The VPCAR activity is significant because it represents the development of the next generation of life support water recovery technology. It also shows how the research and development capabilities of one NASA center can be integrated into the operational requirements of another NASA center to reduce the cost of human spaceflight programs. Ames has been involved from the first principle definition to the model development, bench-scale and lab-scale prototype development, and contract management of the development of a human-rated version of the technology for transfer to a NASA spaceflight center. Johnson Space Center will develop the final spaceflight version.

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Human-Centered Computing Studies on the NASA Haughton-Mars Project

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During the past two field seasons, July 1998 and 1999, Ames researchers investigated the field practices of scientists and engineers at Haughton Crater on Devon Island in the Canadian Arctic, 500 miles north of the Arctic Circle, under the auspices of the NASA Haughton-Mars Project (HMP). On the HMP, human-centered computing (HCC) studies (part of Exploration Research) are aimed at determining how human explorers might live and work on other planetary objects, in particular on Mars.

This broad HCC investigation of field life and work practice spans social and cognitive anthropology, psychology, and computer science. The investigation involved systematic observation and description of work activities, locations, and learning in the field, constituting an ethnography of field science at Haughton. The focus was on human behaviors—what people do, where, when, with whom, and why. By locating behavior in time and place—in contrast to a purely functional or "task-oriented" description of work—the group identified patterns constituting the choreography of interaction between people, their habitat, and their tools.

To develop requirements for new kinds of tools for living and working on Mars, the group focused on the existing representational tools (such as documents and measuring devices), learning and improvisation (such as use of the Internet or informal assistance), and prototype computational systems brought to the field.

In addition to observing by participating in the expedition, human-centered computing scientists took extensive photographs and videos, which were analyzed for patterns. For example, to understand the relation between how technologies were used in different work and living spaces, a video camera was placed between the shared work tent, the natural sciences tent, and the large dome tent, with a view of the all-terrain vehicles (ATV) parked on the terrace in front (figure 1). During a three-hour period, quarter-size video frames (320 x 240 pixels) were directly captured to computer disk every 3 seconds (a compromise between storage and visible information). This video therefore logged occupation and motion between four key areas of the base camp, as well as capturing use of some personal tents. The layout was of special interest because motion between the work and dome tents might correspond to the upper and lower decks in a Mars habitat.

The resulting video was coded on a spreadsheet. Durations of visits and number of people occupying each area were calculated in Excel. Averages and

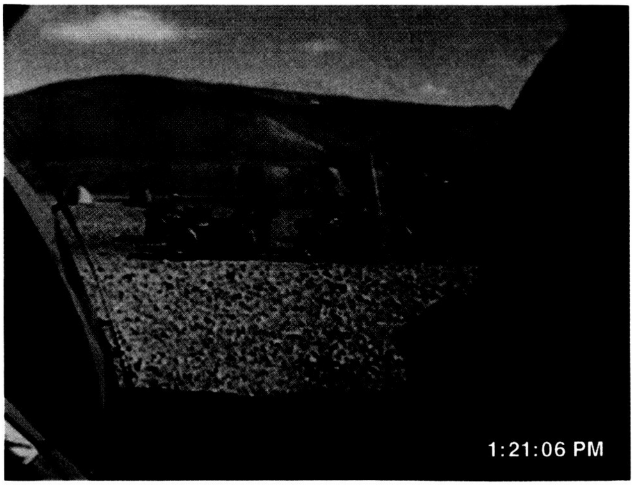

Fig. 1. Example frame, showing an exit event from work tent and (at least) two people at the ATV staging area.

totals were graphed to show correlations (see figure 2). One unexpected result is that the data allows measuring the effect of a schedule change (delay in departure of a traverse by 1.5 hours) on both individual and group occupation of the different areas. For example, movement between the dome and work tents (the two "floors") peaked each time occupation at the ATV area peaked, and reached a minimum during the delay period. Further analysis showed a great variation that was later explained by considering the actual activities of individuals and their roles in the camp, as revealed by observation, interviews, and surveys.

Topics especially relevant to computer system design were highlighted by a written survey completed by the participants in the month following the expedition. Important findings are summarized in table 1. The greatest surprise was the number of people who downloaded and/or learned to use new software. Aside from laptop computers, the most prevalent use of computing was with the digital camera. The average number of digital photographs was 137, yet only two people used a photo database

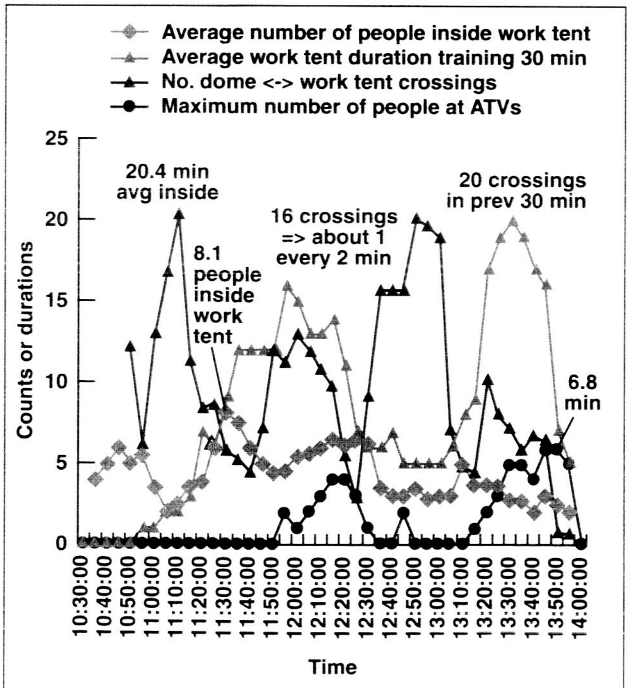

Fig. 2. Average number of people inside work and dome tents and at ATVs, showing correlation at noon and 1:40 p.m. expected EVA departure times. During intervening wait, work tent duration increased dramatically and crossings between tents dropped.

Table 1. Computer and digital device usage during HMP-99 expedition (N = 25)

Computer Usage	Percentage
Used a computer	92%
Browsed web	68%
Downloaded software	32%
Learned to use new software	52%
Sent e-mail	88%
Used e-mail daily	60%
Sent digital photographs	52%
Informed colleagues or sought advice	64%
Watched a full DVD movie	76%
Used a digital camera	64%
Used a computer outside or in personal tent	16%

(on average 204 conventional photographs were taken per person).

These investigations suggested several hypotheses that are shaping operations planning and technology design:

- Exploration is not just about covering the most area in the most time; continuously revisiting places is essential.
- During an expedition like the Haughton-Mars Project, conceptual change includes organizational roles, not just scientific theories.
- Living on Mars might change scientific practice, physically constraining how the work is done, and how analysis and publication are coordinated.
- An important use of computers will be for life support automation and mediating communication with Earth, not just for assisting scientists in direct field exploration.
- Protocols for Mars/Earth communications should be designed to help Mission Control learn about human activities on Mars, and adjust its support role as surface practices develop.

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