Mars Exploration Program:
Expected Data Volumes and Data Access Requirements for Research and Public Engagement

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1. Executive Summary

The Mars Exploration Program (MEP) encompasses a series of missions with launches through at least 2005. Plans also exist for missions beyond 2005, including the 2007 Smart Lander and associated rover, Mars Scouts, and, eventually, Mars Sample Return (MSR). MEP missions have produced and will continue to produce large volumes of data that present challenges for archiving and distribution, along with opportunities for breakthrough research and unprecedented ways of engaging the public. Specifically, Mars Global Surveyor will produce approximately 1,200 gigabytes of data after the extended mission finishes in April 2002. Odyssey is projected to produce over 2,500 gigabytes of data by 2004, MER 26 to 105 gigabytes in 2004, and MRO over 64,000 gigabytes by 2008. Based in part on planetary science community input, we recommend that data distribution move to a mixture of online and on-demand hard media (e.g. DVDs). Further, we recommend sharing the excitement of exploration and discovery with the public by quickly releasing raw and derived data in ways that enable a true sense of participation in the missions.

2. Mars Exploration Program

The Mars Exploration Program is a long lasting series of Mars Missions over at least the next decade aimed at exploring ancient climatic conditions on the red planet, looking for evidence of life, and establishing the availability of water. Mars Global Surveyor (MGS), the first in the series of MEP missions, was launched in November 1996. The Standard Mapping Mission lasted from March 1999 until January 31, 2001. The Extended Mission began immediately following the conclusion of the standard mission and will last until April 2002. The Mars Odyssey Orbiter was launched April 7, 2001, and will conduct mapping from January 2002 through June 2004, and relay data through at least September 2005. The two Mars Exploration Rovers (MER) will be launched in spring and summer 2003 and will conduct surface operations in two separate locations for a 90-sol Primary Mission and a possible additional 90-sol Extended Mission in early 2004. The Mars Reconnaissance Orbiter (MRO) is scheduled to launch in August 2005 with a Primary Mission lasting from December 2006 to December 2008. Plans are now underway for the Smart Lander mission in 2007, with precision landing to an exciting location, lander-based measurements, and an all-terrain rover capable of exploring "difficult" terrain. Mars Scout mission concepts are also under study, with an initial Scout slated for 2002.

For background, a timeline of the missions through MRO is shown in Figure 1, and the instruments for MGS, Odyssey, MER, and MRO are described in Tables 1—4.

2.1 MGS

Mars Global Surveyor proved to be a highly successful mission, producing nearly 600 gigabytes of telemetry, experiment data records (EDRs), and reduced data records (RDRs) by the end of its Standard Mission (January 31, 2001). The Extended Mission began February 1, 2001 and will continue through the spring of 2002. The total volume of data returned is expected to be approximately the same as that of the Standard Mission.

Telemetry, EDR, and RDR data delivered to the PDS as of January 31, 2001, from the Standard Mission are summarized in Table 5 and plotted in Figure 2. Note that the table and graph show that approximately 282 gigabytes of data had been delivered to PDS by the end of the Standard Mission; however, not all Standard Mission data have been delivered yet, since deliveries occur three to six months after acquisition. The estimate of 600 gigabytes for the total volume of Standard Mission archives is a projection based on previous deliveries.

2.2 ODYSSEY

The Mars Odyssey Orbiter was launched on April 7, 2001, will arrive in October 2001, and will begin its science mission in January 2002. The science mission will last 917 days until June, 2004. The Mars Radiation Environment Experiment (MARIE) will operate for the duration of the mission; its purpose is to characterize aspects of the Martian near-space radiation environment. Due to instrument requirements, the Thermal Emission Imaging System (THEMIS) and Gamma Ray Spectrometer (GRS, with neutron spectrometer and high energy neutron detector) instruments will not operate for the entire duration of the science mission. THEMIS will have two periods of high quality data gathering, from December 2001 through October 2002 and from September 2003 through June 2004, the end of the science mission. THEMIS consists of two components, the IR camera and the VIS camera. GRS will commence operation in March 2002 and continue until the conclusion of the science mission. After the science mission, the orbiter will operate for 457 days in a relay-only phase, ending in December 2005.

The Odyssey instruments will return an unprecedented amount of data, the majority of which will come from the THEMIS instrument, intended to determine the surface mineralogy of

Mars. It is estimated that the primary, relay, and extended mapping mission downlink returns for THEMIS alone will be 242 gigabytes. Estimates for processed data from primary and extended missions could be as much as 5 terabytes for the THEMIS instrument alone. The GRS is estimated to produce 8.5 gigabytes telemetry data, processed into 17 gigabytes of EDRs and RDRs for the primary mission. The Mars Radiation Environment Experiment (MARIE) should downlink 0.31 gigabytes during the primary mission, processed into 0.62 gigabytes.

This large amount of data requires a re-evaluation of standard methods for archiving and distributing such large quantities. Total telemetry, EDR, and RDR data volumes for the mission are provided in Table 6.

2.3 MER

The Mars Exploration Rover mission is scheduled to launch two rovers in spring 2003 that will land in the winter of 2004. These rovers will land in different locations on the surface to traverse across Mars and collect scientific data. Each will contain identical Athena Science Payloads. A deployable mast houses Pancam and Navcam to image the surface and Mini-TES, a thermal emission spectrometer. Mounted on the deployable arm are two spectrometers, APXS (Alpha Particle X-Ray Spectrometer) and Mössbauer, along with a Microscopic Imager and a Rock Abrasion Tool. Hazcams are rover-mounted and will be used to aid in obstacle avoidance. Suncams will be used to determine rover orientation.

The two rovers will downlink data using a daily Direct to Earth (DTE) link in addition to a UHF link to the Odyssey orbiter. For the nominal return scenarios, the two rover missions combined could return as much as 0.87 gigabytes total data in their primary 90-sol missions. If both rovers have extended missions lasting an additional 90-sols each, then the total return could be roughly 1.75 gigabytes. Extremely optimistic outcomes could result in another doubling of the data return, or 3.5 gigabytes. For purposes of this document, we will use an expected telemetry range from 0.87 to 3.5 gigabytes. After processing the telemetry data, assuming an expansion factor of 30, the total MER data volume would be in the range of 26.3 to 105 gigabytes.

2.4 MRO

The strawman payload for MRO includes an atmospheric sounder, wide and medium angle cameras, visible and near-infrared imaging spectrometer, high-resolution imager, and a sub-millimeter sounder. Data return rates of 1.5 —13.8 gigabytes per sol are expected, for an average data downlink of 4 gigabytes per sol. The telemetry returns would be 3,091 gigabytes for the entire Primary Mission. Using expansion factors of 20—100, the possible processed data volume ranges from 61,820—309,100 gigabytes of data.

2.5 Summary

Plans for missions in 2007 and beyond are taking shape now. As noted, proposals include Mars Scouts and the Smart Lander and associated rover. The data volumes depend on the payloads, robots, and landers selected. Even without including missions beyond MRO, or missions flown by our international colleagues, it is clear that data volumes will grow dramatically in the next several years (Table 7 and Figure 3).

3. Data Distribution Challenges and Opportunities

3.1 Overview

The dramatic growth in data volumes demands that new approaches be utilized for data access. New opportunities are also opened, particularly for the engagement of the public. In this section planetary research community desires are summarized, and new paradigms are recommended for data access for research, education, and outreach.

The first step in developing a new strategy for data distribution was to survey the planetary science community regarding their needs and desires for the distribution of data. In February 2001, users of Mars Global Surveyor data were sent a letter inquiring about the frequency of their use of the distributed CD-ROMs and about their willingness to switch to DVDs or online distribution for the Extended Mission due to the quantity of data and the high cost of CD distribution. PDS users responded to an online questionnaire regarding which PDS data nodes they used and proposed PDS changes, such as moving to DVD or online data distribution and improving the PDS online search capabilities. The NASA Regional Planetary Image Facilities (RPIFs), who have long been repositories of planetary data and who serve the planetary science community, were also queried. Finally, an informal person-to-person survey was conducted at the Lunar and Planetary Science Conference in March 2001.

3.2 MGS Users

MGS Standard Mission data users were asked to reply to the following questions:

- Would online access to the MGS Extended Mission data be adequate for your work?
- Do you frequently use the copies of MGS CDs you have received to date? Which data sets are important to you?
- Would DVD distribution be an acceptable alternative or augmentation for online distribution?
- Do you have any other comments?

Results from the 46 responses are summarized in Table 8 and Figure 4.

Overall, the users of the MGS Standard Mission data are willing to switch away from CDs to online and/or DVD data distribution, with DVDs being the favored option. Of those preferring one method to the other, the DVD-only faction was much more vocal about their reasons for opposing online distribution. Several respondents cited a slow PDS server for their opposition to online data distribution. In addition to concerns over time required to download data, many commented that online data distribution needs to improve search capabilities to allow researchers to search based on specific constraints, especially using location or time as parameters. Those preferring online distribution over DVDs cited storage space concerns and infrequent use of MGS data as reasons for their opinions.

3.3 PDS User Survey

Recently, the PDS asked the planetary science community to answer a number of questions regarding the usefulness of the PDS and to respond to proposed changes to operations of the PDS. This document focuses on responses regarding PDS-proposed improvements. Results are summarized in the Table 9 and Figure 5.

Fifty-two percent of respondents believe DVD would be a useful means to distribute data. Eighty-three percent favor using the Internet as a means of data distribution, and no one believes this means would *not* be useful. Eighty-two percent see the need for a better web interface, with 85 percent supporting finer-grained searching capabilities. While several were not sure as to the need to improve web distribution capabilities, none negated the proposed improvements. Sixty-eight percent expressed interest in the ability to order custom data collections. Overall, the PDS survey shows that users strongly support online data distribution and also believe that improving the web system would be very beneficial.

3.4 RPIF

From discussions with members of the RPIF community, a very different sentiment is evident. The RPIFs receive data from all NASA planetary missions via the PDS, and make it available to scientists who use their facilities. (The RPIFs themselves do not distribute data.) As recipients of planetary data, RPIFs favor hard media (i.e. CDs and DVDs) over online access. They do not trust the Internet's capacity to adequately provide them with Mars Mission data. Concern centers around slow downloading, unreliable Internet connections, and costs of local storage. They still see a need for possessing hard copies of all data and therefore would feel the need to download all data sets and produce their own hard copies if data were distributed solely online. This process would require computer resources such as hard disk space and CD and DVD writing equipment, since downloaded data would most likely then be transferred to hard media by each RPIF.

3.5 LPSC Informal Survey

PDS representatives conducted an informal survey of participants of the Lunar and Planetary Science Conference, March 2001, by asking their preferences regarding data distribution on CDs, DVDs, and online. Results tended to reinforce the responses to the MGS data users' survey. Most participants recognized that CD-ROM distribution was rapidly becoming inadequate, and preferred to use online access or DVDs, with a slight majority favoring DVDs. Several users said that they would probably use both DVDs and online access.

3.6 Conclusion

From information collected from the planetary science community, specifically those currently using PDS, users recognize the need for new distribution methods as data volume increases. MGS data recipients prefer DVD distribution, though online distribution followed close behind. Surveyed users of the PDS favor online data distribution. RPIFs tend to distrust online distribution and prefer the use of hard media. Overall, online data is necessary due to large volumes of information. The online option would be most favorable if search functions were refined and download time reduced.

4. New Paradigm for Data Access for Research and Engagement of the Public

4.1 Why The Need for a New Paradigm

Over the past ten or fifteen years, since the inception of the Planetary Data System, the focus of NASA data providers has been on ensuring complete, high quality, stable archives of science data acquired by planetary missions. Recognizing that planetary data archives are a valuable and irreplaceable resource, the PDS and data providers have expended great care and effort on archive design, standards, documentation, and overall quality control. These efforts have resulted in an archiving system that is now well-established and mandated for use by all NASA planetary missions. However, tools to help users identify, locate, obtain, and read the archives have often been provided on a best-efforts basis, due to limits on resources and technology. It was expected that the user would bear at least part of the burden of these tasks, thus effectively limiting data access to those scientists with sufficient technical resources. While this situation has been gradually improving over the years, the time has come for a leap forward in making planetary data accessible.

While generating reliable *archives* remains the highest priority for science data providers, two changes have made the issue of reliable data *distribution* more pressing than ever before. First, planetary missions are returning ever-increasing volumes of science data, as demonstrated earlier in this document. The cost of distributing these new, larger archives on CD-ROMs or DVD-ROMs is becoming prohibitive; further, the resulting thousands of volumes of media would be highly impractical to use. Second, advances in the World-Wide Web and improvements in computer technology available on every desktop have made instant access to information the norm. Users' expectations are much higher now than before.

Another important issue is the question of what kinds of data are made available for archiving and distribution. In the past, some data providers have limited their deliveries to EDR products alone; that is, raw, uncalibrated data products that require the application of some basic processing steps before they can be scientifically useful. This practice presents yet another obstacle to those scientists who do not have the resources to invest in generating their own derived products from the EDRs. It is unreasonable to expect each user to study the intricacies of instrument operation and develop data-set-specific processing software; at best it promotes an unnecessary duplication of effort, and at worst it leads to inaccurate interpretations of the data based on faulty processing. A more efficient and practical approach would be to provide the processed data products to the user, either by requiring the data provider to deliver them with the EDRs, by incorporating into the distribution system the capability to generate processed data upon request, or by including processing software and instructions with the EDR products.

Clearly the time has come for a new paradigm for the distribution of planetary science data. As a guideline for the development of new policies, we propose the statement below, with specific recommendations in the sections following.

> Data from NASA planetary missions should be made readily available to scientists, educators, and the general public, in ways that reduce or eliminate, as much as possible, barriers between the users and the data. Specifically, users should be easily able to find out what data exist, to select the portions of data appropriate to their needs, and to obtain copies of the selected data for their own use, along with related documentation. Finally, visualization tools and other tools for examining the data should be made available.

4.2 Education and Public Outreach Opportunities

An added advantage to improving data accessibility for science users is that the same improvements can be extended to the general public. In fact, this change of paradigm is an unprecedented opportunity for education and public outreach. Properly implemented policies for early release of data on the Internet, availability of easy-to-use Web-based tools for data access and visualization, and a strong, consistent outreach program could all be used to engage the public's interest, evoking a sense of participation in the adventure and discovery of active planetary missions as never before. It can happen only with a firm commitment from participants at all levels.

4.3 General Recommendations

Online access to planetary data should be the primary method for data distribution. For online access to work, better access tools must be provided to help users find what data exist, narrow it down to their areas of interest, and get it into their hands. If users are to rely on online access alone instead of having their own copies of data, then the systems that provide this access must be committed to a high standard of reliability. The goal should be data availability at all times, 24 hours a day every day, with quick response to problems. Speed of access should be optimized via high-speed network connections and server hardware. Access tools should include the ability to search for data products across different instruments and across missions.

Data should be made publicly available as soon as possible. Currently most missions incorporate a data preparation and validation period, typically six months after acquisition, before the data must be released. The purpose of the delay is to give investigators time to ensure the quality of their archives, and this rule should still apply. However, it should not prevent the quick release of EDRs and RDRs specifically generated for public engagement, if possible within days of downlink.

Even though online access is the primary distribution method, copies of data on physical media should be made available to users on demand. These may be "custom-designed" volumes containing only selected data of interest to the user, or they may be copies of standard archive volumes. (It is understood that while data distribution may occur primarily online, archival copies of data must always exist on physical media.) Custom volumes should typically be made on write-once media, e.g. DVD-R or CD-R. Copies of standard archive volumes can be made on either write-once or factory-produced media (DVD-ROM or CD-ROM), whichever is more cost-efficient.

Users should have access to the kinds of data that fit their needs. Different groups of users have different data requirements. These groups may include people involved in mission operations, planetary scientists outside the mission, educators and students, and the general public. For example, scientists should have access to derived data products if the raw data are not in a form that permits scientific analysis. Educators and the public should have access to data products intended specifically for their use.

"Special collections" containing data of high interest should be published on physical media. For example, derived data products such as global maps would be candidates for such a publication. These would typically be published on factory-produced media for wide distribution.

4.4 Recommendations for Specific Missions

4.4.1 MGS

For the Standard Mission, the majority of data sets were distributed as CD volumes and online. For the Extended Mission, we recommend a combination of online and DVD distribution. The MGS Archives web site (http://wufs.wustl.edu/missions/mgs, with links to MGS data online at various PDS nodes) and the Planetary Image Atlas (http://www-pdsimage.jpl.nasa.gov/ PDS/public/Atlas/Atlas.html) should continue to be the primary tools for online distribution of all MGS data sets. MOC, MOLA, TES and MAG/ER data sets should also be distributed on DVD-ROMs to the planetary scientists who have signed up to receive MGS data.

4.4.2 Odyssey

For Mars Odyssey Orbiter, data distribution should involve a combination of online, DVD, and CD data distribution for the MARIE, GRS, and THEMIS instruments. All Odyssey products should be accessible online. The volume of MARIE data will probably be small enough to be distributed on two or three CD-ROMs. For GRS, raw and processed spectra should be made available on DVD-Rs upon request, and more highly derived map products (a very small volume) should be distributed as a special collection on CD-ROM. THEMIS DVD-Rs should be custom produced as consumers demand specific products. In order to accommodate distribution of the large volume of expected data, Arizona State University (THEMIS) and University of Arizona (GRS) are expected to host PDS data nodes to handle distributing and archiving the data from their respective instruments.

4.4.3 MER

It is recommended that data acquired by the two MER rovers be available both online and via DVD-ROM media. Subsets of the archive will be available online through JPL's Planetary Atlas and Planetary Photojournal. The archives will also be accessible online and on DVDs using the Analyst's Notebook concept developed by Washington University. The Notebook provides interfaces for operational, professional, student, and public users. It provides access to all mission data organized by time, by specific instruments, and by targets encountered.

4.4.4 MRO and Beyond

Data from the Mars Reconnaissance Orbiter, and from future missions such as the proposed 2007 operations, should be released according to the policy outlined above. Specifically, the primary method of distribution should be online, with DVDs or CDs available on demand. Special edition DVDs or CDs containing data of widespread interest should also be released.

Table 1. MGS Instruments

INSTRUMENT	DESCRIPTION
MAG/ER (Magnetometer/Electron Reflectometer)	Up to 16 magnetic field vectors per second. Electron reflectometer determines electron pitch angle distribution, field strength, and altitude dependence of field. Continuous operation.
MOC (Mars Orbiter Camera)	Wide angle imaging able to generate global map in one Sol with 7.5 km/pixel resolution. Wide angle for regional imaging with 250 m/pixel resolution at nadir. Global imaging using blue or red filters. Narrow angle (NA) cross track widths with 1.4m/pixel resolution. NA images are accompanied by simultaneously acquired WA context images.
MOLA (Mars Orbiter Laser Altimeter)	Distances from spacecraft to nadir surface locations with vertical resolution of several meters. Surface reflectivity at 1.06 micrometer from backscattered power. Operates continuously at 10 pulses/second.
TES (Thermal Emission Spectrometer)	Emitted radiance from 6.25 to 50 micrometer from surface and atmosphere with 10 cm^{-1} (apodized) resolution; solar radiance from 0.3 to 3.9 micrometers; broadband radiance from 0.3 to 100 micrometers. Three kilometer field of view at nadir. Nadir observations; fore and aft surface observations to vary emission angle; limb observations.
RS (Radio Science)	Radio occultation measurements of polar atmosphere to obtain profiles of refractive index, number density, temperature, and pressure for lowest several scale heights. Atmospheric scintillation measurements also obtained. Radio tracking of spacecraft for information on gravitational field. Orbital decay due to air drag by analysis of spacecraft orbital evolution.
ACCEL (Accelerometer)	Atmospheric density measurements obtained during aerobraking.

Table 2. Odyssey Instruments

INSTRUMENT	DESCRIPTION
THEMIS (Thermal Emission Imaging System)	THEMIS will determine the mineralogy of the Martian surface using multi-spectral, thermal infrared images that have 10 spectral bands between 6.5 and 14.5 micrometers. It will also acquire visible-light images with 20 meters per pixel resolution in either monochrome or color.
GRS (Gamma Ray Spectrometer)	GRS will perform full planet mapping of elemental abundance with an accuracy of 10% or better and a spatial resolution of about 300 km, by remote gamma ray spectroscopy, and full planet mapping of the hydrogen (with depth of water inferred) and CO_2 abundance by remote neutron spectroscopy.
MARIE (Mars Radiation Environment Experiment)	MARIE will measure the accumulated absorbed dose and dose rate tissue as a function of time, determine the radiation quality factor, determine the energy deposition spectrum from 0.1 keV/µm, and separate the contribution of protons, neutrons, and HZE particles to these quantities.

Table 3. MER Athena Payload

INSTRUMENT	KEY PARAMETERS	PURPOSE
Mast Mounted		
Pancam	Eleven filters (0.4 to 1.0 ìm) for stereoscopic multispectral imaging plus two color solar ND filter imaging; 0.28 mrad IFOV; 16° by 16° FOV	Detailed imaging of surface for geologic and topographic characterization; atmospheric optical depth and scattering properties
Navcam	Monochrome stereo imaging, 0.77 mrad IFOV, 45°x45° FOV	Acquires panoramas for traverses and Instrument Arm deployment support
Mini-TES (Thermal Emission Spectrometer)	Emission spectra (5 to 29 ìm, 10 cm^{-1} resolution) with 8 or 20 mrad FOV	Mineralogical mapping of key targets identified using imaging data; thermophysical properties of surfaces; determination of pressure, temperature, water vapor profiles
Arm-Mounted *In-Situ* Package		
APXS (Alpha Particle X-Ray Spectrometer)	244Cm alpha particle sources, solid-state alpha and X-ray detectors, FOV 4 cm in diameter	Elemental abundances for rock and soil targets
MB (Mössbauer Spectrometer)	^{57}Fe spectrometer in backscatter mode; Co/Rh source and Si-PIN diode detectors; field of view approximately 1.5 cm^2	Identification of iron-bearing minerals and iron oxidation states
MI (Microscopic Imager)	Monochrome imaging, 30 ìm per pixel, 3x3 cm FOV, 6 mm depth of focus	Close-up imaging of texture and mineralogy of surfaces
RAT (Rock Abrasion Tool)	Capable of removing up to 5 mm of rock from a circular region 4.5 cm in diameter	Remove dust, loose debris, weathered material, and surface coatings from rock, exposing fresh rock for analysis by instruments
Body-Mounted		
Hazcams	Monochrome stereo imaging, 2.0 mrad IFOV, 120°x120° FOV	Front and rear stereo cameras used for hazard avoidance during traverses and for planning purposes
Suncam	Monochrome ND Filter imaging, 0.82 mrad IFOV, 45°x45° FOV	Determine rover orientation and tilt given time of day

Note: Navcam, Hazcam, and Suncam are engineering instruments, but will be archived with Athena data.

Table 4. MRO Strawman Payload

Proposed Element	Function	Description/Capabilities
Pressure Modulator Infrared Radiometer (PMIRR-MkII)	Atmospheric Sounder - Water vapor mapping	High vertical resolution (~5 km), polar energy balancing capability, profile atmospheric dust. Design improved from that of MCO, eg. <10 kg.
Mars Color Imager (MARCI) Wide Angle (WA) camera	Low-spatial resolution; helps characterize Martian weather; provides context for atmospheric sounders.	Rebuilt MCO instrument. 2 UV channels – one to map atmospheric ozone, another with several color channels to help separate dust from water ice
MARCI Medium Angle (MA) camera	To be a facility experiment to ensure context imaging for a high-resolution imager and an imaging spectrometer	Three-color imager w/ spatial resolution of 7.5 m/pixel from 400 km altitude and swath width of 40 km.
Visible near-infrared imaging spectrometer (VISNIR)	Able to identify unambiguously key aqueous minerals of interest.	0.4 – 3.6 micron wavelength range with 10 nm spectral sampling at wavelengths 20 nm sampling at other wavelengths. Signal-to-noise SNR>400 at 2.3 microns for representative targets (albedo of 0.3 at 30°phase angle); spatial footprints 50 m/pixel from 400 km with a required typical target swath size 10 km downtrack and crosstrack, with 20 km x 20 km desired.
High- Resolution Imager (HRI)	High-resolution imaging of ~1% Martian surface	SDT recommends 60 cm/pixel from orbital altitude of 400 km and 30 cm/pixel from 200 km. Swath widths at least 3 km, with 4-6 desired.
Subsurface Sounding Radar	Subsurface sounding capability to detect water and profile ice.	1 km into subsurface, 10 m vertical resolution sounding required (~ 5 km with 100 m vertical resolution desired).
Submillimeter Atmospheric Sounder	Complimentary to PMIRR-MkII. Sounding for water and temperature without affects from atmospheric dust.	Limb or nadir with vertical resolution of order 10 km and an extended altitude range of 0-100 km. May also measure wind at precision of ± 15 m/s at 2-3 levels about 40 km altitude.

Table 5. Cumulative Raw and Derived Data Delivered to PDS for Each MGS Instrument as of 1/31/01

Instrument	Standard Mission Data Returns (Gbytes)
MOC	97.36
MOLA	30.70
TES	62.11
MAG/ER	22.04
RS	66.77
ACC	0.20
SPICE	3.45
TOTAL	282.63

Table 6. Expected Data Returns for Odyssey

Instrument	Primary Mission Downlink (Gbytes)	Estimated Derived Data Volume, Primary Mission (Gbytes)
THEMIS	117.75	2500
GRS	8.5	17
MARIE	0.31	0.62
TOTAL	**126.56**	**2517.62**

Table 7. Estimated Data Volumes for Mars Program

Mission	Instrument	Telemetry Data (Gbytes)	Processed Data (Gbytes)	Comments
MGS Primary		110	600	PDS estimates
MGS Extended		110	600	Assumed to be similar to Primary Mission
Odyssey*	THEMIS	117	2500	Primary mission only
	GRS	8.5	17	Downlink from archive plan, processed 2x downlink
	MARIE	0.31	0.62	Downlink from archive plan, processed 2x downlink
MER		0.87 - 3.5	26.3 - 105	Based on nominal mission of 90 sols, maximum mission of 180 sols
MRO		3091	61830 - 309100	36 Gbits / Day, 687days for downlink, processed 20x - 100x

Table 8. Results of MGS Data Users Survey

	Yes	No	No answer	N/A	% Yes
Online access okay?	32	12	2		73
Use CDs Frequently?	28	10	7	1	74
DVDs acceptable?	35	7	4		83

Table 9. Results of PDS Users Survey

	Very Useful	Somewhat Useful	Not Sure	Not Useful
Data Distribution on DVD	22	12	25	6
All Data Distributed on the Internet	43	11	11	0
A Better Web Interface	43	10	12	0
Finer-grained Searching	40	15	10	0
Ordering Customized Collections of Data	22	22	17	4

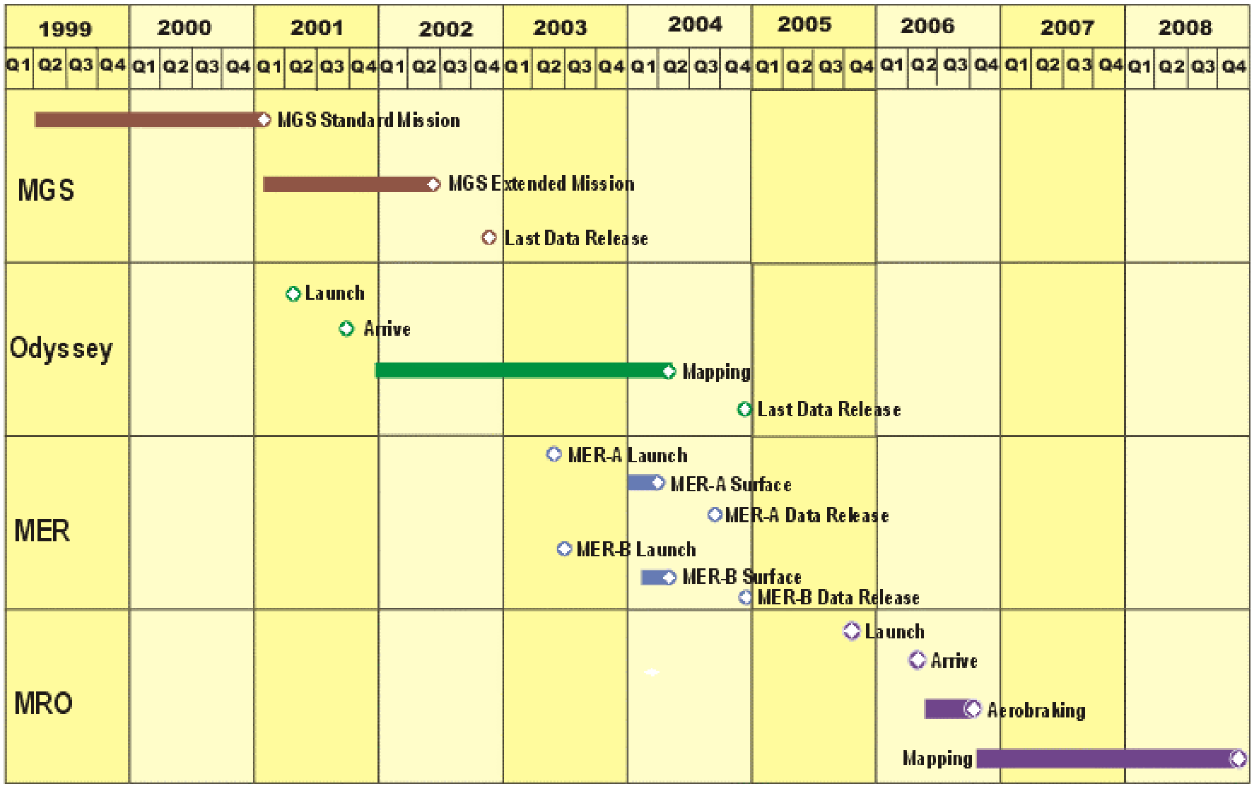

Figure 1. Mission Timeline

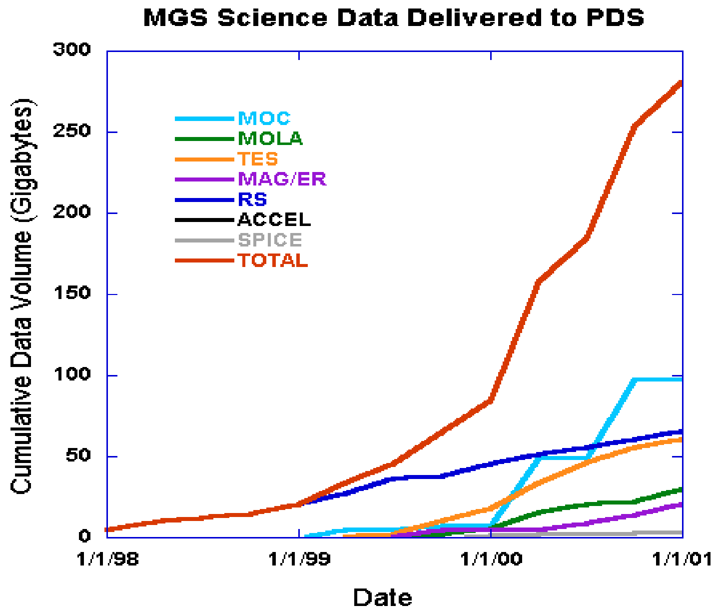

Figure 2. Total MGS raw and derived data delivered to the PDS as of January 31, 2001.

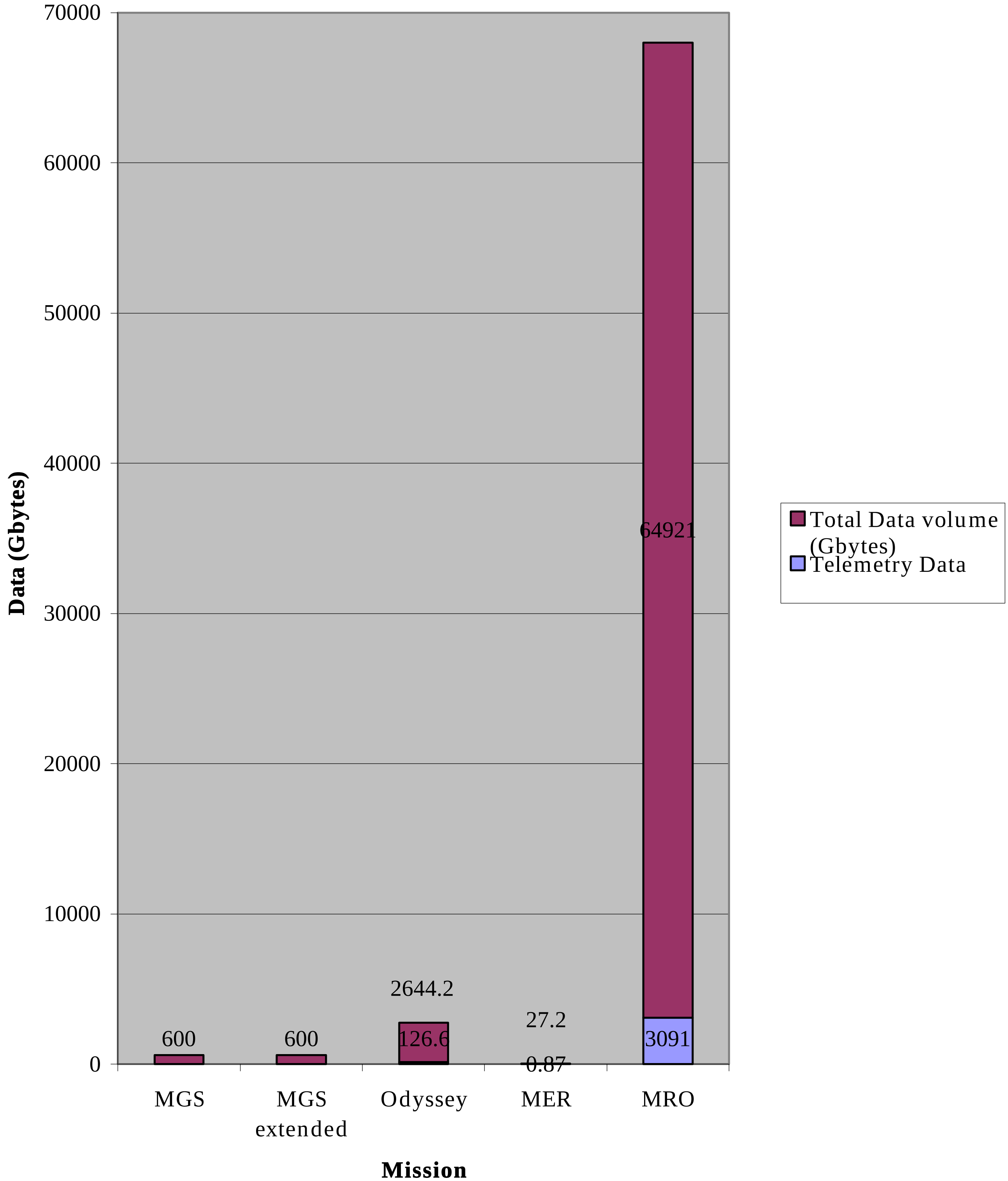

Figure 3. Downlink and processed data volumes for MEP.

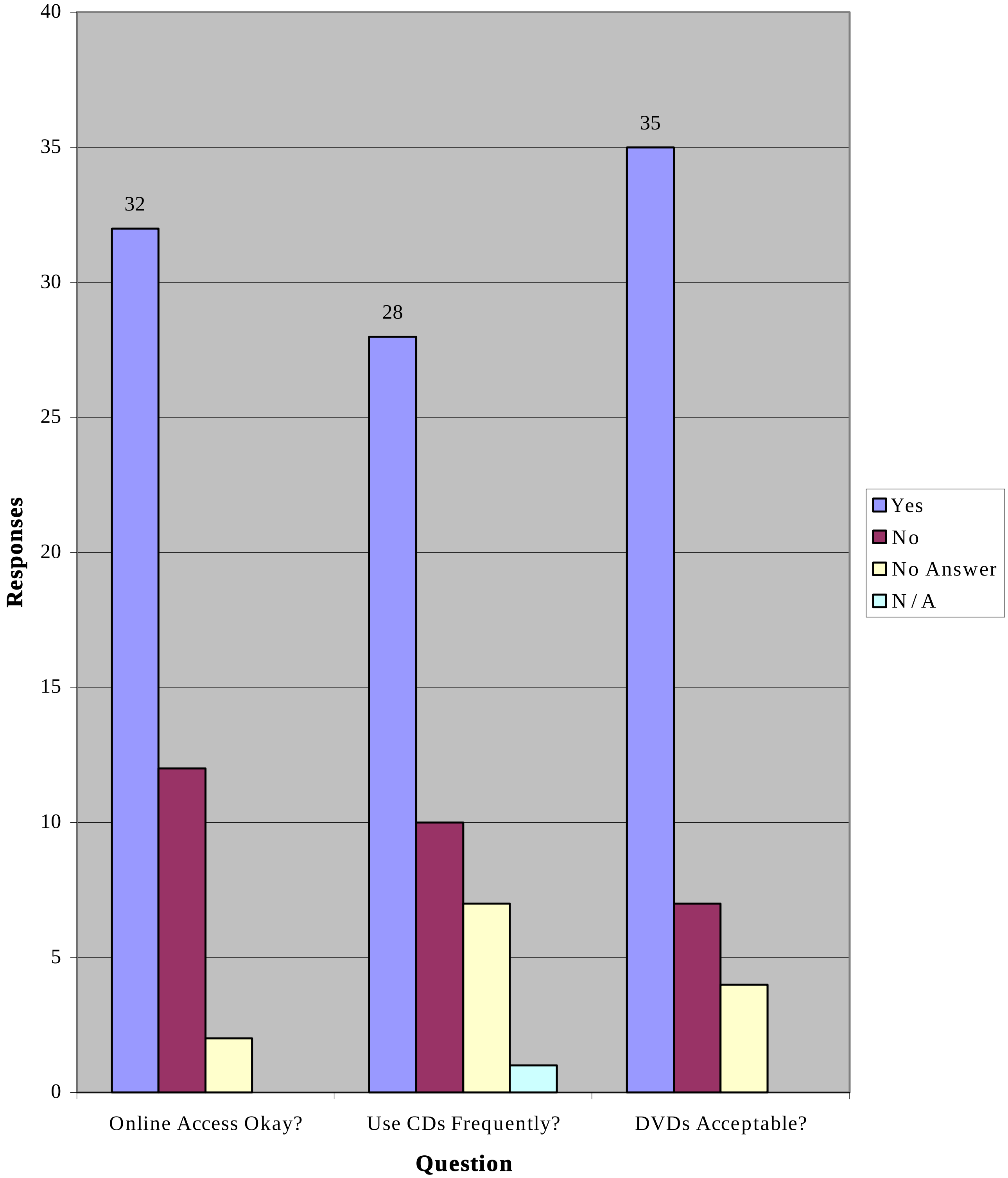

Figure 4. Results of MGS Data Users Survey

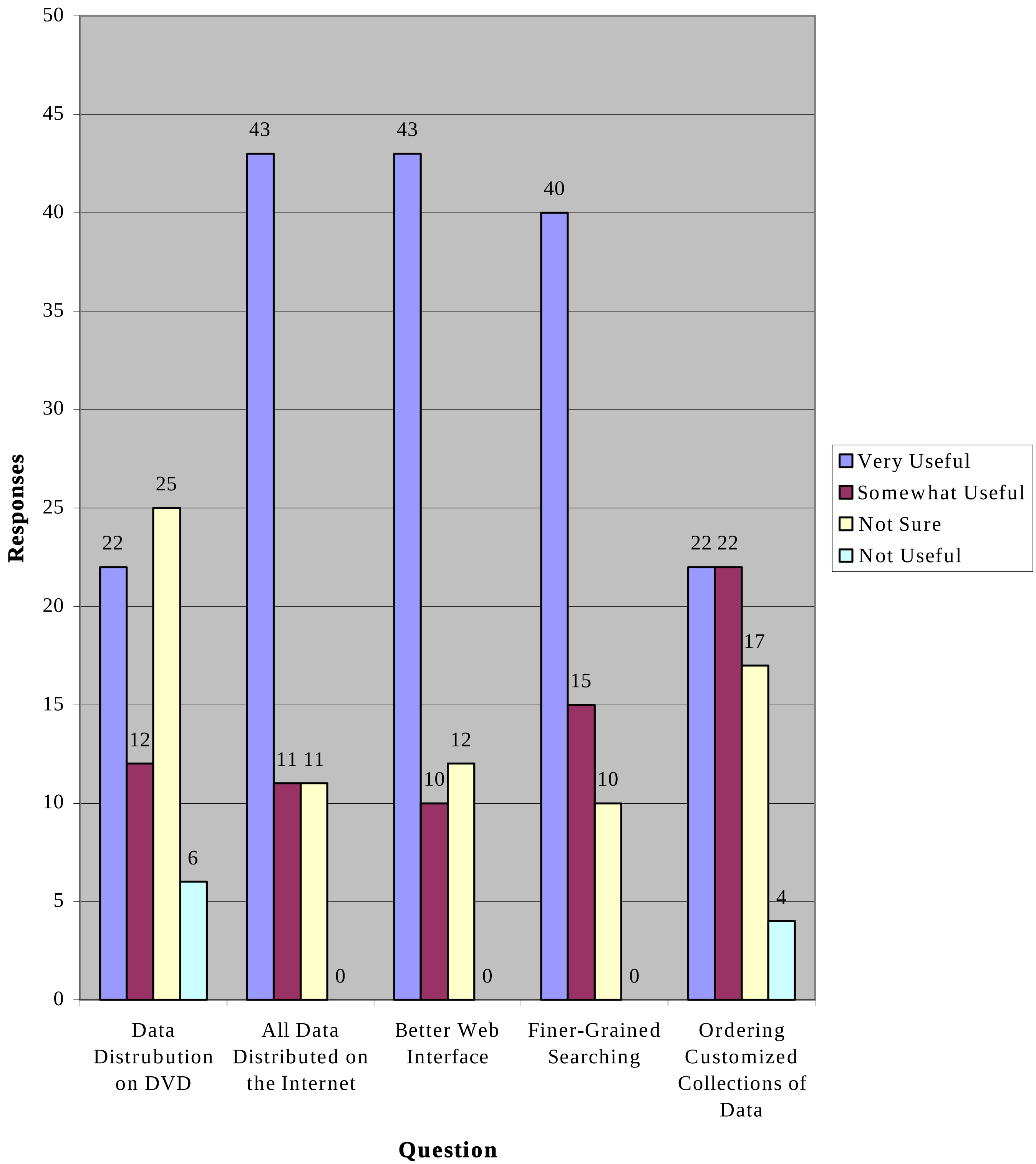

Figure 5. Results of PDS Users Survey

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