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Final Report on Joint Research Interchange between NASA-Ames and San Jose State University Foundation

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Title of Joint Research: Micro-pressure sensors for future Mars missions

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Duration of JRI: June 21, 1995 to March 21, 1996 (9 months)

Final Report: Micro-pressure sensors for future Mars missions

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The joint research interchange effort was directed at the following principal areas:

- further development of NASA-Ames' Mars *Micro-meteorology* mission concept as a viable NASA space mission especially with regard to the science and instrument specifications

- interaction with the flight team from NASA's New Millennium "Deep-Space 2" (DS-2) mission with regard to selection and design of micro-pressure sensors for Mars

- further development of micro-pressure sensors suitable for Mars

The research work undertaken in the course of the Joint Research Interchange should be placed in the context of an ongoing planetary exploration objective to characterize the climate system on Mars. In particular, a network of small probes globally-distributed on the surface of the planet has often been cited as the only way to address this particular science goal. A team from NASA Ames has proposed such a mission called the *Micro-meteorology* mission, or "Micro-met" for short. Surface pressure data are all that are required, in principle, to calculate the Martian atmospheric circulation, provided that simultaneous orbital measurements of the atmosphere are also obtained. Consequently, in the proposed Micro-met mission a large number of landers would measure barometric pressure at various locations around Mars, each equipped with a micro-pressure sensor. Much of the time on the JRI was therefore spent working with the engineers and scientists concerned with Micro-met to develop this particular mission concept into a more realistic proposition.

Time was invested in assessing and calculating the measurement requirements for the Micro-met mission. This effort led to a long and detailed paper which represents the only full discussion of a meteorological network mission on Mars or indeed on any of the other planets (excluding the Earth, of course). The paper addressed a number of issues. Firstly, following a review of the current understanding of the Martian atmosphere, the outstanding problems and consequent objectives were identified. A methodology to achieve the science objectives was detailed. This was with reference to the general theory which governs the dynamics of the atmosphere and to terrestrial experience in solving similar problems. For the surface network on Mars, the number and distribution of stations were assessed on the basis of fulfilling the science objectives and accounting for possible landing sites of the stations, calculated assuming deployment of probes using a spinning carrier method. The required accuracy, precision, zero drift, and sampling strategy for the micro-pressure sensors aboard such probes were calculated according to the consequent errors in the derived wind speeds from pressure gradients and/or the ability to discriminate low frequency, small-amplitude atmospheric waves that are theoretically expected on Mars. The accuracy with which the station location and altitude must be known was also examined. Some analysis of the Viking lander spacecraft annual pressure cycle data was done which demonstrated the plausibility of using annual mean pressures from landed probes to estimate the relative elevations of the landers within the desired uncertainty specification for a global network mission. Finally, the specifications for an orbital atmospheric sounder to be used in coordination with the global meteorological network on Mars were investigated. These included the required temporal and spatial coverage (i.e. the necessary parameters of the spacecraft orbit) and the desired measurement specifications for the remote sounding instrument.

In late 1995, NASA's New Millennium program decided to support a mission to send a pair of penetrator probes to Mars by piggy-backing them on the Mars Surveyor lander scheduled for launch in early 1999. This penetrator mission is called "Deep Space 2" (DS-2) and each penetrator probe will carry a micro pressure sensor. Efforts were made to help the DS-2 flight team with appropriate pressure sensor specifications and instrument interface information. Also it was agreed that I should help undertake the testing of candidate pressure sensors for DS-2 and this is ongoing. An advanced, automated test system for Mars pressure sensors was designed and some hardware items procured for this purpose. The purpose of the test system is to qualify sensors within the pressure and temperature regime one expects on Mars. This is especially important for the DS-2 mission concept which employs no active thermal control of the pressure sensors so that they are subject to the large daily temperature swings of the Martian atmosphere. The design of the system incorporates a small environmental chamber for measuring the thermal sensitivity of the sensors and a computer system principally to control the chamber pressure and log data. It was not possible to get a tested, up-and-running system within the duration of the JRI tenure due to funding and procurement delays for key pieces of apparatus but this effort has continued beyond the end of tenure. It is hoped that DS-2 personnel will be able to supply appropriate pressure sensors for tests towards the end of 1996.

Laboratory work was accomplished in testing interface electronics for the micro-pressure sensor. A new, low-powered (17 mW), single-chip capacitive interface integrated circuit (IC) was tested which gives an output directly proportional to change in capacitance. A previous investigation of mine had shown that capacitive micro pressure sensors (which change capacitance with a variation of pressure) are best suited for Mars. Consequently, the capacitive interface IC chips are highly appropriate. In assessing the capacitive interface ICs, pressure sensors were simulated with variable capacitors and the output of the interface chip was tested for non-linearity and drift. The aim was to see if the ICs have appropriate resolution and the necessary low-drift to be compatible with pressure sensing on Mars for meteorological purposes. With the addition of a single component (op-amp), the interface circuit appears to be appropriate and could considerably reduce the size and mass of the overall pressure sensor instrument. This would be of great benefit in meteorological network probes such as those planned for Micro-met.

Some collaboration was undertaken with graduate students at Stanford University's Dept of Aeronautics and Astronautics in developing a command, data and handling electronics sub-system for the micro pressure sensors that would be used for Micro-met probes. The pressure sensor and interface chip would plug-in directly into such a sub-system and together these would form the core of a Mars lander probe for the Micro-met mission.

With regard to further work, currently, efforts are ongoing in developing the automated test system for DS-2 micro pressure sensors and future efforts will include characterizing the sensors that are supplied by DS-2. In particular, work will concentrate on testing the sensors characteristics over a range of pressures and temperatures appropriate for Mars. DS-2 will have to employ ingenious methods to mount the pressure sensors since they are placed in a part of the penetrator probe that is subject to very large shocks on landing: up to 80,000g. This is further complicated by the fact that the mounting method is something that can affect the sensitivity of the sensor considerably by exerting stress which is falsely registered as a change in pressure. Hence all these factors will need to be investigated for a flight instrument.

It is also planned to propose the Mars global meteorology network mission later this year as a candidate for the next mission in NASA's Discovery Program. Much further work will obviously be involved in detailing the science, engineering and cost for such a project.

Publications

R. M. Haberle and D. C. Catling. A Micro-Meteorology Mission for Global Network Science on Mars: Rationale and Measurement Requirements. *Planetary and Space Science*, 1996 (in press).