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Analysis of the acceptance of autonomous planetary science data collection by field of inquiry

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Abstract

The acceptance of autonomous control technologies in planetary science has met significant resistance. Many within this scientific community question the efficacy of autonomous technologies for making decisions regarding what data to collect, how to process it and its processing. These technologies, however, can be used to significantly increase the scientific return on mission investment by removing limitations imposed by communications bandwidth constraints and communications and human decision making delays. A fully autonomous mission, in an ideal case, could be deployed, perform most of the substantive work itself (possibly relying on human assistance for dealing with any unexpected or unexplained occurrences) and return an answer to a scientific question along with data selected to allow scientists to validate software performance. This paper presents the results of a survey of planetary scientists which attempts to identify the root causes of the impediments to the use of this type of technology and identify pathways to its acceptance. Previous work considered planetary science as a single large community. This paper contrasts the differences in acceptance between component fields of planetary science.

Keywords: Artificial intelligence; Planetary science; Autonomy; Acceptance of autonomous systems; Space technology

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1. Introduction

The use of autonomous control technologies can provide significant benefit to planetary science missions. The miniaturization of electronics is allowing smaller and lighter spacecraft to perform missions that were previously the domain of much larger ones. While these smaller craft are able to perform many exploration functions, their smaller size limits the level of power generation possible (and thus available for communications) and antenna size (and consequentially, possible gain). Given this, it is desirable to be able to perform more science with less communications. Autonomy is a solution for this.

Smaller craft, however, are not the only reason for using autonomous control technologies. Other drivers for the use of this technology include facilitating missions further away from Earth. For these more distant missions, communications delay time (waiting for human commands) grows more substantial and the amount of time lost to the transmission, human decision making response cycle can dramatically reduce spacecraft performance. This was shown in the case of the Spirit and Opportunity Mars rovers, which significantly increased their daily movement capability via autonomous control (Jet Propulsion Laboratory, 2009). Increasing autonomy also reduces the draw on the limited ground station resources of the Deep Space Network. The reduced need for human control decreases mission costs through allowing missions to run with less staff.

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Autonomous control, thus, facilitates lower cost missions with higher levels of science return (as a function of cost) and higher levels of science return, in general, for a given craft. While legitimate considerations do exist (examples of which include the limitations of the present generation of control software and an unexpected discovery being missed by a logical and non-creative artificial intelligence system), the negative perception of autonomous control (for example, being responsible for the "seven minutes of terror" when Curiosity was landing out of human control on Mars (Kerr, 2012)) is disproportionate. This paper seeks to facilitate a greater understanding of this concern, particularly as it relates to certain disciplines of planetary science, and how these concerns can be satisfied. By looking at this from a component-discipline perspective, prospective areas for lower-resistance trials can be identified allowing more comfort to be gained by scientists, which may lead to wider acceptance in the longer term.

2. Background

This section provides an overview of various autonomous control technologies: both historical ones and possible future technologies. This provides a foundational understanding of the prospective benefits of using more autonomy for planetary science missions. This must, obviously, be contrasted with the elements of risk (both actual and the impact of perceived risk on program funding) that are incurred by utilizing autonomous technologies.

The use of autonomous control has been demonstrated successfully in space, both by the United States and others. It has been shown, for example in the Deep Space One mission, to significantly reduce ground staffing needs (Northwestern University Qualitative Reasoning Group, 2009), reduce the amount of ground station time required (National Aeronautics and Space Administration, 2009) and increase the level of science data transmission (Northwestern University Qualitative Reasoning Group, 2009). A beacon methodology (Bernard et al., 1999) allows a spacecraft to operate autonomously most of the time and request controller aid only when required. The ability to perform complex maneuvers in space and in proximity to other planets has been demonstrated: both the United States (Young, 2007) and Soviet Union (Hinman and Bushman, 1991) have demonstrated autonomous docking. Autonomous entry, descent and landing capabilities have also been demonstrated (Mendeck and McGrew, 2013) as have close proximity landing and ascent to a comet (Clark and Meech, 2005; Kubitschek, 2005).

While some failures have occurred (e.g., Marshall Space Flight Center, 2004), autonomy technology has largely been shown to be beneficial. It has increased performance by eliminating certain tasks from requiring humans and optimized others. The Spirit and Opportunity rovers are a prime example of this: autonomous driving significantly increased the distance that they are able to travel in a day while eliminating tasks that humans must perform (Jet Propulsion Laboratory, 2009).

Autonomous control systems are poised to provide greater benefit in the future. Fink's work on "tier scalable" mission architectures (Fink, 2006; Fink et al., 2007a,b), sensorwebs (Chien et al., 2010, 2007; Sherwood et al., 2006; Kinnebrew et al., 2007; Sherwood and Chien, 2007; Tsatsoulis, 2008) and data-driven mission management techniques (Straub, 2012a,b,c) are just a few of the autonomous control developments which are poised to enable higher-value, lower-cost missions. While these technologies are at various levels of maturity, their acceptance by and the trust of the community of prospective users is key to their ability to be used to provide mission benefits.

3. Methods

A survey was administered to 230 attendees at the 2013 Lunar and Planetary Science Conference (LPSC), as described in Straub (2013a,b). These individuals represented a wide range of age groups, levels of experience and disciplines of planetary science. Fig. 1 depicts the distribution

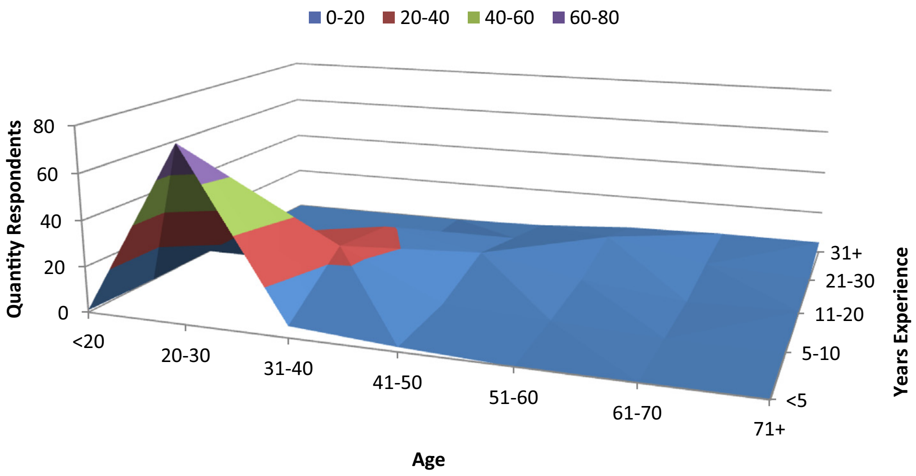

Fig. 1. Correlation between age and years' experience.