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DATA-LINK ALTERNATIVES FOR THE NASA PILOT DATA SYSTEMS

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SUMMARY

There are several preliminary, or Pilot, efforts for developing data systems for supporting NASA science research. The Pilot Data Systems consist of the Pilot Land Data System (PLDS), the Pilot Ocean Data System (PODS), the Pilot Climate Data System (PCDS), and the Pilot Planetary Data System (PPDS). The Pilot Data Systems will transition into operational systems in the 1990s. The PLDS is likely to have the greatest communications needs of the various Pilots. Communications issues and requirements are examined here in the context of the mature PLDS as it may exist by 1990. PLDS is seen as a distributed processing system linking resources at a number of NASA research centers and outside universities. Large image data sets, including Landsat Multi-Spectral Scanner (MSS) and Thematic Mapper (TM) scenes, are a major data type to be moved along the PLDS communications network. The unusually large size of these data files requires examining new technologies that may allow efficient and affordable communication at rates of up to 60 megabits per second. Potentially useful developments include portable satellite ground stations, and Time Division Multiple Access for sharing high-speed satellite links. PLDS alone, or any other single data system, is unlikely to justify operational access to these services due to cost. Future pooling of communications for the various data systems into a single network would reduce costs and may make economic justification of access to the required data rates possible.

INTRODUCTION

There are several "pilot" (i.e., prototype) efforts now under way to build new computerized data systems in support of NASA research. They are the Pilot Land Data System, the Pilot Climate Data System, the Pilot Ocean Data System, and the Pilot Planetary Data System. These projects are intended to build prototypes of the systems to be operational in the mid-1990s. The latter will be designed to support Earth and planetary science research activities within NASA by providing user-friendly comprehensive data management and analysis tools to science researchers. This will free the researchers from the need to spend much of their time conducting data processing rather than research, a pressing current problem.

Most of the communications needs for the NASA Pilot Data Systems can be attributed to requirements for the Pilot Land Data System (PLDS). Therefore, this initial analysis focuses on defining appropriate data link specifications for the mature PLDS communications network.

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The PLDS, unlike the other Pilot systems, is envisioned as a distributed, rather than centralized, data management system (NASA, 1983; Working Group, 1984). The system is intended to link computer processing facilities at five NASA Centers that are actively involved in Earth science research: Ames Research Center (ARC), Moffett Field, Calif.; Goddard Space Flight Center (GSFC), Greenbelt, Md.; Jet Propulsion Laboratory (JPL), Pasadena, Calif.; Johnson Space Center (JSC), Houston, Tex.; and National Space Technology Laboratory (NSTL), Bay St. Louis, Miss. Each NASA Center will act as one node of the PLDS network and as a network port for a number of universities and other institutions.

Within the next 2 yr the five NASA Centers are to be linked, as well as several universities. A more mature version of the network, connecting an undetermined number of sites, is envisioned for creation by 1990. For the purposes of this report, approximately 60 remote users are assumed (12 per NASA host), with these being linked into the PLDS through the five NASA network hosts (fig. 1). By 1995, the PLDS will have evolved into its final form--an operational Land Data System. During the total developmental period, extensive application-specific software will be written in the areas of geographic information processing, database management, image processing, and artificial intelligence.

SCOPE OF THIS REPORT

To limit the scope of the problem, assumptions are made for many system design parameters. The focus here will be on the physical data-link alternatives, some cost issues, and a comparison of the level of service (data rates) with response times for the movement of individual data sets.

NETWORK DESIGN ASSUMPTIONS

This report examines the design of a mature PLDS communications system, assumed to be operational by 1990. The five NASA Centers are the assumed hosts for all system activity, while some applications processing will be unloaded to local workstations. An approximate conceptual structure for the logical links within the network is already defined. This structure consists of a long-haul network between the NASA Centers, with regional lines connecting remote users to designated NASA Centers. The long-haul network is conceived as a full-mesh structure connecting all the Centers via satellite or ground lines. The linking of remote users to the designated hosts can be considered to be five regional star networks. A general schematic of the connections required is shown in figure 1.

Each host is assumed to have a DEC VAX computer to act as "gateway" into the network. The gateway computer will interface with the other host installations and be accessible as a port facility by outside users. The gateway at each Center will also be interfaced with a local area network (LAN). The LAN at each Center will allow local NASA users to access the network and outside users to access bulk processors (Class VI computers in the 100- to 250-million instructions per second (MIPS) range) existing at several of the NASA Centers. While consideration of the structure of individual LANs falls outside the scope of this report, they are assumed to be transparently accessible through the VAX gateways.

In addition to the gateway VAX computers, appropriate hardware (including modems, multiplexers, concentrators, and satellite receiving stations) will be required by the network. These items are not considered in the present report. They will be supplied as part of the overall link which will be procured on a performance basis.

An assumption is made that each NASA host will support 12 remote users (mostly universities) involved in NASA research activities. This requires that some form of communication be extended to about 60 remote facilities. Remote users are assumed to be using some type of intelligent workstation or computer operating in the 0.1- to 4-MIPS range. Most users are assumed to have facilities capable of carrying out many operations locally and to have privileges allowing them to bring small- or intermediate-sized data sets (100 kilobits or 336 megabits) to their local processor. Larger data sets are assumed to be sent mostly by magnetic tape or disk, rather than by communication lines between NASA Centers.

In designing the network, the seven International Standards Organization (ISO) communications protocol layers will be considered. For nonsatellite, long-haul communications, the X.25 packet-switching protocol is assumed to be used for the lower three ISO Open Standards Interface (OSI) communications protocol layers (physical, data link, and network protocols). Because X.25 is throughput inefficiently over high-bandwidth satellite links, it is assumed that alternatives using satellite communications will require the selection of special protocols, possibly including forward error correction. DECNET software will be used, at least initially, for the four higher-level protocols. The PLDS will require augmentation of the DECNET protocols to ensure the optimal system transparency and security. Specifically, added session protocols need to be developed to ensure appropriately distributed network control and accounting; data standards (image formats, etc.) need to be established and built into the presentation layer; and some network services, transparency measures, and security augmentation of the applications layer is desirable. These topics are being addressed by PLDS working groups.

The PLDS is to be a distributed system. Already planned is a central data directory at GSFC. Because of organizational considerations and the large size of the planned database, actual data archives are planned to be distributed in nonreplicated form at the various Centers. Data processing will be carried out at the user's workstation whenever possible. Otherwise, facilities available on the network will be utilized.

Data to be transmitted between sites are assumed to fall into four maujor size categories: 2.5 Gbits (full-frame Thematic Mapper (TM) images), 336 Mbits (Multispectral Scanner (MSS) or partial TM scenes), 8.4 Mbits (partial scenes consisting of 4-band, 512- by 512-pixel windows), and 100 kbits (statistics, polygon map files, or mail and other text data).

Several assumptions about system utilization are summarized.

	Data set size			
Number of movement requests per month	2.5 Gbits (TM)	336 Mbits (MSS)	8.4 Mbits (512 x 512 x 4)	100 kbits (text, etc.)
Per host	8	40	400	2400
Total	40	200	2000	12,000

Of the data transport requests listed, only the 100-kbit data sets will be fully movable through all communications lines within the system. Larger data sets will be sent only between the network hosts, or transported via a physical media such as magnetic tape. The assumed loads may appear overly high, but might well be those that actually will be encountered once these communications capabilities are made available.

An additional load assumption is that each remote user will access the PLDS for 30 hr of prime time (between 8 a.m. and 5 p.m.) per month. To simplify the problem, evening loads which, in any case, will tax the system less than daytime use, are not considered.

A 1.544-Mbit/sec link is already being established among the five NASA hosts. There is a need to upgrade these rates to greater bandwidths by 1990, and alternatives for doing so are examined in this report. The link between hosts is eventually expected to support at least the movement of data sets in the 336-Mbit size range. Data sets too large for practical transmission over communications lines will continue to be transported via magnetic tape or other physical media. Most university connections are assumed to require only the capability to move 100-kbit data sets, although a limited number (about 10%) of these institutions will probably acquire higher-capability lines. Alternatives for accomplishing these links can be found in the "design" sections of this report.

HOST-TO-HOST LONG-HAUL COMMUNICATIONS NETWORK DESIGN

Any proposal for long-haul lines among PLDS hosts must be reconciled with NASA policy requirements. Despite the existence of several NASA communications satellites (ATS-1, ATS-3, Tracking Data Relay Satellite (TDRS) East), government regulations require that the PLDS must utilize vendor-supplied lines leased through NASA's Program Support Communications Network (PSCN). Relevant aspects of the PSCN are that some spare line capacity will be available, NASA already leases much of the satellite ground station and other communications hardware that PLDS might need, and the economies of scale are such that adding PSCN lines will result in marginal added costs.

It is possible that the PLDS could conduct communications tests through the NASA NASCOM network, rather than through the PSCN, although this option would require some flexibility in current roles. NASCOM may soon acquire a 60-Mbit/sec inter-Center line with Time-Division Multiple Access (TDMA) burst capability (personal communications with Harry Jones, Communications Engineer, Ames Research Center, Feb. 1984).

TDMA is a useful technology that could provide many benefits if used in a PLDS network. This would be accomplished by leasing a full satellite transponder from a private vendor, purchasing or leasing TDMA equipment to augment existing ground stations, and configuring these facilities into a mesh network. With the appropriate hardware options, the TDMA could accept input data at rates of 1.544, 3, 6, or 12 Mbit/sec; buffer the data; and send it out over the satellite link at a burst rate of 60 Mbit/sec. The use of TDMA, with dynamic allocation of bandwidth among users, allows much more efficient operation than the conventional time or frequency division multiplexing approach in which each user is allocated a fixed bandwidth or time slot. TDMA also allows all users to take advantage, for short periods of time, of the maximum possible bandwidth available over the satellite transponder to achieve faster response times.

Long-Haul Communication Lines

Based on the assumption that response times between hosts must be 15 min or less (to minimize queuing for line use), the minimum-line bandwidths are 1.544 Mbit/sec for MSS and 12.36 Mbit/sec for TM data transfers:

MSS Data Flow

Bandwidth (kbit)	Time (min)
9.6	1,668
56	288
1,544	10.4
12,360	1.3

TM Data Flow

Bandwidth (kbit)	Time (min)
9.6	12,420
1,544	779
12,360	9.6
60,000	2.0

PLDS needs could be met through the acquisition of a permanent 1.544 Mbit/sec link, and occasional burst use of a 12.36-Mbit/sec link. However, this is less desirable than the use of TDMA burst facilities of 60 Mbit/sec which may be installed by NASCOM. Burst transmission of all PLDS communications at 60 Mbit/sec would result in short response times (2.0 min per TM image). The 60-Mbit/sec line should be able to accommodate PLDS traffic using spare capacity, as the PLDS average load can be calculated to be 919 kbit/sec or 1.5%.

If access to TDMA facilities cannot be acquired, either for testing purposes through the NASCOM or on a more permanent basis through the PSCN, then a reasonable alternative is to seek a permanently dedicated 1.544-Mbit/sec line backed up with occasional access to a 12.36-Mbit/sec line. The 12.36-Mbit/sec line would support movement of TM images, which each request taking 9.6 min, assuming the task is not limited by tape input/output (I/O) speeds. Mid- and small-sized data sets, including MSS, four-band, 512 by 512 images, and text files, would travel over the permanent 1.544-Mbit/sec line. There are 14,200 requests per month falling within this volume range or 710 daily requests to the network, at an average 6 Mbits per request. The average response time over the 1.544-Mbit/sec link can be calculated to be 11.1 sec (assuming throughput efficiency is 35%), resulting in 131 min of use per day. Assuming all the load is during an 8-hr day, the line would be busy 27% of the time. This would entail frequent conflicts, but little delay. Contentions of line use would become a problem if TM images were also sent over the 1.544-Mbit/sec line, because they each require 77 min of transmittal time each.

Data Flow

If TDMA burst lines of 60 Mbit/sec are acquired, PLDS communications will be limited only by the speed of the network hosts and their peripherals. Data-flow bottlenecks can occur at three points within the system: (1) between remote users and NASA hosts, (2) between hosts, and (3) between hosts and their I/O devices (tape and disc drives). Flow within the network will be limited by the speed of the slowest communication link. The PLDS communication system must be designed to accommodate peak data loads because, whereas PLDS average loads are low, the peak capacity must be high to ensure adequate response times:

Total Data Volume per Month

40 x 2.5 Gbit =	100,000 Mbit
200 x 336 Mbit =	67,200 Mbit
2,000 x 8.4 Mbit =	16,800 Mbit
12,000 x 100 kbit =	1,200 Mbit
Total	185,200 Mbit

Average Load

$$\frac{185{,}200{,}000\ \text{kbit}}{160\ \text{hr} \times 3{,}600\ \text{sec} \times 0.35\ (\text{throughput efficiency})} = 919\ \text{kbit/sec}$$

Peak Load when Moving One TM Image

Bandwidth (Mbit/sec)	Response time (min)
1.544	77
12.36	9.6
60	2.0

A conceptual diagram of data flow is shown in figure 2. The length of time required to transport the largest standard data set, a TM image (2.5 Gbit), over the various links was shown previously. Clearly, TM data scenes cannot be transmitted over 9.6-kbit/sec lines because of the excessive time (207 hr) needed to do so (assuming 35% throughput efficiency). Any requests by the remote users for TM scenes should be met by mailing them a computer tape. TM transfers at any rate between 1.544 and 60 Mbit/sec would be acceptable between hosts; however, rates over 1.544 Mbit/sec are desirable to prevent excessive response times and line contention.

The long-haul communications could be limited by thespeed of the peripherals at the network hosts. A major concern is that PLDS long-haul communications appear to be limited by tape I/O speeds. Despite drive ratings at approximately 6 Mbit/sec, tape reads of TM currently are done at an effective speed of between 200 kbit/sec when using high-level language I/O (FORTRAN, etc.) and 2 Mbit/sec when assembly language I/O routines are used (determined through tests at Ames). Operation at 2 Mbit/sec (21 min to read a TM image) is marginally acceptable, while operation at 200 kbit/sec (3.5 hr read time) is not. Applications packages using high-level languages for tape I/O should be replaced with assembly routines if the PLDS is not to be limited by I/O speeds. Ultimately, all image archives should be placed on high-speed/high-density optical-disc media to eliminate this bottleneck.

Costs

If access to burst lines of 60 Mbit/sec is acquired by the PLDS and shared with NASCOM users, a reasonable assumption would be that PLDS traffic would comprise 1% of the total volume. As a satellite transponder, plus full services, can be leased for about $2,500,000/yr; the PLDS prorated costs for this line would be about $25,000 yearly for all its long-haul lines. If the 60-Mbit/sec burst link is not available to the PLDS, some lines may need to be leased through the PSCN. Individual, 1.544-Mbit/sec lines can be leased for about $190,000/yr (personal communications with Harry Jones, Communications Engineer, Ames Research Center, Feb. 1984).

REGIONAL NETWORK DESIGN

Earth science research using the PLDS is to be performed not only by NASA but also by research groups in universities and other government agencies. This research will be carried out under grants and contracts funded by NASA. The extension of the PLDS to most of these remote users willbe paid for by NASA either as a direct cost or as part of the grant/contract fee. Therefore, the design of the regional network is a direct concern to the PLDS.

Communication paths and modems have been investigated for such a network. The following assumptions and considerations were used in the regional network design:

1. Multiple data sets of 100,000 bits are involved in interactive sessions averaging 30-min connect time.

2. The average time for each remote-site user of the PLDS is 30 hr/mo of connect time during normal business hours.

3. Six data sets of 100,000- bits, on the average, will be transferred during each 30-min session.

4. Excessive response time of 41 min at 9.6 kbit/sec (listed are figures that preclude transfers of four-banded 512- by 512-pixel-image subsections over the regional lines):

Line bandwidth	Time
4.8 kbit/sec	82 min
9.6 kbit/sec	41 min
56 kbit/sec	7.1 min
1.544 Mbit/sec	15.5 sec

5. Half of the remote sites will account for 80% of the transactions in any one month. The estimated total is 2400 data sets per month.

6. Efficiency of protocol overhead is 80% (the efficiency percentage equals the ratio of data over data plus character and block parity bits).

7. Efficiency of the throughput is 50%.

8. Investigation of the western regional networks will provide sufficient information to allow design of regional networks.

9. The ratio of the human/machine processing time to the network/telecommunication time ratio in the real-time network transactions is about 9 to 1 (nine units of time for human setup and database retrieval manipulation to one unit of time for network data handling).

Data Flow

As an example scenario used to identify costs and other issues, the above assumptions are applied to the ARC and JPL nodes of the PLDS (fig. 3). Twelve sites are listed in the Ames network and 10 in the JPL network. When a throughput efficiency of 50% is used, analysis indicates that an 8.8 kbit/sec link to each site is required.

Check of the 50/50 Data to Setup Turnaround Ratio[a]

	Time (msec)
Modem turnaround time	250
Block transmission time	1250
Modem delay	10
Propagation delay (1.5 msec/100 miles)	7.5
Receiving-terminal training time	250
Modem turnaround time	250
Acknowledgment transmission time	50
Modem delay	10
Propagation delay	7.5
Transmission modem training time	250

[a]Throughput efficiency = 1250/2335 = 53.5% ≈ 50%.

The calculation of the data bit rate required the transfer of a 100 kbit data set:

$$30 \text{ sec} = 1 \text{ request} + 1 \text{ data set} = 110{,}000 \text{ bits} \quad (1)$$

where request protocol equals 10 kbits. For protocol overhead of 80%

$$110{,}000/0.8 = 132 \text{ kbits} \quad (2)$$

Throughput efficiency is

$$0.5 = 30 \text{ sec} \times 0.5 = 15 \text{ sec} \quad (3)$$

Data rate required is

$$132 \text{ kbits}/15 \text{ sec} = 8.8 \text{ kbits/sec} \quad (4)$$

The user terminals at the remote sites are assumed to be workstations with a communications port to allow access to the PLDS, as well as to any local (at the remote site) computing facilities that might be available. Figures 4 and 5 depict how the remote workstations would link into the gateway and other hardware at the NASA host facility.

The high-speed end of voice-grade communication (7200-9600 kbit/sec) required by the remote user facility narrows the hardware selection to equipment with the advanced synchyronous communication capability. The high-speed modems now available have line quality monitoring and automatic line-equalization circuits to permit dial-up voice circuits to be used to link the remote site with the research center node. The communication line and modem availability were researched through Datapro Reports (ref. 2). Each is presented in the paragraphs below.

Regional communication lines- The dial-up, value-added networks (VAN) and leased lines are compared in table 1. Twelve remote-user sites to the ARC node and 10 sites to the JPL node are listed. The costs per month for each type of service are tabulated for comparison.

Direct-dial-up telephone service is presented in the first column. The cost for 30 hr/mo of daytime use was derived on the basis of 30-min calls; the first minute plus 29 additional minutes were prices and averaged to get the "perminute" rate.

The AT&T "800"-line service is presented in the next column. Four "800" lines were prices in the "over 80 hr/mo" bracket at $14.50/hr. The total cost was prorated to 11 sites. A voice-grade dial up was added for Alaska. The inward WATS is not offered for Alaska.

VANs (Tymnet, Telenet) do not compete well at these data rates. Their service is focused on the lower-data-rate services market.

Leased lines (AT&T 2000 MPL service) do not cost much more than 30 hr of dial-up service (table 1, cols. 4 and 8). When termination fees are subtracted, the leased line costs less than short-distance dial up. There is another advantage with leased lines--security from hackers and wrong numbers. Leased lines keep outsiders out of the network.

The tabulation in table 1 indicates that the regional network line costs would be 12% to 14% less with the "800" line (inward WATS) than with direct, long-distance, dial-up service. Leased lines offer added availability and added security for a small increase in cost.

Data modems-The high-speed synchronous-data modems required by the regional network are available. The requirement for a 9.6 kbit/sec link is easily met, but this rate over dial-up voice-grade lines is not so easily met. However, the sophisticated microprocessor-driven modems with line-quality monitor and automatic line equalization are available in sufficient variety to say with confidence that modems will be available and affordable for the network now and even more so in the next 5 yr. Eight vendor models are listed in table 2 with pertinent features and price, if available.

These eight modems all use quadrature modulation and feature the RS232-C communication protocol for the model-to-terminal link. All but one are microprocessor driven. All have automatic line equalization built in. With line monitoring, the modems sense the line impedance and match the line to optimize signal transmission. Also, if too many negative acknowledgments are received, the modem pairs agree to switch to a lower rate to optimize throughput on the link.

Other features (table 2), such as reverse channel, can increase throughput by receiving acknowledgments/negative acknowledgments on the reverse channel (essentially full duplex). The alternate voice feature allows human voice communication as well as machine-to-machine interaction. With auto-answer, the receiving machine answers its own phone and, if properly programmed, knows how to respond. Lastly, built-in diagnostics allow the modem to check itself (self-test) and check the connections (local loop-back and remote loop-back).

The prices for these modems range from $2740 to $6500. The modems available to the network in the near future will have the above features as standard features rather than options and will be prices at about $5000.

Regional Network Communications Architecture

In the discussion of architecture configuration an assumption has been made that the research center will handle not more than four remote users at any one time. This is sufficient to accommodate the assumed 30 hr/mo of daytime access (660 of the available 800 working hours during the month are used), while minimizing possible overloading of the PLDS gateway. Four modems must be on-line ready to do business (see fig. 4). The number of ports required at the gateway facility varies. Line switching equipment with 12 ports is required if the lines are leased; five ports are required if the lines are "800" lines (four "800" lines plus one regular dial-in line for non-"800" users, which requires switching), or four ports if dial-up service is chosen (no switching).

Leased lines provide security, an important consideration if security becomes a serious requirement. User-access screening (secret passwords, etc.) is required if the "800" lines or regular telephone service is chosen. A combination of the various lines is best so that all the above may be required. Figure 4 shows the four modems between the regional-network communications processor and the telecommunication equipment. The communications processor also serves as the gateway processor for the PLDS node (a DEC VAX). Communication lines fan out from the telephone equipment to up to 12 remote-user sites. Each remote user requires the telephone hookup and a modem interfaced to its communications processor.

The remote-user configuration is blocked out in figure 5. The scientific workstation is expected to have sufficient processor power and storage to do serious research, and may be tied into other local computer facilities.

For communication from remote sites to the NASA research center, the communications processor will receive data from the workstation (provided by direct memory access), block the data, install headers and trailers, and send the data over the RS232-C interface to the modem and telephone equipment (fig. 5). The data transfers from NASA are handled in reverse sequence.

RECOMMENDATIONS

PLDS long-haul communication needs can best be met through use of 60-Mbit/sec TDMA burst links between NASA centers. Because this capability is provided only over satellite communication links, X.25 protocols are unsuitable. Special satellite-compatible protocols must be used to achieve high-throughput efficiencies. The I/O speeds of peripheral devices at the various PLDS host facilities should be upgraded to fall within the 2- to 60-Mbit/sec range to prevent communications delays. Specifically, high-level language I/O should be replaced with assembly routines, and magnetic-tape archives should be moved to fast optical-disc-storage devices.

The regional networks within the PLDS can be built using the Direct Distance Dialing (DDD) telephone system. Initially, up to four telephone numbers are required at each NASA node, along with the same number of modems. As the remote sites become active, it may become beneficial to purchase in-WATS ("800"-line) services. The voice-grade-switched services will provide adequate channels when using adaptive, high-speed modems. The advantage in using dial-up lines is easy, economical growth. The disadvantage is interference from wrong numbers, telephone solicitors, and hackers. Security can be added, as required, to this simple design base.

The communications for all the NASA Pilot data systems should be integrated if efficiency is to be maximized and cost are to be minimized. If link access is not shared, the data systems may not acquire the high bandwidths they need. Shared use between the various data systems of TDMA facilities can ensure fast response times at a low prorated cost for individual user groups. If shared access to 60-Mbit/sec TDMA burst lines can be acquired, the prorated line costs to the PLDS will be about $25,000/yr.

The long-haul line costs for the PLDS are small compared to the costs of dial-up lines for remote users. Generalizing from equations (1)-(4), the dial-up cost for each remote user averages about $8500/yr, or $510,000 yearly for all regional lines. A follow-up analysis should be conducted to examine the feasibility of installing ground stations at all remote sites. ARC has already demonstrated on an experimental basis the successful use of portable, experimental, 6-m dish-antenna ground stations. If they are mass-produced, it is estimated that stations of this type could be produced for under $40,000 each (personal communications with Harry Jones, Communications Engineer, Ames Research Center, Feb. 1984), or for a total of about $2,400,000 if they are acquired by all remote users. It may be possible to recover the investment in a ground station of this type within 5 yr, when its costs are compared against dial-up charges.

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3. NASA Headquarters: The Pilot Land Data System: Report of the Planning Workshops. NASA TM-86250, 1984.

TABLE 1.- REMOTE USER SITE TO NASA HOST LINKS

Location of remote site	Distance, miles	Cost of direct dial-up,		Cost of AT&T (800), $/mo	VAS (Tymnet-Telenet)		Leased AT&T (2000) MPL, $/mo
		$/min	$/mo		4.8 kbit per sec, $/mo	9.6 kbit per sec, $/mo	
Ames Research Center, Mountain View, CA							
Spokane, WA	780	0.45	810	530[a]	925	1,400	890
Butte, MT	800	.45	810	530[a]			910
Boise, ID	500	.45	810	530[a]			676
Anchorage, AK	2,900	.57	1,026	1,026[b]			2,200
Salt Lake, UT	600	.45	810	530			723
Cheyenne, WO	980	.46	830				1,080
Davis, CA	83	.35	630				226
Berkeley, CA	35	.32	576				147
Stanford, CA	10	.06	108				97
Santa Clara, CA	10	.06	108				97
Reno, NV	195	.41	740				342
Humboldt, CA	265	.45					501
			8,068	6,826	11,100	16,800	7,890[c]
Jet Propulsion Lab, Pasadena, CA							
Flagstaff, AZ	390	.45	810	485[d]	925	1,400	526
Kansas City, KS	1,375	.46	830	485[d]			1,317
Honolulu, HI	3,000	.52	936	936			2,260
Phoenix, AZ	370	.45	810	485			507
Denver, CO	840	.46	830				949
Ft. Collins, CO	860	.46	830				969
Santa Barbara, CA	95	.35	630				244
Los Angeles, CA	10	.06	108				97
Riverside, CA	45	.32	576				164
San Diego, CA	118	.35	630				270
			6,990	5,300	9,250	14,000	7,300

[a]Four "800" lines, 90 hr each.
[b]No "800" service.
[c]Station termination not included ($72/mo each).
[d]Three "800" lines, 90 hr each.

TABLE 2.- FEATURES AND COSTS OF HIGH-SPEED ADAPTIVE MODEMS[a]

	Burroughs CP1009	General Data Com 9604	Paradyne T96	Prentice PV29/9600	Comspec 9600C	Micom M4096/DBT	NCR Comten Model 7165	Rockwell Int'l. R96DP
Data rate (kbit/sec)	9.6 7.2 4.8	9.6 7.2 4.8	9.6 7.2 4.8	9.6 7.2 4.8	9.6 7.2 4.8	9.6 7.2 4.8	9.6	9.6 7.2 4.8
Modulation	QAM	QAM	QAM	QAM	QAM	QAM	QAM	QAM
Turnaround (msec)	--	--	250	--	--	--	--	265
Training (msec)	253	--	253	250	--	253	24	253
Calling original/ answer	opt	--	--	--	orig/ ans	--	ans	--
Terminal I/F	RS232C	RS232C	RS232C	RS232C	RS232C	RS232C	RS232C	RS232C
Reverse channel	--	--	opt	no	--	--	--	opt
Alternate voice	--	--	opt	no	--	--	--	opt
Automatic answer	opt	--	--	no	std	std	yes	no
Equalization	auto	auto	auto	auto	auto	auto	auto	auto
Microprocessor	yes	yes	no	yes	yes	yes	yes	yes
Diagnostics	loop back	loop back	loop back	loop back	loop back	loop back	loop back	loop back
Price	$6500	$4200	$2740	contact vendor	contact vendor	$3795	$5800	contact vendor

[a]From Data Pro Reports 1982 and 1983, 1983 Telecommunications, Data Pro Research Corp.

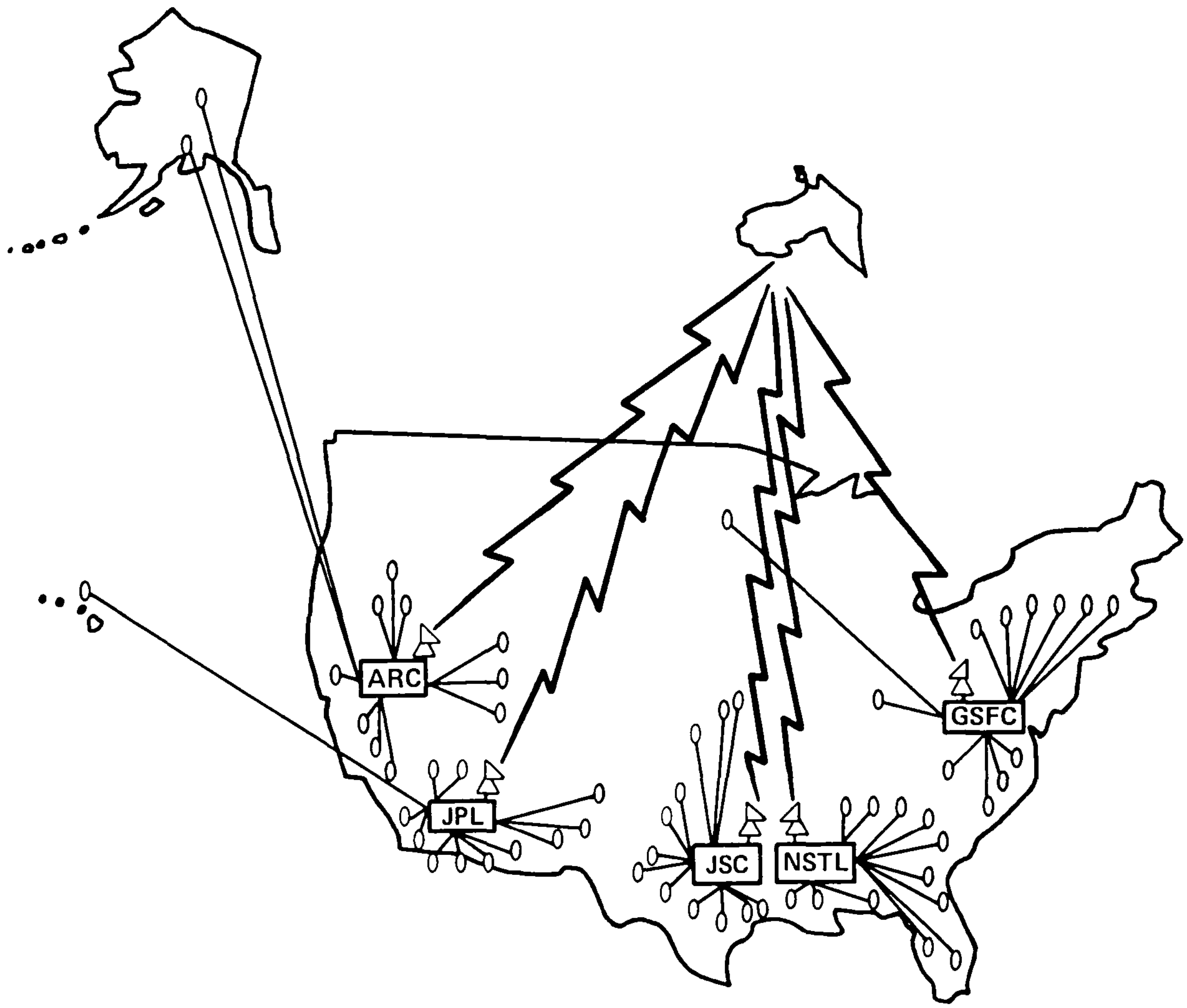

Figure 1.- Planned connections within the mature NASA PLDS. Five NASA Centers are mesh-linked via a communications satellite, with 12 remote users tied into each NASA host.

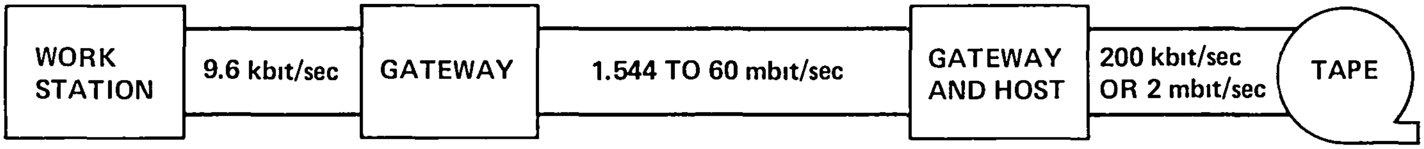

Figure 2.- Conceptual data flow.

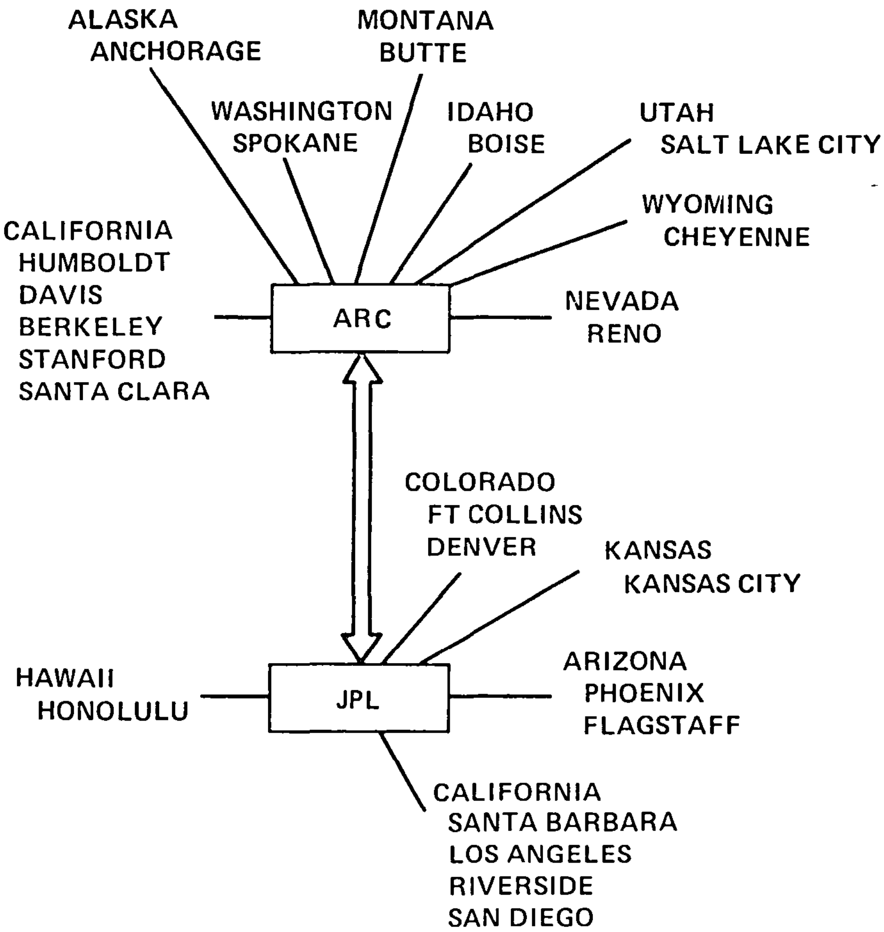

Figure 3.- Representative regional network allocations.

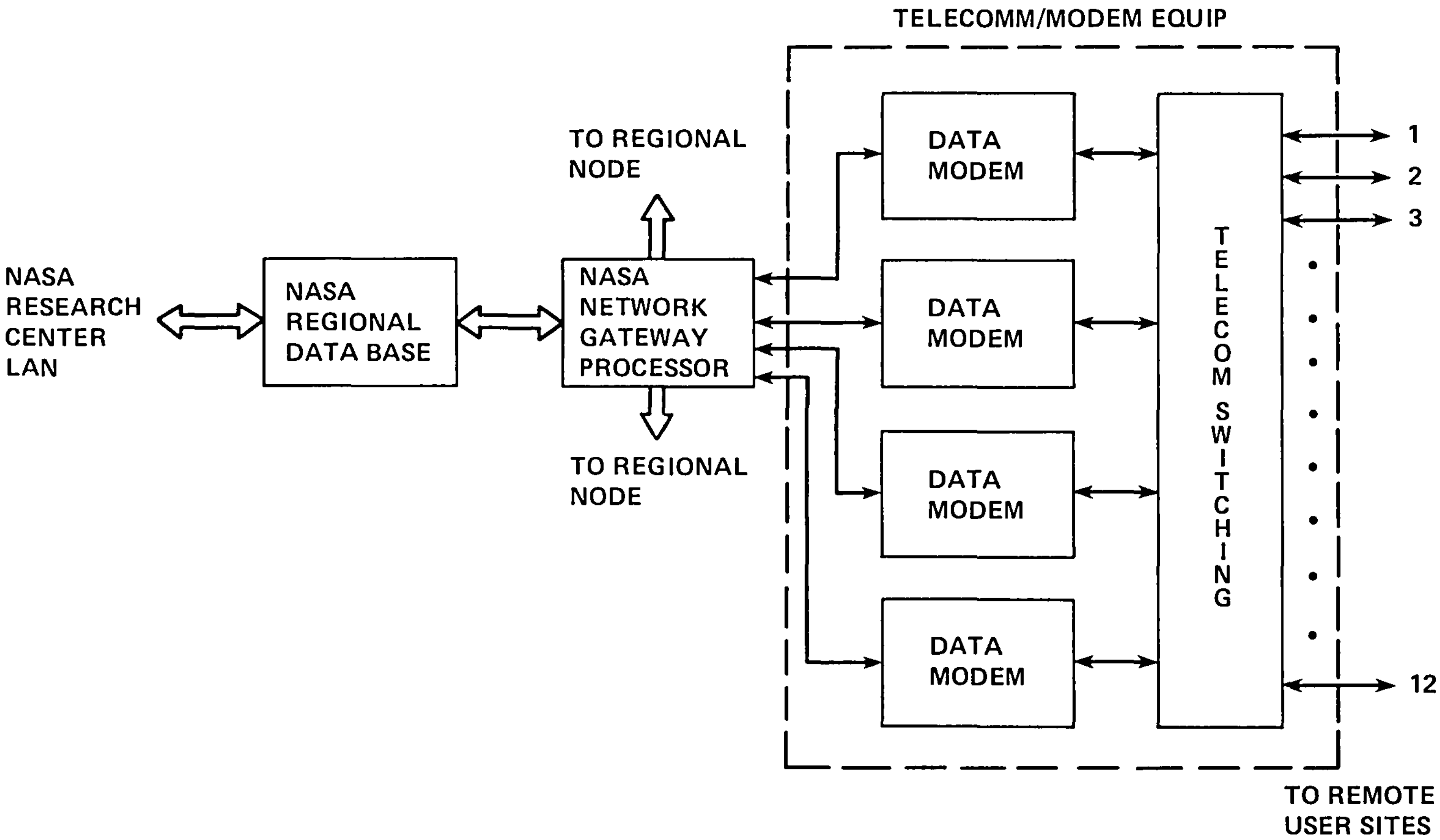

Figure 4.- NASA regional node block diagram.

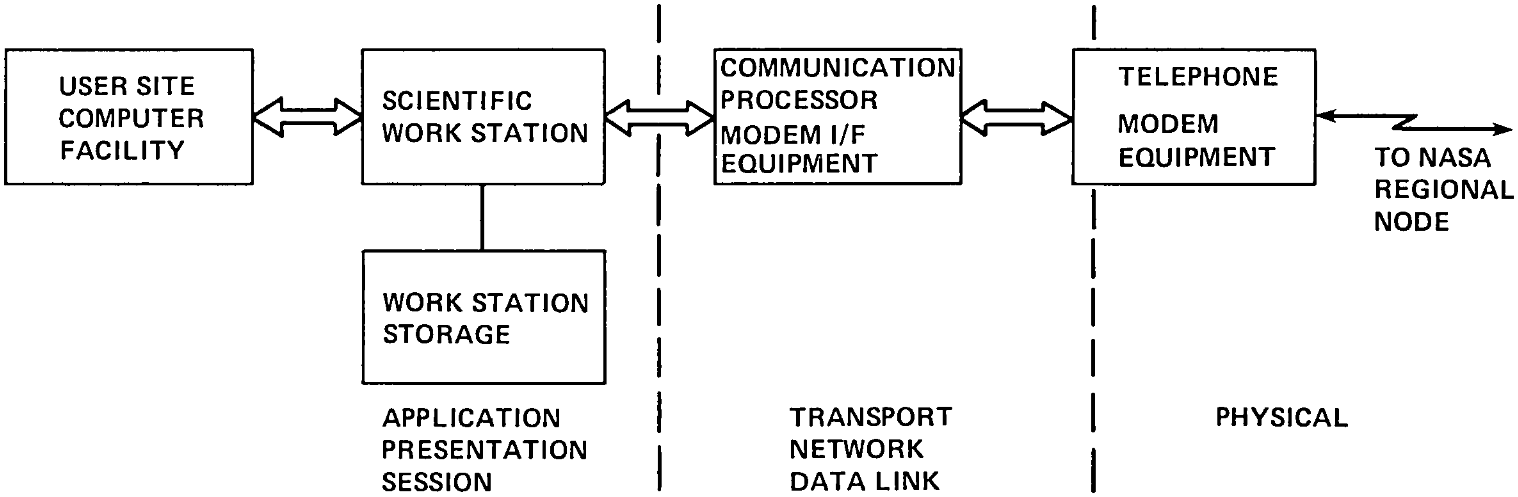

Figure 5.- Remote-user site configuration block diagram.

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16 Abstract

There are several preliminary, or Pilot, efforts for developing data systems for supporting NASA science research. The Pilot Data Systems consist of the Pilot Land Data System (PLDS), the Pilot Ocean Data System (PODS), the Pilot Climate Data System (PCDS), and the Pilot Planetary Data System (PPDS). The Pilot Data Systems will transition into operational systems in the 1990s. The PLDS is likely to have the greatest communication needs of the various Pilots. Communications issues and requirements are examined here in the context of the mature PLDS as it may exist by 1990. PLDS is seen as a distributed processing system linking resources at a number of NASA research centers and outside universities. Large image data sets, including Landsat Multi-Spectral Scanner (MSS) and Thematic Mapper (TM) scenes, are a major data type to be moved along the PLDS communications network. The unusually large size of these data files requires examining new technologies that may allow efficient and affordable communication at rates of up to 60 megabits per second. Potentially useful developments include portable satellite ground stations, and Time Division Multiple Access for sharing high-speed satellite links. PLDS alone, or any other single data system, is unlikely to justify operational access to these services due to cost. Future pooling of communications for the various data systems into a single network would reduce costs and may make economic justification of access to the required data rates possible.

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