LOOKING TO 2050: THE USGS INTEGRATED SOFTWARE FOR IMAGERS AND SPECTROMETERS (ISIS), T. L. Becker, K. L. Edmundson, S. Sides, T. M. Hare, J. R. Laura, U. S. Geological Survey, Astrogeology Science Center, Flagstaff AZ (tbecker@usgs.gov).

Introduction: Since 1971, the U. S. Geological Survey (USGS) Astrogeology Science Center (ASC) has developed scientific software to process NASA planetary image data [1]. At version 3, the system, currently called The Integrated Software for Imagers and Spectrometers (ISIS), has supported a diverse set of missions including flybys, orbiting spacecraft, landers, rovers and sample return missions funded by NASA, the European Space Agency (ESA), the Japanese Space Agency (JAXA), and the Indian Space Research Organization (ISRO). ISIS provides support for 63 sensor models (camera models). Data from these varied sensors represent spatial and spectral images of solid target bodies and rings throughout our Solar System from Mercury to Kuiper Belt dwarf planets.

Calibrated and controlled geospatial products are critical to support the integration and scientific comparison of data across missions, sensor types, and data scales, i.e., horizontal and vertical data. ISIS not only supports planetary research but the selection of safe landing sites and in-situ planning for robots and humans [2].

With a diverse workforce that includes Planetary Geologists, Computer Scientists, Photogrammetrists, Cartographers, Geodesists, Archive Specialists and Data Curators, the ASC recognizes the evolving needs of the planetary science community. The exploration of bodies within our Solar System depends upon these spatial computational capabilities today and will continue to do so in 2050. Predicting the future of hardware and software technology is difficult ten years-out and near impossible thirty-five years-out. Thus below, we offer a vision of how ISIS, in support of critical planetary spatial data infrastructure, may evolve as we approach the year 2050.

Open Technologies: We continue to develop and utilize open source software and are working toward providing functionality that will contribute to interoperability between tools used by the planetary science community. A long-term goal is to provide open standards and streamline data processes. To support this, it will be critical to integrate existing scientific and computational libraries and standard methodologies such that our community can concentrate on the idiosyncrasies within our planetary domain. Innovations developed within our community will then need to be incorporated back into those libraries to evolve the technology.

For example, more recent ISIS efforts include: 1) new and improved photogrammetric functionality and visualization environment [3]; 2) true 3D shape model formats and map projections in support of mapping irregularly shaped bodies [4]; 3) innovative techniques for efficient and accurate image matching; and 4) utilization of the Community Sensor Model [5]. The increased use of standards-driven software development cannot be understated; technology will undoubtedly progress rapidly over coming decades and standards-driven capabilities facilitate backwards compatibility, interoperability, and specialization within software libraries. Each of these initiatives are purposely built on existing ideas and technologies but are targeted for our planetary applications. To evolve with technological advancement, the solutions we derive will need to be documented and maintained in an open manner.

Innovative Needs Towards 2050: Photogrammetric control has been essential for accurate placement and exploitation of spatial data for almost 180 years and we see no indication that this will change over the next fifty years. The creation of controlled and geometrically precise image mosaics utilizing tens to thousands of individual images can be extremely challenging and time-consuming given the uncertainties of spacecraft pointing and sensor behavior. ASC can envision hardware and software capabilities progressing to a point that controlled mosaics can be created in real-time from data collected by drones (UAV), rovers, or humans. Further progress will enable the onboard, real-time creation of these products.

We anticipate the adoption of machine learning algorithms to support spatial data processing and classification. Challenges of scale disparity, extreme viewing conditions, and diverse cross instrument fusions will remain a challenge and the work being advanced within the terrestrial face and pattern recognition, remote sensing, and biological imaging sciences will be critical to adapt for planetary usage.

Fifty-plus years of planetary exploration has produced vast amounts of data and the exponential increase will continue unabated. We identify Big Data Software-as-a-Service (SaaS) infrastructures as continuing to play a significant role in supporting data discovery, analysis, and exploitation. Innovations in SaaS are strongly backed by the cyber infrastructure arm of the National Science Foundation (NSF, e.g.
Earth Cube initiative [6]). This is a movement toward portable code that ships along-side huge data sets in the cloud for distributed processing. ISIS must play a key role integrating into said distributed High Performance Computing (HPC) analysis environments.

Volume, Velocity, and Veracity characteristics of planetary Big Data are areas where significant technological headway is being made. We see this progress continuing and the ISIS software library is poised to focus on the trends in computing to meet these challenges.

**Conclusion:** As the past has shown, geometrically and radiometrically accurate spatial data products are required to explore and support the diverse sciences applied to planetary bodies. The future will continue to require these same products to supply the geospatial framework used to make decisions about landing sites, and resource availability. Scientists will need to compare past and future data sets using unified stable tools. For over 30 years, ASC has accomplished this for the existing 63 sensors in ISIS and is in a position to continue providing the necessary stability through the next 30 years while adapting to changes in hardware, software, sensor capabilities, and science requirements. This effort will require continuous maintenance along with major upgrades to take advantage of new technologies.