APPLICATIONS OF EXTENDED AUTONOMOUS NAVIGATION CAPABILITIES AT MARS C. A. Halsell (Allen.Halsell@jpl.nasa.gov) and You, T-H. (Tung-Han.You@jpl.nasa.gov), Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, California 91109 USA.

Introduction: The successful use of Autonomous Navigation systems for primitive body encounters presents an opportunity to reduce risk and decrease cost for Mars missions, particularly those that make use of aerobraking techniques. On the one hand, the AutoNav system has completed successful encounters with several small bodies in the past few years. AutoNav uses on-board optical measurements to make real-time adjustments to the spacecraft trajectory, instrument pointing and observation timing when in-the-loop ground processing is impractical or impossible. This robust system has been applied to the Deep Space 1 [1], Stardust and Stardust-NExT missions [2], Deep Impact [3] and EPOXI [4]. The advanced state of this system makes it a natural starting point for the development of new technologies.

On the other hand, the usefulness of aerobraking at Mars is also well established. The Mars Reconnaissance Orbiter mission, Mars Odyssey mission, and Mars Global Surveyor mission all used the technique of repeated low-altitude atmospheric passes to reduce orbit period, thus tremendously reducing propellant mass and enabling the delivery of far more capable instrumentation to Mars orbit. The major drawback to date is that missions must accept a higher degree of risk due to the notoriously variable Martian atmosphere. These risks have been mitigated through near-continuous spacecraft monitoring, accepting these ground costs for mission operations personnel and DSN tracking. The adaptation of AutoNav to such missions would allow the full benefit of aerobraking to be realized.

Autonomous Aerobraking: As stated above, AutoNav has already demonstrated the capability to process onboard optical data to improve knowledge of spacecraft position and velocity. The system is currently being upgraded to support an autonomous aerobraking capability at Mars, via NESC grant in partnership with Langley Research Center and others. This improved system is expected to operate without ground intervention for at least 7 days, and simulations indicate this can be extended to 20 days or more. Orbit control maneuvers would adjust the periapsis altitude within a specified density / heating rate / dynamic pressure control corridor. Direct measurements of drag via accelerometer and IMU data would be used to update the spacecraft state and predict times for future events such as drag passes and occultations.

High Accuracy Onboard Clock: Additional technologies are being developed which would extend the mission set for such an autonomous system. In particular the Deep Space Atomic Clock (DSAC) is intended to provide ephemeris estimation accuracies typical of JPL deep space navigation using only a carrier signal (i.e., two-way Doppler accuracy with one-way hardware). This would simplify the operations of ground-operated interplanetary missions, but enable a number of new possibilities when coupled with the autonomous capability.

Possible Applications: The expansion of AutoNav to include aerobraking and onboard radiometric data processing in addition to optical / landmark tracking could be applied to Phobos or Deimos exploration, whether by chemical or solar-electric propulsion. The ability to detect sample return capsules has been addressed in the past, and these could be autonomously collected. Similarly, surface sample capsules could be gathered and cached at Phobos or in Mars orbit for return to Earth without extensive ground monitoring.

The onboard clock capability has the potential to provide in-situ navigation services to other near-Mars assets. The other assets would need to be equipped with the DSAC but would receive information on their own position / velocity from the AutoNav "server" spacecraft. For instance, a spacecraft equipped with AutoNav and DSAC could transmit state messages via simple communications link to a network of cubesats, a non-US asset from ESA, ISRO, or other organization, or an atmospheric sampling mission. No specialization on the AutoNav side would be necessary as long as the basic physics of the mission were modeled onboard.

References: [1] Riedel, J.E. et al. (2006) *AIAA GNC Conf.*, AIAA-2006-6708. [2] Bhaskaran, S. et al. (2004) *AAS/AIAA Astrodyn. Spec Conf.*, AAS-04-236. [3] Kubitschek, D. G. et al. (2006) *AAS G&C Conf.*, AAS 06-081. [4] Abrahamson, M. et al. (2012) *SpaceOps 2012*, pre-print.