EXTRATERRESTRIAL CAVES: A SOLAR SYSTEM-WIDE PROSPECTUS. P.J. Boston[1,2], [1]EES Dept. New Mexico Institute of Mining & Technology, 801 Leroy Place, Socorro, New Mexico 87801; pboston@nmt.edu, [2] National Cave and Karst Research Institute, 1400 Commerce Dr. Carlsbad, NM 88220.

Introduction: Evidence of caves on other bodies in the Solar System was presented early on in the Apollo era for the moon [1], and has more recently been confirmed for that body [2,3]. Cave forming mechanisms and evidence for caves have been suggested for a number of bodies in the Solar System [4], and recently confirmed for Mars [5]. Our dawning awareness of the presence of cavity forming processes on other bodies in the Solar System is beginning to enter a more serious phase and thus it is timely to consider the broad sweep of disciplines and topics that will impinge on this newly acknowledged class of geological phenomenon. Areas of interest include the formation mechanisms of caves (speleogenesis), their ability to preserve indicators of previous planetary conditions (repositories of past climate data, sedimentation, etc.), insights into surface geology from a subsurface perspective, hydrological or volcanological information from specific types of caves, the potential role of caves as habitat for extraterrestrial life (astrobiology) or timecapsules preserving life remains and geochemical traces (biosignatures), caves as ideal habitats for confining the potential for forward and backward planetary contamination, and the possibility of cave use for future human exploration purposes. All of these areas of interest are accompanied by engineering needs for subsurface geophysical detection methodologies, robotic access, new scientific and orientation instrumentation, and EDL (entry, descent & landing) approaches to rugged terrain for landed missions hoping to access caves.

Geological Processes: The fundamental mechanisms of planetary geology have both been inspired by our geological study of Earth and in return have repaid geology by providing a broader outside-the-system perspective which advances our understanding of Earth geology. Such comparative planetology can now be extended to cave formation processes that will cause us to think more deeply about the fundamental physics and chemistry involved in their production [4]. The picture we can gain of basic stratigraphy, diagenesis, porosity and permeability, and lava rheology provided by various types of caves is a very different and complementary enhancement of what we can learn from outcrop and surface geomorphology alone. In addition, geological evidence that is destroyed by weathering and erosion in surface expressions can be preserved in caves and may be all that remains of a prior widespread phenomenon of general interest.

Surficial and Atmospheric Processes: On Earth, over the past hundred years or so, we have used caves to advance our knowledge of complex mineralogy, indeed many minerals are known only from caves [6]. Sediments trapped in caves tell of ancient floods and may also contain evidence of past vegetation cover. We know that many caves contain ices year round even while the aboveground climate would not support that and recently a theoretical treatment of the potential for trapped volatiles in Martian caves has been published [7]. Importantly, on Earth we are at the dawn of using cave secondary mineral deposits (speleothems) as indicators of past surface climates [8].

Astrobiology: The potential for microbial life or its remains to be found in the subsurface of Mars has been suggested [9,10,11]. Excellent preservation of life traces in Earth caves and the unusual, abundant, and diverse microbial communities that we find inspire hope for the astrobiological potential of extraterrestrial caves [11,12].

Human Utilization: Humanity has long used caves, rock shelters, and other natural geological features for survival and cultural purposes. The use of such natural features in future human exploration of Mars and Earth's moon could be a timely and practical solution to a number of potential dilemmas presented by the extreme and challenging nature of the environments on these bodies. Limited preliminary work has been conducted to begin to examine the feasibility of such extraterrestrial cave use [13].

Engineering: The complex internal topology of caves are often exceedingly challenging for human explorers to navigate here on Earth. The potential to explore caves robotically offers yet more challenges to our engineering imaginations and expertise. In return, meeting the demands of such terrain will stretch the field of robotics to achieve great advances. In addition, new instrumentation developments will be required to meet the stringent demands of low mass, limited power availability, and ruggedness required by the cave environment.

Conclusions: The dawn of the age of exospeleology or astrospeleology is upon us. The ramifications of this extend into all of the scientific, engineering, and exploration activities that have been conducted in Earth caves before. Now we contemplate the demanding task of applying what we have learned here on Earth to the extraterrestrial realm.

References: [1] V.R. Oberbeck et al (1969) *Mod. Geol. 1:*75-80. [2] J. Haruyama, et al (2009) *Geophys Res Lett* 36:L21206. [3] Arya et al (2011) *Curr. Sci.* 100(4):524-529. [4] P.J. Boston (2004) *Encycloped. Cave Karst Sci*. Fitzroy-Dearborn Publishers, Ltd., London, UK. Pp. 355-358. [5] G.E. Cushing et al (2007) *Geophys. Res. Lett.* 34(17):L17201. [6] C.A. Hill and P. Forti (1997) *Cave Minerals of the World*, 2nd ed. Nat. Speleol. Soc.463 p. [7] K.E. Williams et al (2010) *Icarus* 209(2):358-368. [8] J. B. Martin & W. B. White (2008) SP 13, KWI Sp. Pap. [9] P.J. Boston et al (992) *Icarus* 95:300-308. [10] E.A. Grin et al (1998) Abstr. 29th Ann. *NASA Lunar and Planet. Sci. Conf.*, Houston, Texas. [11] P.J. Boston et al (2001) *Astrobiology Journal* 1(1):25-55. [12] R.J. Leveille & S. Datta (2010) *Planet Space Sci. Special Issue* 58(4):592-598. [13] P.J. Boston et al (2004) *Space Tech. & Applic. Forum 2003 Proc.*. AIP #654. Amer. Inst. of Physics, College Park, MD.