STANDARDS SUPPORTING COOPERATION ON MISSION PLANNING AND DATA ANALYSIS WITHIN A BROAD-BASED MARS EXPLORATION PROGRAM

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Introduction

The continued exploration of Mars must be an international venture, featuring close cooperation amongst those nations eager to participate in the planning, operations and data analysis phases. There exists good precedence for such multilateral cooperation, and the scope of these activities is increasing. The foundation for such cooperation is built upon shared goals, and, a realization that no one nation can afford to conduct a comprehensive Mars exploration program on its own.

Cooperating nations must employ an array of common practices, standards and tools to achieve technical success within available financial and schedule resources. Common business practices, use of the metric system for measurements, use of the English language for human-to-human communications and use of the ASCII computer codes for exchange of electronic information are well established standards. There are also commonly accepted standards for scientific measurements. But there is room for more use of standards to advance common goals.

In recent years NASA's policy on proprietary rights to scientific data has evolved--such data must now be released to the science community rather quickly, after an appropriate period for validation and initial analysis. As a consequence, the supplementary or ancillary data needed by a scientist to help deepen or broaden the understanding of an investigation must also be made readily available and easy to apply.

To further facilitate cooperation on the design and execution of Mars missions, and on the timely and correct interpretation of scientific data obtained from these missions, it seems advisable to establish data standards and develop tools for the exchange and use of ancillary or engineering data. (This paper leaves the questions of establishing standards for science instrument data to others.)

About fifteen years ago the U.S. space science community made a strong recommendation to NASA for the establishment of new information systems and their attendant standards to help make ready access to, and use of, archived scientific data more of an expectation and less of a dream. While most of the discussion focused on data obtained directly from instruments, included in this recommendation was the establishment of standards and processes for obtaining and using the relevant ancillary/engineering data needed to help fully understand science instrument measurements, and to correlate results across instruments and missions. Out of this

recommendation was born NASA's "SPICE" ancillary information system.

It has been reported that members of the International Mars Exploration Working Group (IMEWG) have agreed in principle to the use of some data standards, but it does not appear that such agreements have so far lead to substantive specific actions. The process of adopting standards on an international scope can be quite difficult, and experience on just the national level in the U.S. has shown that efforts to establish standards and deploy related tools is also not easy and is often not started in a timely fashion.

This paper is presented in part as a reminder to the Mars exploration community to include ancillary information system accommodations in the earliest phases of Mars exploration program development. Further, it describes the SPICE system--including the most recent additions and plans for further development--and offers this technology and related experience as a starting point for definition of an ancillary information system that can support the international Mars exploration adventure.

Why Establish International Ancillary Data Standards ?

The arguments for establishing ancillary data standards on a national level are equally if not more compelling in the international scene. Such standards can help promote the exchange of good ideas for mission design. They can help distributed team members and adjunct scientists participate in constructing detailed observation sequence design, or in simply understanding what the planned observations are. They help maximize the complete and precise interpretation of scientific data returned from those observations, and particularly so when cross correlation between datasets is attempted. They facilitate the later access to such data by future scientists who might have improved data or methods for analyzing old data. And they can reduce local data system development costs, particularly as re-use comes into play.

What Vehicles Should Be Supported ?

The challenges of planning observations and providing ancillary data to help analyze the data returned from those observations are found in every imaginable kind of robotic vehicle in use today and planned for the future exploration of Mars. This includes interplanetary spacecraft, orbiters of planets and satellites, landers, balloons and rovers. With well conceived, flexible design an ancillary information system should be at home in any of these exploration domains. (Flexibility should allow these same techniques to support exploration of the entire solar system, including the Earth, moon and sun.)

Prime Components of an Ancillary Information System

Data are the fundamental component of an ancillary information system. Ancillary data provide vehicle position and velocity; target body size, shape and orientation; vehicle or instrument pointing; instrument or aperture size, shape and orientation; and logs of commands and events. Reference systems are another key component: coordinate systems and time systems are prime examples. Documents providing precise and complete definitions of the data and reference systems are a third component. Archives that provide easy and timely access to the data and other information system components are important and must exist for pre-flight, mission operations, and post-flight long-term data analysis phases.

Software that helps a scientist find, acquire and utilize ancillary data should also be considered a prime information system component. Adding software to this "mix" makes the job of building an ancillary information system much larger, but if well done the payoff is well worth this extra investment. This category could include general applications programs, utility programs and scripts, and subroutine libraries used by scientists in building their own applications.

Requirements on Ancillary Information System Components

A number of requirements are mandatory to ensure meeting expectations of the large and diverse customer community. Portable: data files and software must be useable on and easily moved between all popular computing platforms. Extensible: it must be easy to add or extend functionality. Correct: all components must be thoroughly tested and validated, including peer review where appropriate. Precise: generally all calculations must be done to meet the needs of the most demanding customer; the use of approximations is often appropriate but must be carefully controlled. Documented: data and software must be clearly, fully documented. Experience suggests this aspect is often given too little attention. Convenient: all components must be freely available and easily obtained by all interested parties. Supported: at least some help for customers must be available. It also seems that providing a fully open system–providing source code for software–invites extra confidence and participation of the user community. (Providing source code also helps ensure widespread portability.)

A Starting Point

NASA offers its SPICE ancillary information system as a starting point for developing capabilities fostering international cooperation on the planning, operation and science data analysis for the Mars armada. SPICE strives to address the needs and suggested core requirements outlined above. The primary data components of SPICE are depicted in Figure 1.

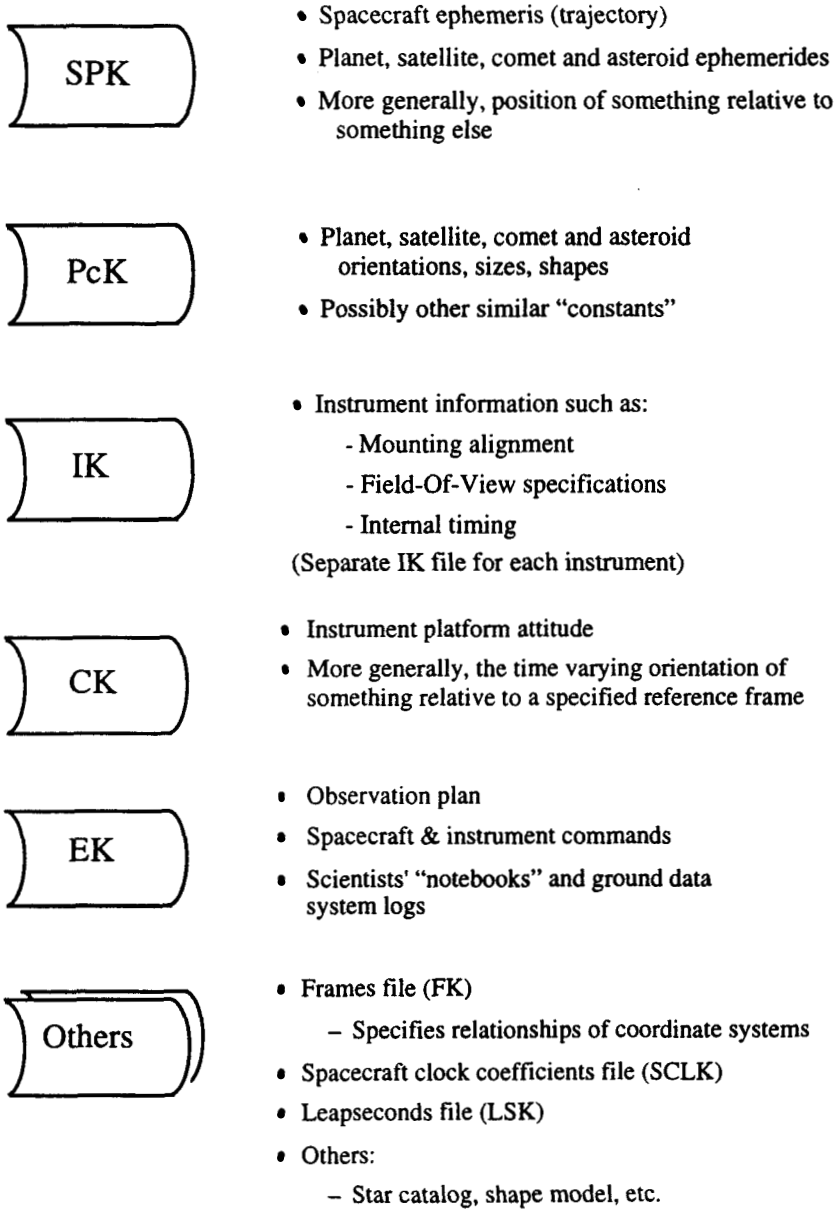

Figure 1 Primary Data Components of SPICE

Also key to the SPICE system is the SPICE Toolkit, a large suite of software consisting of:

- SPICELIB subroutine library, used to
  - write SPICE files
  - read SPICE files
  - compute quantities derived from SPICE data

- Utility programs, used to:
  - summarize SPICE data files
  - manage SPICE data files

- Cookbook programs, used to:
  - provide basic examples of using SPICE Toolkit software and with SPICE data

- Documentation, providing:
  - tutorials
  - user guides
  - subsystem design references

Within NASA's Mars Exploration Program at JPL the various elements of SPICE are used in mission design, observation planning, mission operations (including visualization), and science data analysis. The SPICE Toolkit is available in both FORTRAN 77 and C, and is supported on most popular platforms. SPICE is included in JPL's Mars Characterization program--intended to ensure that critical data from on-going missions are available to planners of future missions. And soon the ephemeris component of SPICE will become the standard for customer's of NASA's Deep Space Network.

The SPICE system has been in constant development for over eight years. While widely used, there are numerous extensions and additions that are needed. As example, a prototype plate model applicable to small, irregularly shaped bodies is nearing completion; this could be suitable for modeling Phobos and Deimos. Also, NAIF staff have recently started considering means for incorporating the diverse sets of Mars control net information being produced by several research institutions. But lots of work remains.

Examples of possible core extensions include:

- integration of standard shape models for Mars
- integration of high degree and order gravity models for Mars
- design and implementation of a closely integrated surface features database
- design and implementation of a more robust instrument model
- design and implementation of routines to search for specified geometric conditions
- design and implement means to incorporate and properly handle trajectory/orbit accuracy information
- address the always special needs of radio science investigations

Examples of possible application programs include:

- a highly evolved orbit characterization program
- tools to facilitate cooperative mission/observation planning in a distributed environment
- tools to facilitate planning for relay links
- visualization tools

Examples of possible data management capabilities include:

- design and implement means for aggregating a collection of files into an information "library"
- design and implementation of a user-focused SPICE files library mechanism
- establishment and operation of mirror sites

Development of more and better tutorial materials–possibly in multiple languages, possibly using an interactive WWW interface–would also be of benefit to the growing user community. Devising methods of applying these ancillary data to education and public outreach initiatives should also be considered.

It is hoped this brief review of ancillary data needs and some existing capabilities will serve to stimulate the timely consideration of this subject amongst Mars program science managers, mission architects and ground system developers. And it is dreamed that such interest might stimulate substantive cooperation on evolution of existing techniques into a truly international system.

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