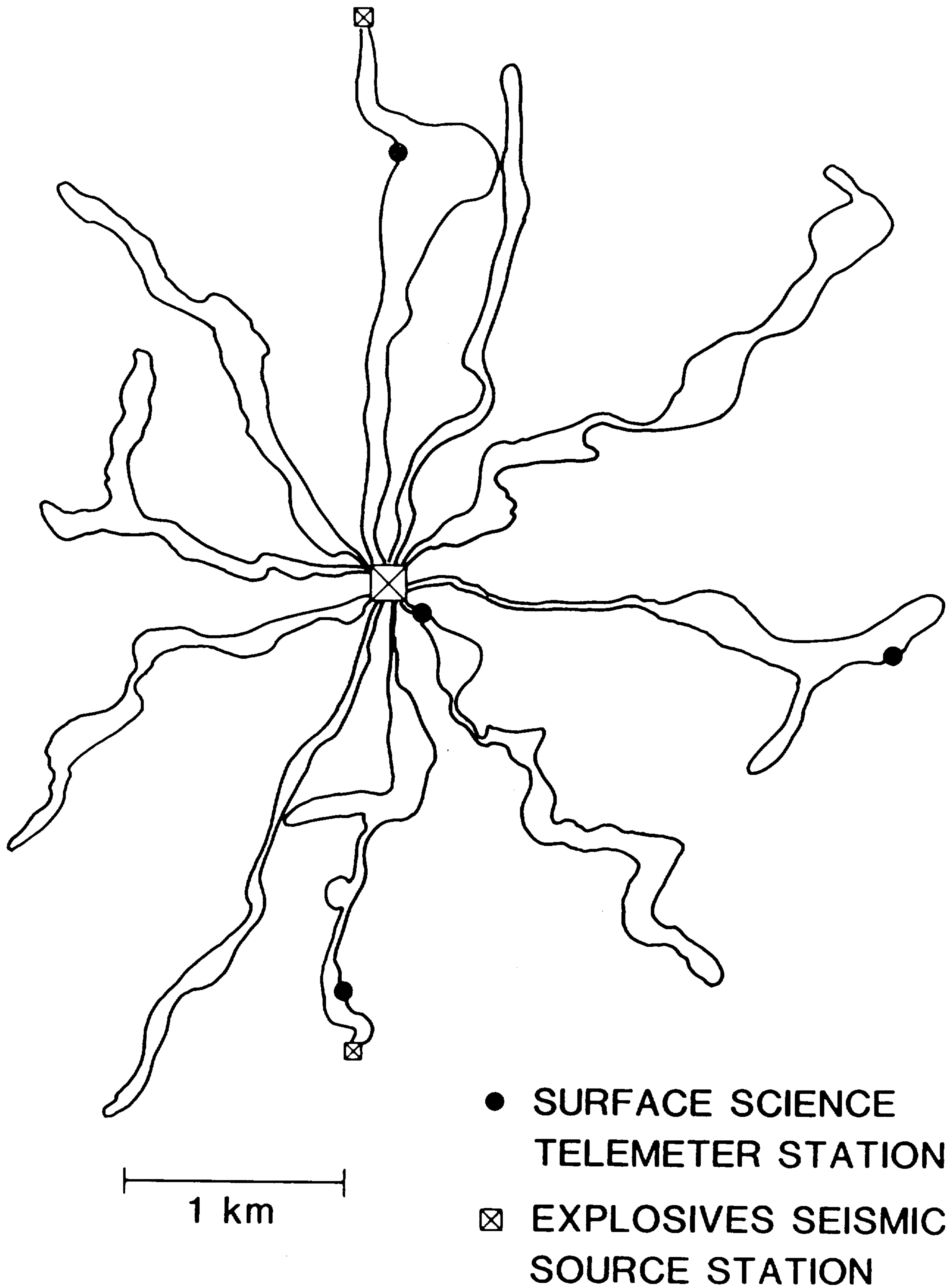

FIGURE 2. Schematic plan view of proposed EVA rover science traverses. Possible placements of Surface Science Telemeter Stations and explosive sources for a seismic refraction line are indicated.

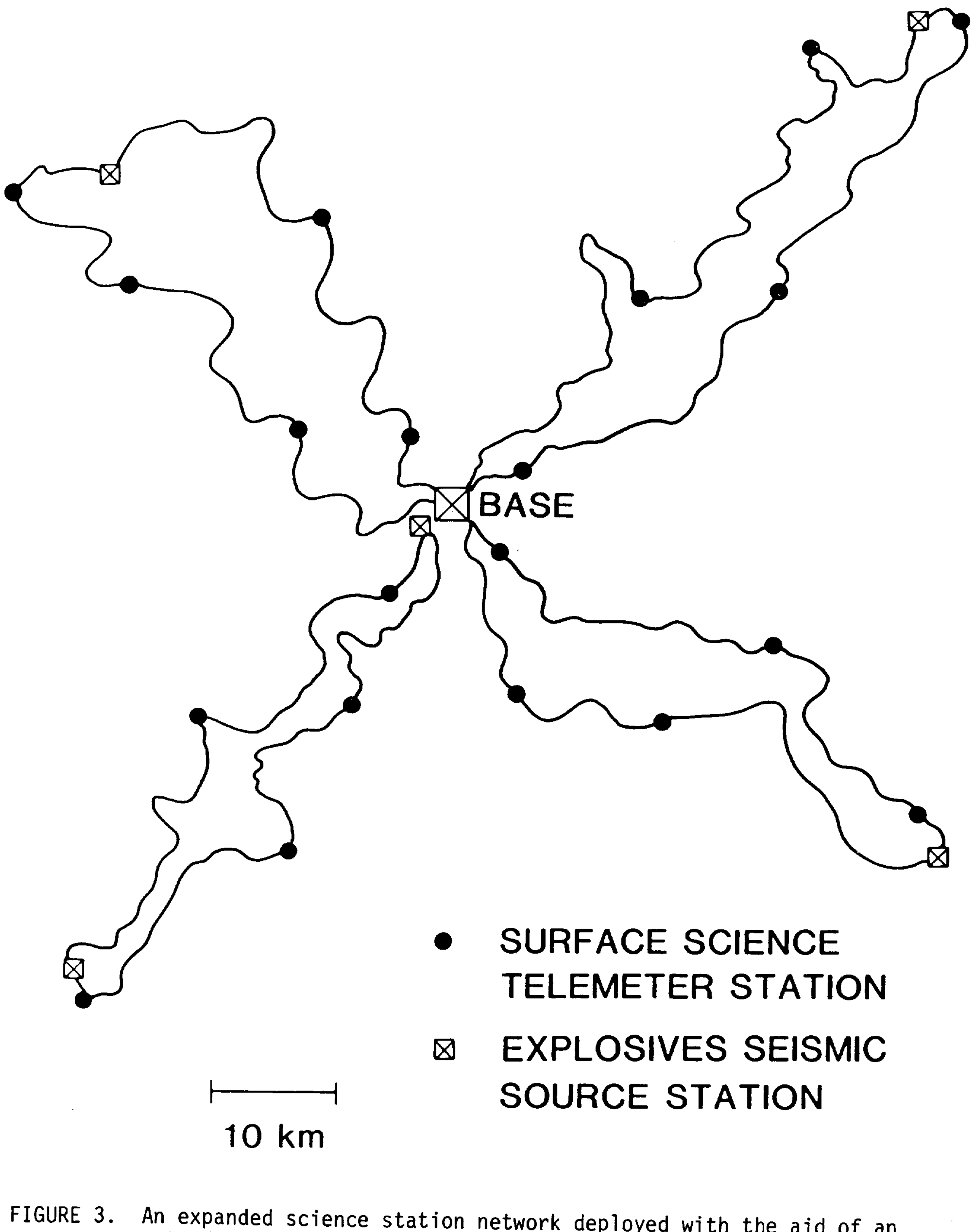

FIGURE 3. An expanded science station network deployed with the aid of an extended range SS rover. Two, approximately perpendicular seismic lines are shown.

the installation of five SSTSs and explosives (100 kg) for one radio armed and detonated seismic-source hole located at the extreme range of each traverse. Both rover types (EVA and SS) will be manned by a crew of at least two. In addition to adequate life support consumables and motive fuel, the rovers must transport a drill rig and compressor for the station holes. The SS rover will also carry a self-leveling gravimeter that will automatically make a gravity measurement at each stop (typically every several hundred meters).

Gravimeter: MASS: 10 kg

POWER: 1/2 w

A separate, portable passive EM system that measures three components of the H-field and two components of the E-field from 10^1 to 10^4Hz will be carried on the rovers. This system will be used for rapid reconnaissance around each SSTS to measure very near surface tensor electrical resistivity that will yield information on geologic structure as well as the possible presence of ground ice.

Portable EM system: MASS: 75 kg

POWER: 0.5w

The crews will alternate for each traverse with the main base crew who will be performing other activities such as monitoring the traverse and station installation, examining samples from previous traverses, and performing long-range remotely-piloted-vehicle (Mars airplane) surveys.

Mars airplane

A remotely-piloted airplane or drone will be assembled by the crew at the permanent base and used to perform long range (1000+km) airborne geophysical surveys from about 100-1000m altitude. The surveys will include magnetic, photographic, low resolution gravity, atmospheric composition, and gamma spectrometric measurements. On-board TV will help guide the vehicle to interesting surface features. At the farthest distance from the lander, the drone will be landed to deploy a seismology/meteorology station.

Mars Airplane [5]: MASS: 300 kg

SUMMARY

A summary of the mass and power requirements for the major elements of the surface science equipment and sample collection is given in Table 1. We estimate that 1-5 metric tons, including mass for generation of

TABLE 1

SUMMARY OF MASS AND POWER REQUIREMENTS
FOR SURFACE SCIENCE ACTIVITIES

ELEMENT	MASS (kg/landing)	POWER (kwe/landing)	DEPLOYMENT	COMMENTS
Rock, Soil, and Core Samples	500	1 (refrigeration)	EVA, Rovers	25% of total will be kept in environmental storage.
Petrology/ geochemistry system	255	2	Lander	Analytical equipment will be left on the surface.
Rock Properties	48	0.0025	Rovers	———
SSTS	162*	.037*	Rovers	* Mass & power are for a single station. 3-20 stations landing are envisioned.
Explosives	100-150*	0.001*	Rovers	* Mass is for 1 seismic source event. 2-5 events per landing are envisioned.
Drill Rigs	3800/400	37/5	Lander/Rovers	Large rig for 100m-deep hole smaller rig for 10m-deep hole [7].
Mars Airplane	300	--	Lander	40-100kg of total mass is for instruments.

1-2kw electrical power, will need to be landed on the martian surface to support the basic physical science activities. To these must be added masses and powers for the drilling equipment, rover vehicles, and airplane plus any strictly operational equipment (e.g., propellant manufacturing plant).

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