Geometry: The Drive Train of Planetary Data Analysis

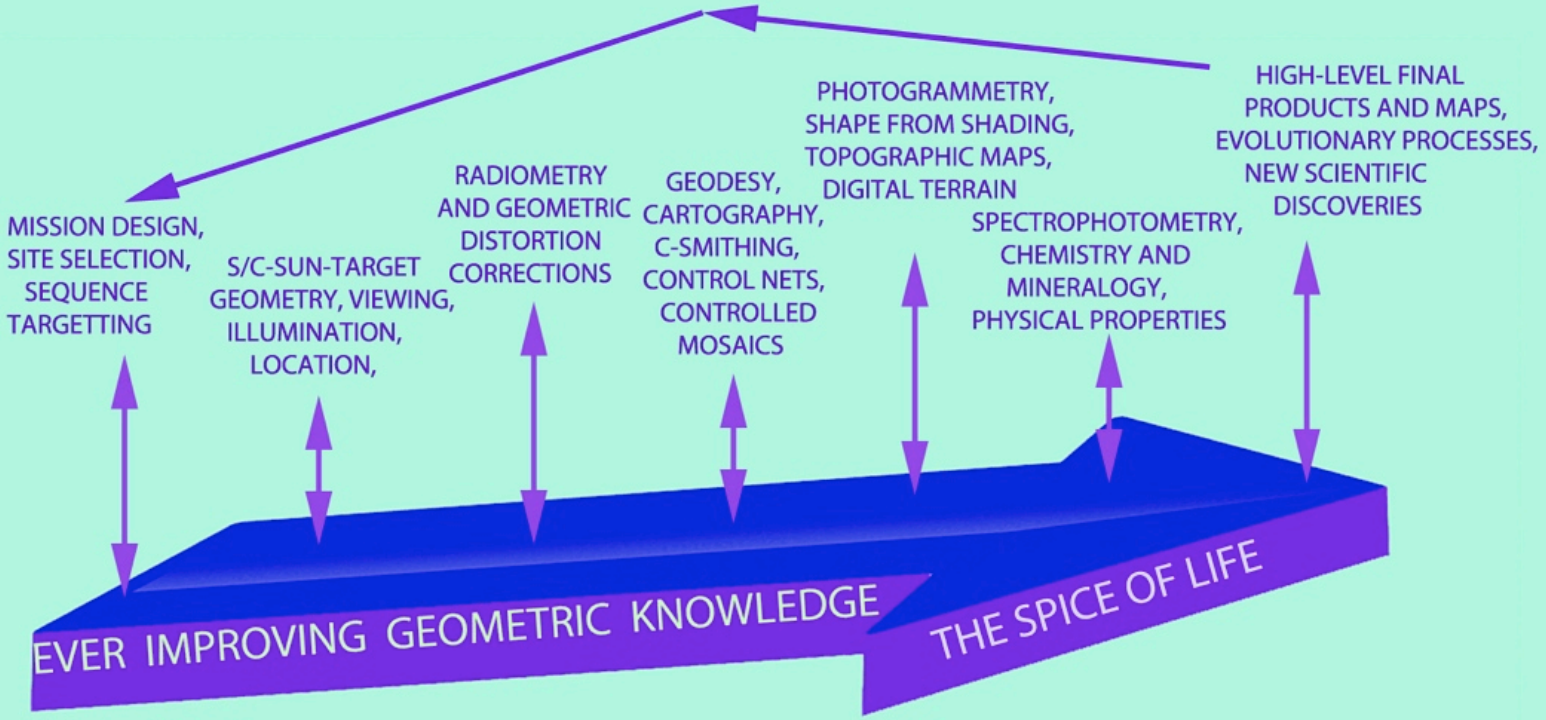
some perspectives on 40 years of its history, politics, evolution, and future

Larry Soderblom, USGS Astrogeology

NASA Planetary Data Workshop

Flagstaff AZ - June 27, 2012

THE DRIVE TRAIN OF PLANETARY DATA ANALYSIS



USGS
science for a changing world

ASTROGEOLOGY SCIENCE CENTER

Today's subject: history, progress, and future needs in managing the geometric components of our planetary data

A bit of history 1970-present: how did we get where we are today?

What things did we do well managing geometric data…where were our disasters?

What needs to be changed for missions of the future that will generate even larger, more complex data sets?

Status of Planetary Data by the late 1970s

- The planetary data archive was in disrepair
  - Magnetic tapes, the primary records of our data, have finite lifetime & were decaying or would soon
  - Software to process raw data from mission investigations was not being archived
  - Our ability to read, interpret, process the original data was thereby disappearing
  - There were no comprehensive requirements on mission teams to organize and archive data
  - Some archives were in PI's office file cabinets
  - The context under which the observational data were collected (of what and for what) was being lost
- *NASA turned to NRC's CODMAC for what to do*

NAS-NRC COMMITTEE ON DATA MANAGEMENT AND COMPUTATION

1982 REPORT, Chairman Ralph Bernstein, IBM

Problems with mission data-systems:

- Data system and analysis functions are not adequately funded
- Scientists responsible for data management are not identified.

Many problems of data distribution:

- Very long delays between data receipt and delivery to the user are common.
- Investigators who are obliged to deliver reduced data do not do so.
- Even when data are delivered, documentation is incomplete making data unusable.
- The user has great difficulty in finding out what data are available.
- Contents of data centers are not well known or widely publicized.
- Data centers are often simply unable to meet user data requests.

NAS-NRC COMMITTEE ON DATA MANAGEMENT AND COMPUTATION

1982 REPORT, Ch. Ralph Bernstein, IBM

Problems related to data standardization:

- Lack of standards & multiple formats are impossible for interdisciplinary users.
- Data archives contain insufficient information about original intent for data.
- Ancillary data are insufficient (time, attitude, orbit, or sensor calibration).
- Some data are only resident at a PI location and are difficult to obtain.

Problems related to software development:

- S/W is not transportable from lack of documentation & a transportability design.
- Lack of transportability increases cost as S/W may be repeatedly developed.

Problems with mass storage and retrieval of data:

- Data catalogs don't exist or don't provide enough useful information for users.
- Archives do not include browse capabilities to let users explore data.
- Magnetic tape, used for most science data, has serious deterioration problems!!!!

The SEDR – how ancillary data for planetary missions were then handled

- During the period of the Pioneers, Mariners, Voyagers, Vikings most planetary data were released in the following form at the end of mission:
  - EDRs Engineering Data Records (raw science instrument data-still today)
  - SEDRs Supporting Data Records (final integrated ancillary data)
  - RDRs Reduced Data Records (final set of calibrated, mapped data)
- Major problems arose from the method and quality of the SEDR
  - The SEDR integrated S/C trajectory files, planetary emphemerides, S/C orientation & pointing telemetry, S/C clock and times files, and instrument geometrical calibration data, *into a single set of solutions* (for each data file in the EDR archive e.g. lat, lon, g, i, e, S/C lat & lon, Sun lat & lon, etc)
  - Many of these input files were later improved but to regenerate the SEDR post mission was difficult and costly and not done-*SEDRs became stagnant and were not further refined*

Following the NRC CODMAC report, NASA Solar System Exploration Division convened a key workshop

- In response to the Bernstein report, NASA convened a Planetary Data Workshop in 1983, chaired by Hugh Kieffer, Astrogeology, USGS, Flagstaff.
- Recommendations for improving/salvaging the planetary archive included:
  - EDRs are fundamental and should be maintained in multiple copies (periodically rewritten)
  - Critical to archive the S/W methods and tools by which the EDR can be reprocessed
  - Should archive contextual information about the scientific intent of mission data collections
  - Calls for proposals for investigations in response to mission AOs must include a requirement for archiving and delivery of investigation data sets meeting defined standards
- With respect to the stagnant SEDR problem, Kieffer's workshop recommended:
  - Rather than generating/archiving the SEDR, *missions should separately archive the individual, fundamental ancillary data* sets (S/C traj., planet ephem. and surface def., instrument geometric def., time-based files, S/C orientation and instrument pointing files) *later dubbed the SPICE kernels*
  - These *individual files could EACH be subsequently and independently refined!!*
  - *Geometric parameters* for data processing/analysis should be *derived directly from these files*

NASA establishes a Pilot Planetary Data System, and NAIF

- Early in 1984, the NASA Solar System Exploration Division was forming a new "pilot" to implement the NRC CODMAC recommendations.
- A key component in the plan (derived from the recommendations of the Kieffer Workshop) was to include a new system for managing ancillary information
- As the pilot project evolved this ancillary data element of the nascent PDS would develop into NAIF (the Navigation and Ancillary Information Facility)
- Chuck Acton, the NAIF leader, worked with Kieffer, scientists, NAIF staff, to design the system for developing and maintaining the SPICE system, as it had been coined by Kieffer: (S/C, Planet, Instrument, C-matrix: pointing, Event)
- Voyager tested many of the SPICE concepts and Magellan was the first mission to officially use SPICE from the beginning.
- The SPICE kernels and NAIF, that maintains the system and develops S/W of highest standards, remains a main buttress in today's Planetary Data System

Ongoing issue: Establishing UPCs (Unified Planetary Coordinate Systems)

Background:

- The SPICE system and IAU conventions became *de facto* standards required for NASA missions by late 1980s.
- Even though delivery of archives at EOM became AO reqm'ts., use of standard planetary coordinate systems were not mandated.
- Standard practice by flight investigations was to use arbitrary (sometimes invented) planetary coordinate systems for data products, with unapproved coordinate systems, non-uniform geodetic definitions, arbitrary planetary definition files (shapes)
- This resulted in a mishmash of products that were uncorrelateable from investigation-to-investigation, let alone mission-to-mission.

Ongoing issue: establishing UPCs (Universal Planetary Coordinate Systems)

The (nascent) Solution:

- Define a consistent set of planetary coordinate systems complying with established IAU definitions and archived to PDS standards; require (in NASA AO's) and enforce (by NASA management) their use in generating high- and low-level mission data products.
- Up-to-now, this has been attempted by persuasion *"to do the right thing*:" success has been a mixed bag, *some investigations have continued to ignore the requirements* to adhere to IAU conventions in generating and delivering products, others set stellar examples:
  - LRO and MESSENGER have both adopted consistent UPC systems
  - Hence, for the Moon and Mercury this will insure consistency allowing direct comparison of data sets between past, current, and future missions

Returning to the original NRC CODMAC findings:

SO HOW HAVE WE DONE? - 1

Problems with mission data-systems:

- Data system and analysis functions are not adequately funded
- Scientists responsible for data management are not identified

Many problems of data distribution:

- Very long delays between data receipt and delivery to the user are common
- Investigators who are obliged to deliver reduced data do not do so
- Even when data are delivered, documentation is incomplete making data unusable
- The user has great difficulty in finding out what data are available
- Contents of data centers are not well known or widely publicized
- Data centers are often simply unable to meet user data requests

Key:
Little progress
Progress
Good progress

ASTROGEOLOGY SCIENCE CENTER

Returning to the original NRC CODMAC findings:

SO HOW HAVE WE DONE? -2

Problems related to data standardization:

- Lack of standards & multiple formats are impossible for users (due to the UPC issue)
- Data archives contain insufficient information about original intent for data
- Ancillary data are insufficient (time, attitude, orbit, or sensor calibration)
- Some data are only resident at a PI location and are difficult to obtain

Problems related to software development:

- S/W is not transportable from lack of documentation & a transportability design
- Lack of transportability increases cost as S/W may be repeatedly developed.

Problems with mass storage and retrieval of data:

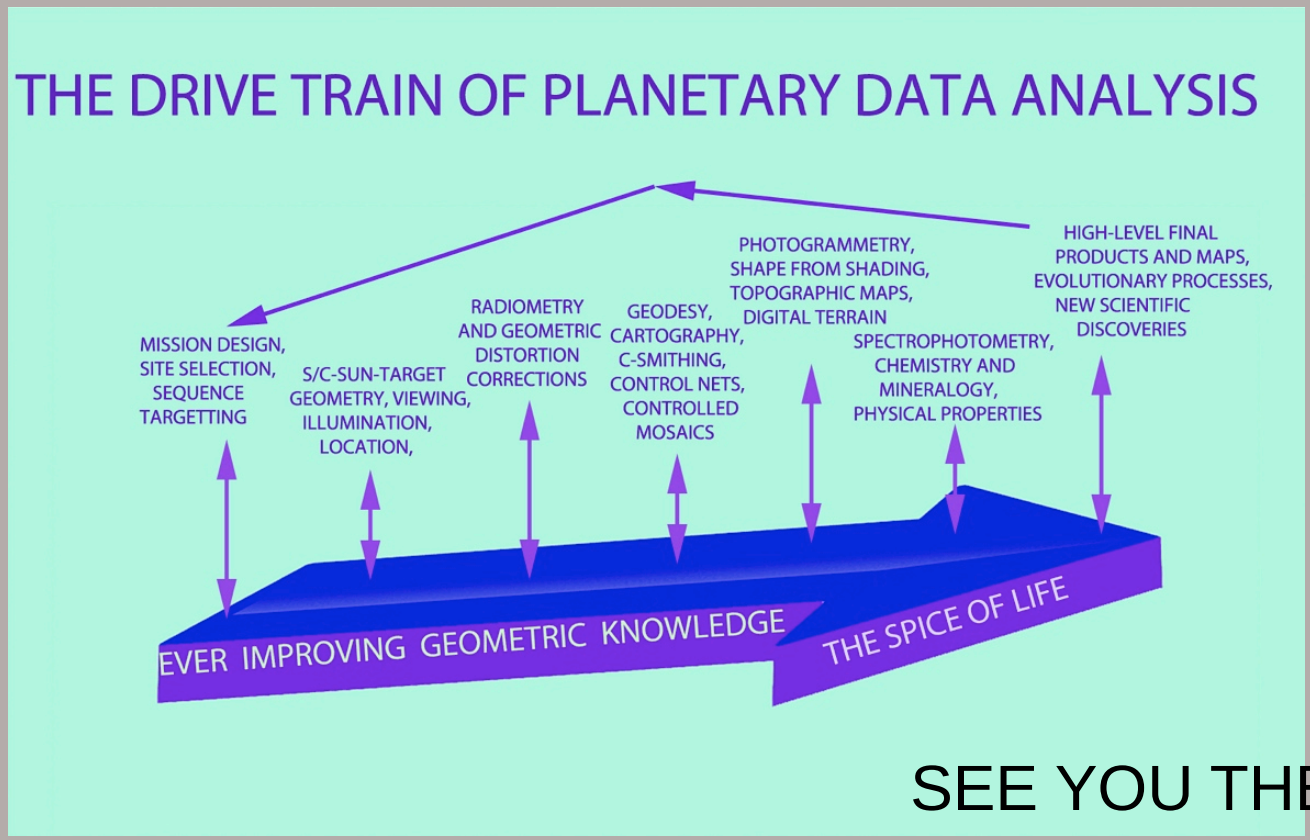
- Data catalogs don't exist or don't provide enough useful information for users.
- Archives do not include browse capabilities to let users explore data.
- Magnetic tape, used for most science data, has serious deterioration problems!!!!

Key:
Little progress
Progress
Good progress

Here's a start at a must-do list for the future

- CATALOGS AND DATA SEARCHES: The PDS, missions, investigators, & users are working hard to create user-friendly, self-explanatory, comprehensive tools for finding and retrieving data; *they're better now, but we're not there yet!*
- SENSOR MODELS: We need PDS standards to describe/deliver sensor data. Building sensor models (e.g., camera models) can be an expensive, time-intensive task. Semiautomatic generation of sensor models from these archives is a goal.
- UPCs: The IAU-PDS-NASA that jointly share the essential expertise and authority need to establish standards for planetary coordinates (UPCs) and ***enforce*** their adoption by all NASA mission investigators.
- *An important task of this Workshop must be to expand this list to capture all the crucial needs we can now identify for the next decade!*

If advances over the next 30 years are as productive as the last, our 2042 Data Workshop will be truly mind-boggling!!



SEE YOU THERE!!!